Permit to Construct Application

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared For:

Johnston County Department of Public Utilities
309 E. Market Street
Smithfield, North Carolina 27577

APPROVED
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
DATE 31 AUG 06 BY TWYCHE JONES
PTC 51-03 V.3 ATTACH. 1 PART II DOC

Prepared By:

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

October 2005

G.N. RICHARDSON & ASSOCIATES, INC.

CLEAN

Engineering and Geological Services

TRANSMITTAL FORM

If enclosures are not as noted or
if you require additional information,
please notify us immediately

May 19, 2006 **HAND DELIVERED**

Ms. Toni Wyche
NC DENR Division of Waste Management
401 Oberlin Road, Suite 150
Raleigh, NC 27605
(919) 508-8400

SUBJECT: **Johnston County - C&D Landfill - Area 2 - Permit to Construct Application**

GNRA PROJECT NO: JOHNSTON-22

We are sending you the following items:

COPIES	ITEM	DESCRIPTION
2	Binder	Edits (See Cover Letter for Description)

These are transmitted as checked below:

- [ ] For Information
- [ ] As Requested
- [ ] For Review and Comments
- [ ] For Revision
- [X] For Approval
- [ ] Approved
- [ ] Approved as Noted
- [ ] Approved as Noted-Revise and Resubmit
- [ ] Not Approved-Revise and Resubmit
- [ ] For Record and File
- [ ] Submittal
- [ ] For Recording

REMARKS:

cc:

Pieter K. Scheer, P.E.

G.N. RICHARDSON & ASSOCIATES
Engineering and Geological Services

May 19, 2006

Ms. Toni Wyche, Environmental Engineer II
NC DENR - Division of Waste Management
401 Oberlin Road, Suite 150
Raleigh, NC 27605

RE: Johnston County Landfill (Permit No. 51-03)
C&D Landfill - Area 2
Edits to Permit to Construct Application

Dear Toni:

Per our conversation, G.N. Richardson & Associates, Inc. (GNRA) would like to submit the following edits to the permit to construct application for the Area 2 C&D landfill unit:

Attachment A: Facility and Engineering Plan

1. Section 2.2.3.2 (Maximum Disposal Rates):

   Revised this section to reflect the wording in the local government approval (see Appendix B). Also, deleted Table 2.1C (Projected Maximum MSW Tonnages) as this information is summarized in the revised text.

2. Section 2.2.4 (Service Area):

   Revised this section to reflect the wording in the local government approval (see Appendix B).

3. Capacity and Volume Information:

   Revised Tables 2.2B, 2.3, 2.6, and 2.8 to reflect minor capacity and earthwork quantity changes due to the revised grading plans prepared and submitted in March 2006. The respective calculations in Appendix A were also revised.

Attached is a revised copy of the Facility and Engineering Plan up through Appendix A (Appendix B remains the same). Please replace the applicable text in your copy.

Attachment D: Operations Manual

1. Section 3.3.3 (Leachate Quality Sampling):

   Revised section to include sampling the Area 2 C&D landfill unit at the side risers (Note that Detail 4/LM2 of the permit drawings shows the location of the sampling port.).

Attached is a revised copy of the Operations Manual text (All Appendices remain the same). Please replace the applicable text in your copy.

Should you have any questions or comments on this submittal, please contact me at your earliest convenience.

Sincerely,
G.N. Richardson & Associates, Inc.

Pieter K. Scheer, P.E.
Project Manager

Attachments: Revised Facility and Engineering Plan (through Appendix A)
Revised Operations Manual (Text Only)

cc: Johnston County (x2)

G.N. RICHARDSON & ASSOCIATES

Engineering and Geological Services

2 docs updated 6-15-06

March 8, 2006

Ms. Ellen Lorscheider
NCDENR - Division of Solid Waste Management
Solid Waste Section
1646 Mail Service Center
Raleigh, NC 27699-1646

RECEIVED MAR 09 2006 SOLID WASTE SECTION

RE: Permit Application Additions
Johnston County Proposed C&D Landfill
Smithfield, North Carolina

Dear Ms. Lorscheider:

Per our recent discussions, I am forwarding the following items to be included in the previously submitted permit application for the above referenced site.

1) Geotechnical laboratory data of consolidation analysis.

2) Documentation of Local Government Approval

3) A revised Figure 1 from Attachment D, indicating that no irrigation will occur on the Phase 3 MSW landfill.

Johnston County personnel have continued to collect water levels in the proposed landfill area and by our tabulation the January 2005 data contains the most wells with the highest water levels detected thus far. Although February data is slightly lower than the January data, we are awaiting the March data to complete the spring time water level analysis and finalize the landfill subgrade based upon the highest water levels detected. Upon receipt of the March data, and completion of the revised subgrade we will submit revised potentiometric surface data and design information.

If you have any questions, please contact me at your earliest convenence.

Sincerely,
G. N. Richardson and Associates, inc.

Joan A. Smyth

Joan A. Smyth, P.G.
Project Hydrogeologist

CC: Tim Broome, P.E. - Johnston County
Haywood Phthisic - Johnston County

2docs updated 6-15-06

G.N. RICHARDSON & ASSOCIATES
Engineering and Geological Services

LETTER OF TRANSMITTAL

If enclosures are not as noted or if you require additional information, please notify us immediately

Received
MAY 2006
Solid Waste Section

DATE: 4/28/06

TO: Ellen Lorscheider

By: US Mail [ ]
Overnight Mail [ ]
Hand [X]
Other [ ]

RE: Johnston Co. C&D landfill permit PROJECT NO:

We are sending you the following items:

COPIES	ITEM	DESCRIPTION
2		Revised Site Hydrogeologic Report

These are transmitted as checked below:

[ ] For Information
[ ] As Requested
[ ] For Review and Comments
[ ] For Revision
[ ] For Approval
[ ] Approved

[ ] Approved as Noted
[ ] Approved as Noted-Revise and Resubmit
[ ] Not Approved-Revise and Resubmit
[ ] For Record and File
[ ] Submittal
[ ] For Recording

REMARKS: Ellen-
Enclosed are copies of the revised Site Hydrogeology Drawings for the Johnston Co. C&D Landfill. I believe this completes the revision for this application. I will be out May 1st - 6th, but will be checking voice mail, or you can contact Pieter with questions.

CC:

Joan Smyth
Signature

Permit to Construct Application

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared For:

Johnston County Department of Public Utilities
309 E. Market Street
Smithfield, North Carolina 27577

Prepared By:

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

October 2005

PERMIT TO CONSTRUCT APPLICATION

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

GNRA Project No. JOHNSTON-22

NORTH CAROLINA PROFESSIONAL SEAL 021666 ENGINEER PIETER K. SCHEER

12/1/05

Pieter K. Scheer, P.E.
Project Manager

October 2005

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

PERMIT TO CONSTRUCT APPLICATION

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EXECUTIVE SUMMARY

GENERAL

The following is a Permit to Construct Application submitted on behalf of Johnston County for construction of the Area 2 construction and demolition debris (C&D) disposal unit at the County's existing landfill facility. Area 2 will be a lined landfill unit located adjacent to and east of the closed Phase 3 municipal solid waste (MSW) landfill unit in a former borrow area. A portion of Area 2 will overlie (piggyback) the Phase 3 side slopes. It is the intent of Johnston County to proceed with the construction of Area 2 in spring 2006. Johnston County anticipates that it will run out of space in the existing Area 1 disposal unit (a vertical expansion on the closed Phase 4 MSW landfill unit) by 2007.

The proposed Area 2, which includes Cells 1 and 2, will occupy approximately 15.8 acres (lined). At the projected gate rates as described in the Facility and Engineering Plan (**Attachment A**), Cell 1 of Area 2 has been designed for approximately 6 years of disposal volume.

Area 2 will have a liner system consisting of the following components (bottom-up):

Type 1:

- a 12 inch thick compacted soil liner with a permeability of no more than 1 x 10^{-5} cm/sec.;
- a 40 mil LLDPE geomembrane liner; and
- a leachate collection system (LCS).

OR

Type 2:

- a 12 inch thick layer of structural fill (no permeability criteria);
- a geosynthetic clay liner (GCL);
- a 40 mil LLDPE geomembrane liner; and
- a LCS.

Leachate generated from Area 2 will be collected in a sump located at the northwest side of the disposal unit. From the sump, the leachate will be pumped using side riser pumps and a forcemain to the existing leachate storage lagoon located to the northwest end of the facility.

This document also provides a conceptual design for all future MSW and C&D landfill units currently planned for development. The disposal volumes and estimated life expectancy of these future landfill units are given in the Facility and Engineering Plan.

REGULATORY REFERENCES

This submittal has been prepared in accordance with the requirements of the North Carolina Solid Waste Management Rules (C&D: 15A NCAC 13B.0500; MSW: 15A NCAC 13B.1600) and the North Carolina Sedimentation Control Rules (15A NCAC 4) which are enforced by the Division of Waste Management (DWM) and the Division of Land Quality, respectively, of the North Carolina Department of Environment and Natural Resources. Included in this submittal are the following documents:

Facility and Engineering Plan;
Technical Specifications;
Construction Quality Assurance (CQA) Manual;
Operations Manual;
Erosion and Sedimentation Control Plan;
Slope Stability, Settlement, and Bearing Capacity Evaluation;
Project Drawings; and
Design Hydrogeologic Report.

Received
MAY 2006
Solid Waste
Section

Facility And Engineering Plan

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

October 2005
Revised: May 2006

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

FACILITY AND ENGINEERING PLAN

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SECTION 1.0
INTRODUCTION

1.1 OVERVIEW

The Johnston County Landfill facility is located on County Home Road off Highway 210 near Smithfield, North Carolina and operates under NC Solid Waste Permit 51-03. The landfill facility includes an active ± 22 acre Subtitle D municipal solid waste (MSW) landfill (Phase 4A - Cells 1 & 2), a separate active construction and demolition debris (C&D) landfill unit (Area 1), a landfill office, scales and scalehouse, a citizen's convenience center, and a yard waste processing area.

Based on current projections, the active C&D landfill unit (Area 1), which is a vertical expansion over the closed unlined Phase 4 MSW landfill unit, is expected to remain in operation until 2007. Once Area 1 has reached capacity, the County will need to move operations to a new unit (Area 2) constructed to the east and partially overlying the closed unlined Phase 3 MSW landfill unit. It is the intent of Johnston County to proceed with the construction of Area 2 in spring 2006.

The purpose of this Facility and Engineering Plan is to present the plans for the development of the Area 2 C&D landfill unit. Specifically, the detailed design of Area 2 - Cell 1 is presented herein.

This section gives a brief overview of this report and a description of the site. Section 2 gives a description of the development of the Johnston County Landfill facility including the currently proposed Area 2 C&D landfill unit as well as planned future MSW landfill units. Sections 3 through 5 of this report focus on the detailed design of geosynthetics, the leachate management system, and the final cover system of the Area 2 disposal unit, respectively.

1.2 SITE DESCRIPTION

The Area 2 site is situated within the currently approved facility boundary, which consists of approximately 500 acres. Existing conditions are shown on **Drawing S1** of the Project Drawings **(Attachment G** to the Permit to Construct Application).

The proposed Area 2 C&D landfill unit will occupy approximately 15.8 acres (lined). At the projected gate rates described in **Section 2.0** (Facility Report), Area 2 has been designed for approximately 11 years of disposal volume (Cell 1 has a life expectancy of approximately 6 years). In that Area 2 will partially overlie the closed Phase 3 MSW landfill unit, the Area 2 landfill unit has been designed to meet current DWM setback and horizontal buffer requirements for MSW landfills: 300 feet from property lines; 500 feet from residences or active water wells.

SECTION 2.0
FACILITY REPORT

2.1 OVERVIEW

This section presents a plan for the development of the Area 2 C&D landfill unit of the Johnston County Landfill facility. In that the presently approved Facility Plan is being modified with this application, this report has been prepared in accordance with the requirements of Rule .1619 of the North Carolina Solid Waste Management Regulations.

2.2 FACILITY SERVICES AND WASTE STREAM

2.2.1 Facility Services

Currently, the following activities or services are provided at the Johnston County Landfill facility:

- Scales and scale house facilities
- Administrative offices
- Maintenance building
- Convenience center
- Lined municipal solid waste (MSW) landfill - (Phase 4A - Cells 1&2) (NC Permit No. 51-03)
- Construction and demolition debris (C&D) landfill - (Area 1) (NC Permit No. 51-03).

The following facilities are proposed for the facility:

- C&D landfill - Area 2
- Lined MSW landfill - Phase 4A - Cell 3 and Phases 6-10.

2.2.2 Types of Waste

The Johnston County Landfill accepts mixed municipal solid waste (MSW) originating from residential, commercial, and industrial sources, construction and demolition debris (C&D), and other wastes (i.e. white goods, tires, and yard waste). These wastes are segregated and directed to on-site facilities for disposal/processing as described below.

2.2.3 Disposal Rates and Estimated Variances

2.2.3.1 Projected County Disposal Rates

Based on the 2004-2005 Solid Waste Management Annual Report information provided by the County, the landfill accepted 108,751 tons of MSW and 31,233 tons of C&D waste from 7/1/04 to 6/30/05 (MSW: average 9,063 tons per month or 349 tons per day based on 312 operating days per year; C&D: average 2,603 tons per month or 100 tons per day based on 312 operating days per year). The population served during this time period was estimated as 145,968 which translates to 0.75 tons/person/year of MSW and 0.21 tons/person/year of C&D waste being disposed of at the landfill.

Based on the anticipated population figures and increases projected through 2030 from the NC Demographics Unit and the current per capita disposal rate, **Table 2.1A and Table 2.1B** give the projected annual and monthly tonnages to be disposed of at the Johnston County Landfill facility (in-County waste only) for MSW and C&D waste, respectively. Note that monthly variances shown in the tables are based on County records which indicate that the maximum anticipated monthly variance is about plus or minus 20 percent from average. Also note that population figures after 2030 are based on an assumed constant percentage increase from 2030 onward.

2.2.3.2 Maximum Disposal Rates

Based upon the projected in-County disposal rates shown in **Tables 2.1A and 2.1B** and the maximum out-of-County disposal rate stated below, the landfill facility will accept waste at the following maximum rates (tons/day is based on 312 operating days per year):

2006-2015	350,000 tons/year (1,122 tons/day)
2016-2025	401,000 tons/year (1,285 tons/day)
2026-2035	452,000 tons/year (1,449 tons/day)
2036-2045	505,000 tons/year (1,619 tons/day)
2046-2055	568,000 tons/year (1,821 tons/day)

Of the rates shown, a maximum of 156,000 tons/year (500 tons/day) will be from outside the County.

2.2.4 Service Area

The landfill serves the State of North Carolina.

2.2.5 Procedures for Waste Segregation

Procedures for waste segregation at the proposed landfill will be similar to existing operations. A brief description of planned procedures is as follows.

Wastes are segregated at the scales. Operators at the scalehouse are trained to classify and segregate the waste stream. MSW and C&D wastes are directed to the active MSW or C&D landfill unit. Yard wastes are directed toward the yard waste processing area. Tires and white goods are stockpiled temporarily for disposal by private recycling contractors. directed to the white goods processing area. Small loads and recyclables are directed toward the citizen's convenience center.

Employees at the landfill are trained in the safety procedures for the handling and detection of illegal waste. The screening of unacceptable waste is done through the random checking of incoming loads by a County employee at the scale house and at the tipping area. When unacceptable waste is detected at the scale house, the load is rejected and not permitted into the facility. If hazardous waste is found at the tipping area, identification of the truck or persons is made (if possible) and documented, then the hazardous waste is identified and placed in a hazardous waste container and taken to a designated hazardous waste staging area for proper disposal. If this occurs, the event is reported to the appropriate authorities.

2.2.6 Equipment Requirements

The equipment required for operation and maintenance of the proposed landfill units are anticipated to be the same as or similar to those currently used at the facility.

2.3 LANDFILL CAPACITY

2.3.1 Total Operating Capacity and Life Expectancy

2.3.1.1 MSW Landfill Units

Drawing S2 (Site Development Plan - Base Grades) and **Drawing S3** (Site Development Plan - Final Cover Grades), show conceptual subgrade and final cover grades for the development of Phases 4A and 6 through 10. The final cover side slopes will be at a 4H to 1V slope, then transition at flatter slopes (5 - 8%) to the peak elevations.

2.3.1.2 C&D Landfill Units

Drawing S2 (Site Development Plan - Base Grades) identifies the conceptual subgrade grades for the development of Area 2. **Drawing S3** (Site Development Plan - Final Cover Grades), identifies the final configuration of Areas 1 and 2. The final cover side slopes will be at a 4H to 1V slope, then transition at flatter slopes (5 - 8%) to the peak elevations.

The estimated total gross and net operating capacities, life expectancies, and areas of existing and planned MSW and C&D landfill units are shown in **Tables 2.2A and 2.2B**, respectively. Note that the approximate total capacities and waste footprint areas for closed unlined MSW landfill units are also shown in **Table 2.2A**. The net capacity for waste and corresponding life expectancy of each disposal area accounts for daily and intermediate cover and/or final cover. For MSW landfill units, a range of life expectancies are given to cover projected County-only tonnages (longer life expectancy) through the maximum disposal rates given in **Section 2.2.3.2** (shorter life expectancy). For C&D landfill units, a range of life expectancies are given to cover projected County-only tonnages (longer life expectancy) through projected County-only tonnages plus the anticipated 20% variance (shorter life expectancy).

2.3.2 In-Place Ratio of Waste to Soil and Compaction Factors

2.3.2.1 MSW Landfill Units

The capacities obtained above were based on a 15 percent periodic cover ratio and a compaction factor ranging from 1,200 to 1,400 pounds per cubic yard (pcy). The assumed periodic cover ratio is indicative of the County's current practices of using a tarp as an alternative to placing 6 inches of daily cover soil. The assumed compaction factor of 1,200 pcy is based on past analyses of waste density adjusted upward for increased waste heights. A compaction factor of 1,400 pcy was assumed for areas with the greatest height (i.e. Phase 4A - Cell 3, Phase 9, and Phase 10).

2.3.2.2 C&D Landfill Units

The capacities obtained above were based on a 10 percent periodic cover ratio and a compaction factor of 1,200 pounds per cubic yard. The assumed periodic cover ratio is typical for C&D landfills. The assumed compaction factor is based on a recent analysis of waste density in Area 1.

Note that changes in landfill operations (i.e. changes in the use of alternative daily cover and/or compaction equipment/methods) may affect the values assumed above and, thus, alter the life of the various landfill units.

2.4 AVAILABLE SOIL RESOURCES AND REQUIRED SOIL QUANTITIES

2.4.1 Earthwork Quantities

The soils required to construct and operate the existing and planned MSW and C&D landfill units will be removed from on-site borrow sources or will be imported from off-site. The soils removed during excavation of landfill units may be used for structural fill, compacted soil liner, and/or general fill. These excavation (cut) and structural fill (fill) volumes are shown in **Table 2.3**.

2.4.2 Soil Liner

The soil required for the soil liner will be on-site or imported soils. The in-place volume required for each landfill unit is shown in **Table 2.4**.

2.4.3 Leachate Collection System (LCS) and Protective Cover

Overlying the liner system is the leachate collection system and protective cover. This layer is 24 inches thick on both the landfill base and side slopes. The required in-place volume of protective cover for each disposal area is shown in **Table 2.5**. A portion of this volume will consist of aggregate, which will come from off-site sources.

2.4.4 Daily and Intermediate Cover

Assuming the previously mentioned periodic cover ratios, the required in-place volume for use as daily and intermediate cover during landfill operations is shown in **Table 2.6**.

2.4.5 Vegetative Soil Layer

On the basis of the 2 foot thick vegetative soil layer required for the landfill final cover, the in-place volume required for each landfill unit is shown in **Table 2.7**.

2.4.6 Soil Summary

The above on-site and off-site soil quantities are summarized in **Table 2.8**. Note that, based on the proposed base grades, long-term there is a soil deficit, which will be made up from off-site sources.

2.5 FACILITY DESIGN CRITERIA

2.5.1 MSW Landfill Units

The Johnston County MSW landfill base liner and final cover systems will be constructed in accordance with Section .1624 (b)(8)(9) of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B including the following requirements.

2.5.1.1 Horizontal Separation Requirements

The horizontal separation requirement between the disposal boundary (edge of waste) and the property lines is a minimum of 300 feet, the minimum buffer between private residences and wells and the disposal boundary is 500 feet, and the minimum buffer between any surface water (stream, river, creek) and the disposal boundary is 50 feet. The proposed design satisfies all buffer requirements.

2.5.1.2 Vertical Separation Requirements

The post-settlement bottom elevation of the base liner system will meet the minimum requirement of four feet above the seasonal high groundwater table and bedrock.

2.5.2 C&D Landfill Units

The Johnston County C&D landfill is designed and operates in accordance with Sections .0503 and .0505 of the North Carolina Administrative Code, Title 15A, Chapter 13, Subchapter 13B including the following requirements.

2.5.2.1 Horizontal Separation Requirements

The horizontal separation requirement between the disposal boundary (edge of waste) and the property lines is a minimum of 50 feet (actually ≥ 100 feet per Solid Waste Section policy), the minimum buffer between private residences and wells and the disposal boundary is 500 feet, and the minimum buffer between any surface water (stream, river, creek) and the disposal boundary is 50 feet. In that Area 2 will partially overlie the closed Phase 3 MSW landfill unit, the Area 2 landfill unit has been designed to meet current DWM setback and horizontal buffer requirements for MSW landfills (see above)

2.5.2.2 Vertical Separation Requirements

The Area 2 subgrade has been designed to meet the minimum requirement of four feet above the seasonal high groundwater table (State rules) and bedrock (Solid Waste Section policy).

2.6 CONTAINMENT AND ENVIRONMENTAL CONTROL SYSTEMS

Technical specifications and construction quality assurance requirements for the materials used in the Area 2 construction can be found in **Attachments B and C**, respectively. Geosynthetics used in the Area 2 construction are discussed in greater detail in **Section 3.0** (Geosynthetics Design) of this document.

2.6.1 Landfill Subgrade and Perimeter Berms

The landfill subgrade elevations for lined landfill units have been designed for minimum post-settlement slopes of 2 percent (NCAC .1624(b)(7)). The subgrade elevations will be achieved by excavation or placement of compacted structural fill (embankment). During excavation, a determination of unsuitable soils (i.e. soils which are too soft, wet, or organic) will be made. Where unsuitable soils are found, the soils will be undercut and backfilled with structural fill. Some areas may also require placement of a bridge lift prior to placement of structural fill.

In addition to providing the liner foundation in fill areas, structural fill will be used for berm and roadway construction. Structural fill will consist of on-site soils removed during excavation of the landfill units or imported borrow soils, except that no CH, OL, or OH soils will be allowed.

2.6.2 Base Liner System

The following is a general discussion of the base liner systems for MSW landfill units and lined C&D landfill units. The specific design requirements are discussed in the permit applications for each individual unit.

2.6.2.1 MSW Landfill Units

The base liner areas for Phase 4A - Cell 3, and Phases 6-10 are shown on **Drawing S2** (Site Development Plan - Base Grades). The base liner will consist of either a standard composite liner system or an alternative liner system as allowed under North Carolina regulations. The components of this liner system will consist of the following components (bottom-up):

Standard Liner System - Phases 6-10:

- a 24 inch thick compacted soil liner with a permeability of no more than 1 x 10^{-7} cm/sec.;
- a 60 mil HDPE geomembrane liner; and
- a leachate collection system (LCS) consisting of natural and/or geosynthetic drainage media and collection piping.

OR

Alternative Liner System - Phase 4A - Cell 3:

- a 40 mil LLDPE geomembrane liner;
- a drainage geocomposite (leak detection system);
- a geosynthetic clay liner (GCL);
- a 60 mil HDPE geomembrane liner; and
- a LCS (components as listed above for the standard liner system).

Alternative Liner System - Phases 6-10:

- an 18 inch thick compacted soil liner with a permeability of no more than 1 x 10^{-5} cm/sec.;
- geosynthetic clay liner (GCL);
- a 60 mil HDPE geomembrane liner; and
- a LCS (components as listed above for the standard liner system).

2.6.2.2 Lined C&D Landfill Units

The base liner area for Area 2 is shown on **Drawing S5** (Area 2 - Composite Liner Grading and Leachate Collection System Plan). Area 2 will have a liner system consisting of the following components (bottom-up):

Type 1:

- a 12 inch thick compacted soil liner with a permeability of no more than 1×10^{-5} cm/sec.;
- a 40 mil LLDPE geomembrane liner; and
- a leachate collection system (LCS) consisting of:

  Base and Side Slopes:
  - a drainage geocomposite;
  - a system of collection pipes and gravel columns.

  OR

Type 2:

- a 12 inch thick layer of structural fill (no permeability criteria);
- a geosynthetic clay liner (GCL);
- a 40 mil LLDPE geomembrane liner; and
- a LCS (components as listed above for the Type 1 liner system).

The compacted soil liner (if used) will consist of compacted on-site or imported borrow soils. The compacted soil liner will be placed and compacted in 6 inch lifts to achieve the required permeability and strength requirements.

The GCL (if used) will consist of a layer of sodium bentonite bonded between two geotextiles. The GCL will provide a maximum hydrated permeability of 5×10^{-9} cm/sec.

The geomembrane components of the liner systems will consist of a 40 mil thick Linear Low Density Polyethylene (LLDPE) synthetic liner (Phase 4A - secondary geomembrane; Area 2 - primary geomembrane) and/or a 60 mil thick High Density Polyethylene (HDPE) synthetic liner (Phase 4A and Phases 6-10 - primary geomembrane). These geomembranes will be installed by a qualified contractor.

For the Area 2 C&D landfill unit, all geosynthetics have been selected to comply with the performance requirements identified in **Section 3.0** (Geosynthetics Design) as well as the Specifications presented in **Attachment B**.

Note that, for the purposes of this report and the calculations of volumes, the above listed Type 1 liner (Area 2 C&D) and alternative liner system (Phase 4A - Cell 3 and Phases 6-10) have been assumed. It is possible that a different alternative liner system will be proposed at a future date for future areas.

2.6.3 Leachate Collection System (LCS)

The LCS will be constructed directly above the geomembrane on both the base and side slopes of the landfill. Components of the LCS will be as listed above (see **Section 2.6.2**). The LCS functions to collect leachate as quickly as is practical and to conduct the fluid out of the landfill via the sumps. The goal of the LCS is to minimize the hydraulic head acting on the liner, thereby reducing the leak potential. For the Area 2 C&D landfill unit, a detailed discussion of the LCS can be found in **Section 4.0** (Leachate Management System Design).

2.6.4 Protective Cover

A protective cover layer of soil or stone may be used as the upper component of the LCS. For the Area 2 C&D landfill unit, 24 inches of protective cover soil will be placed over the drainage geocomposite. Where soil is used, a separator/filter geotextile is required between drainage aggregate and the soil.

2.6.5 Stormwater/Leachate Separation System

In order to increase facility operating efficiency by reducing the leachate treatment quantities, stormwater/leachate separation is planned for each landfill unit. Leachate is considered to be any precipitation or fluid that comes in direct contact with the waste. This liquid will be collected by the LCS and pumped to the leachate storage lagoon. Precipitation that falls in areas where it does not contact waste, such as within inactive areas, does not have to be treated as leachate. This fraction of the precipitation is treated as stormwater - that is, treated for removal of sediment only.

For disposal areas that have waste placed in them, precipitation is allowed to percolate or run-off into the LCS. For areas that have no waste, the percolation or run off to the sump where a pump conducts the water to a perimeter drainage structure. This runoff does not contact waste or leachate. At their discretion, the County may also employ the use of geosynthetic rain cover (GRC) to further segregate leachate and stormwater. The GRC, if used, is removed and discarded as each portion of an area is placed into active operation. For additional discussion of the leachate-stormwater separation system, see the Operations Manual (**Attachment D**).

2.6.6 Final Cover System

As a minimum, the components of the final cover system (bottom up) will consist of a 6 to 12 inch foundation layer (daily or intermediate cover), 30 mil textured LLDPE geomembrane, drainage geocomposite (pore pressure reduction), and a 24 inch thick vegetative soil layer which includes a 6 inch thick topsoil layer. For the MSW landfill units, this system differs from the standard regulatory final cover in that an 18 inch layer of 1×10^{-5} cm/sec soil below the geomembrane is removed and the drainage geocomposite is added above the geomembrane. The addition of the drainage geocomposite reduces head on the geomembrane for both reduced infiltration through the geomembrane and increased stability of the overlying soil veneer.

For the Area 2 C&D landfill unit, a detailed discussion of final cover system design can be found in **Section 5.0** (Final Cover System Design).

2.6.7 Erosion and Sedimentation Control

Erosion and sedimentation control structures provided will be designed and maintained to manage the run-off generated by the 24-hour, 25-year storm event, and conform to the requirements of the North Carolina Sedimentation Pollution Control Law (15A, NCAC, 4).

For the Area 2 C&D landfill unit, a detailed discussion of site erosion and sedimentation control can be found in the Project Erosion And Sedimentation Control Plan (**Attachment E**).

2.6.8 Landfill Gas Control

2.6.8.1 MSW Landfill Units

Landfill gas (LFG) control will consist of a series of vertical wells and/or collector trenches which are connected to passive vents or utility flares or to an active gas extraction system. The selected system will be designed to limit the gas pressures on the final cover geosynthetics.

Note that the volume of waste projected in the Phase 4A - Cell 3 unit will cause the total volume of MSW waste at the facility to exceed the 2.75 million ton threshold of the EPA's New Source Performance Standards (NSPS) on landfill gas emissions and will, therefore, bring this facility under these guidelines. In accordance with State requirements, a Title V air quality permit application will be made once the Phase 4A - Cell 3 unit receives its Permit to Operate. The final design will be made as part of the required Collection and Control System Design Plan.

2.6.8.2 C&D Landfill Units

For the Area 1 C&D landfill unit, which overlies the closed unlined Phase 4 MSW landfill unit, LFG control will consist of a series of vertical wells and/or collector trenches which are connected to passive vents or utility flares or to an active gas extraction system. The selected system will be designed to limit the gas pressures on the final cover geosynthetics. Likewise, a series of collector trenches has been designed to be placed under the portion of the Area 2 C&D landfill unit which overlies the Phase 3 unlined MSW landfill unit. Due to the limited amount of LFG expected from the C&D waste, no LFG control features are planned as part of the Area 2 final cover system.

Also refer to the facility Operations Manual (**Attachment D**) for a discussion of LFG monitoring and record keeping requirements.

2.6.9 Access and Roadways

The site has been designed to provide all-weather access to active areas as well as areas under intermediate cover. Access ramps into the lined areas will be provided where necessary.

2.7 SLOPE STABILITY AND SETTLEMENT

The slope stability of the overall waste mass and perimeter berms, the protective cover veneer, and the final cover veneer, as well as estimates of foundation settlement are addressed in **Attachment F**. Slope stability analyses indicated that the proposed Area 2 landfill configuration will be stable. Veneer stability analyses on the liner system side slopes and final cover showed that for maximum slopes, these areas will be stable.

2.8 LEACHATE MANAGEMENT

The general leachate management system includes the collection, storage, treatment (if required), and disposal of the leachate generated. The collection and transmission of leachate to the on-site storage lagoon will be as described above. From the storage lagoon, the leachate will be pumped via force main on a regular basis to a local wastewater treatment plant (WWTP) for disposal. Pretreatment, if required, will be employed on-site to meet the standards for disposal into the WWTP.

For the Area 2 C&D landfill unit, a detailed discussion of the leachate management system, including anticipated leachate volumes, can be found in **Section 4.0** (Leachate Management System Design).

2.9 SPECIAL ENGINEERING FEATURES

Special engineering features proposed for Area 2 includes an alternative liner system.

2.9.1 Alternative Liner Systems

Alternative liner systems, as described above, are proposed for use at the facility due to the lack of 1 x 10^{-7} cm/sec soil on-site.

TABLE 2.1A
PROJECTED (COUNTY-ONLY) MSW TONNAGES

Year	Population	Projected Annual MSW Tonnage	Projected Average Monthly MSW Tonnage	Projected Monthly Variance (± 20%)
2005	145,968	108,751	9,063	7,250 - 10,875
2006	150,557	112,169	9,347	7,478 - 11,217
2007	155,226	115,648	9,637	7,710 - 11,565
2008	159,970	119,182	9,932	7,945 - 11,918
2009	164,801	122,782	10,232	8,185 - 12,278
2010	169,566	126,332	10,528	8,422 - 12,633
2011	173,978	129,619	10,802	8,641 - 12,962
2012	178,498	132,986	11,082	8,866 - 13,299
2013	183,133	136,440	11,370	9,096 - 13,644
2014	187,923	140,008	11,667	9,334 - 14,001
2015	192,811	143,650	11,971	9,577 - 14,365
2016	197,748	147,328	12,277	9,822 - 14,733
2017	202,850	151,129	12,594	10,075 - 15,113
2018	208,113	155,050	12,921	10,337 - 15,505
2019	213,560	159,109	13,259	10,607 - 15,911
2020	218,946	163,121	13,593	10,875 - 16,312
2021	223,754	166,703	13,892	11,114 - 16,670
2022	228,689	170,380	14,198	11,359 - 17,038
2023	233,760	174,158	14,513	11,611 - 17,416
2024	239,003	178,064	14,839	11,871 - 17,806
2025	244,330	182,033	15,169	12,136 - 18,203
2026	249,653	185,999	15,500	12,400 - 18,600
2027	255,141	190,088	15,841	12,673 - 19,009
2028	260,783	194,291	16,191	12,953 - 19,429
2029	266,606	198,629	16,552	13,242 - 19,863
2030	271,075	201,959	16,830	13,464 - 20,196

Year	Population	Projected Annual MSW Tonnage	Projected Average Monthly MSW Tonnage	Projected Monthly Variance (± 20%)
2031	275,619	205,344	17,112	13,690 - 20,534
2032	280,239	208,786	17,399	13,919 - 20,879
2033	284,937	212,286	17,691	14,152 - 21,229
2034	289,713	215,845	17,987	14,390 - 21,584
2035	294,569	219,463	18,289	14,631 - 21,946
2036	299,507	223,142	18,595	14,876 - 22,314
2037	304,527	226,882	18,907	15,125 - 22,688
2038	309,632	230,685	19,224	15,379 - 23,069
2039	314,822	234,552	19,546	15,637 - 23,455
2040	320,099	238,484	19,874	15,899 - 23,848
2041	325,465	242,481	20,207	16,165 - 24,248
2042	330,921	246,546	20,545	16,436 - 24,655
2043	336,468	250,679	20,890	16,712 - 25,068
2044	342,108	254,881	21,240	16,992 - 25,488
2045	347,843	259,153	21,596	17,277 - 25,915
2046	353,673	263,497	21,958	17,566 - 26,350
2047	359,602	267,914	22,326	17,861 - 26,791
2048	365,630	272,405	22,700	18,160 - 27,241
2049	371,758	276,971	23,081	18,465 - 27,697
2050	377,990	281,614	23,468	18,774 - 28,161
2051	384,326	286,335	23,861	19,089 - 28,663
2052	390,768	291,134	24,261	19,409 - 29,113
2053	397,319	296,014	24,668	19,734 - 29,601
5054	403,979	300,976	25,081	20,065 - 30,098
2055	410,751	306,021	25,502	20,401 - 30,602

TABLE 2.1B
PROJECTED (COUNTY-ONLY) C&D TONNAGES

Year	Population	Projected Annual C&D Tonnage	Projected Average Monthly C&D Tonnage	Projected Monthly Variance (+ 20%)
2005	145,968	31,233	2,603	2,082 - 3,123
2006	150,557	32,215	2,685	2,148 - 3,221
2007	155,226	33,214	2,768	2,214 - 3,321
2008	159,970	31,229	2,852	2,282 - 3,423
2009	164,801	35,262	2,939	2,351 - 3,526
2010	169,566	36,282	3,024	2,419 - 3,628
2011	173,978	37,226	3,102	2,482 - 3,723
2012	178,498	38,193	3,183	2,546 - 3,819
2013	183,133	39,185	3,265	2,612 - 3,918
2014	187,923	40,210	3,351	2,681 - 4,021
2015	192,811	41,256	3,438	2,750 - 4,126
2016	197,748	42,312	3,526	2,821 - 4,231
2017	202,850	43,404	3,617	2,894 - 4,340
2018	208,113	44,530	3,711	2,969 - 4,453
2019	213,560	45,695	3,808	3,046 - 4,570
2020	218,946	46,848	3,904	3,123 - 4,685
2021	223,754	47,877	3,990	3,192 - 4,788
2022	228,689	48,933	4,078	3,262 - 4,893
2023	233,760	50,018	4,168	3,335 - 5,002
2024	239,003	51,139	4,262	3,409 - 5,114
2025	244,330	52,279	4,357	3,485 - 5,228
2026	249,653	53,418	4,452	3,561 - 5,342
2027	255,141	54,593	4,549	3,640 - 5,459
2028	260,783	55,800	4,650	3,720 - 5,580
2029	266,606	57,046	4,754	3,803 - 5,705
2030	271,075	58,002	4,833	3,867 - 5,800

TABLE 2.2A
TOTAL OPERATING CAPACITY AND LIFE EXPECTANCY - MSW LANDFILL UNITS

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity (CY/Tons)	Life Expectancy (Years)
Unlined Landfill Units				
Phase 1/2	22.1	732,363	495,790 CY 297,474 Tons	Closed
Phase 3	25.4	1,174,139	819,136 CY 491,482 Tons	Closed
Phase 4	37.3	1,631,731	1,133,533 CY 680,120 Tons	Closed
Total (Unlined):	84.8	3,538,233	2,448,459 CY 1,469,076 Tons	Closed
Lined (Subtitle D) Landfill Units				
Phase 5	19.2	1,087,199	884,625 CY 514,181 Tons	Inactive
Phase 4A (Cells 1&2)	22.0	1,086,783	923,766 CY 521,078 Tons	1.6 - 2.6[1]
Phase 4A (Cell 3)	7.4	1,426,682	1,117,815 CY 782,471 Tons	2.8 - 6.1
Phase 6	21.1	1,402,016	1,163,319 CY 697,992 Tons	2.5 - 4.8
Phase 7	19.8	1,758,991	1,456,422 CY 873,853 Tons	3.0 - 5.3
Phase 8	25.2	1,844,867	1,482,308 CY 889,385 Tons	2.9 - 4.8
Phase 9	22.5	6,684,914	5,599,252 CY 3,919,476 Tons	11.8 - 17.2
Phase 10	17.5	3,075,968	2,508,093 CY 1,755,665 Tons	4.8 - 5.5
Total (Lined):	154.7	18,367,420	15,135,600 CY 9,954,101 Tons	29.4 - 46.3
Total (Overall):	239.5	21,905,653	17,584,059 CY 11,423,177 Tons	29.4 - 46.3

Notes:

1. Life expectancies for the active Phase 4A - Cells 1 & 2 shown above is from 3/21/05.

TABLE 2.2B
TOTAL OPERATING CAPACITY AND LIFE EXPECTANCY - C&D LANDFILL UNITS

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity (CY/Tons)	Life Expectancy (Years)
Area 1	16.2	572,734	479,645 CY 289,285 Tons	2.0 - 2.4[1]
Area 2 - Cell 1	11.3	451,611	389,897 CY 233,938 Tons	5.5 - 6.4
Area 2 - Cell 2	4.5	462,658	387,062 CY 232,237 Tons	4.6 - 5.3
Total:	32.0	1,487,003	1,256,604 CY 755,460 Tons	11.9 - 14.2

Notes:
1. Life expectancy for the active Area 1 unit shown above is from 3/21/05.

TABLE 2.3
GENERAL EARTHWORK QUANTITIES

Landfill Unit[1]	Cut (CY)	Fill (CY)
MSW Landfill Units		
4A - Cell 3	362	3,275
Phase 6	279,493	55,613
Phase 7	222,037	85,202
Phase 8	242,630	105,976
Phase 9	68,999	178,758
Phase 10	151,736	21,326
C&D Landfill Units		
Area 2	44,610	77,952

Notes:
1. Includes site roads and infrastructure.

TABLE 2.4
SOIL LINER QUANTITIES

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 6	51,062
Phase 7	47,916
Phase 8	60,984
Phase 9	54,450
Phase 10	42,350
C&D Landfill Units	
Area 2[1]	25,491

Notes:
1. Or structural fill layer.

TABLE 2.5
LEACHATE COLLECTION SYSTEM/PROTECTIVE COVER QUANTITIES

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
4A - Cell 3	23,877
Phase 6	68,083
Phase 7	63,888
Phase 8	81,312
Phase 9	72,600
Phase 10	56,467
C&D Landfill Units	
Area 2	50,981

TABLE 2.6
DAILY AND INTERMEDIATE COVER QUANTITIES

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
4A - Cells 1 & 2	86,088[1]
4A - Cell 3	214,002
Phase 6	210,302
Phase 7	263,849
Phase 8	276,730
Phase 9	1,002,737
Phase 10	461,395
C&D Landfill Units	
Area 1	18,075[1]
Area 2	86,329

Notes:
1. Volumes shown above for Phase 4A Cells 1&2 and Area 1 is from 3/21/05.

TABLE 2.7
VEGETATIVE SOIL LAYER QUANTITIES

Landfill Unit	Required Volume (CY)
MSW Landfill Units	
Phase 4A	94,864
Phase 5	61,952
Phase 6	68,083
Phase 7	63,888
Phase 8	81,312
Phase 9	72,600
Phase 10	56,467
C&D Landfill Units	
Area 1	35,816
Area 2	50,981

TABLE 2.8
SOIL SUMMARY

Material	Quantity (CY)
Excavation	1,009,867
Structural Fill	(528,102)
Soil Liner	(282,253)
LCS/Protective Cover[1]	(417,208)
Daily/Intermediate Cover	(2,619,507)
Vegetative Soil Layer	(585,963)
Total[2]:	(3,423,166)

Notes:

1. A portion of this material will come from off-site sources.
2. Soil deficit shown will be made up from off-site sources.

SECTION 3.0
GEOSYNTHETICS DESIGN

3.1 OVERVIEW

This section addresses the design and selection of the geosynthetics to be incorporated into Area 2. The geosynthetic requirements are outlined in detail in the Project Specifications (**Attachment B**) and Project Drawings (**Attachment G**).

3.2 GEOSYNTHETIC COMPONENTS AND DESIGN PARAMETERS

3.2.1 Geosynthetic Clay Liner (GCL)

A GCL will be used as a barrier layer in the Type 2 base liner system. The selected material for the GCL will consist of a layer of sodium bentonite bonded between two geotextiles. The selected GCL will provide a maximum hydrated permeability of 5×10^{-9} cm/sec and will be reinforced to prevent potential shearing in the bentonite layer. The GCL also offers the addition of self healing capabilities, there is no required seaming, and the bentonite has a high cation exchange rate.

3.2.2 Base Geomembrane

The selected material for the base geomembrane is 40 mil thick textured Linear Low Density Polyethylene (LLDPE). The particular product to be installed will be approved for use in the facility prior to construction.

The design of Area 2 as well as its construction and CQA procedures are all intended to reduce unusually high puncture, impact, or tearing stresses on the geomembrane. Due to the selection of textured LLDPE geomembrane on facility side slopes, all interface friction angles for geosynthetics are expected to be greater than the 3H:1V side slope angle. Thus, negligible stresses will be placed on geosynthetics and the system will be stable. In addition, **Attachment F** includes an analysis which demonstrate that the anticipated tensile stresses in the liner system due to settlement of underlying subgrade will be minimal.

The anchor trench size (i.e. depth and width) was selected to allow pullout of the geomembrane before the yield stress is achieved (see calculations in **Appendix A**). In this way, the anchor trench provides sufficient resistance to prevent pullout during anticipated loading conditions. Large scale yielding or tearing of the geomembrane is, however, prevented under extreme loading conditions since the geomembrane is designed to pull out of the anchor trench rather than yield.

3.2.3 Drainage Geocomposite

The drainage geocomposite will consist of a polyethylene drainage net (geonet) bonded on both sides with a nonwoven, needle-punched geotextile. This material will be used in the LCS of the base liner system (landfill base and side slopes) and in the final cover system (pore pressure reduction layer).

The Project Specifications (**Attachment B**) require a minimum transmissivity of 7.5 x 10^{-4} m^3/m/sec and 1 x 10^{-3} m^3/m/sec for the base liner and final cover systems, respectively, which account for long-term reduction factors and an overall factor of safety. **Appendix A** contains an analysis of the drainage geocomposite to be used in the LCS (see Leachate Collection Pipe Spacing calculations) and final cover drainage layer.

3.2.4 Separator (Type GT-S) Geotextile

A nonwoven separator (Type GT-S) geotextile (optionally a woven geotextile) will be used as a separator in several applications. A Type GT-S geotextile will be used as a separator between leachate collection media and soil protective cover (where used), in facility roadways, and in some erosion control applications. This geotextile will be selected to minimize soil migration while allowing free flow of water.

The geotextiles to be incorporated into the construction of Area 2 that function as separators were evaluated for particle loss potential using conservative filter/retention matching criteria. The geotextile must prevent large scale migration of soil particles into the underlying drainage media while at the same time not clogging. Separator criteria were applied to geotextiles that protect the natural or geosynthetic drainage media from the soil protective cover (or vegetative soil layer in the final cover system). Calculations presented in **Appendix A** indicate a very low soil loss potential exists for the geotextile between drainage media and soil protective cover. Due to the low hydraulic head requirement of the Area 2 design, high gradients within the leachate collection system (LCS) are improbable (likewise in the final cover system). The specified opening size of the separator geotextile selected is considered adequate to provide protection against excessive soil piping.

3.2.5 Geosynthetic Rain Cover (GRC)

The GRC will consist of a thin geomembrane. The GRC will be used at the option of the County to prevent stormwater infiltration through the protective cover and the gravel columns of the LCS in inactive cells. Where used, the GRC will be removed by operations personnel prior to activation of an individual disposal area or portion thereof.

3.2.6 Final Cover Geomembrane

A geomembrane will be used as the barrier layer in the final cover system. The selected material for the final cover geomembrane is a 30 mil thick textured Linear Low Density Polyethylene (LLDPE) geomembrane. The particular product to be installed will be approved for use in the facility prior to construction.

SECTION 4.0
LEACHATE MANAGEMENT SYSTEM DESIGN

4.1 OVERVIEW

The leachate management system for the proposed landfill consists of the leachate collection system (LCS), the leachate discharge piping, pumps, valves, and leachate storage lagoon. The LCS consists of natural and/or geosynthetic drainage media on the base and side slopes of the landfill as well as a collection pipe network and a sump with side riser pumps. All major collection/discharge piping of the Area 2 leachate management system will be high density polyethylene (HDPE) piping. HDPE piping was selected due to its favorable behavior when exposed to a variety of chemical leachates and its ability to be welded together to create a leak-free conduit (solid wall piping).

This section addresses the hydraulic and mechanical design of the leachate management system. Each of the major components of the system are covered separately.

4.2 LEACHATE COLLECTION SYSTEM (LCS)

The LCS will be constructed directly above the geomembrane on both the base and side slopes of the landfill. Components of the LCS will be as follows:

- a drainage geocomposite; and
- a 24-inch thick layer of protective cover soil.

Also part of the LCS is a series of perforated collection pipes. Collection pipes have coarse aggregate placed over and around them and are referred to as "gravel columns" (see **Drawing S5** (Area 2 - Composite Liner Grading and Leachate Collection System Plan)). These gravel columns provide a significant amount of storage, provide primary leachate removal capacity, and are designed to be resistant to biological clogging. Since the gravel column aggregate extends through the protective cover and is in direct contact with the waste (no geotextile is placed between the waste and gravel), the long-term clogging potential is significantly reduced. Cleanout ports are provided, where possible, at the end of leachate collection piping along the perimeter berm to allow periodic hydro-washing of the piping when necessary.

The collection piping of the LCS conducts the leachate to the sumps for the removal from the landfill by side riser pumps. Sumps are filled with coarse aggregate in order to maximize storage and fluid removal rates. From the sumps, the leachate will be pumped to the leachate storage lagoon via an HDPE force main.

4.2.1 <u>LCS Pipe Spacing</u>

Spacing of the LCS collection pipes is selected to ensure that the maximum hydraulic head on the base geomembrane is less than 1 foot during normal operating conditions. The analysis (see **Appendix A**) was conducted using McEnroe's mounding equations.

For this analysis, an impingement rate equal to the assumed average daily flow under active conditions (1,200 gallons/acre/day) was used (Note that this is a higher value than predicted by the HELP Model.). The analysis conservatively includes reduction factors for intrusion, creep deformation, chemical clogging, and biological clogging plus an overall factor of safety.

Assuming a maximum allowable leachate head of 1 foot, various bottom slopes, and actual pipe spacings, it was determined that all conditions will produce less than 1 foot of hydraulic head on the base geomembrane (Note that for the drainage geocomposite actual maximum heads will remain within the thickness of the geonet drainage core << 1 foot).

Based on the pipe spacing calculations, a minimum transmissivity of 7.5×10^{-4} $m^3/m/sec$ was selected for the drainage geocomposite component of the LCS.

4.2.2 LCS Pipe Sizing

The capacity of LCS piping was evaluated by comparing the maximum capacity of a 6-inch pipe diameter with the peak daily leachate generation rate (14,000 gallons/acre/day) (see **Attachment C**). Based on this evaluation, either a 6-inch diameter HDPE (SDR 17) (I.D. = 5.8-inches) will handle a maximum drainage area of 17 acres with a factor of safety of 2.0. This maximum drainage area exceeds the maximum drainage area to be drained by any one pipe.

4.2.3 LCS Pipe Mechanical Properties

The LCS collection pipes will be perforated HDPE pipe. The required pipe standard dimension ratio (SDR) (ratio of outside pipe diameter to wall thickness) was selected based upon anticipated static and dynamic load conditions both during and after construction. Both the static and dynamic criteria are discussed briefly below. Pipe stress analyses for HDPE pipe are presented in **Appendix A**.

4.2.3.1 Static Load Requirement

The vertical stress applied by the fully constructed landfill, including waste and final cover, was used to calculate the required SDR. Calculations were performed for both crushing and buckling.

The analyses for static loading were performed using the highest normal compressive stress computed for the facility (approximately 73 psi assuming a maximum waste/cover thickness of $\pm$150 feet and a waste density of 70 pcf). The selected SDR of 17 has a factor of safety greater than 2.0 for both crushing and buckling under maximum static loading conditions.

4.2.3.2 Equipment Loading (Dynamic Load Requirement)

During construction of the LCS, it may be necessary for certain construction equipment to operate over the pipe while the LCS is being placed. Under this worst case condition, a dynamic impact factor of 1.5 was used to account for equipment loading. Under no circumstances should tracked vehicles allowed to turn when operating over the pipe.

For analysis, typical construction and operations equipment were selected for calculation of dynamic crushing loads.

On the basis of the selected SDR, the following equipment limitations will be employed:

- Placement of the protective cover and No. 57 stone (18 inch minimum cover (including gravel column) over LCS piping) - low ground pressure (LGP) equipment only.
- Placement of initial lift of waste (with 3 foot minimum cover (including gravel column) over LCS piping) - no equipment limitations.

4.3 LEACHATE DISCHARGE AND STORAGE SYSTEM

Leachate from the Area 2 LCS is collected in the leachate sump as shown on **Drawing S7** (Leachate Forcemain Plan and Profile). The leachate collected in the sump is pumped to the leachate storage lagoon via a HDPE forcemain.

4.4.1 Leachate Sump

The typical sump and side riser layout is shown on **Drawing LM2** (Leachate Management System Details - Sheet 2 of 3). As designed, each sump has a storage capacity of over 2,000 gallons (accounting for 30% porosity in the stone). Two side riser pumps will be used in the leachate sump. The pumps selected for this application will be rated at a minimum flow of 75 to 100 gpm. The pumps and control system will include alarms for power outage, high level, and no-flow conditions. A flow meter will be included to monitor leachate production. During normal operations, the pumps will alternate to reduce wear on one particular pump. Under high flow conditions, both pumps will operate in tandem to keep the head on the liner system to a minimum.

4.3.2 Leachate Discharge Piping

The leachate discharge piping consists of HDPE (SDR 17) pipe. The required pipe SDR was selected as described above for the LCS based upon the maximum static and dynamic loading conditions to be placed on the pipe. Pipe stress analyses for HDPE pipe are presented in **Appendix A.**

4.3.3 Leachate Storage Lagoon

Leachate from Area is routed to the existing leachate storage lagoon which has a capacity of approximately 4,300,000 gallons (not including 2 feet of freeboard). The leachate storage lagoon is lined with a composite liner system consisting of 24 inches of compacted clay liner ($k \leq 1 \times 10^{-7}$ cm/sec) overlain by a 60 mil HDPE geomembrane and a 6 inch Fabri-Form concrete liner. The lagoon drains to an existing pump station. From this pump station, the leachate is either pumped back to the leachate recirculation system injection trenches in Phase 5 or pumped via a 4 inch PVC forcemain to a local wastewater treatment plant (WWTP) owned and operated by Johnston County.

4.4 LEACHATE PRETREATMENT

Pretreatment of the leachate may be required in order to discharge to the local WWTP. Experience with new lined landfills indicates that leachate pretreatment is generally not required during the initial three plus years of landfill operations. The majority of the leachate generated during this time comes from precipitation that has had little contact with waste. Under these conditions, the only pretreatment that may be required is pH buffering by addition of lime.

As the landfill becomes mature, the concentrations of constituents in the leachate will increase - although the leachate volume may decrease with time. At this point the County may add a pretreatment system if required by the WWTP. As future flow volumes and quality dictates, additional units can easily be added to the pretreatment system.

It should be noted that as Federal and State mandated waste screening and prohibition is continued (e.g. for lead acid batteries, household hazardous waste, etc.) the impact on leachate quality is expected to reduce the future potential need for pretreatment.

4.5 LEACHATE GENERATION

The leachate management system for Area 2 has been designed to minimize head on the liner system and to maximize effective operations. The leachate generation rate for the landfill is heavily dependent on the following:

- Design storm event(s);
- Amount of waste in the cell; and
- Method of landfill operations.

An evaluation of leachate generation rates was performed to estimate flow rates during active, interim, and closed conditions (see **Appendix A**). The Hydrologic Evaluation of Landfill Performance (HELP) Model (version 3.07) was used to confirm the volume of leachate anticipated during these three discrete phases. It was found that the HELP Model values were similar or somewhat lower than empirical generation rates for these conditions which are based upon actual data. Thus, the empirical rates were applied to the proposed operational conditions to yield leachate generation rates for various stages of landfill development.

In order to determine typical leachate flow rates, empirical daily leachate generation values of 1,200 gallons per acre per day (gpapd) for active, 500 gpapd for interim, and 100 gpapd for final were applied to the proposed operational scenarios. Each operational scenario is basically a "snapshot" developed to depict the typical combination of areas which are being operated, under active, interim, and final cases.

In order to simulate a “surge” volume, the precipitation event of 3.2 inches for a 1-year, 24-hour storm was applied over up to a three acre open area of the landfill and added to the leachate being produced under active, interim, and final conditions. The 1-year recurrence interval was selected since it is a conservative representation of the timeframe that an area will be open and only partially filled across the bottom. As shown by the calculations, the flow rate with the 1-year, 24-hour storm event is estimated at approximately 300,000 gallons. This should be considered as a "worst case" scenario. Once covered by waste, the potential for a “surge” event in the landfill is essentially eliminated due to the ability of the waste to absorb and slowly release precipitation. The more typical flow rate for Area 2 operations is anticipated to be less than 50,000 gallons per day (includes flow from Phase 4A and Phase 5).

The ability to prevent ponding in the landfill rests on the ability to hold leachate in the storage lagoon. As noted above, the capacity of the storage lagoon is approximately 4,300,000 gallons, which is much greater than the total volume of leachate that can be generated by the “surge” event. This means that little to no ponding of leachate will occur in the landfill when the lagoon can handle the entire design storm.

In order to minimize the ponding potential in the landfill, the County will remove leachate from the storage lagoon at a rate to maintain a typical volume of 3,000,000 gallons (approximate 6 foot depth), or less, of leachate in the lagoon until all areas are covered by waste.

SECTION 5.0
FINAL COVER SYSTEM DESIGN

5.1 OVERVIEW

This section addresses the design of the final cover system for the proposed Area 2 landfill unit. The final cover incorporates a landfill gas (LFG) management system, a barrier system, surface water infiltration/pore pressure reduction layer, and a vegetative soil layer.

Technical specifications and CQA requirements for final cover system components are included in **Attachments B and C**, respectively. Slope stability calculations for the final cover veneer are presented in **Attachment F**.

5.2 DESCRIPTION OF COMPONENTS

The main functions of the final cover are:

- Minimize infiltration into the waste.
- Function with a minimum of maintenance over the life of the landfill.

Each component is described below. Refer to **Drawings FC1, FC2, and FC3** which display the final cover grades for Area 2 and typical final cover details which illustrate the final cover components.

5.2.1 Intermediate Cover

The intermediate cover is a nominal 1 foot thick layer of soil that is placed over waste that has been filled to proposed finished grades. This cover layer separates the waste from and provides a foundation for the overlying geosynthetics. The intermediate cover will be placed by the landfill operator and will consist of on-site or imported soils. The intermediate cover will also be used for leveling or fine grading or for bridging of localized soft areas, as required.

5.2.2 Landfill Gas (LFG) Management System

Due to the limited amount of LFG expected from the C&D waste, no LFG control features are planned as part of the Area 2 final cover system.

5.2.3 Final Cover Geomembrane

The function of the final cover geomembrane is to prevent any water that infiltrates through the overlying vegetative soil layer from entering the waste and producing leachate. A 30 mil thick textured LLDPE geomembrane has been selected for this application. The design of Area 2 provides for a minimum of penetrations through the geomembrane. The only required penetrations are for the surface water management system (down pipes).

5.2.4 Drainage Geocomposite

A layer of drainage geocomposite overlies the final cover geomembrane. The function of this layer is to conduct infiltration through the vegetative soil layer to the surface water drainage features (i.e. side slope swales, down pipes, and perimeter channels) and, thus, reduce the head on the final cover geomembrane. The selected drainage geocomposite will have adequate transmissivity to handle the expected flows (see calculations in **Appendix A**).

5.2.5 Vegetative Soil Layer

The vegetative soil layer consists of 2 feet of on-site or imported soil with at least 6 inches of topsoil. This layer functions to provide support for vegetation while undergoing a minimum of erosion. This layer will also provide protection against puncture and freezing of the underlying geosynthetics.

5.2.6 Surface Water Control Devices

Surface water runoff and its associated erosion are controlled in the final cover by a system of drainage breaks (rain gutters) that limit the distance the water flows and collects the water for conveyance (via down pipes) to one of the sediment basins. Final cover drainage devices were designed based on the peak runoff from a 50-year storm. Further descriptions and calculations related to the sizing of this system are provided in **Appendix A** and in the Project Erosion and Sedimentation Control Plan (**Attachment E**).

SECTION 6.0
LOCAL GOVERNMENT APPROVAL

6.1 OVERVIEW

The approval of the Area 2 C&D landfill unit as well as the addition and modification of proposed MSW landfill units to the landfill facility plan represent a significant change in the capacity of the landfill facility. Thus, local government approval is required.

6.2 DOCUMENTATION

Documentation of the County's enabling approvals are presented in **Appendix B**. This documentation includes the following information:

Public Meeting Information:

- Copy and documentation of Legal Advertisement of Public Meeting
- Copy of Resolution
- Minutes of Public Meeting

Letter Demonstrating Consistency with Zoning Ordinances:

- Letter from the Johnston County Planning Department

Letter Demonstrating Consistency with the City's Solid Waste Management Plan:

- Letter from the Johnston County Department of Public Utilities

Appendix A

Landfill Design Calculations

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

FACILITY AND ENGINEERING PLAN
APPENDIX A: LANDFILL DESIGN CALCULATIONS

TABLE OF CONTENTS

Objective To determine the volumes of existing landfill units.

Assumptions
1. Density of Waste.
2. Waste to Periodic Cover (i.e. daily and intermediate) Ratio.

Analysis The volume will be calculated by taking cross sections of the landfill, using a planimeter to measure the area of the cross sections, and using the average end area method. Alternatively, AutoCAD will be used to generate volumes.

EXISTING LF VOLUMES.WPD

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SHEET: 2, 10
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County Landfill
Analysis of Existing Landfill Volumes

Disposal Area	Area (Acres)	Total Gross Capacity (CY)	Total Net Capacity (CY)	Total Net Capacity (Tons)	Comment
Unlined MSW Landfill Units					
Phase 1/2 (Closed)	22.1	732,363	495,790	297,474	See Attached
Phase 3 (Closed)	25.4	1,174,139	819,136	491,482	See Attached
Phase 4 (Closed)	37.3	1,631,731	1,133,533	680,120	See Attached
Total (Unlined MSW)	84.8	3,538,233	2448459	1469076	
Lined MSW Landfill Units					
Phase 5 (Inactive)	19.2	1,087,199	884,625	514,181	See Attached
Phase 4A (Cell 1) (Active) (See Note 1)	16.0	512,862	435,933	228,378	See Attached
Total (Lined MSW)	35.2	1,600,061	1,320,558	742,559	
C&D Landfill Units					
Area 1 (Vertical Expn.) (Active) (See Note 1)	16.2	391,981	352,783	213,168	See Attached
Total (C&D)	16.2	391,981	352,783	213,168	

Notes:
1. In-place volumes as of March 21, 2005.

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET:	2/31
JOB #:	JOHNSTON-9
DATE:	11/3/99
BY:	PKS
CHKD BY:	GMR

Johnston County Landfill - Phases 1/2
Existing Volume/Tonnage

Waste Parameters:

Unit Weight (pcy) =	1200	(Assumed)
Unit Weight (tcy) =	0.6	
Percentage of Periodic Cover =	25	(Assumed)
Area of Waste Footprint (Ac.) =	22.1	

Volume Calculations:

Cross Section	Separation (ft)	Area Fill (sf)	Volume Fill (cy)
0		0	
	160		45511
A		15360	
	200		134111
B		20850	
	200		165889
C		23940	
	200		185815
D		26230	
	200		144519
E		12790	
	200		54407
F		1900	
	60		2111
0		0	

FILL = 732,363 cy

Adjustment For Other Layers:

2 feet of Final Cover = 71309 cy

Sum = 71,309 cy

Volume of Waste and Periodic Cover In-Place (cy) = 661,054

Volume of Periodic Cover In-Place (cy) = 165,263

Volume of Waste In-Place (cy) = 495,790

Waste Tonnage In-Place (Tons) = 297,474

EXISTING LF VOLUMES.WB3(1)

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 3/31
JOB #: JOHNSTON-9
DATE: 11/3/99
BY: PKS
CHKD BY: GNR

Johnston County Landfill - Phase 3
Existing Volume/Tonnage

Waste Parameters:

Unit Weight (pcy) =	1200	(Assumed)
Unit Weight (tcy) =	0.6	✓
Percentage of Periodic Cover =	25	(Assumed)
Area of Waste Footprint (Ac.) =	25.4	

Volume Calculations:

Cross Section	Separation (ft)	Area Fill (sf)	Volume Fill (cy)
0		0	
	200		0
A		0	
	200		42852
B		11570	
	200		101148
C		15740	
	200		138556
D		21670	
	200		153852
E		19870	
	200		132630
F		15940	
	200		124519
G		17680	
	200		146963
H		22000	
	200		171407
I		24280	
	200		120685
J		8305	
	60		9228
0		0	
Additional 5 feet (Avg.)			32300
		FILL =	1,174,139 cy

Adjustment For Other Layers:

2 feet of Final Cover =	81957 cy
Sum =	81,957 cy

Volume of Waste and Periodic Cover In-Place (cy) =	1,092,182
Volume of Periodic Cover In-Place (cy) =	273,045
Volume of Waste In-Place (cy) =	$\boxed{819,136}$
Waste Tonnage In-Place (Tons) =	$\boxed{491,482}$

G.N. Richardson & Associates

ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 4/31
JOB #: JOHNSTON-9
DATE: 11/3/99
BY: PKS
CHKD BY: GNR

Johnston County Landfill - Phase 4
Existing Volume/Tonnage

Waste Parameters:

Unit Weight (pcy) =	1200	(Assumed)
Unit Weight (tcy) =	0.6	
Percentage of Periodic Cover =	25	(Assumed)
Area of Waste Footprint (Ac.) =	37.3	

Volume Calculations:

Cross Section	Separation (ft)	Area Fill (sf)	Volume Fill (cy)
0		0	
	140		18796
A		7250	
	200		97704
B		19130	
	200		176667
C		28570	
	200		218074
D		30310	
	200		224407
E		30280	
	200		208667
F		26060	
	200		183815
G		23570	
	200		171000
H		22600	
	200		152778
I		18650	
	200		121926
J		14270	
	200		56889
K		1090	
	50		1009
0		0	

FILL = 1,631,731 cy

Adjustment For Other Layers:

2 feet of Final Cover = 120355 cy

Sum = 120,355 cy

Volume of Waste and Periodic Cover In-Place (cy) = 1,511,377

Volume of Periodic Cover In-Place (cy) = 377,844

Volume of Waste In-Place (cy) = 1,133,533

Waste Tonnage In-Place (Tons) = 680,120

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ENGINEERING AND GEOLOGICAL SERVICES

SHEET: 1 / 2
JOB #: JOHNSTON-2
DATE: 7/15/03
BY: PKS
CHKD BY:

Johnston County MSW Landfill - Phase 5
Analysis of Waste Density

Input Parameters:

Percentage of Periodic Cover =	15	(Assumed)
Area of Waste Footprint (Ac.) =	19.2	
Quantity of Waste In-Place (Tons) =	514,181	(Per Scale Records Through 6/4/03)

Volume Calculations:

Volume (Gross) From AutoCAD =	1,087,199	cy	(See Attached) (6/4/03 vs. 1997)

Adjustment For Other Layers:

1.5 feet of Intermediate Cover =	46,464	cy
Sum =	46,464	cy

Volume of Waste and Periodic Cover (cy) =	1,040,735
Volume of Periodic Cover (cy) =	156,110
Volume (Net) of Waste (cy) =	884,625
Waste Density (tons/cy) =	0.581
Waste Density (lbs/cy) =	$\boxed{1,162}$

7/10
2/2

volume-report-070303.txt

Johnston County Phase 5 Airspace

Project: LAND PROJECTS Thu July 03 17:15:06 2003

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: PHASE 5 AIRSPACE				
Stratum: PHASE 5 ~~BASE~~ Protective Cover GRADES TO 061603 SURVEY				
	19	1,087,218	1,087,199 (F)	Composite

514,181.45 Tons

– Subtract 18" Int. Cov.

– Subtract ≈ 15% Cover

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SHEET: 8/10
JOB #: JOHNSTON-26
DATE: 7/27/05
BY: PKS
CHKD BY:

Johnston County MSW Landfill - Phase 4A (Cells 1 & 2)
Volume Study: Filling Rate & Density Calculations

Density and Filling Rate Calculations:

Start Date	Period of Interest End Date	Total Time (years)	Volume Filled (cy)	Quantity of Waste Disposed (tons)	Waste Filling Rate* (lbs/cy)	Periodic Cover Assumed %	Periodic Cover Volume (cy)	Waste Volume (cy)	Waste Density** (lbs/cy)
1/9/2003	5/21/2004	1.36	312,843	139,098	**889**	15	46,926	265,917	**1,046**
5/22/2004	3/21/2005	0.83	200,019	89,280	**893**	15	30,003	170,016	**1,050**
			Σ= 512,862	228,378				Σ=435,933	Avg. = **1,048**

Notes:
*Waste Filling Rate = (Tons of Waste Disposed)/(Volume Filled).
**Waste Density = (Tons of Waste Disposed)/(Volume Filled - Volume of Periodic Cover).

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SHEET: 9, 10
JOB #: JOHNSTON-26
DATE: 7/27/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 1 (Vertical Expn.)
Volume Study: Filling Rate & Density Calculations

Density and Filling Rate Calculations:

Start Date	Period of Interest End Date	Total Time (years)	Volume Filled (cy)	Quantity of Waste Disposed (tons)	Waste Filling Rate* (lbs/cy)	Periodic Cover Assumed %	Periodic Cover Volume (cy)	Waste Volume (cy)	Waste Density** (lbs/cy)
4/1/1999	5/21/2004	5.14	343,193	187,514	**1,093**	10	34,319	308,874	**1,214**
5/22/2004	3/21/2005	0.83	48,788	25,654	**1,052**	10	4,879	43,909	**1,169**
			Σ = 391,981	213,168				Σ = 352,783	Avg. = 1,191

Notes:
*Waste Filling Rate = (Tons of Waste Disposed)/(Volume Filled).
**Waste Density = (Tons of Waste Disposed)/(Volume Filled - Volume of Periodic Cover).

10/10

volume report 072405.txt

Johnston County Landfill

Project: land projects Sun July 24 22:47:25 2005

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method

==

Site: AIRSPACE CHANGED AREAS

MSW area volume represents latest aerial topo (I didn't know the ~~date~~ 3/21/05) vs. the 052104 topo with phase 4A cell 2 grades pasted in.

If you look at the isopach, a lot of the cut occurs around the perimeter of cell 2. As expected, the majority of the fill is in cell 1.

Stratum: msw area topo-052104-cell2-paste survey-msw-area

	12,817	200,019	187,202 (F)	Composite

Ignore Cut

MSW remaining represents latest survey vs. phase 4A fill sequence 2, (shown in figure 2).

Stratum: msw area remaining topo-052104-changed-areas-paste phase4a-fill-seq-3

	4,852	597,179	592,327 (F)	Composite

C&D area volume represents the two dates, latest (date unknown) vs. 052104.

The C&D volume is straight forward, fill is on top and west side.

Stratum: cd area topo-052104-cell2-paste survey-cd-area

	1,282	50,070	48,788 (F)	Composite

CD remaining represents latest survey vs. final cover grades, (shown in figure 2)

Stratum: cd area remaining topo-052104-changed-areas-paste cd-fcvr-120503

	7149	187902	180753 (F)	Composite

PROJECT	Johnston County C&D Landfill - Area 2	SHEET	1 OF 19
		JOB NO.	JOHNSTON-22
		DATE	7/14/05
SUBJECT	Landfill Life Expectancy	COMPUTED BY	PKS
		CHECKED BY	

Objective To determine the expected life of the landfill given the proposed contours and the current loading rate.

Assumptions
1. Density of Waste.
2. Waste to Periodic Cover (i.e. daily and intermediate) Ratio.

Analysis The volume will be calculated by taking cross sections of the landfill, using a planimeter to measure the area of the cross sections, and using the average end area method. Alternatively, AutoCAD will be used to generate volumes.

LIFE.WPD

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SHEET: 2/19
JOB #: JOHNSTON-22
DATE: 5/18/05
BY: PKS
CHKD BY:

Johnston County Landfill
Summary of Capacity/Life Expectancy

Landfill Unit	Area (Acres)	Gross Capacity (CY)	Net (Waste) Capacity		Life Expectancy (Years) (Min/Max)	
			(CY)	(Tons)		
Unlined MSW Landfill Units						
Phase 1/2 (Closed)	22.1	732,363	495,790	297,474	Closed	
Phase 3 (Closed)	25.4	1,174,139	819,136	491,482	Closed	
Phase 4 (Closed)	37.3	1,631,731	1,133,533	680,120	Closed	
Total (Unlined MSW)	84.8	3,538,233	2,448,459	1,469,076	Closed	
Lined MSW Landfill Units						
Phase 5 (Inactive)	19.2	1,087,199	884,625	514,181	Inactive	
Phase 4A (Cells 1 & 2) (Active) (See Note 1)	22.0	1,086,783	923,766	521,078	1.6	2.6
Phase 4A (Cell 3)	7.4	1,426,682	1,117,815	782,471	2.8	6.1
Phase 6	21.1	1,402,016	1,163,319	697,992	2.5	4.8
Phase 7	19.8	1,758,991	1,456,422	873,853	3.0	5.3
Phase 8	25.2	1,844,867	1,482,308	889,385	2.9	4.8
Phase 9	22.5	6,684,914	5,599,252	3,919,476	11.8	17.2
Phase 10	17.5	3,075,968	2,508,093	1,755,665	4.8	5.5
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
C&D Landfill Units						
Area 1 (Vertical Expn.) (Active) (See Note 1)	16.2	572,734	479,645	289,285	2.0	2.4
Area 2 - Cell 1	11.3	451,611	389,897	233,938	5.5	6.4
Area 2 - Cell 2	4.5	462,658	387,062	232,237	4.4	5.4
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

Notes:
1. Life Expectancy as of March 21, 2005.

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SHEET: 3 / 19
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 4A (Cells 1&2)
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200 (From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60
Percentage of Periodic Cover =	15

Volume Calculations:

Volume From AutoCAD (cy) = 573,921

Gross Volume (Top of Protective Cover to Top of Intermediate Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	22.0
0 feet	Compacted Soil Liner =	0 cy
0 feet	LCS/Protective Cover =	0 cy
	Sum =	0 cy
	Gross Volume (cy) =	573,921

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	0
2 feet	Vegetative Soil Layer =	0 cy
	Sum =	0 cy
	Volume of Periodic Cover (cy) =	86,088
	Net (Waste) Volume (cy) =	487,833
	Net (Waste) Volume (tons) =	292,700

Life:

County Only:
Start = 2005.2

$87{,}001\ (=.8 \times 2005) + 112{,}169\ (2006) + \frac{93{,}530}{115{,}648}\ (2007)$

$\Rightarrow 2007.8\ (= 2.6\ \text{YRS})$

+500 TPD:
Start = 2005.2

$87{,}001\ (=.8 \times 2005) + \frac{205{,}699}{268{,}168}\ (2006)$

$\Rightarrow 2006.8\ (= 1.6\ \text{YRS})$

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SHEET: 4/19
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 4A (Cell 3)
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,400	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 1,450,559

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	7.4
0 feet	Compacted Soil Liner =	0 cy
2 feet	LCS/Protective Cover =	23,877 cy
	Sum =	23,877 cy

Gross Volume (cy) = $\boxed{1,426,682}$

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	29.4 (Cells 1-3)
2 feet	Vegetative Soil Layer =	94,864 cy
	Sum =	94,864 cy

Volume of Periodic Cover (cy) = 214,002

Net (Waste) Volume (cy) = $\boxed{1,117,815}$

Net (Waste) Volume (tons) = $\boxed{782,471}$

Life:

County Only:
Start=2007.8

22,118 (2007) + 630,901 (2008-2012) + $\frac{129,452}{136,440}$ (2013)

⇒ 2013.9 (=6.1 YRS.)

+500 TPD:
Start=2006.8

62,469 (2006) + 546,830 (2007-2008) + $\frac{173,172}{278,782}$ (2009)

⇒ 2009.6 (2.8 YRS.)

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SHEET: 5 / 19
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 6
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 1,521,161

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	21.1	
1.5 feet	Compacted Soil Liner =	51,062	cy
2 feet	LCS/Protective Cover =	68,083	cy
	Sum =	119,145	cy
	Gross Volume (cy) =	**1,402,016**	

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	8.8	
2 feet	Vegetative Soil Layer =	28,395	cy
	Sum =	28,395	cy
	Volume of Periodic Cover (cy) =	210,302	
	Net (Waste) Volume (cy) =	**1,163,319**	
	Net (Waste) Volume (tons) =	**697,992**	

Life:

County Only:
Start = 2013.9

6,988 (2013) + 582,115 (2014 - 2017) + $\frac{108,889}{155,050}$ (2018)

⇒ 2018.7 (4.8 YRS.)

+500 TPD:
Start = 2009.6

105,610 (2009) + 567,951 (2010 - 2011) + $\frac{24,431}{288,986}$ (2012)

⇒ 2012.1 (2.5 YRS.)

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Johnston County Landfill - MSW Phase 7
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 1,870,795

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	19.8
1.5 feet	Compacted Soil Liner =	47,916 cy
2 feet	LCS/Protective Cover =	63,888 cy
	Sum =	111,804 cy
	Gross Volume (cy) =	1,758,991

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	12.0
2 feet	Vegetative Soil Layer =	38,720 cy
	Sum =	38,720 cy
	Volume of Periodic Cover (cy) =	263,849
	Net (Waste) Volume (cy) =	1,456,422
	Net (Waste) Volume (tons) =	873,853

Life:

County Only:
Start = 2018.7

$46{,}161\ (2018) + 659{,}313\ (2019-2022) + \frac{168{,}379}{174{,}158}\ (2023)$

$\Rightarrow$ 2024.0 (5.3 YRS.)

+500 TPD:
Start = 2012.1

$264{,}555\ (2012) + 588{,}448\ (2013-2014) + \frac{20{,}850}{299{,}650}\ (2015)$

$\Rightarrow$ 2015.1 (3.0 YRS.)

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Johnston County Landfill - MSW Phase 8
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 1,987,163

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	25.2	
1.5 feet	Compacted Soil Liner =	60,984	cy
2 feet	LCS/Protective Cover =	81,312	cy
	Sum =	142,296	cy
	Gross Volume (cy) =	1,844,867	

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	26.6	
2 feet	Vegetative Soil Layer =	85,829	cy
	Sum =	85,829	cy
	Volume of Periodic Cover (cy) =	276,730	
	Net (Waste) Volume (cy) =	1,482,308	
	Net (Waste) Volume (tons) =	889,385	

Life:

County Only
start = 2024.0

$5,779\ (2023) + 736,184\ (2024-2027) + \frac{147,422}{194,291}\ (2028)$

$\Rightarrow$ 2028.8 (4.8 YRS)

+500 TPD
Start = 2015.1

$278,800\ (2015) + 610,457\ (2016-2017) + \frac{128}{311,050}\ (2018)$

$\Rightarrow$ 2018.0 (2.9 YRS)

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Johnston County Landfill - MSW Phase 9
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,400	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 6,811,964

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	22.5
1.5 feet	Compacted Soil Liner =	54,450 cy
2 feet	LCS/Protective Cover =	72,600 cy
	Sum =	127,050 cy
	Gross Volume (cy) =	$\boxed{6{,}684{,}914}$

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	25.7
2 feet	Vegetative Soil Layer =	82,925 cy
	Sum =	82,925 cy
	Volume of Periodic Cover (cy) =	1,002,737
	Net (Waste) Volume (cy) =	$\boxed{5{,}599{,}252}$
	Net (Waste) Volume (tons) =	$\boxed{3{,}919{,}476}$

Life:

County Only:
start = 2028.8

$46{,}869\,(2028) + 3{,}869{,}797\,(2029\text{-}2045) + \frac{2810}{263{,}497}\,(2046)$

$\Rightarrow 2046.0$ (17.2 YRS.)

+500 TPD:
start = 2018.0

$310{,}922\,(2018) + 3{,}323{,}947\,(2019\text{-}2028) + \frac{284{,}607}{354{,}629}\,(2029)$

$\Rightarrow 2029.8$ (11.8 YRS.)

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Johnston County Landfill - MSW Phase 10
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,400	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.70	
Percentage of Periodic Cover =	15	

Volume Calculations:

Volume From AutoCAD (cy) = 3,174,785

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	17.5	
1.5 feet	Compacted Soil Liner =	42,350	cy
2 feet	LCS/Protective Cover =	56,467	cy
	Sum =	98,817	cy
	Gross Volume (cy) =	3,075,968	

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	33.0	
2 feet	Vegetative Soil Layer =	106,480	cy
	Sum =	106,480	cy
	Volume of Periodic Cover (cy) =	461,395	
	Net (Waste) Volume (cy) =	2,508,093	
	Net (Waste) Volume (tons) =	1,755,665	

Life:

County Only:
Start = 2046.0

$260{,}687\ (2046) + 1{,}362{,}401\ (2047-2050) + \frac{132{,}577}{286{,}335}\ (2051)$

$\Rightarrow$ 2051.5 (5.5 YRS.)

+500 TPD:
Start = 2029.8

$70{,}022\ (2029) + 1{,}452{,}376\ (2030-2033) + \frac{233{,}267}{371{,}845}\ (2034)$

$\Rightarrow$ 2034.6 (4.8 YRS.)

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Johnston County Landfill - C&D Area 1
Volume Study: Life Expectancy Calculations

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60	
Percentage of Periodic Cover =	10	

Volume Calculations:

Volume From AutoCAD (cy) = 180,753 (AutoCAD - 2005 Volume Study)

Gross Volume (Top of Protective Cover to Top of Final Cover):

Adjustment For Other Layers:

	Area of Waste Footprint (Ac.) =	16.2
0 feet	Compacted Soil Liner =	0 cy
0 feet	LCS/Protective Cover =	0 cy
	Sum =	0 cy
	Gross Volume (cy) =	180,753

Net (Waste) Volume:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	11.1
2 feet	Vegetative Soil Layer =	35,816 cy
	Sum =	35,816 cy
	Volume of Periodic Cover (cy) =	18,075
	Net (Waste) Volume (cy) =	126,862
	Net (Waste) Volume (tons) =	76,117

Life:
Start = 2005.2

AVG 24,986 (=.8×2005) + 32,215 (2006) + $\frac{18,916}{33,214}$ (2007)
⇒ 2007.6 (2.4 YRS.)

+20% 29,983 (=.8×2005) + 38,658 (2006) + $\frac{7,476}{39,856}$ (2007)
⇒ 2007.2 (2.0 YRS.)

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Johnston County Landfill
Capacity Evaluation - C&D Area 2 (Cell 1)

Waste & Periodic Cover Parameters:

Waste Density (pcy) = 1,200 (From Filling Rate and Density Calcs.)
Waste Density (tcy) = 0.60
Percentage of Periodic Cover = 10

Volume Calculations:

Volume From AutoCAD (cy) = 451,611 (Pro. Cover to Top of Cell 1 Grades) **(= Gross Capac.)**

Net (Waste) Capacity:

Adjustment For Other Layers:
Area of Final Cover (Ac.) = 5.7

2 feet Vegetative Soil Layer = (18,392) cy

Sum = (18,392) cy

Volume of Waste and Periodic Cover (cy) = 433,219

Volume of Periodic Cover (cy) = (43,322)

Net (Waste) Capacity (cy) = 389,897

Net (Waste) Capacity (tons) = 233,938

Life Expectancy Calculations:

Average:

Start Time	End Time	Tons Disposed	Total Tons	Remainder	
2007.6	2013	195,491	195,491	38,447	
2013	2013.98	38,447	233,938	0	See Waste Generation Analysis

Landfill Life Expectancy (years) = 6.4

+20 Percent:

Start Time	End Time	Tons Disposed	Total Tons	Remainder	
2007.2	2012	203,979	203,979	29,959	
2012	2012.65	29,959	233,938	0	See Waste Generation Analysis

Landfill Life Expectancy (years) = 5.5

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Johnston County Landfill
Capacity Evaluation - C&D Area 2 (Cell 2)

Waste & Periodic Cover Parameters:

Waste Density (pcy) =	1,200	(From Filling Rate and Density Calcs.)
Waste Density (tcy) =	0.60	
Percentage of Periodic Cover =	10	

Volume Calculations:

Volume From AutoCAD (cy) = 462,658 (Pro. Cover to Top of Cell 1 Grades) **(= Gross Capac.)**

Net (Waste) Capacity:

Adjustment For Other Layers:

	Area of Final Cover (Ac.) =	10.1
2 feet	Vegetative Soil Layer =	(32,589) cy
	Sum =	(32,589) cy
	Volume of Waste and Periodic Cover (cy) =	430,069
	Volume of Periodic Cover (cy) =	(43,007)
	Net (Waste) Capacity (cy) =	387,062
	Net (Waste) Capacity (tons) =	232,237

Life Expectancy Calculations:

Average:

Start Time	End Time	Tons Disposed	Total Tons	Remainder
2013.98	2014	738	738	231,499
2014	2019	212,450	213,188	19,049
2019	2019.42	19,049	232,237	0

See Waste Generation Analysis

Landfill Life Expectancy (years) = 5.4

+20 Percent:

Start Time	End Time	Tons Disposed	Total Tons	Remainder
2012.65	2013	15,873	15,873	216,364
2013	2017	211,428	227,301	4,936
2017	2017.1	4,936	232,237	0

See Waste Generation Analysis

Landfill Life Expectancy (years) = 4.4

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Johnston County Landfill
Waste Generaton Analysis - MSW (County-Only)

Per-Capita Disposal Rate (tons/person/yr.) = 0.74503 (Based on FY 2004-05 Data)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

Year	Population (See Note 1)	% Increase From Previous	Projected County Tonnage	Projected Out of County Tonnage	Projected Avg. Monthly Tonnage	Projected Monthly Variance (Min.)	Projected Monthly Variance (Max.)
2005	145,968	----	108,751	0	9,063	7,250	10,875
2006	150,557	3.14	112,169	0	9,347	7,478	11,217
2007	155,226	3.10	115,648	0	9,637	7,710	11,565
2008	159,970	3.06	119,182	0	9,932	7,945	11,918
2009	164,801	3.02	122,782	0	10,232	8,185	12,278
2010	169,566	2.89	126,332	0	10,528	8,422	12,633
2011	173,978	2.60	129,619	0	10,802	8,641	12,962
2012	178,498	2.60	132,986	0	11,082	8,866	13,299
2013	183,133	2.60	136,440	0	11,370	9,096	13,644
2014	187,923	2.62	140,008	0	11,667	9,334	14,001
2015	192,811	2.60	143,650	0	11,971	9,577	14,365
2016	197,748	2.56	147,328	0	12,277	9,822	14,733
2017	202,850	2.58	151,129	0	12,594	10,075	15,113
2018	208,113	2.59	155,050	0	12,921	10,337	15,505
2019	213,560	2.62	159,109	0	13,259	10,607	15,911
2020	218,946	2.52	163,121	0	13,593	10,875	16,312
2021	223,754	2.20	166,703	0	13,892	11,114	16,670
2022	228,689	2.21	170,380	0	14,198	11,359	17,038
2023	233,760	2.22	174,158	0	14,513	11,611	17,416
2024	239,003	2.24	178,064	0	14,839	11,871	17,806
2025	244,330	2.23	182,033	0	15,169	12,136	18,203
2026	249,653	2.18	185,999	0	15,500	12,400	18,600
2027	255,141	2.20	190,088	0	15,841	12,673	19,009
2028	260,783	2.21	194,291	0	16,191	12,953	19,429
2029	266,606	2.23	198,629	0	16,552	13,242	19,863
2030	271,075	1.68	201,959	0	16,830	13,464	20,196
2031	275,619	1.68	205,344	0	17,112	13,690	20,534
2032	280,239	1.68	208,786	0	17,399	13,919	20,879
2033	284,937	1.68	212,286	0	17,691	14,152	21,229
2034	289,713	1.68	215,845	0	17,987	14,390	21,584
2035	294,569	1.68	219,463	0	18,289	14,631	21,946
2036	299,507	1.68	223,142	0	18,595	14,876	22,314
2037	304,527	1.68	226,882	0	18,907	15,125	22,688
2038	309,632	1.68	230,685	0	19,224	15,379	23,069
2039	314,822	1.68	234,552	0	19,546	15,637	23,455
2040	320,099	1.68	238,484	0	19,874	15,899	23,848
2041	325,465	1.68	242,481	0	20,207	16,165	24,248
2042	330,921	1.68	246,546	0	20,545	16,436	24,655
2043	336,468	1.68	250,679	0	20,890	16,712	25,068
2044	342,108	1.68	254,881	0	21,240	16,992	25,488
2045	347,843	1.68	259,153	0	21,596	17,277	25,915
2046	353,673	1.68	263,497	0	21,958	17,566	26,350
2047	359,602	1.68	267,914	0	22,326	17,861	26,791
2048	365,630	1.68	272,405	0	22,700	18,160	27,241
2049	371,758	1.68	276,971	0	23,081	18,465	27,697
2050	377,990	1.68	281,614	0	23,468	18,774	28,161
2051	384,326	1.68	286,335	0	23,861	19,089	28,633
2052	390,768	1.68	291,134	0	24,261	19,409	29,113
2053	397,319	1.68	296,014	0	24,668	19,734	29,601
2054	403,979	1.68	300,976	0	25,081	20,065	30,098
2055	410,751	1.68	306,021	0	25,502	20,401	30,602

Notes:
1. Population figures and increases from 2005 to 2030 are from the NC Demographics Unit. Figures after 2030 are based on an assumed constant percentage increase from 2030 onward.

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Johnston County Landfill
Waste Generaton Analysis - MSW (+500 TPD Out of County)

Per-Capita Disposal Rate (tons/person/yr.) = 0.74503 (Based on FY 2004-05 Data)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

Year	Population (See Note 1)	% Increase From Previous	Projected County Tonnage	Projected Out of County Tonnage	Projected Total Tonnage	Projected Avg. Monthly Tonnage	Projected Monthly Variance (Min.)	Projected Monthly Variance (Max.)
2005	145,968	-----	108,751	0	108,751	9,063	7,250	10,875
2006	150,557	3.14	112,169	156,000	268,169	22,347	17,878	26,817
2007	155,226	3.10	115,648	156,000	271,648	22,637	18,110	27,165
2008	159,970	3.06	119,182	156,000	275,182	22,932	18,345	27,518
2009	164,801	3.02	122,782	156,000	278,782	23,232	18,585	27,878
2010	169,566	2.89	126,332	156,000	282,332	23,528	18,822	28,233
2011	173,978	2.60	129,619	156,000	285,619	23,802	19,041	28,562
2012	178,498	2.60	132,986	156,000	288,986	24,082	19,266	28,899
2013	183,133	2.60	136,440	156,000	292,440	24,370	19,496	29,244
2014	187,923	2.62	140,008	156,000	296,008	24,667	19,734	29,601
2015	192,811	2.60	143,650	156,000	299,650	24,971	19,977	29,965
2016	197,748	2.56	147,328	156,000	303,328	25,277	20,222	30,333
2017	202,850	2.58	151,129	156,000	307,129	25,594	20,475	30,713
2018	208,113	2.59	155,050	156,000	311,050	25,921	20,737	31,105
2019	213,560	2.62	159,109	156,000	315,109	26,259	21,007	31,511
2020	218,946	2.52	163,121	156,000	319,121	26,593	21,275	31,912
2021	223,754	2.20	166,703	156,000	322,703	26,892	21,514	32,270
2022	228,689	2.21	170,380	156,000	326,380	27,198	21,759	32,638
2023	233,760	2.22	174,158	156,000	330,158	27,513	22,011	33,016
2024	239,003	2.24	178,064	156,000	334,064	27,839	22,271	33,406
2025	244,330	2.23	182,033	156,000	338,033	28,169	22,536	33,803
2026	249,653	2.18	185,999	156,000	341,999	28,500	22,800	34,200
2027	255,141	2.20	190,088	156,000	346,088	28,841	23,073	34,609
2028	260,783	2.21	194,291	156,000	350,291	29,191	23,353	35,029
2029	266,606	2.23	198,629	156,000	354,629	29,552	23,642	35,463
2030	271,075	1.68	201,959	156,000	357,959	29,830	23,864	35,796
2031	275,619	1.68	205,344	156,000	361,344	30,112	24,090	36,134
2032	280,239	1.68	208,786	156,000	364,786	30,399	24,319	36,479
2033	284,937	1.68	212,286	156,000	368,286	30,691	24,552	36,829
2034	289,713	1.68	215,845	156,000	371,845	30,987	24,790	37,184
2035	294,569	1.68	219,463	156,000	375,463	31,289	25,031	37,546
2036	299,507	1.68	223,142	156,000	379,142	31,595	25,276	37,914
2037	304,527	1.68	226,882	156,000	382,882	31,907	25,525	38,288
2038	309,632	1.68	230,685	156,000	386,685	32,224	25,779	38,669
2039	314,822	1.68	234,552	156,000	390,552	32,546	26,037	39,055
2040	320,099	1.68	238,484	156,000	394,484	32,874	26,299	39,448
2041	325,465	1.68	242,481	156,000	398,481	33,207	26,565	39,848
2042	330,921	1.68	246,546	156,000	402,546	33,545	26,836	40,255
2043	336,468	1.68	250,679	156,000	406,679	33,890	27,112	40,668
2044	342,108	1.68	254,881	156,000	410,881	34,240	27,392	41,088
2045	347,843	1.68	259,153	156,000	415,153	34,596	27,677	41,515
2046	353,673	1.68	263,497	156,000	419,497	34,958	27,966	41,950
2047	359,602	1.68	267,914	156,000	423,914	35,326	28,261	42,391
2048	365,630	1.68	272,405	156,000	428,405	35,700	28,560	42,841
2049	371,758	1.68	276,971	156,000	432,971	36,081	28,865	43,297
2050	377,990	1.68	281,614	156,000	437,614	36,468	29,174	43,761

Notes:

1. Population figures and increases from 2005 to 2030 are from the NC Demographics Unit. Figures after 2030 are based on an assumed constant percentage increase from 2030 onward.

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Johnston County Landfill
Waste Generaton Analysis - C&D

Per-Capita Disposal Rate (tons/person/yr.) = 0.21397 (Based on FY 2004-05 Data)
Estimated Monthly Tonnage Variance (%) = 20 (Estimated by County)

Year	Population (See Note 1)	% Increase From Previous	Projected County Tonnage	Projected County Tonnage (+20%)	Projected Avg. Monthly Tonnage	Projected Monthly Variance (Min.)	Projected Monthly Variance (Max.)
2005	145,968	—	31,233	37,479	2,603	2,082	3,123
2006	150,557	3.14	32,215	38,658	2,685	2,148	3,221
2007	155,226	3.10	33,214	39,856	2,768	2,214	3,321
2008	159,970	3.06	34,229	41,075	2,852	2,282	3,423
2009	164,801	3.02	35,262	42,315	2,939	2,351	3,526
2010	169,566	2.89	36,282	43,538	3,024	2,419	3,628
2011	173,978	2.60	37,226	44,671	3,102	2,482	3,723
2012	178,498	2.60	38,193	45,832	3,183	2,546	3,819
2013	183,133	2.60	39,185	47,022	3,265	2,612	3,918
2014	187,923	2.62	40,210	48,252	3,351	2,681	4,021
2015	192,811	2.60	41,256	49,507	3,438	2,750	4,126
2016	197,748	2.56	42,312	50,775	3,526	2,821	4,231
2017	202,850	2.58	43,404	52,085	3,617	2,894	4,340
2018	208,113	2.59	44,530	53,436	3,711	2,969	4,453
2019	213,560	2.62	45,695	54,835	3,808	3,046	4,570
2020	218,946	2.52	46,848	56,217	3,904	3,123	4,685
2021	223,754	2.20	47,877	57,452	3,990	3,192	4,788
2022	228,689	2.21	48,933	58,719	4,078	3,262	4,893
2023	233,760	2.22	50,018	60,021	4,168	3,335	5,002
2024	239,003	2.24	51,139	61,367	4,262	3,409	5,114
2025	244,330	2.23	52,279	62,735	4,357	3,485	5,228
2026	249,653	2.18	53,418	64,102	4,452	3,561	5,342
2027	255,141	2.20	54,593	65,511	4,549	3,640	5,459
2028	260,783	2.21	55,800	66,960	4,650	3,720	5,580
2029	266,606	2.23	57,046	68,455	4,754	3,803	5,705
2030	271,075	1.68	58,002	69,602	4,833	3,867	5,800
2031	275,619	1.68	58,974	70,769	4,915	3,932	5,897
2032	280,239	1.68	59,963	71,955	4,997	3,998	5,996
2033	284,937	1.68	60,968	73,161	5,081	4,065	6,097
2034	289,713	1.68	61,990	74,388	5,166	4,133	6,199
2035	294,569	1.68	63,029	75,635	5,252	4,202	6,303

Notes:
1. Population figures and increases from 2005 to 2030 are from the NC Demographics Unit. Figures after 2030 are based on an assumed constant percentage increase from 2030 onward.

16/A

volume report 100505.txt

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method

Site: PHASE 4A

Cut/Fill

Stratum: paste topo msw to ph4a cell3 sgrd topo-msw-052104-cd-paste phase4a-cell3-sgrd

	362	3,275	2,913 (F)	Composite

Stratum: topo 0605 to ph4a cell ~~1-2 i~~cvr topo-060205 ph4a-cell1-2-icvr

	4,729 Perimeter-Isnag	573,921 Remainder cells 1&2	569,192 (F)	Composite

Stratum: paste topo 0605 to ph4a fcvr topo-060205-ph4a-cell1-2-icvr-paste-3 phase4a-fcvr

	141	1,450,700	1,450,559 (F) PH4A-Cell3	Composite

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volume report 092905.txt

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: SITE2				
PH6 Stratum: sgrd-cell-6-10 to fcvr-cell-6 sgrd-~~cell6-10 f~~cvr-cell6	491	1,521,652	1,521,161 (F)	Composite
~~Stratum: sgrd-cell-6-10 to fcvr-cell-7 sgrd-cell6-10 fcvr-cell7~~	~~1,037~~	~~3392987~~ cells 6+7	~~3,391,950~~ (F)	Composite
PH8 Stratum: paste-sgrd-ph7-to-fcvr-6-8 paste-sgrd-~~cell6-10~~-to-fcvr-7 fcvr-cell6-8	100	1,987,263	1,987,163 (F)	Composite
PH7 Stratum: paste-sgrd-fcvr-ph6 to fcvr-cell7 paste-sgrd-cell6-10-to-fcvr-6 ~~fcvr~~-cell7	547	1,871,341	1,870,795 (F)	Composite
Stratum: topo 032105 to sgrd cell 6 topo-032105 sgrd-cell-6	279,493	55,613	223,879 (C)	Composite
Stratum: topo 032105 to sgrd cell 7 topo-032105 sgrd-cell7	222,037	85,202	136,834 (C)	Composite
Stratum: topo 032105 to sgrd cell 8 topo-032105 sgrd-cell8	242,630	105,976	136,654 (C)	Composite
Stratum: topo 032105 to sgrd cell 9 topo-032105 sgrd-cell9	68,999	178,758	109,759 (F)	Composite
Stratum: topo 032105 to sgrd cell 10 topo-032105 sgrd-cell10	151,736	21,326	130,410 (C)	Composite

18/19

volume report 090905.txt

Project: land projects Fri September 09 16:53:05 2005

Site Volume Table: Unadjusted

Cut yards	Fill yards	Net yards	Method

Site: CELL 6-10

Stratum: cell 6-10 fcvr airspace sgrd-cell6-10 fcvr-cell6-10

30	15,374,052	15,374,022 (F)	Composite

Stratum: cell 6-10 sgrd cut-fill topo-032105 sgrd-cell6-10

962,425	431,448	530,977 (C)	Composite

Stratum: cell 6-8 fcvr airspace sgrd-cell6-10 fcvr-cell6-8

1	5,386,536	5,386,535 (F)	Composite

Stratum: cell 9 fcvr airspace sgrd-cell6-10-fcvr8-paste fcvr-cell9

82	6,812,047	6,811,964 (F)	Composite

Stratum: cell 10 fcvr airspace sgrd-cell6-10-fcvr9-paste fcvr-cell10

0	3,174,786	3,174,785 (F)	Composite

C&D - Area 2

19/19

Index	Surface Pair		Volume			
	Base Surface	Comparison Surface	Cut	Fill	Net	Net Graph
1	TOPO-060205	SGRD	44610.31 Cu. Yd.	77951.65 Cu. Yd.	33341.34 Cu. Yd. <Fill>	
2	FGVR	FGVR CELL 1	302.14 Cu. Yd.	451912.78 Cu. Yd.	451610.63 Cu. Yd. <F...	
3	[illegible]	[illegible]	67.90 Cu. Yd.	462726.08 Cu. Yd.	462658.18 Cu. Yd. <F...	

Cell 2

$\Sigma = 914,269$

Objective To determine the required volumes of soil and aggregate required for the construction and operation of the landfill.

Analysis The volumes of each material will be calculated by taking design thicknesses and/or cross sections and multiplying by design areas and/or lengths. Areas and lengths are determined using AutoCAD, a planimeter, and/or direct measurement.

EARTHWORK.WPD

G.N. Richardson & Associates
Engineering and Geological Services
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Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 2 / 14
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 4A - Cells 1&2
Earthwork Quantities

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) = 86,088 **(From Life Expectancy Calcs.)**

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DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 4A - Cell 3
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	362	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	3,275	**(From AutoCAD - See Attached)**

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	7.4
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	23,877

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	214,002	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	29.4	**(From AutoCAD) (Cells 1-3)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	94,864	

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JOB #:	JOHNSTON-22
DATE:	10/6/05
BY:	PKS
CHKD BY:	

Johnston County Landfill - MSW Phase 5
Earthwork Quantities

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	19.2	**(From AutoCAD) (Cells 1-3)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	61,952	

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DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 6
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	279,493	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	55,613	**(From AutoCAD - See Attached)**

Compacted Soil Liner (CSL) Volume:

Area of CSL (Ac.) =	21.1	**(From AutoCAD)**
Thickness of CSL (ft) =	1.5	
Volume of CSL (cy) =	51,062	

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	21.1
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	68,083

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	210,302	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	21.1	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	68,083	

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SHEET:	6, 14
JOB #:	JOHNSTON-22
DATE:	10/6/05
BY:	PKS
CHKD BY:	

Johnston County Landfill - MSW Phase 7
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	222,037	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	85,202	**(From AutoCAD - See Attached)**

Compacted Soil Liner (CSL) Volume:

Area of CSL (Ac.) =	19.8	**(From AutoCAD)**
Thickness of CSL (ft) =	1.5	
Volume of CSL (cy) =	47,916	

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	19.8
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	63,888

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	263,849	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	19.8	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	63,888	

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SHEET: 7 / 14
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 8
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	242,630	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	105,976	**(From AutoCAD - See Attached)**

Compacted Soil Liner (CSL) Volume:

Area of CSL (Ac.) =	25.2	**(From AutoCAD)**
Thickness of CSL (ft) =	1.5	
Volume of CSL (cy) =	60,984	

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	25.2
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	81,312

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	276,730	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	25.2	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	81,312	

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SHEET: 8 / 14
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 9
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	68,999	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	178,758	**(From AutoCAD - See Attached)**

Compacted Soil Liner (CSL) Volume:

Area of CSL (Ac.) =	22.5	**(From AutoCAD)**
Thickness of CSL (ft) =	1.5	
Volume of CSL (cy) =	54,450	

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	22.5
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	72,600

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	1,002,737	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	22.5	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	72,600	

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DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - MSW Phase 10
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	151,736	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	21,326	**(From AutoCAD - See Attached)**

Compacted Soil Liner (CSL) Volume:

Area of CSL (Ac.) =	17.5	**(From AutoCAD)**
Thickness of CSL (ft) =	1.5	
Volume of CSL (cy) =	42,350	

LCS/Protective Cover Volume:

Area of LCS/Pro. Cover (Ac.) =	17.5
Thickness of LCS/Pro. Cover (ft) =	2.0
Volume of LCS/Pro. Cover (cy) =	56,467

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) =	461,395	**(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	17.5	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	56,467	

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SHEET: 10, 14
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County Landfill - C&D Area 1
Earthwork Quantities

Daily and Intermediate Cover Volume:

Volume of Periodic Cover (cy) = 18,075 **(From Life Expectancy Calcs.)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	11.1	**(From ACAD) (Portion Not Covered by Ph. 4A - Cell 3)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	35,816	

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SHEET: 11 / 14
JOB #: JOHNSTON-22
DATE: 5/18/06
BY: PKS
CHKD BY:

Johnston County Landfill - C&D - Area 2
Earthwork Quantities

Subgrade Cut and Fill Volumes:

Volume of Cut (cy) =	44,610	**(From AutoCAD - See Attached)**
Volume of Fill (cy) =	77,952	**(From AutoCAD - See Attached)**

Soil Liner Volume:

Area of Soil Liner (Ac.) =	15.8	**(From AutoCAD - See Attached)**
Thickness of Soil Liner (ft) =	1.0	
Volume of Soil Liner (cy) =	25,491	

LCS/Protective Cover Volume:

Area of LCS/Protective Cover (Ac.) =	15.8	**(From AutoCAD - See Attached)**
Thickness of LCS/Protective Cover (ft) =	2.0	
Volume of LCS/Protective Cover (cy) =	50,981	

Periodic Cover Soil Volumes:

Volume of Periodic Cover (cy) =	86,329	**(From Volume/Life Calculations)**

Vegetative Soil Layer (VSL) Volume:

Area of VSL (Ac.) =	15.8	**(From AutoCAD)**
Thickness of VSL (ft) =	2.0	
Volume of VSL (cy) =	50,981	

12/14

volume report 100505.txt

Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: PHASE 4A				
Stratum: paste topo msw to ph4a cell3 sgrd topo-msw-052104-cd-paste phase4a-cell3-sgrd (Cut/Fill)	362	3,275	2,913 (F)	Composite
Stratum: topo 0605 to ph4a cell ~~1-2~~ icvr topo-060205 ph4a-cell1-2-icvr	4,729 ← Perimeter-Ignore	573,921 ← Remainder cells 1&2	569,192 (F)	Composite
Stratum: paste topo 0605 to ph4a fcvr topo-060205-ph4a-cell1-2-icvr-paste-3 phase4a-fcvr	141	1,450,700	1,450,559 (F) PH4A-Cell3	Composite

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Site Volume Table: Unadjusted

	Cut yards	Fill yards	Net yards	Method
Site: SITE2				
PH6 Stratum: sgrd-cell-6-10 to fcvr-cell-6 sgrd-cell6-10 fcvr-cell6	491	1,521,652	1,521,161 (F)	Composite
~~Stratum: sgrd cell 6-10 to fcvr cell 7 sgrd-cell6-10 fcvr-cell7~~	~~1,037~~	~~3392987~~ Cells 6+7	~~3,391,950~~ (F)	Composite
PH8 Stratum: paste-sgrd-ph7-to-fcvr-6-8 paste-sgrd-cell6-10-to-fcvr-7 fcvr-cell6-8	100	1,987,263	1,987,163 (F)	Composite
PH.7 Stratum: paste-sgrd-fcvr-ph6 to fcvr-cell7 paste-sgrd-cell6-10-to-fcvr-6 fcvr-cell7	547	1,871,341	1,870,795 (F)	Composite
Stratum: topo 032105 to sgrd cell 6 topo-032105 sgrd-cell-6	279,493	55,613	223,879 (C)	Composite
Stratum: topo 032105 to sgrd cell 7 topo-032105 sgrd-cell7	222,037	85,202	136,834 (C)	Composite
Stratum: topo 032105 to sgrd cell 8 topo-032105 sgrd-cell8	242,630	105,976	136,654 (C)	Composite
Stratum: topo 032105 to sgrd cell 9 topo-032105 sgrd-cell9	68,999	178,758	109,759 (F)	Composite
Stratum: topo 032105 to sgrd cell 10 topo-032105 sgrd-cell10	151,736	21,326	130,410 (C)	Composite

C&D-Area 2

Index	Surface Pair		Volume			
	Base Surface	Comparison Surface	Cut	Fill	Net	Net Graph
1	TOPO-060205	SGRD	44610.31 Cu. Yd.	77951.65 Cu. Yd.	33341.34 Cu. Yd. <Fill>	
2	PCVR	FGVR CELL 1	302.14 Cu. Yd.	451912.78 Cu. Yd.	451610.63 Cu. Yd. <F...	
3	[illegible]	[illegible]	67.90 Cu. Yd.	462726.06 Cu. Yd.	462658.13 Cu. Yd. <F...	

Cell2

$\Sigma = 914,269$

14/14

Objective To analyze the geomembrane anchor trench to ensure that it will anchor the membrane during normal construction and operation but will pull out before the sheet tears under excessive loads. Note that LLDPE geomembranes do not yield as do HDPE geomembranes.

Assumptions
1. Max. Anchorage (σ_{max}) = 1,300 psi
2. Min. Anchorage (σ_{min}) = 20 psi

Analysis Use the procedure outlined in Equation 3.21 page III-23, "Geosynthetic Design Guidance For Hazardous Waste Landfills & Surface Impoundments."

- Trench Resisting Force (T) (lb/ft):

$$T = \frac{qL\tan\delta + (K_P + K_A)\tan\delta(0.5\gamma d^2 + qd)}{FS_{\min}\cos\beta - \sin\beta\tan\delta}$$

Where:
β = slope angle (degrees)
L = trench set-back from crest (feet)
d = trench depth (feet)
FS_{min} = minimum factor of safety

Backfill Parameters:

ϕ = internal friction angle (degrees)
δ = friction angle between backfill & geomembrane (degrees)
(20 -25+° for textured LLDPE)
γ = backfill unit weight (pcf)
K_A = active soil pressure coef. = $\dfrac{1-\sin\phi}{1+\sin\phi}$
K_P = Passive Soil Pressure Coefficient
(Varies from K_o (AT REST) = 1 - $\sin\phi$ to $K_P = 1/K_A$)
q = $d\gamma$

Determine T over range of δ. Compute stress in geomembrane by taking T/A, where A = Thickness of Geomembrane (ft) over unit width of 1 foot. Compare stress with allowable anchorage requirements. Also, compare stress of the geomembrane (40 mil LLDPE σ_{break} = 1,500 psi.).

ANCHORTR.WPD

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SHEET: 2/2
JOB #: JOHNSTON-22
DATE: 7/14/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Anchor Trench Analysis

Input Parameters:

Side Slope Angle: 18.4 degrees

Geomembrane:

Yield Stress (σ_{max}) = 1,500 psi

Thickness = 0.04 in

Backfill Parameters:

Internal Friction Angle (ϕ)= 25 degrees K_A = 0.41

Unit Weight (γ) = 110 pcf K_P = 2.46

Trench Parameters:

Set-Back (L) = 3.0 feet

Depth (d) = 1.5 feet

$FS_{min.}$ = 1.5

Stress Calculations:

δ	tan δ	T (lb/ft)	Stress in GM (psi)	FS_{break}
10	0.176	201.2	419.1	3.6
15	0.268	312.3	650.7	2.3
20	0.364	434.1	904.3	1.7
25	0.466	570.2	1,187.9	1.3

PROJECT	Johnston County C&D Landfill - Area 2	JOB NO.	JOHNSTON-22
		DATE	7/14/05
SUBJECT	Filter Geotextile Analysis	COMPUTED BY	PKS
		CHECKED BY	

Objective To determine the maximum geotextile apparent opening size (AOS) to provide proper retention to protect drainage media from piping and clogging from adjacent soil. Additionally, to determine the minimum required geotextile permittivity to provide proper drainage from the adjacent soil.

References Koerner, R.M., Designing With Geosynthetics, Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 1999, pp. 84-91.

Mirafi - Geotextile Filter Design, Application, and Product Selection Guide, Ten Cate Nicolon Corp. (www.mirafi.com).

Analysis

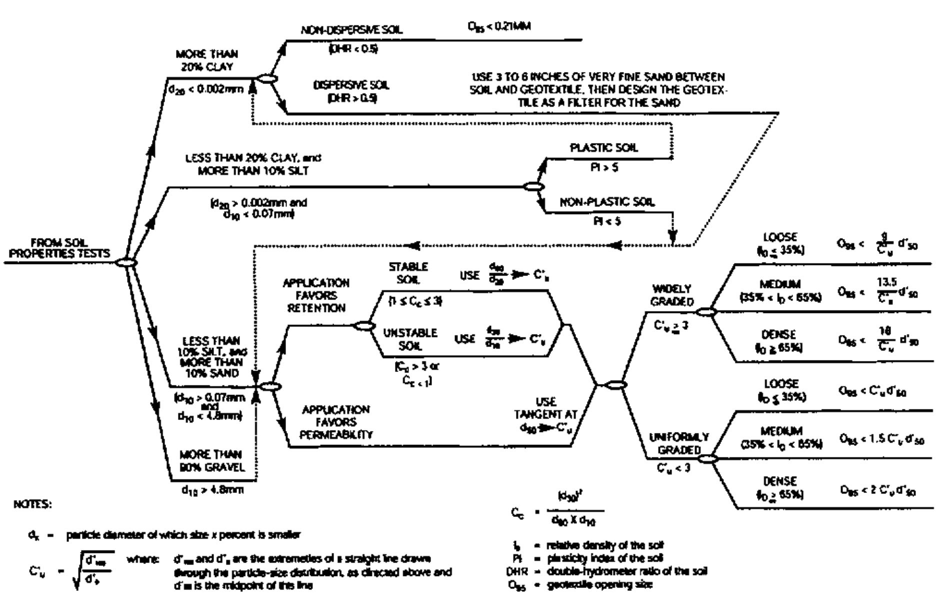
Steps 1 and 2:

Determine the application and function of the geotextile (i.e. where the geotextile is to be used and whether retention or permeability is the key function of the material) and also the confining stress (i.e. high - leachate collection system; low - final cover system) and flow conditions (i.e. steady-state - landfill drains; dynamic - shoreline protection).

Step 3:

Determine the soil retention requirements (maximum AOS). For steady-state conditions, use the following chart.

Chart 1. Soil Retention Criteria of Steady-State Flow Conditions



GT FILTER.WPD

U.S. Sieve vs. Opening Size:

U.S. Sieve	Opening Size (mm)
100	0.150
80	0.180
70	0.212
60	0.250
50	0.300
40	0.425
30	0.600

Step 4:

Determine the geotextile permittivity requirements:

$$\Psi = \frac{k_g}{t_g} \qquad (\text{sec}^{-1})$$

Where:
- Ψ = minimum required geotextile permittivity (sec^{-1})
- k_g = minimum allowable geotextile permeability (cm/sec)

$$k_g \geq i_S k_S$$

- t_g = geotextile thickness under design load (cm)
- i_S = hydraulic gradient (use 1.5 for landfills)
- k_S = permeability of retained soil (cm/sec).

Other Considerations:

Other things to consider in the design of a filter geotextile include anti-clogging requirements and survivability/durability requirements. For anti-clogging, it is generally best to use the largest AOS that satisfies the retention criteria. For non-woven geotextiles used in landfill applications, an AOS of 0.21 mm (No. 70 sieve) is typically the largest AOS that is available. For survivability/durability concerns, generally an adequately UV stabilized geotextile made from polypropylene or polyester with an AASHTO M288 Strength Class of 2 is suitable for use in subsurface drainage applications.

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SHEET: 35
JOB #: JOHNSTON-22
DATE: 7/14/05
BY: PKS
CHKD BY:

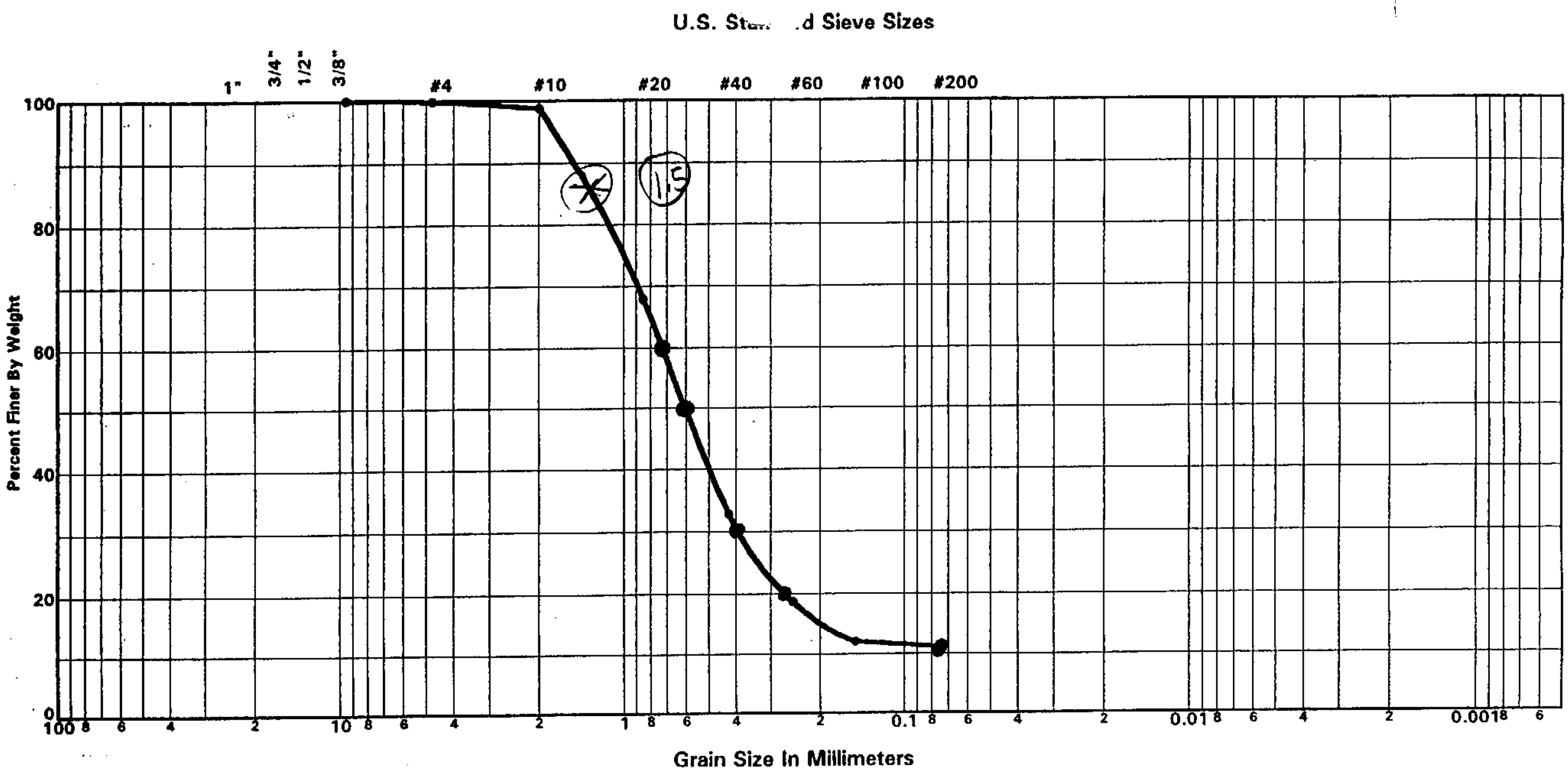
Johnston County C&D Landfill - Area 2
Filter Geotextile Analysis

Application: Drainage Geocomposite (LCS or Final Cover)
Primary Function: Retention
Relative Confining Stress: Low to High
Flow Conditions: Steady-State

Soil Evaluated

	B-2	CC-61-P	
Soil Description:	Clayey Silty Sand	Silty Clayey Sand	
Soil Type:	SM	SC-SM	
D_{80}:	0.720	0.340	
D_{50}:	0.600	0.280	
D_{30}:	0.400	0.010	
D_{20}:	0.280	0.001	
D_{10}:	0.007	0.001	
PI:	16	20	
C_c	31.75	0.29	
Soil Dispersion (When Applicable):	Is Soil Dispersive? (Y/N) N	Is Soil Dispersive? (Y/N) N	
Recommended Maximum AOS (mm) (When Applicable):	**0.210** **No. 70 Sieve**	**0.210** **No. 70 Sieve**	
Soil Stability (When Applicable):	NA	NA	
C'_u (When Applicable):			
Soil Relative Density (I_D) (Losse (L), Medium (M), Dense (D) (When Applicable):			
Recommended Maximum AOS (mm) (When Applicable):			
Required Geotextile Properties:	—	—	
Hydraulic Gradient (i_s):	1.5	1.5	
Estimated Soil Permeability (k_s) (cm/sec):	5.0E-04	5.0E-04	
Min. Allowable Geotextile Permeability (k_g) (cm/sec):	7.5E-04	7.5E-04	
Geotextile Thickness (t_g) (cm):	0.25	0.25	
Min. Required Geotextile Permittivity (Ψ) (sec^{-1}):	**0.003**	**0.003**	

Typ. Range of Soils
Anticipated As
Protective Cover (LCS)
or Vegetative Soil Layer (FCS)



GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
2			45.0	29.0	16.0	Orange Slightly Clayey Silty SAND (SM)

Project:

G.N. Richardson & Associates Lab Services
Raleigh, North Carolina

Job No.: 1-95-0084 CA

Date: 4/17/98

GRAIN SIZE DISTRIBUTION

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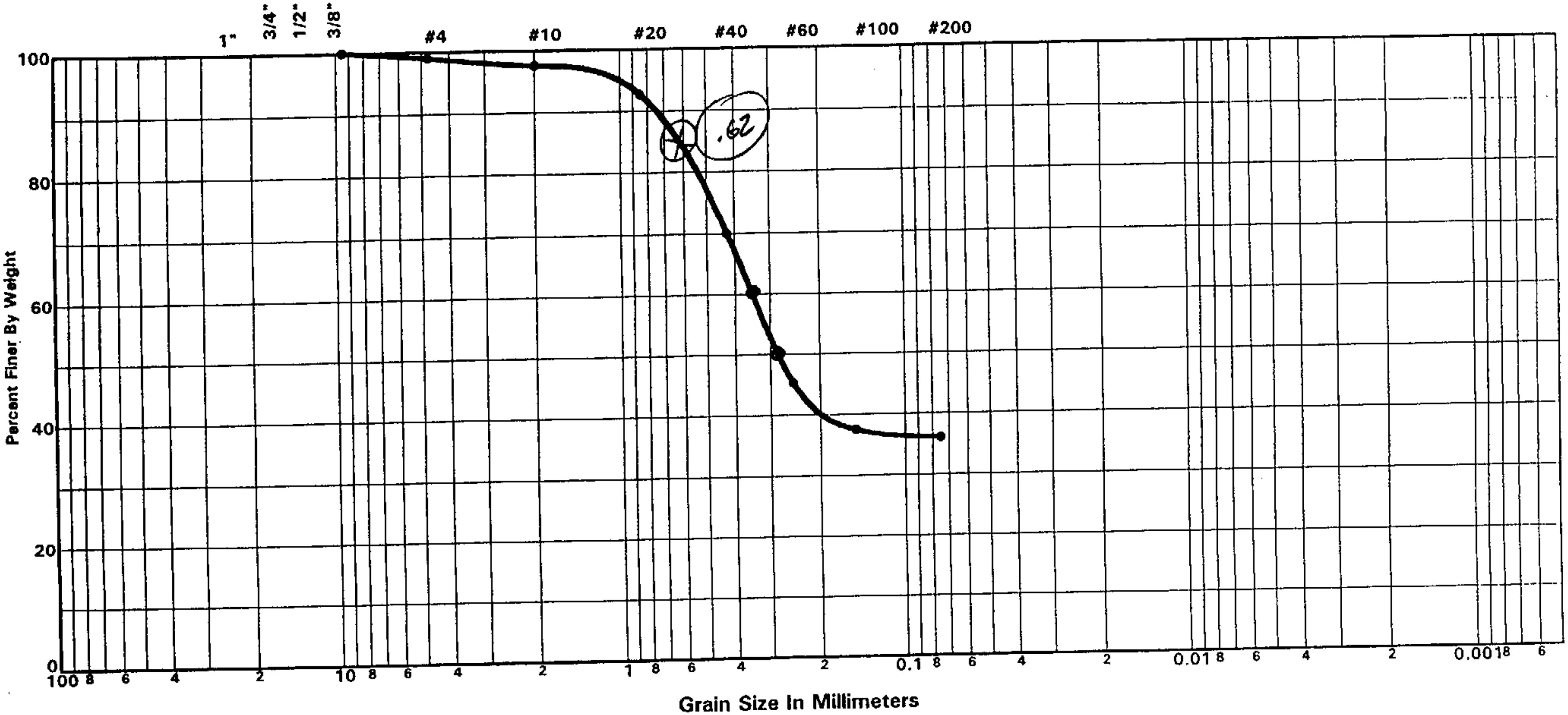

GRAVEL		SAND			FINES	
COARSE	FINE	COARSE	MEDIUM	FINE	SILT SIZES	CLAY SIZES

Boring No.	Elev./Depth	Nat. W.C.	L.L.	P.L.	P.I.	Soil Description or Classification
CC-61-P	3rd Lift		46.0	26.0	20.0	Orange Tan Silty Clayey Medium to Fine SAND (SC-SM)

Project:

Johnston County Landfill
Johnston County, North Carolina

Job No.: 1-98-1034-CA

Date: 12/9/98

GRAIN SIZE DISTRIBUTION

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PROJECT	Johnston County C&D Landfill - Area 2	JOB NO.	JOHNSTON-22
		DATE	7/14/05
SUBJECT	Cushion Geotextile Analysis	COMPUTED BY	PKS
		CHECKED BY	

Objective To evaluate the required weight of cushion geotextile to adequately protect the base geomembrane against the possibility of puncture.

Reference Koerner, R.M., Designing With Geosynthetics, Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 1999, pp. 535-537.

Richardson, G.N. (1996), "Field Evaluation of Geosynthetic Protective Cushions," *Geotechnical Fabrics Report*, (vol. 14, no. 2, March), pp. 20-25.

Richardson, G.N. and Johnson, S. (1998), "Field Evaluation of Geosynthetic Protective Cushions: Phase 2," *Geotechnical Fabrics Report*, (October - November), pp. 44-49.

Analysis Use the equation given below to determine the required mass per unit area of a cushion geotextile to protect a 60 mil HDPE (40 mil LLDPE in this case) geomembrane under final design loads. The selected cushion geotextile should be a minimum of 12 oz. per square yard to provide adequate protection during construction loading (Richardson, 1996 & 1998).

$$p_{allow} = (50 + 0.00045\frac{M}{H^2})\frac{1}{MS_S\, MF_{PD}\, MF_A} \bullet \frac{1}{RF_{CR} RF_{CBD}} \qquad \text{(Koerner Eqn. 5.33)}$$

Where:

p_{allow}	=	allowable pressure (kPa)
	=	$p_{actual}\, x\, FS$
p_{actual}	=	actual pressure (kPa)
FS	=	factor of safety
M	=	geotextile mass per unit area (g/m^2)
H	=	protrusion height (m) (assume H = d_{50} = soil particle size (mm) for which 50% of the total soil is finer)
MF_S	=	modification factor for protrusion shape
MF_{PD}	=	modification factor for packing density
MF_A	=	modification factor for arching in solids
RF_{CR}	=	reduction factor for long-term creep
RF_{CBD}	=	reduction factor for long-term chemical/biological degradation

GT CUSHION.WPD

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SHEET: 2 / 3
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Cushion Geotextile Analysis

Input Parameters:

Maximum Height of Waste (ft) =	150	**(User Input)**
Waste Density (pcf) =	70	**(User Input)**
P_{actual} (psf) =	10,500	**(=Max Height x Waste Density)**
P_{actual} (kPa) =	503	
Factor of Safety, FS =	3	**(User Input)**
P_{allow} (kPa) =	1,509	

Type of Stone	Stone Information: Stone Angularity	Stone d50 (in)	Stone d50 (mm)	Protrusion Height (m)	Modification Factors: MF_S	MF_{PD}	MF_A	Reduction Factors: RF_{CR}	RF_{CBD}	Geotextile Mass Per Unit Area (g/m^3)	(oz/sy)
Coarse Aggregate (NCDOT No. 57)	Angular	0.750	19.1	0.019	1.00	0.67	0.25	1.5	1.3	357	**10.5**

Dr. Geocomposite w/
Z-6054 Non-Woven
OK

3/3

TABLE 5.18 MODIFICATION FACTORS AND REDUCTION FACTORS FOR GEOMEMBRANE PROTECTION DESIGN USING NONWOVEN NEEDLE-PUNCHED GEOTEXTILES

Modification Factors

MF_S		MF_{PD}		MF_A	
Angular	1.0 *	Isolated	1.0	Hydrostatic	1.0
Subrounded	0.5	Dense, 38 mm	0.83	Geostatic, shallow	0.75
Rounded	0.25	Dense, 25 mm	0.67 *	Geostatic, mod.	0.50
		Dense, 12 mm	0.50	Geostatic, deep	0.25 *

Reduction Factors

RF_{CBD}		RF_{CR}: Mass per unit area (g/m²)	Protrusion (mm): 38	25	12
Mild leachate	1.1	Geomembrane alone	N/R	N/R	N/R
Moderate leachate	1.3 *	270	N/R	N/R	> 1.5
Harsh leachate	1.5	550	N/R	1.5	1.3
		1100	1.3	1.2	1.1
		> 1100	≅ 1.2	≅ 1.1	≅ 1.0

N/R = Not recommended

p_{allow} = allowable pressure using different types of geotextiles and site-specific conditions.

Based on a large number of ASTM 5514 experiments, an empirical relationship for p_{allow} has been obtained, Eq. (5.33). It requires the set of modification factors and reduction factors given in Table 5.18.

$$p_{\text{allow}} = \left(50 + 0.00045\,\frac{M}{H^2}\right)\left[\frac{1}{MF_S \times MF_{PD} \times MF_A}\right]\left[\frac{1}{RF_{CR} \times RF_{CBD}}\right] \tag{5.33}$$

where

p_{allow} = allowable pressure (kPa),
M = geotextile mass per unit area (g/m²),
H = protrusion height (m),
MF_S = modification factor for protrusion shape,
MF_{PD} = modification factor for packing density,
MF_A = modification factor for arching in solids,
RF_{CR} = reduction factor for long-term creep, and
RF_{CBD} = reduction factor for long-term chemical/biological degradation.

Note that in the above all MF values ≤ 1.0 and all RF values ≥ 1.0.

REF: DESIGNING WITH GEOSYNTHETICS, KOERNER 4th EDITION, 1997

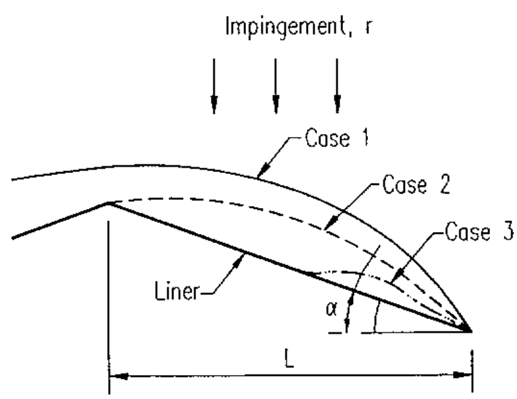
PROJECT Johnston County C&D Landfill - Area 2	SHEET 1 OF 3
	JOB NO. JOHNSTON-22
	DATE 7/14/05
SUBJECT Leachate Collection Pipe Spacing	COMPUTED BY PKS
	CHECKED BY

Objective To evaluate the required leachate collection pipe spacing which will maintain at most 1 foot of head on the geomembrane under Normal Operating Conditions. Analysis will calculate the maximum head using required values for permeability (leachate collection media) or transmissivity (drainage geocomposite). If the selected pipe spacing indicates an acceptable head, then the selected pipe spacing is acceptable.

References McEnroe, Bruce (1993), "Maximum Saturated Depth Over Landfill Liners," Journal of Environmental Engineering, Vol. 119, No. 2, pp. 262-270.

Richardson, G.N., Giroud, J-P. and Zhao, A. (2000), Design of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Analysis The McEnroe equations require the input of an impingement rate, a drainage media permeability, pipe spacing, and a liner slope. This information is used to find the maximum head on the liner. The McEnroe solution is for three cases (see figure below). Case 1 is for a saw-tooth bottom, with the liquid mound overtopping the peak. Case 2 has the liquid mound starting at the peak of the saw-tooth. Case three has the mound starting below the peak of the tooth. Cases two and three are appropriate for modeling a liner on an infinite slope with collector pipes uniformly spaced down the slope.



LCS PIPE SPACE.WPD

Step 1: Input the necessary physical factors: slope, permeability and impingement rate.

Step 2: The controlling value R is calculated

$$R = \frac{r}{k \sin^2 \alpha}$$

Where:
- r = impingement rate
- k = permeability of the drainage media (for Drainage Geocomposite, k = transmissivity/thickness)
- α = slope angle of the liner

Step 3: The maximum head is calculated, using a formula dependent on the value of R:

For R > 1/4 (Case 1):

$$h_{max} = SL\left(R - RS + R^2S^2\right)^{\frac{1}{2}} \exp\left[\frac{1}{B}\arctan\left(\frac{2RS-1}{B}\right) - \frac{1}{B}\arctan\left(\frac{2R-1}{B}\right)\right]$$

For R = 1/4 (Case 2):

$$h_{max} = SL\frac{R(1-2RS)}{1-2R}\exp\left[\frac{2R(S-1)}{(1-2RS)(1-2R)}\right]$$

For R < 1/4 (Case 3):

$$h_{max} = SL\left(R - RS + R^2S^2\right)^{\frac{1}{2}}\left[\frac{(1-A-2R)(1+A-2RS)}{(1+A-2R)(1-A-2RS)}\right]^{\frac{1}{2A}}$$

Where:
- h_{max} = maximum head (m - convert to desired units)
- L = horizontal length of pipe spacing or distance to peak (m) (see figure above)
- S = liner slope (m/m)
- A = $(1 - 4R)^{0.5}$
- B = $(4R - 1)^{0.5}$

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SHEET: 3 / 3
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Leachate Collection Pipe Spacing

Drainage Geocomposite:

Maximum Allowable Head (h_{max}):	0.25 inches	(= Thickness of Geonet Drainage Core)
Impingement (r):	1.3E-06 cm/sec	(= 1,200 gpad - Conservative for Active Case Based on HELP Model)
Drainage Geocomposite Transmissivity (θ):	7.5E-04 m^3/m/sec	(Specified Minimum)
Thickness of Geonet Drainage Core:	0.25 inches	(Specified Minimum)
Reduction Factors for Drainage Geocomposite:		(Per Richardson, Zhao, & Giroud)
$RF_{intrusion}$:	1.2	
RF_{creep}:	2.0	
$RF_{chemical\ clogging}$:	2.0	
$RF_{biological\ clogging}$:	2.0	
Overall Factor of Safety:	2.0	
Reduction Factor for Drainage Geocomposite in LCS:	19.2	(Conservative for Short-Term Load on Geocomposite)
Design Drainage Geocomposite Transmissivity (θ):	3.9E-05 m^3/m/sec	
Design Drainage Geocomposite Permeability (k):	0.62 cm/sec	(Design Transmissivity/Thickness of Geonet Drainage Core)

Slope (%)	Slope (Deg.)	S	R	Pipe Spacing (ft)	Pipe Spacing (m)	A	B	h_{max} (in) R < 0.25	R = 0.25	R > 0.25	Comment
2	1.15	0.020	0.00529	200	61.0	0.989	NA	0.25	N/A	N/A	O.K.
2.2	1.26	0.022	0.00437	200	61.0	0.991	NA	0.23	N/A	N/A	O.K.

↑ Flow In Net - O.K. << 1'

Note: Spreadsheet Converts Units as Required.

Objective To design leachate collection pipes to handle the maximum leachate generation rate.

References Cedargren, Harry R. (1974), Drainage of Highway and Airfield Pavements, John Wiley & Sons, New York, pp. 166-167.

Debo, T.N., and Reese, A.J. (1995), Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, pp. 438-442.

Malcom, H. Rooney (1989), Elements of Urban Stormwater Design, N.C. State University, Raleigh, NC.

Analysis

1. For each pipe size, determine the maximum area (A), to handle the predicted flow (Q) with an added factor of safety. Compare the full flow capacity of each pipe size with the calculated peak flow rate to verify the desired factor of safety. Also, analyze leachate collection pipes based on partial flow to determine flow depth and velocity.

2. Determine the allowable perforation size for leachate collection pipes based on the size of the stone in the gravel columns.

3. Analyze leachate collection pipe perforations as orifice flow to ensure adequate flow capacity into collection piping.

Calculations

- Determine Peak Flow Rate:

Use the peak daily leachate generation rate from the active condition (see leachate generation calculations).

Determine the drainage area (A) to each pipe such that $Q_{max}/Q \geq 2.0$, where Q_{max} is the full flow capacity (see below).

LCS PIPE SIZE.WPD

- Leachate Collection Pipes:

Determine Flow Capacity (Q_{max}):

$$Q_{\max} = \frac{0.463 D^{\frac{8}{3}} S^{\frac{1}{2}}}{n} \qquad \text{(D\&R Equation 8.24)}$$

Where:
- Q_{max} = Flow capacity (cfs)
- D = Pipe inside diameter (in)
- S = Pipe slope (ft/ft)
- n = Manning's roughness coefficient

Determine Factor of Safety (FS):

$$FS = \frac{Q_{\max}}{Q}$$

Determine Flow Depth:

$$h = \frac{1}{2}\left(1 - \cos\left(\frac{\theta}{2}\right)\right) D \qquad \text{(D\&R Equation 8.29)}$$

Where:
- h = Flow depth (inches)
- θ = Central angle

$$\theta = \frac{3\pi}{2}\left[1 - (1 - \pi K)^{\frac{1}{2}}\right]^{\frac{1}{2}} \qquad \text{(D\&R Equation 8.28)}$$

K = Constant

$$K = 0.673 Q_n^{\frac{-8}{3}} S^{\frac{-1}{2}} \qquad \text{(D\&R Equation 8.27)}$$

Determine Flow Velocity:

$$V = \frac{Q}{A} = \frac{Q}{D^2 \frac{(\theta - \sin\theta)}{8}}$$ (D&R Equation 8.30 for "A")

Where: V = Flow velocity (ft/sec)
A = Cross-sectional area of flow (ft^3)

- Leachate Collection Pipe Perforations:

Determine Maximum Allowable Size of Perforations (D_{max}):

$$D_{max} = \frac{D_{85}}{F}$$ (Reformulation of Cedargren Equation 5.11)

Where: D_{max} = Maximum perforation diameter to provide particle retention
D_{85} = Particle size of pipe bedding material for which 85% by weight of the particles are finer
F = Factor varying between 1 and 2 (F = 1.2 for slots)

Determine Flow Capacity (Q_{max}):

$$Q_{max} = C_d A \sqrt{2gh}$$ (Malcom Equation I-7)

Where: Q_{max} = Flow capacity (cfs)
C_d = Coefficient of discharge
A = Cross-sectional area of flow (ft^3)
g = Acceleration of gravity (32.2 ft/sec^2)
h = Driving head - centroid of orifice to water surface (ft)

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

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SHEET: 4.4
JOB #: ABC-1
DATE: 8/29/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Leachate Collection System (LCS) Pipe Sizing - HDPE Pipe

Input Parameters:

Manning's Rougness Coefficient =	**0.009**		**(HDPE Pipe)**
Design Leachate Flow =	**14,000**	gal/acre/day	**(Peak Daily Leachate Generation - Active Condition)**
Design Leachate Flow =	0.02	cfs/acre	
Orifice Coef. Of Discharge (LCS Pipe Perforations) =	**0.6**		

LCS Piping

ID	Drainage Area (AC)	Peak Flow Rate (Q) (CFS)	Pipe I.D. (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 2.0)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 6"	17.0	0.37	**5.8**	**1**	0.74	2.0	0.155	181	2.93	0.09	3.96

> Max. - O.K.

LCS Pipe Perforations

Determine Maximum Perforation Size:

Stone Used for Pipe Bedding:	**No. 57**		
D_{85} =	**0.750**	inches	**(Typ. for No. 57 Stone)**
F =	**1.5**		
Max. Diameter - Circular Holes/Max. Width - Slots =	0.50	inches	

Circular Holes

ID	Drainage Area (AC)	Peak Flow Rate (Q) (CFS)	Hole Diameter (IN)	Allowable Head (IN)	X-Sectional Area (SF/Hole)	Flow Capacity (Q_{max}) (CFS/Hole)	No. Holes/LF	Min. Length of Collection Pipe (FT)	Actual Length of Collection Pipe (FT)	Factor of Safety (>/= 2.0)
Max. Area - 6"	**14.1**	0.31	**0.50**	**4**	0.001	0.004	**4**	20	300 +	14.9

Note: Conservatively Neglects Upper Holes (Where Used).

LCS Pipe Dimensions

Standard Dimension Ratio (SDR) of Pipe = **17** **(From Pipe Stress Calculations)**

Nominal Pipe Size (IN)	Pipe O.D. (IN)	Min. Wall Thickness (IN)	Pipe I.D. (IN)
6	**6.625**	0.390	5.8

Note: User Input Values are in **Bold**.

Objective Evaluate collection pipe stresses due to long-term static (overburden) and short-term dynamic (equipment) loads. For long-term static loads, check crushing and buckling failure modes as well as ring deflection. For short-term dynamic loads, check crushing failure mode.

References

The Performance Pipe Engineering Manual, (2002), CPChem Performance Pipe, Chapters 5 and 7.

Guidelines for HDPE Pipes in Deep Fills, (1998), Chevron Phillips Chemical Co.

Driscopipe Systems Design Manual, (1991), Phillips Driscopipe, Inc., p. 47.

Holtz, R.D., & Kovacs, W.D. (1981), An Introduction To Geotechnical Engineering, Prentice-Hall, Englewood Cliffs, NJ, p. 348.

Analysis Use FS_{min} (Static) = 2.0, FS_{min} (Dynamic) = 2.0.

Equations

- Crushing Failure:

$$S = \left(\frac{P_T}{288}\right) SDR$$ (Perf. Pipe Eng. Man. Eq. 7-23)

Where: S = Compressive Stress in Pipe Wall (psi)

SDR = Standard Dimensional Ratio = $\frac{\text{Outside Diameter}}{\text{Thickness}}$

P_T = External Pressure (psf)

$$FS_{crush} = \frac{\sigma_{yield}(HDPE = 1{,}600\,psi)}{S}$$

- Buckling Failure (Constrained Wall):

$$P_{CR} = 1.63\sqrt{\frac{RB'E'E}{(SDR-1)^3}}$$ (Guidelines - HDPE - Deep Fills - Eq. 10)

Where:

P_{CR} = Critical Buckling Soil Pressure (psi)

R = Groundwater Buoyancy Factor

$$= 1 - 0.33\frac{H_{GW}}{H}$$

B' = Elastic Support Coefficient

$$= \frac{1}{1+4e^{(-0.065H)}}$$

E' = Constrained Soil Modulus (psi) (See Attached Table)

H = Height of Fill (ft)

H_{GW} = Height of Groundwater (ft)

E = Long-Term Modulus of Elasticity of Pipe (psi) (See Attached Table)

$$FS_{buckle} = \frac{P_T}{P_{CR}}$$

- Ring Deflection:

For constrained HDPE pipe, pipe deflection equals the strain in the surrounding bedding soil. The safe pipe deflection for each SDR is shown on the attached table.

$$\text{Pipe Deflection (\%)} = \frac{P_T}{E'}$$ (Driscopipe p. 47)

-Equipment Loading:

Line Loads: (H&K Eq. 8-26)

$$P_T = P_L = \frac{2WZ^3}{\pi Z^5}$$

Point Loads: (Perf. Pipe Eng. Man. Eq. 7-13)

$$P_T = P_P = \frac{3WZ^3}{2\pi Z^5}$$

Where: W = Dynamic Equipment Load (lbs/ft or lbs) (= 1.5 times weight of machine)

Z = Vertical Distance From the Point of Loading to the Top of the Pipe (feet)

Using the above calculations for P_T, calculate the factor of safety for crushing failure as shown above.

PROJECT Johnston County C&D Landfill - Area 2

SUBJECT HDPE Pipe Stress Analysis

Table : Typical Design Values* for Constrained Modulus, E'

Vertical Soil Stress (psi)	Gravelly Sand/Gravels 95% Std. Proctor (psi)	Gravelly Sand/Gravels 90% Std. Proctor (psi)	Gravelly Sand/Gravels 85% Std. Proctor (psi)
10	3000	1500	500
20	3500	1700	650
40	4500	2100	900
60	5500 *	2500	1150
80	6000	2900	1300
100	6500	3200	1450

(GUIDELINES FOR HDPE PIPE IN DEEP FILLS - TABLE 1)

Table · Typical Elastic Modulus for DRISCOPLEX™ PE 3408

Load Duration	Elastic Modulus†, 1000 psi (MPa), at Temperature, °F (°C)							
	-20 (-29)	0 (-18)	40 (4)	60 (16)	73 (23)	100 (38)	120 (49)	140 (60)
Short-Term	300.0 (2069)	260.0 (1793)	170.0 (1172)	130.0 (896)	110.0 (758)	100.0 (690)	65.0 (448)	50.0 (345)
10 h	140.8 (971)	122.0 (841)	79.8 (550)	61.0 (421)	57.5 (396)	46.9 (323)	30.5 (210)	23.5 (162)
100 h	125.4 (865)	108.7 (749)	71.0 (490)	54.3 (374)	51.2 (353)	41.8 (288)	27.2 (188)	20.9 (144)
1000 h	107.0 (738)	92.8 (640)	60.7 (419)	46.4 (320)	43.7 (301)	35.7 (246)	23.2 (160)	17.8 (123)
1 y	93.0 (641)	80.6 (556)	52.7 (363)	40.3 (278)	38.0 (262)	31.0 (214)	20.2 (139)	15.5 (107)
10 y	77.4 (534)	67.1 (463)	43.9 (303)	33.5 (231)	31.6 (218)	25.8 (178)	16.8 (116)	12.9 (89)
50 y	69.1 (476)	59.9 (413)	39.1 (270)	29.9 (206)	* 28.2 (194)	23.0 (159)	15.0 (103)	11.5 (79)

† Typical values based on ASTM D 638 testing of molded plaque material specimens.

(PERFORMANCE PIPE ENG. MANUAL - TABLE 5-1)

Table · Safe Pressure Pipe Deflection

DR	Safe Deflection as % of Diameter
32.5	8.5
26	7.0
21	6.0
17	5.0
13.5	4.0
11	3.0
9	2.5

(PERFORMANCE PIPE ENG. MANUAL - TABLE 7-9)

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue Tel: 919-828-0577
Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 5 / 5
JOB #: JOHNSTON-22
DATE: 9/8/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
HDPE Pipe Stress Analysis - LCS Piping

Case 1: Long-Term Static Loading

>> >Max.

Max. Height of Fill (H) (ft) = 150
Avg. Unit Weight (pcf) = 70

Max. Vertical Stress (P_T) (psf) = 10,500
Max. Vertical Stress (P_T) (psi) = 73

Height of Groundwater (H_{GW}) (ft) = 1 **(12" Max. Head)**
Constrained Soil Modulus (E') (psi) = 5,500
Long-Term Modulus of Elasticity of Pipe (E) (psi) = 28,200
Groundwater Buoyancy Factor (R) = 0.998
Elastic Support Coefficient (B') = 1.000

Calculate Safety Factors Against Crushing, Buckling, and Ring Deflection:

SDR	S (psi)	E (psi)	P_{CR} (psi)	FS_{Crush}	FS_{Buckle}	Ring Defl. (%)	Comment
17	620	28,200	317	2.58	4.34	1.3	**O.K.**
13.5	492	28,200	459	3.25	6.29	1.3	**O.K.**
11	401	28,200	641	3.99	8.79	1.3	**O.K.**

Case 2: Short-Term Dynamic (Equipment) Loading

SDR (Determine From Static Loading Analysis) = 17

Line Loads:

Equipment	Weight* (lbs)	Track Length (ft)	Dynamic Line Loads (psi) 6" Cover	12" Cover	18" Cover	S 6" Cover	12" Cover	18" Cover	FS 6" Cover	12" Cover	18" Cover
D4 Bulldozer (D4C-II)	19,485	6.74	19	10	6	163	81	54	9.8	19.6	29.5
D6 Bulldozer (D6H-II)	46,305	8.63	36	18	12	302	151	101	5.3	10.6	15.9
D8 Bulldozer (D8L)	95,838	10.5	61	30	20	514	257	171	3.1	6.2	9.3
953 Track Loader	37,560	7.5	33	17	11	282	141	94	5.7	11.3	17.0
963Track Loader	48,914	8.08	40	20	13	341	171	114	4.7	9.4	14.1

Point Loads:

Equipment	Weight* (lbs)	Number of Tires	Dynamic Point Loads (psi) 6" Cover	12" Cover	18" Cover	S 6" Cover	12" Cover	18" Cover	FS 6" Cover	12" Cover	18" Cover
950 Wheel Loader	48,628	4	242	60	27	2,056	514	228	0.8	3.1	7.0
615 Scraper	91,000	4	453	113	50	3,847	962	427	0.4	1.7	3.7
621 Scraper	115,195	4	573	143	64	4,870	1,217	541	0.3	1.3	3.0
816B Compactor	45,477	4	226	57	25	1,923	481	214	0.8	3.3	7.5
826C Compactor	69,733	4	347	87	39	2,948	737	328	0.5	2.2	4.9

* Includes Blades, Loaded Buckets, etc.

OPS. RESTRICTIONS HANDLE THIS

PROJECT Johnston County C&D Landfill - Area 2	SHEET 1 OF 12
	JOB NO. JOHNSTON-22
	DATE 10/6/05
SUBJECT Evaluation of Leachate Generation Rates	COMPUTED BY PKS
	CHECKED BY

Objective To predict leachate generation rates for various operational conditions and evaluate rates of removal for the "surge" condition.

Assumptions Assume four operational conditions as follows:

Open -	Small quantity of waste in cell; almost all of runoff is leachate
Active -	One 10 foot lift of waste in place; no runoff
Interim -	40 feet of waste in place under intermediate cover
Final -	Final cover in-place; minimal infiltration.

Assume that the design storm for the landfill unit during initial filling (placement of initial lift of waste over open cells) is the 1-year 24-hour storm. This value is used to estimate leachate generation for "open" conditions.

Assumed empirical leachate generation rates are as follows for the above operational conditions:

Active -	1,200 gallons/acre/day
Interim -	500 gallons/acre/day
Final -	100 gallons/acre/day.

These rates are based on back calculations from observed generation rates from High Point, NC (Phase 1), Alamance County, NC, and several New York facilities (Reference Robert Pheneuf (NY-DEC)).

Analysis

Step 1: Determine the leachate generation rates for the above conditions using the HELP (v. 3.07) Model. These rates are as follows (see attached computer output files):

Active -	678 gallons/acre/day
Interim -	537 gallons/acre/day
Final -	0.11 gallons/acre/day.

Step 2: Compare results from the HELP Model with the empirical rates shown above. In that the empirical results are greater (or about the same), use the empirical values in estimating the leachate generation rates.

LEACHATEGENERATION.WPD

Step 3: Estimate leachate generation rates using empirical values for the various conditions expected before, during, and after landfill operations. In this case, leachate generation rates are predicted for the following scenarios:

A. Completion of Phase 5 and Phase 4A - Cells 1 and 2 (MSW) operations (Phase 5 and Phase 4A - Cells 1 and 2 (MSW) under Interim conditions);

B. Initial filling of Area 2 (various areas under Open, Active, and Interim conditions) (maximum value is taken as the surge event for Area 2); and

C. Waste covers Area 2 (no areas Open; various areas under Active and Interim conditions) (maximum value is taken as the typical generation rate for Area 2).

Step 4: Based on the leachate generation rates determined above, estimate the pumping rates required to ensure that enough capacity remains in the leachate storage lagoon to handle the surge event. Also, estimate the days of capacity for the lagoon under typical Area 2 operations.

3/12

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**   HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE   **
**   HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)   **
**   DEVELOPED BY ENVIRONMENTAL LABORATORY   **
**   USAE WATERWAYS EXPERIMENT STATION   **
**   FOR USEPA RISK REDUCTION ENGINEERING LABORATORY   **

****

PRECIPITATION DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA: D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\JCACTIV.D10
OUTPUT DATA FILE: D:\PKSFIL~1\2ENGPR~1\HELP3\JCACTIV.OUT

TIME: 18:21 DATE: 7/14/2005

****

TITLE: Johnston County C&DLF - Area 2 - Active Condition

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NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	6.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2357 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	120.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3065 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2309 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	200.0 FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	88.20
FRACTION OF AREA ALLOWING RUNOFF	=	0.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000 ACRES
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.966 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	13.574 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.856 INCHES
INITIAL SNOW WATER	=	0.000 INCHES
INITIAL WATER IN LAYER MATERIALS	=	49.441 INCHES
TOTAL INITIAL WATER	=	49.441 INCHES
TOTAL SUBSURFACE INFLOW	=	0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.404	1.729	2.964	2.732	4.210	4.665
	4.191	4.168	2.641	1.296	1.141	1.022
STD. DEVIATIONS	0.154	0.243	0.311	0.925	0.790	1.464
	1.513	1.292	1.115	0.405	0.153	0.172
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	1.1493	1.7106	1.6137	1.2909	0.6079	0.5976
	0.2564	0.1102	0.6624	0.2594	0.1671	0.6833
STD. DEVIATIONS	0.8153	1.1576	1.1032	1.0332	0.4231	0.8138
	0.3488	0.1542	1.9467	0.7273	0.3119	1.1593
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0001	0.0000	0.0000	0.0000

4/12

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0065	0.0107	0.0092	0.0076	0.0035	0.0035
	0.0015	0.0006	0.0039	0.0015	0.0010	0.0039
STD. DEVIATIONS	0.0046	0.0071	0.0063	0.0061	0.0024	0.0048
	0.0020	0.0009	0.0115	0.0041	0.0018	0.0066

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	0.000	(0.0000)	0.00	0.000
EVAPOTRANSPIRATION	32.163	(3.6299)	116753.15	77.973
LATERAL DRAINAGE COLLECTED FROM LAYER 4	9.10874	(5.18516)	33064.723	22.08206
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00037	(0.00019)	1.360	0.00091
AVERAGE HEAD ON TOP OF LAYER 5	0.004	(0.003)		
CHANGE IN WATER STORAGE	-0.023	(1.9521)	-83.56	-0.056

678 gpad

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 4	0.51536	1870.74683
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000017	0.06250
AVERAGE HEAD ON TOP OF LAYER 5	0.091	
MAXIMUM HEAD ON TOP OF LAYER 5	0.179	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	3.5 FEET	
SNOW WATER	1.80	6547.7266
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4806	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0844	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	1.3805	0.2301
2	34.8402	0.2903
3	7.0430	0.2935
4	0.0166	0.0662
5	0.0000	0.0000
6	5.7000	0.4750
SNOW WATER	0.000	

5/12

HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE
HELP MODEL VERSION 3.07 (1 NOVEMBER 1997)
DEVELOPED BY ENVIRONMENTAL LABORATORY
USAE WATERWAYS EXPERIMENT STATION
FOR USEPA RISK REDUCTION ENGINEERING LABORATORY

PRECIPITATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:	D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCINTRM.D10
OUTPUT DATA FILE:	D:\PKSFIL~1\2ENGPR~1\HELP3\JCINTRM.OUT

TIME: 18:21 DATE: 7/14/2005

TITLE: Johnston County C&DLF - Area 2 - Interim Condition

NOTE: INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

LAYER 1

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2268 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 3.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	480.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2960 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 7

THICKNESS	=	24.00 INCHES
POROSITY	=	0.4730 VOL/VOL
FIELD CAPACITY	=	0.2220 VOL/VOL
WILTING POINT	=	0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2322 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.520000001000E-03 CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

THICKNESS	=	0.25 INCHES
POROSITY	=	0.8500 VOL/VOL
FIELD CAPACITY	=	0.0100 VOL/VOL
WILTING POINT	=	0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000 CM/SEC
SLOPE	=	2.00 PERCENT
DRAINAGE LENGTH	=	200.0 FEET

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 36

THICKNESS	=	0.04 INCHES
POROSITY	=	0.0000 VOL/VOL
FIELD CAPACITY	=	0.0000 VOL/VOL
WILTING POINT	=	0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY	=	1.00 HOLES/ACRE
FML INSTALLATION DEFECTS	=	8.00 HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	12.00 INCHES
POROSITY	=	0.4750 VOL/VOL
FIELD CAPACITY	=	0.3780 VOL/VOL
WILTING POINT	=	0.2650 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4750 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.999999975000E-05 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	88.20	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	22.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	5.658	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.386	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.018	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	156.096	INCHES
TOTAL INITIAL WATER	=	156.096	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM RALEIGH NORTH CAROLINA

STATION LATITUDE	=	35.87 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	86
END OF GROWING SEASON (JULIAN DATE)	=	310
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	7.70 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	66.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	78.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	72.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR RALEIGH NORTH CAROLINA AND STATION LATITUDE = 35.87 DEGREES

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.366	0.097	0.169	0.059	0.362	0.176
	0.189	0.554	0.158	0.175	0.244	0.131
STD. DEVIATIONS	0.485	0.116	0.194	0.127	0.554	0.217
	0.258	1.029	0.263	0.273	0.278	0.170
EVAPOTRANSPIRATION						
TOTALS	1.417	1.738	2.976	2.712	4.197	4.281
	3.999	4.060	2.504	1.295	1.173	1.035
STD. DEVIATIONS	0.162	0.246	0.306	0.935	0.784	1.545
	1.460	1.295	1.169	0.405	0.143	0.160
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.7733	1.1764	1.3642	1.2311	0.9787	0.4166
	0.1999	0.0776	0.0861	0.3109	0.1611	0.4388
STD. DEVIATIONS	0.6343	0.5936	0.7360	0.7780	1.0281	0.3702
	0.2524	0.1192	0.1875	0.8946	0.4802	0.6571
PERCOLATION/LEAKAGE THROUGH LAYER 6						
TOTALS	0.0000	0.0000	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0044	0.0073	0.0078	0.0072	0.0056	0.0025
	0.0011	0.0004	0.0005	0.0018	0.0009	0.0025
STD. DEVIATIONS	0.0036	0.0037	0.0042	0.0046	0.0059	0.0022
	0.0014	0.0007	0.0011	0.0051	0.0028	0.0037

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	2.680	(1.8280)	9729.88	6.498
EVAPOTRANSPIRATION	31.386	(3.7355)	113932.33	76.089
LATERAL DRAINAGE COLLECTED FROM LAYER 4	7.21475	(3.58314)	26189.551	17.49052
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00031	(0.00014)	1.109	0.00074
AVERAGE HEAD ON TOP OF LAYER 5	0.004	(0.002)		
CHANGE IN WATER STORAGE	-0.032	(2.2283)	-117.18	-0.078

537 spad

PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	2.948	10701.5029
DRAINAGE COLLECTED FROM LAYER 4	0.18915	686.61426
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000007	0.02534
AVERAGE HEAD ON TOP OF LAYER 5	0.033	
MAXIMUM HEAD ON TOP OF LAYER 5	0.066	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	1.0 FEET	
SNOW WATER	1.80	6547.7266
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3608	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0917	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	2.6406	0.2200
2	140.6111	0.2929
3	6.4959	0.2707
4	0.0025	0.0100
5	0.0000	0.0000
6	5.7000	0.4750
SNOW WATER	0.000	

7/12

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******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**        HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE                     **
**        HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                        **
**        DEVELOPED BY ENVIRONMENTAL LABORATORY                             **
**        USAE WATERWAYS EXPERIMENT STATION                                 **
**        FOR USEPA RISK REDUCTION ENGINEERING LABORATORY                   **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************

PRECIPITATION DATA FILE:      D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCP.D4
TEMPERATURE DATA FILE:        D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCT.D7
SOLAR RADIATION DATA FILE:    D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCS.D13
EVAPOTRANSPIRATION DATA:      D:\PKSFIL~1\2ENGPR~1\HELP3\RALNCE.D11
SOIL AND DESIGN DATA FILE:    D:\PKSFIL~1\2ENGPR~1\HELP3\JCFINAL.D10
OUTPUT DATA FILE:             D:\PKSFIL~1\2ENGPR~1\HELP3\JCFINAL.OUT

TIME: 18:21     DATE:   7/14/2005

******************************************************************************

    TITLE:  Johnston County C&DLF - Area 2 - Final Cover Condition

******************************************************************************

    NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER WERE
           COMPUTED AS NEARLY STEADY-STATE VALUES BY THE PROGRAM.

                               LAYER  1
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =    24.00   INCHES
        POROSITY                   =     0.4730 VOL/VOL
        FIELD CAPACITY             =     0.2220 VOL/VOL
        WILTING POINT              =     0.1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.2318 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.520000001000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                               LAYER  2
                               --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =     0.25   INCHES
        POROSITY                   =     0.8500 VOL/VOL
        FIELD CAPACITY             =     0.0100 VOL/VOL
        WILTING POINT              =     0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0121 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  10.0000000000      CM/SEC
        SLOPE                      =    25.00   PERCENT
        DRAINAGE LENGTH            =   150.0    FEET

                               LAYER  3
                               --------

                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  36
        THICKNESS                  =     0.03   INCHES
        POROSITY                   =     0.0000 VOL/VOL
        FIELD CAPACITY             =     0.0000 VOL/VOL
        WILTING POINT              =     0.0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.399999993000E-12 CM/SEC
        FML PINHOLE DENSITY        =     1.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     6.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  3 - GOOD

                               LAYER  4
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =    12.00   INCHES
        POROSITY                   =     0.4730 VOL/VOL
        FIELD CAPACITY             =     0.2220 VOL/VOL
        WILTING POINT              =     0.1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.2220 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.520000001000E-03 CM/SEC

                               LAYER  5
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER  18
        THICKNESS                  =   480.00   INCHES
        POROSITY                   =     0.6710 VOL/VOL
        FIELD CAPACITY             =     0.2920 VOL/VOL
        WILTING POINT              =     0.0770 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.2920 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                               LAYER  6
                               --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   7
        THICKNESS                  =    24.00   INCHES
        POROSITY                   =     0.4730 VOL/VOL
        FIELD CAPACITY             =     0.2220 VOL/VOL
        WILTING POINT              =     0.1040 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.2220 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.520000001000E-03 CM/SEC

                               LAYER  7
                               --------

                 TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER  20
        THICKNESS                  =     0.25   INCHES
        POROSITY                   =     0.8500 VOL/VOL
        FIELD CAPACITY             =     0.0100 VOL/VOL
        WILTING POINT              =     0.0050 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0100 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  10.0000000000      CM/SEC
        SLOPE                      =     2.00   PERCENT
        DRAINAGE LENGTH            =   200.0    FEET

                               LAYER  8
                               --------

                 TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  36
        THICKNESS                  =     0.04   INCHES
        POROSITY                   =     0.0000 VOL/VOL
        FIELD CAPACITY             =     0.0000 VOL/VOL
        WILTING POINT              =     0.0000 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.399999993000E-12 CM/SEC
        FML PINHOLE DENSITY        =     1.00   HOLES/ACRE
        FML INSTALLATION DEFECTS   =     8.00   HOLES/ACRE
        FML PLACEMENT QUALITY      =  3 - GOOD

                               LAYER  9
                               --------

                 TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
        THICKNESS                  =    12.00   INCHES
        POROSITY                   =     0.4750 VOL/VOL
        FIELD CAPACITY             =     0.3780 VOL/VOL
        WILTING POINT              =     0.2650 VOL/VOL
        INITIAL SOIL WATER CONTENT =     0.4750 VOL/VOL
        EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-05 CM/SEC

           GENERAL DESIGN AND EVAPORATIVE ZONE DATA
           ----------------------------------------

    NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 7 WITH BARE
           GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
           A SLOPE LENGTH OF  300. FEET.

        SCS RUNOFF CURVE NUMBER            =    88.20
        FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
        AREA PROJECTED ON HORIZONTAL PLANE =     1.000  ACRES
        EVAPORATIVE ZONE DEPTH             =    22.0    INCHES
        INITIAL WATER IN EVAPORATIVE ZONE  =     4.985  INCHES
        UPPER LIMIT OF EVAPORATIVE STORAGE =    10.406  INCHES
        LOWER LIMIT OF EVAPORATIVE STORAGE =     2.288  INCHES
        INITIAL SNOW WATER                 =     0.000  INCHES
        INITIAL WATER IN LAYER MATERIALS   =   159.421  INCHES
        TOTAL INITIAL WATER                =   159.421  INCHES
        TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR

                EVAPOTRANSPIRATION AND WEATHER DATA
                -----------------------------------

    NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
           RALEIGH              NORTH CAROLINA

        STATION LATITUDE                        =  35.87 DEGREES
        MAXIMUM LEAF AREA INDEX                 =   2.00
        START OF GROWING SEASON (JULIAN DATE)   =    86
        END OF GROWING SEASON (JULIAN DATE)     =   310
        EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
        AVERAGE ANNUAL WIND SPEED               =   7.70 MPH
        AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  66.00 %
        AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
        AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  78.00 %
        AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  72.00 %

    NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR     RALEIGH              NORTH CAROLINA
```

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.55	3.43	3.69	2.91	3.67	3.66
4.38	4.44	3.29	2.73	2.87	3.14

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    NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR     RALEIGH              NORTH CAROLINA
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NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
39.60	41.60	49.30	59.50	67.20	73.90
77.70	77.00	71.00	59.70	50.00	42.00

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    NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
           COEFFICIENTS FOR     RALEIGH              NORTH CAROLINA
           AND STATION LATITUDE  =  35.87 DEGREES
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8/12

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 20

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	3.44	2.92	3.81	2.20	4.34	3.74
	4.24	5.43	2.40	2.87	3.05	2.80
STD. DEVIATIONS	2.07	1.23	1.51	1.52	2.22	1.98
	1.91	3.72	1.67	2.00	1.79	1.04
RUNOFF						
TOTALS	0.385	0.105	0.182	0.064	0.373	0.181
	0.194	0.575	0.167	0.178	0.250	0.136
STD. DEVIATIONS	0.509	0.121	0.209	0.139	0.575	0.224
	0.266	1.068	0.293	0.281	0.284	0.173
EVAPOTRANSPIRATION						
TOTALS	1.405	1.729	2.912	2.729	3.990	3.628
	3.650	3.757	2.313	1.287	1.195	1.038
STD. DEVIATIONS	0.210	0.287	0.354	0.939	0.916	1.571
	1.366	1.279	1.102	0.406	0.198	0.137
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	1.5498	1.2165	1.1222	0.4777	0.3354	0.3309
	0.3306	0.7587	0.3953	0.2594	0.9335	1.1060
STD. DEVIATIONS	1.0681	0.8922	0.8515	0.4884	0.5255	0.2506
	0.2739	0.9669	0.6473	0.4436	0.9249	0.6307
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0000	0.0002	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
LATERAL DRAINAGE COLLECTED FROM LAYER 7						
TOTALS	0.0002	0.0002	0.0002	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0000	0.0001	0.0002
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0000
	0.0000	0.0001	0.0001	0.0001	0.0001	0.0001
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3						
AVERAGES	0.0006	0.0005	0.0004	0.0002	0.0001	0.0001
	0.0001	0.0003	0.0001	0.0001	0.0003	0.0004
STD. DEVIATIONS	0.0004	0.0004	0.0003	0.0002	0.0002	0.0001
	0.0001	0.0004	0.0002	0.0002	0.0003	0.0002
DAILY AVERAGE HEAD ON TOP OF LAYER 8						
AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 20

	INCHES		CU. FEET	PERCENT
PRECIPITATION	41.25	(8.104)	149735.7	100.00
RUNOFF	2.790	(1.9297)	10129.09	6.765
EVAPOTRANSPIRATION	29.632	(3.6903)	107565.02	71.837
LATERAL DRAINAGE COLLECTED FROM LAYER 2	8.81614	(3.81136)	32002.582	21.37271
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.00144	(0.00048)	5.224	0.00349
AVERAGE HEAD ON TOP OF LAYER 3	0.000	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.00144	(0.00048)	5.212	0.00348
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00000	(0.00000)	0.012	0.00001
AVERAGE HEAD ON TOP OF LAYER 8	0.000	(0.000)		
CHANGE IN WATER STORAGE	0.009	(1.1053)	33.78	0.023

0.11 spad

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 20

	(INCHES)	(CU. FT.)
PRECIPITATION	5.22	18948.600
RUNOFF	2.955	10724.8623
DRAINAGE COLLECTED FROM LAYER 2	1.02055	3704.58569
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.000085	0.30740
AVERAGE HEAD ON TOP OF LAYER 3	0.011	
MAXIMUM HEAD ON TOP OF LAYER 3	0.059	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	0.0 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00008	0.28166
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00007
AVERAGE HEAD ON TOP OF LAYER 8	0.000	
MAXIMUM HEAD ON TOP OF LAYER 8	0.000	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	1.80	6547.7266
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3536	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1040	

*** Maximum heads are computed using McEnroe's equations. ***

Reference: Maximum Saturated Depth over Landfill Liner
by Bruce M. McEnroe, University of Kansas
ASCE Journal of Environmental Engineering
Vol. 119, No. 2, March 1993, pp. 262-270.

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FINAL WATER STORAGE AT END OF YEAR 20

LAYER	(INCHES)	(VOL/VOL)
1	5.7499	0.2396
2	0.0027	0.0110
3	0.0000	0.0000
4	2.6640	0.2220
5	140.1600	0.2920
6	5.3280	0.2220
7	0.0025	0.0100
8	0.0000	0.0000
9	5.7000	0.4750
SNOW WATER	0.000	

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****

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, NC 27603
Tel: 919-828-0577
Fax: 919-828-3899

SHEET: 9/12
JOB #: JOHNSTON-22
DATE: 10/6/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Evaluation of Leachate Generation Rates

LEACHATE GENERATION RATES:

1 Year, 24 Hour Design Storm Depth = 3.20 inches **(US Weather Bureau TP-40)**

Open: 86,888 gallons/acre/day
Active: 1,200 gallons/acre/day
Interim: 500 gallons/acre/day
Final: 100 gallons/acre/day

OPEN		ACTIVE		INTERIM		FINAL		TOTAL
Acres	GPD	Acres	GPD	Acres	GPD	Acres	GPD	GPD
A. Initial Filling of Area 2 (Maximum Value is "Surge" Event) (Phases 4A & Phase 5 under Interim Conditions)								
2.0	173,775	0.0	0	48.6	24,300	0.0	0	198,075
2.0	173,775	2.0	2,400	48.6	24,300	0.0	0	200,475
2.0	173,775	4.0	4,800	48.6	24,300	0.0	0	202,875
2.0	173,775	6.0	7,200	48.6	24,300	0.0	0	205,275
2.0	173,775	8.0	9,600	48.6	24,300	0.0	0	207,675
3.0	260,663	12.8	15,360	48.6	24,300	0.0	0	300,323
B. Waste Covers Area 2 (Value is "Typical" for Area 2)								
0.0	0	15.8	18,960	48.6	24,300	0.0	0	43,260
C. Completion of Area 2 Operations								
0.0	0	0.0	0	64.4	32,200	0.0	0	32,200
D. Closure of Phase 4A, Phase 5, & Area 2 (Value is "Typical" for Post-Closure Conditions)								
0.0	0	0.0	0	0.0	0	64.4	6,440	6,440

SHEET:	10/12
JOB #:	JOHNSTON-22
DATE:	10/6/05
BY:	PKS
CHKD BY:	

REQUIRED REMOVAL RATES:

Case 1: Surge Event:

Quantity of Leachate Produced = 300,323 gallons **(See Above)**
Maximum Storage Capacity = 4,300,000 gallons **(See Below)**

Before Surge Event		After Surge Event		Maximum Detention Time In in Landfill (days)	
Available Storage Capacity (gallons)	Volume Retained in Lagoon (gallons)	Volume Retained in Lagoon (gallons)	Volume Retained in Landfill (gallons)	Pump Rate = 15,000 gpd	Pump Rate = 30,000 gpd
2,000,000	2,300,000	2,600,323	0	0.0	0.0
1,800,000	2,500,000	2,800,323	0	0.0	0.0
1,600,000	2,700,000	3,000,323	0	0.0	0.0
1,400,000	2,900,000	3,200,323	0	0.0	0.0
1,200,000	3,100,000	3,400,323	0	0.0	0.0
1,000,000	3,300,000	3,600,323	0	0.0	0.0
800,000	3,500,000	3,800,323	0	0.0	0.0
600,000	3,700,000	4,000,323	0	0.0	0.0
400,000	3,900,000	4,200,323	0	0.0	0.0
200,000	4,100,000	4,300,000	100,323	6.7	3.3
100,000	4,200,000	4,300,000	200,323	13.4	6.7
0	4,300,000	4,300,000	300,323	20.0	10.0

Case 2: Typical Phase 3 Leachate Generation:

Typical Leachate Generation Rate = 43,260 gallons/day **(See Above)**

Days of Storage Capacity = 99.4 days

Case 3: Typical Post-Closure Leachate Generation:

Typical Leachate Generation Rate = 6,440 gallons/day **(See Above)**

Days of Storage Capacity = 667.7 days

STORAGE CAPACITY OF LEACHATE LAGOON:

Capacity = 4,300,000 gallons **(With 2 Feet of Freeboard)**
(See Attached)

G.N. Richardson & Associates
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, NC 27603
Tel: 919-828-0577
Fax: 919-828-3899

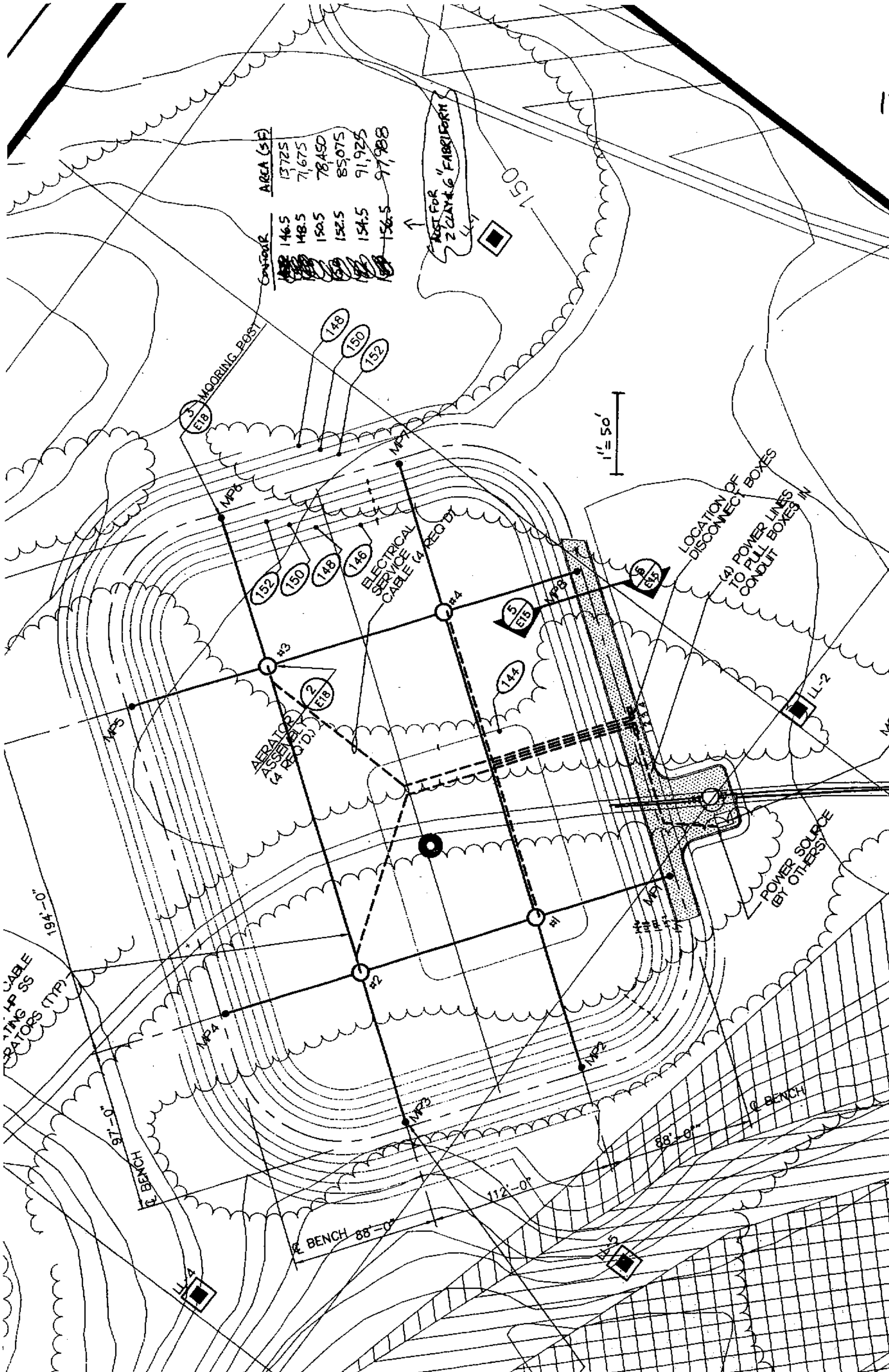
SHEET: 11 / 12
JOB #: JOHNSTON-22
DATE: 9/9/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Volume of Leachate Storage Lagoon

STORAGE CAPACITY OF LEACHATE STORAGE LAGOON:

Contour	Area (SF)	Incr Vol (CF)	Accum Vol (CF)	Accum Vol (Gallons)	Stage (FT)
146.5	13,725		0	0	0
148.5	71,675	85,400	85,400	638,792	2
150.5	78,450	150,125	235,525	1,761,727	4
152.5	85,075	163,525	399,050	2,984,894	6
154.5	91,925	177,000	576,050	4,308,854	8
156.5	97,988	189,913	765,963	5,729,403	10

12/12



CONTOUR
AREA (SF)
146.5 13725
148.5 71,675
150.5 78,450
152.5 85,075
154.5 91,925
156.5 97,988
REQ'T FOR 2 CLAY + 6" FABRIFORM
LL-1
150
MOORING POST
148
150
152
1" = 50'
LOCATION OF DISCONNECT BOXES
(4) POWER LINES TO PULL BOXES IN CONDUIT
ELECTRICAL SERVICE CABLE (4 REQ'D)
AERATOR ASSEMBLY (4 REQ'D)
144
146
148
150
152
MP1
MP2
MP3
MP4
MP5
MP6
MP7
MP8
#1
#2
#3
#4
LL-2
LL-4
LL-5
POWER SOURCE (BY OTHERS)
℄ BENCH
194'-0"
97'-0"
112'-0"
88'-0"

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DATE: 18-Oct-05
BY: SAS
JOB NO: JOHNSTON-21

V PKS

Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

Objective: Determine pumping system parameters for the proposed leachate collection system.

Given:

1. Cell Area:	15.8	AC	------>	Ref. 1
2. Normal Flow Condtions:	20,000	GPD	------>	Leachate Generation Calculations
3. Peak Flow Conditions:	150,000	GPD	------>	Leachate Generation Calculations (Assume use of GRC)
4. Minimum Flow Velocity:	2	fps	------>	Ref. 3 (for "Self Cleaning")
5. Maximum Flow Velocity:	5	fps	------>	Ref. 3 (for "Water Hammer" Reduction)

Reference:

1. Johnston County C&D Landfill Area 2 Permit Drawings
2. Driscopipe Design Manual
3. "Pumping Station Design", 2nd Edition, Robert L. Sanks, Editor in Chief, 1998, by Butterworth Heineman.
4. "Elements of Urban Stormwater Design", H. Rooney Malcom, NCSU

Calculations: The pumps will be designed for critical elements as follows:

- Piping Requirements
- Pump Requirements
- System Cycle Time
- Riser Fit
- System Surge Pressures

1. Piping Requirements

-------> Determine Nominal Pumping Rate

The Nominal Pumping Rate is the greater of 2.5 times normal conditions or equal to peak conditions.

Therefore, @ Normal Conditions, Qreq = 35GPM and @ Peak Conditions, Qreq = 104GPM

Nominal Pumping Rate: $\boxed{100}$ **GPM**

-------> Determine Typical Pipe Size:

Pipes are sized to keep flow velocities within GIVEN ranges to insure turbulent flow.

Use the Continuity Equation for incompressible steady flow to determine flow velocity, Q = V*A

Where: Q = Flowrate (cfs)
V = Velocity (fps)
A = Area (square feet)

Standard Pipe Diameter (I.D.) =	3.088	inches	------>	SDR = 17
Nominal Pumping Rate, Q =	0.223	cfs		
Area, A =	0.052	square feet		
Velocity, V =	4.28	fps	------>	OK!

Therefore, Use 3 Inch - SDR 17 Pipe

2. Pump Requirements

Flow is desired in fully turbulent conditions. The Reynolds, R, number is used to verify this condition as follows:

Reynolds Number, R_e = V*D / υ

Where: V = velocity, fps
D = pipe inside diameter, inches
υ = kinematic viscosity, square feet per second

Velocity, V =	4.28	fps		
Pipe Inside Diameter (I.D.) =	3.09	inches		
kinematic viscosity, υ =	5.58E-06	square feet per second	----->	App. A, Table A-9 @ 130 degrees - Ref. 3

Reynolds Number, Re = 197,573 > 10,000 OK -----> Turbulent flow conditions exist

Pumps will be sized according to balance energy by the Bernoulli equation. The equation has been modified as follows:

$TDH = H_e + H_f + H_m$

Where: TDH = Total Dynamic Head, feet
H_e = Elevation Head, feet
H_f = Friction Head, feet
H_m = Minor Losses, feet

Calculations for these values are continued on a spreadsheet model of the system. Please refer to Table 1 (attached).

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DATE: 19-Oct-05
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JOB NO: JOHNSTON-21

Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

3. System Cycle Time

——> ~~Determine available storage if a wet well.~~

~~Bottom Elevation of Well =~~	~~162~~	~~FT~~	~~——> Ref. 1~~
~~Diameter of Well =~~	~~5~~	~~FT~~	~~——> Ref. 1~~
~~Top Elevation of Well =~~	~~172~~	~~FT~~	~~——> Ref. 1~~
~~Total Volume of Well =~~	~~196~~	~~CF~~	
~~Total Volume of Well =~~	~~1,469~~	~~GAL~~	
~~Pump ON Elevation =~~	~~168~~	~~FT~~	
~~Pump OFF Elevation =~~	~~165~~	~~FT~~	
~~Pump ON to OFF Volume =~~	~~441~~	~~GAL~~	

——> Determine available storage if a sideslope riser.

Storage volume is calculated according to the Average End Area Method. Assumes 3:1 Sideslopes.

Contour Elevation	Length (feet)	Width (feet)	Area (square feet)	Volume* (cubic feet)	Storage, S (cubic feet)	Storage, S (gallons)	Stage Z
0.0	16.0	16.0	256		0	0	0.0
0.5	19.0	19.0	361	154	154	1154	0.5
1.0	22.0	22.0	484	211	366	2734	1.0
1.5	25.0	25.0	625	277	643	4808	1.5
2.0	28.0	28.0	784	352	995	7443	2.0

Note:
* Calculated according to Average End Area Method

Available Volume = 841 cubic feet $\boxed{6289 \text{ gallons}}$
Minimum liquid elevation = 0.50 feet above bottom

The sump is filled with No. 57 Stone therefore volume is reduced. The assumed porosity of the stone is 30%.

If pumps cycle through one (1) foot of elevation volume is 7,443 GAL - 1,154 GAL = 6,289 GALLONS
@ 30% porsity ——> Available Volume = 1887 GALLONS

——> Determine Cycle Time

The pumps should not operate more than 9 times per hour. Minimum cycle time will be determined by the equation below: ——> Sanks, Ref. 3

t = V/(Q-S) + V/S where:
t = Cycle time (min)
V = Volume of Liquid (gallons)
Q = Pumping rate (GPM)
S = Inflow (GPM)

Therefore, V =	1887	GAL ——> from above
Q =	100	GPM ——> Nominal Pumping Rate
S =	14	GPM ——> Normal Flow Conditions
t =	158	minutes

Pump will start once every 3 hours

Pump drawdown time will be 22 minutes

4. Riser Fit

——> Determine minimum dimensions of sideslope riser pipe to allow pump to fit and manage turn at the bottom of the slope

At half of the pump length (L/2), the pump will equally straddle the turn in the pipe and will be at its closest point to the upper edge of the interior of the pipe riser. This value will be compared with the available space with a Factor of Safety of 10% for pipe irregularities.

Pipe Dimensions:

Riser Slope: 3 H to 1 V
Riser Pipe I.D. = 15.882 inches ——> AVAILABLE

Pump Dimensions:
Pump Length, L = 55 inches ——>
Total Width 6.5 inches ——> *Leachator LPS150MSTG12075-04*
Clearance = 4.92 inches

Riser Fit ? **OK ——> USE 18 inch HDPE SDR 17 PIPE**

Standard Pipe Sizes:

Inside* Diameter (inches)	Standard Design Ratio (SDR)	Nominal Pipe Size (inches)
10.432	11	12
11.250	17	12
14.728	11	18
15.882	17	18
19.636	11	24
21.176	17	24

* Ref. 2

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Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

5. *System Surge Pressures*

--------> Determine if pipe is sufficient strength to withstand system surges.

System surge pressure is determined by the equation:

$\Delta P = (a/g)*(\Delta v/2.31)$ ------->Ref. 3, pg. 143.

Where: ΔP = Pressure (psi)
a = Pressure wave velocity (fps)
Δv = Change in velocity (fps)
g = acceleration of gravity (32.1 ft/sec^2)

and

$a = 4822/(1+k/E*(D/t)*C_2)$^0.5 ------->Ref. 3, pg. 144.

Where: k = Bulk modulus of water (psi)
E = Pipe modulus of elasticity (psi)
D = Internal diameter of pipe (inches)
t = Pipe wall thickness (inches)
C_2 = Constant dependent upon pipe constraints
μ = poisson's ratio, use 0.45 for HDPE pipe (buried), Table 6-1, Ref. 2

k = 296,000 psi ------> App. A, Table A-9 @ 40°F - Ref. 3 Conservative Case
E = 100,000 psi ------> HDPE , Ref. 2
Δv = 5 fps ------> Maximum allowable velocity
μ = 0.45
C_2 = 0.80
FS = 1.5 Minimum Allowable

P(allowable) Ref. 2 (psi)	Standard Design Ratio (SDR)	Nominal Pipe Size (inches)	Outside Diameter (inches)	Inside Diameter (inches)	Pipe Wall Thickness (inches)	Pressure Wave Velocity (fps)	Pressure (psi)	Factor of Safety	Comment
267	7	2	2.375	1.697	0.339	1347	91	2.94	OKAY
200	9	2	2.375	1.847	0.264	1152	78	2.57	OKAY
160	11	2	2.375	1.943	0.216	1023	69	2.32	OKAY
128	13.5	2	2.375	2.023	0.176	909	61	2.09	OKAY
110	15.5	2	2.375	2.069	0.153	840	57	1.94	OKAY
100	17	2	2.375	2.095	0.140	800	54	1.85	OKAY
267	7	3	3.500	2.500	0.500	1348	91	2.94	OKAY
200	9	3	3.500	2.722	0.389	1152	78	2.57	OKAY
160	11	3	3.500	2.864	0.318	1022	69	2.32	OKAY
128	13.5	3	3.500	2.982	0.259	908	61	2.09	OKAY
110	15.5	3	3.500	3.048	0.226	841	57	1.94	OKAY
100	**17**	**3**	**3.500**	**3.088**	**0.206**	**799**	**54**	**1.86**	**OKAY**
89	19	3	3.500	3.132	0.184	751	51	1.76	OKAY
80	21	3	3.500	3.166	0.167	713	48	1.66	OKAY
64	26	3	3.500	3.230	0.135	636	43	1.49	NO GOOD
51	32.5	3	3.500	3.284	0.108	565	38	1.34	NO GOOD
267	7	4	4.500	3.214	0.643	1348	91	2.94	OKAY
200	9	4	4.500	3.500	0.500	1152	78	2.57	OKAY
160	11	4	4.500	3.682	0.409	1022	69	2.32	OKAY
128	13.5	4	4.500	3.834	0.333	908	61	2.09	OKAY
110	15.5	4	4.500	3.020	0.290	953	64	1.71	OKAY
100	17	4	4.500	3.970	0.265	800	54	1.85	OKAY
89	19	4	4.500	4.026	0.237	752	51	1.75	OKAY
80	21	4	4.500	4.072	0.214	712	48	1.67	OKAY
64	26	4	4.500	4.154	0.173	635	43	1.49	NO GOOD
51	32.5	4	4.500	4.224	0.138	563	38	2.68	OKAY
267	7	6	6.625	4.733	0.946	1347	91	5.88	OKAY
200	9	6	6.625	5.153	0.736	1152	78	5.15	OKAY
160	11	6	6.625	5.421	0.602	1022	69	4.64	OKAY
128	13.5	6	6.625	5.643	0.491	909	61	4.18	OKAY
110	15.5	6	6.625	5.771	0.427	841	57	3.88	OKAY
100	17	6	6.625	5.845	0.390	799	54	3.71	OKAY
89	19	6	6.625	5.927	0.349	752	51	3.51	OKAY
80	21	6	6.625	5.995	0.315	712	48	3.33	OKAY
64	26	6	6.625	6.115	0.255	635	43	2.99	OKAY
51	32.5	6	6.625	6.217	0.204	565	38	2.68	OKAY

Use 3 Inch HDPE - SDR 17 Pipe

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DATE: 19-Oct-05
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JOB NO: JOHNSTON-21

Leachate Management
Johnston County C&D Landfill
Leachate Pumping System Design

From	To	Flow (GPM)	4. Velocity (1) (FPS)	4a. Pipe Slope (%)	Size (IN)	Length (FT)	7. Friction Loss (2) (PSI)	Sum of Energy Loss Coefficients (3) (K)	9. Minor Losses (4) (PSI)	Elevation Head (5) (FT)	Additional Pressures (PSI)	11. Sum of Losses (PSI)	12. Subtotal Dynamic Head (FT)	13. Total Dynamic Head (FT)
Area 2 Sump	Valve Box	100	4.54	N/A	3.000	50	0.66	23	7.37	12	0.00	13.22	30.51	151
Valve Box	Air Release	100	4.29	N/A	3.088	700	8.04	4	1.14	40	0.00	26.50	61.15	
Air Release	Phase 4A, LDS Manhole	100	5.92	5.00	3.088	1400	16.07	4	2.18	-40	0.00	0.93	2.14	
Phase 4A, LDS Manhole	Low Point (29+00 Profile)	100	5.92	5.00	3.088	800	9.19	4	2.18	-17	0.00	4.00	9.24	
Low Point (29+00 Profile)	Existing Manhole	100	4.29	N/A	3.088	600	6.89	4	1.14	29	0.00	20.59	47.51	
Existing Manhole (See Note 6)	Leachate Storage Lagoon	280	4.59	1.00	7.057	1600	1.93	4	1.31	-12	0.00	-1.96	-4.51	-5

Pipe Roughness, C = 130 ——> Conservative for HDPE Pipe, Ref. 2
Manning's Roughness, n = 0.009 ——> Recommended for HDPE Pipe, Ref. 2

< 0
∴ ok !

Notes:

1. Velocity determined by V = Q/A for forced systems and by V = (sqrt (slope)*D^(2/3))/(8.9*n) for gravity systems
2. Friction losses determined by Hazen-Williams Formula.
3. Enegy Loss Coefficient, K was calculated according to values in Tables B-6 and B-7, "Pumping Station Design", 2nd Edition by Robert L. Sanks.
4. Minor losses determined by a portion of Bernoulli's Principle ($kv^2/2g$).
5. Elevation head determined from the site plan.
6. Flows through existing manhole were evaluated assuming all flows from Phase 5, Phase 4A (Primary and LDS), and from Area II at simultaneous condition.

Pump Schedule: Area II Pump —> USE LEACHATOR PUMP MODEL LPS150MSTG12075-04

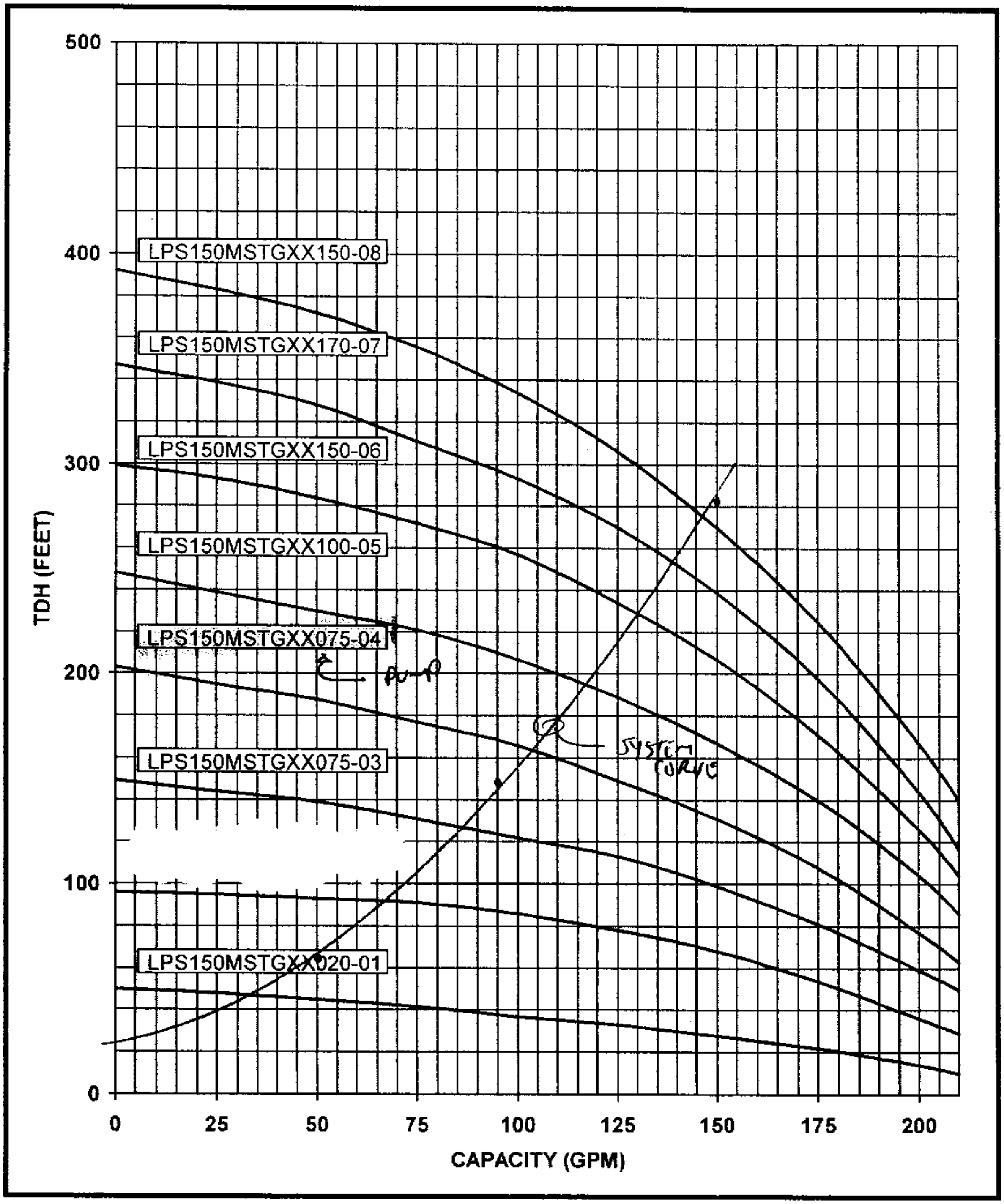
4/6

5/6

MODEL LPS150MSTG

PUMP PERFORMANCE DATA

Performance Curve



SPECIFICATIONS SUBJECT TO CHANGE WITHOUT NOTICE
Performance conforms to ISO 2548 Annex B @ 5 ft. min. submergence.
4" MOTOR STANDARD, 2 – 5HP, 3450 RPM
6" MOTOR STANDARD, 7-1/2 – 60HP, 3450 RPM
8" MOTOR STANDARD, 75HP, 3525

6/6

Models

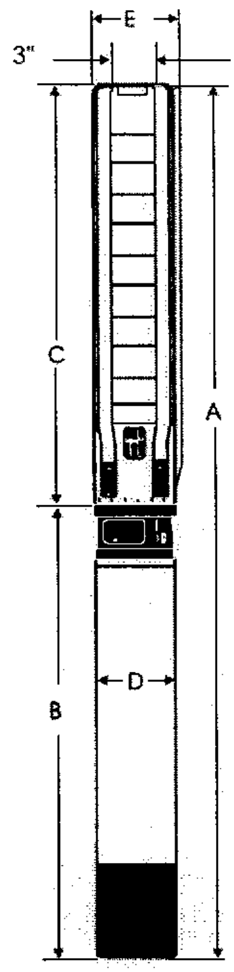
Model Number	Motor Size	HP	RPM	Voltage
LPS150MSTG12020-01	4"	2	3450	230V/1Ph/60Hz
LPS150MSTG3X020-01	4"	2	3450	230-460V/3Ph/60Hz
LPS150MSTG12050-02	4"	5	3450	230V/1Ph/60Hz
LPS150MSTG3X050-02	4"	5	3450	230-460V3Ph/60Hz
LPS150MSTG12075-03	6"	7-1/2	3450	230V/1Ph/60Hz
LPS150MSTG3X075-03	6"	7-1/2	3450	230-460V/3Ph/60Hz
LPS150MSTG12075-04	6"	7-1/2	3450	230V/1Ph/60Hz
LPS150MSTG3X075-04	6"	7-1/2	3450	230-460V/3Ph/60Hz
LPS150MSTG12100-05	6"	10	3450	230V/1Ph/60Hz
LPS150MSTG3X100-05	6"	10	3450	230-460V/3Ph/60Hz
LPS150MSTG12150-06	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-06	6"	15	3450	230-460V3Ph/60Hz
LPS150MSTG12150-07	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-07	6"	15	3450	230-460V/3Ph/60Hz
LPS150MSTG12150-08	6"	15	3450	230V/1Ph/60Hz
LPS150MSTG3X150-08	6"	15	3450	230-460V/3Ph/60Hz

Please insert a "2" (230V) or "4" (460V) to complete the model number.

Dimensions And Weights

Model Number	Disch Size	Dimensions In Inches					Approx. Wt
		A	B	C	D	E	
LPS150MSTGXX020-01	3" NPT	27.3	13.6	13.7	3.75	5.2	55
LPS150MSTGXX050-02	3" NPT	41.1	23.6	17.5	3.75	5.2	75
LPS150MSTGXX075-03	3" NPT	45.5	24.2	21.3	5.38	5.2	101
LPS150MSTGXX075-04	3" NPT	49.9	24.2	25.7	5.38	5.6	135
LPS150MSTGXX100-05	3" NPT	54.9	25.4	29.5	5.38	5.6	148
LPS150MSTGXX150-06	3" NPT	61.3	28.0	33.3	5.38	5.6	167
LPS150MSTGXX150-07	3" NPT	65.0	28.0	37.0	5.38	5.6	169
LPS150MSTGXX150-08	3" NPT	68.8	28.0	40.8	5.38	5.6	174

Note(s): *Dimensions and weight are approximate (subject to change) and does not include the carriage.*



Materials Of Construction

Impeller	304 Stainless Steel
Impeller Seal Ring	Teflon
Motor Adapter	304 Stainless Steel
Inlet Screen	304 Stainless Steel
Pump Shaft	431 Stainless Steel
Coupling	329/416 Stainless Steel
Check Valve Housing	304 Stainless Steel
Check Valve	304 Stainless Steel
Check Valve Seat	Teflon/316 Stainless Steel
Diffuser Chamber	304 Stainless Steel
Fasteners	304 Stainless Steel
Bearing	Teflon/316 Stainless Steel
Suspension Cables	304 Stainless Steel

PROJECT	Johnston County C&D Landfill - Area 2	**SHEET** 1 **OF** 3	
		JOB NO.	JOHNSTON-22
		DATE	7/14/05
SUBJECT	Final Cover Drainage Layer Analysis	**COMPUTED BY**	PKS
		CHECKED BY	

Objective

To evaluate the required transmissivity for the drainage geocomposite placed in the final cover system.

References

Richardson, G.N., Giroud, J.P., and Zhao, A. (2001), Design Manual of Lateral Drainage Systems for Landfills, Tenax Corp., Baltimore.

Analysis

Step 1:

Determine the required transmissivity (θ_{reqd}) of the drainage geocomposite based on the following equation:

$$\theta_{reqd} = \frac{RF_{dc} q_n L i}{\sin\beta} = \frac{RF_{dc} q_n L \cos\beta}{\sin\beta} = \frac{RF_{dc} q_n L}{\tan\beta} \quad (m^3/m/sec)$$

Where:
- RF_{dc} = drainage geocomposite reduction factor (See Note 1)
- q_n = fluid input rate/impingement rate (m/s) (See Note 2)
- L = flow length/drain spacing (horizontally projected) (m)
- β = slope angle of final cover (degrees).

Notes:

1. Based on the recommendations of Richardson, Giroud, & Zhao, use $RF_{dc} = 6$. This accounts for an overall factor of safety of 2, plus a factor of safety of 3 for long-term intrusion, creep, and clogging concerns.

2. Typically the impingement into the drainage geocomposite is determined by the **lessor** of:

   a. Permeability of the Overlying Vegetative Soil Layer(k_{veg}) or
   b. Design Rainfall.

   Per Richardson,Giroud, & Zhao, use $q_n = k_{veg}$ except in arid/semi-arid areas.

Step 2:

Determine the required transmissivity test parameters:

- Normal Stress (Cover Thickness x Unit Weight of Cover Soil) and
- Hydraulic Gradient (Equals Slope of Cover System).

FCS DRAIN LAYER.WPD

Step 3:

Calculate the required total flow capacity (Q) of the drain based on the following equation:

$$Q = q_n A \qquad \text{(cfs)}$$

Where:
- q_n = impingement (ft/s)
- A = total area served by the drain (= L x DL) (ft^2)
- DL = length of drain between outlet locations (ft).

Step 4:

After finding Q for each drain, the designer shall select the appropriate type and size of drain.

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SHEET: 3 / 3
JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Final Cover Drainage Layer Analysis

Input Parameters:

Side Slope Angle (β):	14.0 degrees	
Impingement (q_n):	0.0001 cm/sec	(= Permeability of Vegetative Soil Layer)
Drain Spacing (L):	140 ft	
Reduction Factors for Drainage Geocomposite:		(Per Richardson, Giroud, & Zhao Recommendations)
$RF_{intrusion}$:	1.2	
RF_{creep}:	1.4	
$RF_{chemical\ clogging}$:	1.2	
$RF_{biological\ clogging}$:	1.5	
Overall Factor of Safety:	2.0	
Reduction Factor for Drainage Geocomposite in Final Cover (RF_{dc}):	6.0	
Drain Length (DL):	200 ft	
Final Cover: Thickness:	2.0 ft	
Unit Weight:	110 pcf	

Note: Spreadsheet Converts Units as Required.

Transmissivity Requirements:

Determine Minimum Transmissivity:

θ_{min} = 1.0E-03 m^3/m/sec = 5.0 gpm/ft

Determine Transmissivity Test Parameters:

Min. Normal Stress = 220.0 psf

Hydraulic Gradient = 0.25

Determine Required Drain Capacity:

Calculate Required Total Flow Capacity:

Q = 0.09 cfs

*Based on 200 foot spacing between outlets.

PROJECT	Johnston County C&D Landfill - Area 2	SHEET 1 OF 4	
		JOB NO.	JOHNSTON-22
		DATE	7/14/05
SUBJECT	Rain Gutters & Down Pipe Sizing	COMPUTED BY	PKS
		CHECKED BY	

Objective To design rain gutters and down pipes to handle the maximum flow from the design storm.

References Debo, T.N., and Reese, A.J., Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, 1995, pp. 438-442.

Malcom, H. Rooney, Elements of Urban Stormwater Design, N.C. State University, Raleigh, NC, 1989.

Analysis

1. For each pipe size, determine the maximum area (A), to handle the predicted flow (Q) with an added factor of safety. Analyze rain gutters and down pipes based on partial flow to determine flow depth and velocity then compare the full flow capacity of each pipe size with the calculated peak flow rate to verify the desired factor of safety. Analyze rain gutter drop inlets (inlet to down pipes) as orifices.

2. Analyze rain gutter pipe perforations as orifice flow to ensure adequate flow capacity into rain gutters.

Calculations

- Determine Peak Flow Rate Into Each Respective Conveyance:

Use Rational Method:

$$Q = CIA$$

Where: Q = Flow (cfs)
C = Runoff Coefficient
I = Rainfall Intensity (Use 25-Year, 24-Hour Storm)
A = Drainage Area (Ac.)

Iterate the drainage area (A) to each drainage structure such that $Q_{max}/Q \geq 1.1$, where Q_{max} is the full flow capacity of the conveyance (see below).

FCS RAIN GUTTERS & DPIPES.WPD

PROJECT Johnston County C&D Landfill - Area 2	SHEET 2 OF 4
	JOB NO. JOHNSTON-22
	DATE 7/14/05
SUBJECT Rain Gutters & Down Pipe Sizing	COMPUTED BY PKS
	CHECKED BY

- Rain Gutters & Down Pipes:

Determine Flow Capacity (Q_{max}):

$$Q_{max} = \frac{0.463 D^{\frac{8}{3}} S^{\frac{1}{2}}}{n}$$ (D&R Equation 8.24)

Where: D = Pipe Inside Diameter (in)
S = Pipe Slope (ft/ft)
n = Manning's Roughness Coefficient

Determine Factor of Safety (FS):

$$FS = \frac{Q_{max}}{Q}$$

Determine Flow Depth:

$$h = \frac{1}{2}\left(1 - \cos\left(\frac{\theta}{2}\right)\right) D$$ (D&R Equation 8.29)

Where: h = Flow Depth (inches)
θ = Central Angle

$$\theta = \frac{3\pi}{2}\left[1 - (1 - \pi K)^{\frac{1}{2}}\right]^{\frac{1}{2}}$$ (D&R Equation 8.28)

K = Constant

$$K = 0.673 Q_n^{\frac{-8}{3}} S^{\frac{-1}{2}}$$ (D&R Equation 8.27)

Determine Flow Velocity:

$$V = \frac{Q}{A} = \frac{Q}{D^2 \frac{(\theta - \sin\theta)}{8}}$$ (D&R Equation 8.30 for "A")

Where: V = Flow Velocity (ft/sec)
A = Cross-Sectional Area of Flow (ft^3)

- Down Pipe Drop Inlets and Rain Gutter Pipe Perforations:

Determine Q_{max}:

$$Q_{\max} = C_d A \sqrt{2gh}$$ (Malcom Equation I-7)

Where: C_d = Coefficient of Discharge
A = Cross-Sectional Area of Flow (ft^3)
g = Acceleration of Gravity (32.2 ft/sec^2)
h = Driving Head - Centroid of Orifice to Water Surface (ft)

Determine Factor of Safety (FS):

$$FS = \frac{Q_{\max}}{Q}$$

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SHEET: 4/4
JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Rain Gutter/Down Pipe Design

Input Parameters:

Manning's Rougness Coefficient =	0.009	--> HDPE Pipe
Runoff Coefficient =	0.5	
Rainfall Intensity =	8.19	IN/HR ---> 25 YR - 5 MIN STORM
Allowable Head (Down Pipe Drop Inlets) =	24	INCHES
Orifice Coef. Of Discharge (Down Pipe Drop Inlets) =	0.6	TYPICAL
Hole Diameter (Rain Gutter Pipe Bottom Perforations) =	0.5	INCHES
Allowable Head (Rain Gutter Pipe Bottom Perforations) =	12	INCHES
Orifice Coef. Of Discharge (Rain Gutter Pipe Perforations) =	0.6	TYPICAL

Rain Gutters

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 6"	0.32	1.31	6.1	3	1.47	1.12	0.278	233	4.41	0.16	8.33
Max. Area - 8"	0.67	2.74	8.0	3	3.02	1.10	0.283	235	5.86	0.27	10.01
Max. Area - 10"	1.18	4.83	9.9	3	5.33	1.10	0.282	235	7.24	0.42	11.53
Max. Area - 12"	1.89	7.74	11.8	3	8.52	1.10	0.283	236	8.65	0.60	12.97

Down Pipe Drop Inlets

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	X-Sectional Area (SF)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)
Max. Area - 8"	0.52	2.13	8.0	0.35	2.38	1.12
Max. Area - 10"	0.80	3.28	9.9	0.53	3.64	1.11
Max. Area - 12"	1.14	4.67	11.8	0.76	5.17	1.11
Max. Area - 14"	1.37	5.61	12.9	0.91	6.18	1.10
Max. Area - 16"	1.80	7.37	14.8	1.19	8.14	1.10
Max. Area - 18"	2.27	9.30	16.6	1.50	10.23	1.10

Down Pipes

ID	Drainage Area (AC)	Runoff Volume (Q) (CFS)	Pipe I.D. (SDR 26) (IN)	Pipe Slope (%)	Flow Capacity (Q_{max}) (CFS)	Factor of Safety (>/= 1.10)	K (CONSTANT)	θ (< 265°)	Flow Depth (IN)	Flow Area (SF)	Flow Velocity (FPS)
Max. Area - 8"	1.02	4.18	8.0	7	4.62	1.11	0.282	235	5.85	0.27	15.28
Max. Area - 10"	1.80	7.37	9.9	7	8.15	1.11	0.282	235	7.23	0.42	17.61
Max. Area - 12"	2.88	11.79	11.8	7	13.01	1.10	0.282	235	8.63	0.60	19.81
Max. Area - 14"	3.66	14.99	12.9	7	16.51	1.10	0.283	236	9.45	0.71	21.03
Max. Area - 16"	5.27	21.58	14.8	7	23.81	1.10	0.282	235	10.83	0.94	23.04
Max. Area - 18"	7.17	29.36	16.6	7	32.34	1.10	0.283	236	12.16	1.18	24.88

Rain Gutter Pipe Perforations

ID	Max. Drainage Length (LF)	Runoff Volume/LF Pipe (CFS)	No. Holes/LF	X-Sectional Area (SF/Hole)	Flow Capacity (Q_{max}) (CFS/LF)	Factor of Safety (>/= 1.10)
2 Bottom Perfs. @ 4" O.C.	200	0.019	6	0.001	0.039	2.10

Note: Conservatively Neglects Upper Holes.

Pipe Dimensions

Standard Dimension Ratio (SDR) of Pipe = 26

Nominal Pipe Size (IN)	Pipe O.D. (IN)	Min. Wall Thickness (IN)	Pipe I.D. (IN)
6	6.625	0.255	6.1
8	8.625	0.332	8.0
10	10.75	0.413	9.9
12	12.75	0.490	11.8
14	14	0.538	12.9
16	16	0.615	14.8
18	18	0.692	16.6
24	24	0.923	22.2

Technical Specifications

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:

Johnston County
Department of Public Utilities

October 2005

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

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.

Should it become necessary to remove a tree, bush, brush, or other plants outside the clearing limits, 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 and sod on the site within areas designated on the Contract Drawings shall be stripped to whatever depth it may occur, and stored in locations directed by the Engineer.

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, and bushes shall be removed from the site and disposed of by the Contractor. On-site and off-site disposal areas are subject to approval by the Engineer.

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, subgrade 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.

6. <u>Leachate Seeps:</u>

   Due to the nature of this project, the Contractor is responsible for the control of leachate seeps which develop within the Contract Limits whether created by his construction activities or not. The method(s) of control for leachate seeps shall be subject to the approval of the Owner and the Engineer.

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 with 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 on-site material required for the construction of embankments/fills or for other portions of the work.

c. Select Borrow: shall consist of approved off-site material required for the construction of embankments/fills, roadway subgrade, backfilling, or for other portions of the work as shown on Contract Drawings or in these Specifications. The Contractor shall make his own arrangements for obtaining select borrow and pay all costs involved.

d. 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.

e. 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. Plans of open cut excavations showing side slopes and limits of the excavation at grade.

2. List of disposal site(s) for waste and unsuitable materials.

3. 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.

   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 subgrade 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. Overexcavation and Backfill:

    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, 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	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/ft^3).
ASTM D 1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.

ASTM D 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 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 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 may be either (off-site) Select Borrow or (on-site) 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 SW, SM, SM-SC, SC, ML, CL-ML, or CL (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. Isolated rocks shall be a maximum of 24-inches 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.

2. Descriptive information on the location and source of any off-site borrow material to be used for Embankment, where applicable. Information shall include Standard Proctor curves (ASTM D698) for each borrow material.

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. <u>Subgrade Preparation:</u>

   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. <u>Compaction Requirements:</u>

    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. <u>Backfilling for Structures and Piping:</u>

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 subgrade 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

<table>
<tr><th>ITEM</th><th>Required % Standard Proctor (ASTM D698)[2]</th><th>Required Moisture Content (ASTM D 3017)[3]</th><th>Maximum Lift Thickness (Compacted) (inches)</th></tr>
<tr><td>Embankment</td><td>95</td><td rowspan="4">As Required for Compaction</td><td>8</td></tr>
<tr><td>Embankment Beneath Structures and Roads[1]</td><td>98</td><td>8</td></tr>
<tr><td>Backfill Around Structures</td><td>95</td><td>8</td></tr>
<tr><td>Backfill in Pipe Trenches</td><td>95</td><td>6</td></tr>
<tr><td>Unclassified Fill</td><td>N/A</td><td>N/A</td><td>N/A</td></tr>
</table>

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 ASTM D 2937.
3. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959.
4. The Engineer may allow exceptions to the above criteria for areas outside of the containment area which are not subject to significant long-term loads.

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 landfill gas system, leachate collection system, 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
Drainage Aggregate (Leachate Management)	02710
Drainage Aggregate (Final Cover)	02711
Landfill Gas System	13255
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 nonwoven spunbonded or nonwoven needlepunched synthetic fabric consisting of polyester or polypropylene manufactured in a manner approved by the Engineer. Woven fabrics may be used in certain applications if approved in advance by the Engineer.

3. All Geotextiles shall conform to the properties listed in Table 1 of this section.

C. SUBMITTALS

Prior to the installation of Geotextiles, 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 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 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. Seaming Procedures:

   Submit proposed seaming procedures including proposed method and equipment.

4. 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.

5. 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:

a. The surface receiving the Geotextiles shall be prepared to a relatively smooth condition, free of obstructions, standing water, excessive depressions, debris, and very soft, excessively wet, and/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 continuously sewn or heat bonded with methods approved by the Engineer. Overlapping of seams may also be allowed if approved in advance by the Engineer. All seams must be approved by the CQA Engineer.

b. 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.

c. 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.

d. Seams to be heat bonded shall be bonded using hot plate, hot knife, ultrasonic, or other approved devices.

5. Repair Procedures:

a. Any Geotextile that is torn, punctured, or otherwise damaged 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 18 inches from any point of the rupture. Patches shall be spot sewn or heat bonded 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 or underlying materials 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	VALUE[1] TYPE GT-S
Geotextile Construction (NW = Nonwoven) (W = Woven)	----------	----------	NW[2] or W[3]
Mass per Unit Area (Unit Weight)	ASTM D 5261	oz/yd^2	N/A
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	70
Strength Class[4]	AASHTO M 288	Class	2
Tensile Properties:	ASTM D 4632		
Grab Strength		lbs	160 (NW) 250 (W)
Grab Elongation		%	≥ 50 (NW) < 50 (W)
Puncture Resistance	ASTM D 4833	lbs	55 (NW) 90 (W)
Trapezoidal Tear Strength	ASTM D 4533	lbs	55 (NW) 90 (W)
Burst Strength	ASTM D 3786	psi	200 (NW) 400 (W)
Apparent Opening Size (AOS)	ASTM D 4751	U.S. Sieve	70+
Permittivity	ASTM D 4491	sec^{-1}	1.0

Notes:

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

TABLE 2: REQUIRED MANUFACTURER QUALITY CONTROL TESTS

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
Tensile Properties	ASTM D 4632	200,000 ft^2
Burst Strength (Diaphragm Methods)	ASTM D 3786	200,000 ft^2
Apparent Opening Size (AOS)	ASTM D 4751	Periodic
Permittivity	ASTM D 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 02251

COMPACTED SOIL LINER

Compacted Soil Liner (CSL): The Compacted Soil Liner serves as a component of the containment barrier for the leachate to be developed in the landfill. Compacted on-site or imported soils will be used for CSL such that the compacted permeability of the layer is $\leq 1 \times 10^{-5}$ cm/sec.

A. DESCRIPTION

1. General:

   a. The Contractor shall furnish all labor, material, and equipment to complete installation of the CSL including borrowing, hauling, screening, mixing, stockpiling, discing, compacting, drying or wetting, excavation and removal of embankment material required for benching, removal of surface water runoff, removal of all previously placed material affected by adverse weather conditions or construction disturbance, final grading and sealing, and all necessary and incidental items as detailed or required to complete the CSL, all in accordance with the Contract Drawings and these Specifications.

   b. The Contractor shall provide suitable soil from an on-site borrow site that meets all requirements outlined in these Specifications for CSL.

2. Related Work:

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

Work	Section
Dewatering	02140
Excavation	02222
Embankment	02223
LLDPE Geomembrane	02778
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 422	Standard Test Method for Particle Size Analysis of Soils.
ASTM D 698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3).
ASTM D 1556	Standard Test Method for Density and Unit Weight of Soil in Place by the Sand-Cone Method.
ASTM D 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 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 4318	Standard Test Method for Liquid Limit, Plastic Limit, and Plasticity Index of Soils.
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.
ASTM D 5084	Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter.

4. <u>Quality Assurance:</u>

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

B. MATERIALS

All material for CSL shall conform to the requirements shown in Table 1 of this section.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Before approval is given to proceed with test fill construction, the Contractor shall submit descriptive information on compaction equipment to be used for construction of the CSL.

2. Survey Results:

   Survey results for CSL subgrade shall be submitted for review prior to placement of CSL. After completion of a segment of CSL, survey results shall be submitted for review prior to placement of overlying layers.

D. CONSTRUCTION

1. General:

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

   b. The Contractor shall place and compact the CSL to a minimum thickness of 12 inches and to the lines and grades shown on the Contract Drawings with the exception that a 0.15 foot overbuild at the Contractor's expense is allowed. The Contractor will perform all surveys necessary to establish and verify lines and grades for all CSL.

   c. CSL shall include the soil liner over the bottom and side slopes of the landfill.

2. Borrow Soils:

   a. The Contractor may haul borrow soil to an on-site stockpile area. Borrow soil cannot be hauled directly to the containment area for placement and compaction unless each load is monitored and approved by the CQA Engineer prior to loading at the borrow site.

   b. Any borrow soil not meeting the requirements for CSL shall be rejected and removed from the project site by the Contractor at no cost to the Owner.

3. Test Fill Construction:

The Contractor shall construct a test fill prior to construction of CSL. The test fill shall be at least 20 feet wide by 50 feet long and consist of at least two compacted lifts. The Contractor shall use materials and equipment for test fill construction that the Contractor intends to use during construction.

No CSL construction may be performed until the test fill construction is confirmed to be adequate in accordance with the Project CQA Manual.

The Contractor shall amend construction techniques or equipment in order to meet all criteria outlined for CSL in these Specifications at no cost to the Owner.

4. Subgrade Preparation:

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

b. Prior to placement of CSL, 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 subgrade materials revealed before or during the in-place compaction shall be removed as directed by the CQA Engineer and replaced with structural fill.

5. Placement and Compaction:

a. All CSL shall be placed in loose lifts no greater than the height of the feet on compaction equipment to be used. The loose CSL shall be free from clods greater than ¾ inch in size, or less if required to meet permeability criteria. Where excessive sized clods do occur, the Contractor shall break up the clods using methods approved by the CQA Engineer. Rock fragments in the CSL shall not exceed ½ inch in any dimension within the finished CSL surface. Below the finished CSL surface, the maximum rock size is 1½ inch.

b. Lift compaction shall be performed with an appropriately heavy, properly ballasted, penetrating-foot compactor. Compaction equipment shall be the same as used in the test fill, unless otherwise approved by the Engineer.

   Each lift shall be compacted prior to placement of succeeding lifts. The completed lift thickness shall be no greater than 6 compacted inches. In confined areas, mechanical equipment, suitable for small areas and capable of achieving the density requirements, shall be required.

c. The exposed surface of CSL shall be protected from adverse weather conditions or desiccation of the soil. This is commonly done by rolling the surface of the CSL with a smooth-drum roller at the end of each work day. Alternative means of protecting the CSL may be employed by the Contractor.

d. The in-place CSL shall conform to the requirements shown in Table 2 of this section. If CSL 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.

e. Any CSL surface which is smooth, has a moisture content outside of the specified moisture content range, as defined by ASTM D 698, or exhibits evidence of desiccation cracking ½ inch deep or greater, shall be scarified to a depth of 1 to 3 inches and brought to a proper moisture content prior to placement of a subsequent lift. This includes any CSL surface that was previously seal rolled for protection.

f. No CSL shall be placed or compacted when soil temperatures are so low as to produce ice lenses in the CSL borrow soil.

g. CSL placed on side slopes shall be placed and compacted in lifts which are parallel to the slope. Lift criteria shall be as described herein.

h. The CSL surfaces to be lined with GCL and HDPE-GM shall be free of stones larger than ½ inch in size, roots or other deleterious material, sharp objects, or debris. Such material shall be removed from the CSL surface prior to GCL and HDPE-GM installation. Embedded non-protruding smooth rocks or stones may remain in place on the CSL surface if approved by the CQA Engineer. The subgrade surface shall provide a firm, unyielding foundation for the GCL and HDPE-GM with no sudden or abrupt changes or breaks in grade. GCL and HDPE-GM shall not be installed over subgrade containing standing water, frost, excessive moisture, or on subgrade exhibiting evidence of deep rutting (greater than ¾ inch deep) from construction equipment wheels or tracks. The soil surfaces to be lined with GCL and HDPE-GM, including the landfill side slopes, shall be rolled and sealed with a smooth-drum roller wherever practical. All GCL and HDPE-GM subgrade shall be approved by the CQA Engineer prior to GCL and HDPE-GM placement.

   The Contractor shall work in a cooperative fashion with the GCL and HDPE-GM Installer in coordinating final surface preparations.

i. The Contractor shall maintain the surface of the CSL, including removal of accumulated surface water runoff, until installation of the GCL and HDPE-GM is complete. Temporary covering of the CSL surface may be required prior to installation of the GCL and HDPE-GM.

j. Anchor trenches for geosynthetics shall be backfilled in 6 inch thick lifts and compacted to 90% standard Proctor dry density (ASTM D 698). The Contractor shall be responsible for excavation and backfill of the anchor trench.

k. Surfaces not properly maintained shall be repaired by the Contractor at no cost to the Owner. A suitable surface for GCL and HDPE-GM construction shall be a surface maintained at the specified compaction and moisture content criteria provided in these Specifications.

l. Locations of control stakes, in-place density tests, or other samples in the CSL shall be patched with compacted CSL or sodium bentonite compacted and hydrated in the holes.

6. Surveying:

a. Before placement of a segment of CSL, the CSL subgrade 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 the top of the CSL subgrade slopes at grades specified on the Contract Drawings.

b. After completion of a segment of CSL, but before installation of subsequent layers, the CSL shall be surveyed on 100 foot centers and at slope breaks using the same survey points used for the CSL subgrade to ensure:

(1) The specified thickness has been achieved.

(2) The top of the CSL slopes at grades specified on the Contract Drawings; and

(3) CSL 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.

TABLE 1: COMPACTED SOIL LINER MATERIAL REQUIREMENTS

PROPERTY	TEST METHOD	VALUE
Visual Classification	ASTM D 2488	Clean soil free from organics, debris, or other detrimental material. USCS Classification CL, CH, MH, ML, SC, SM-SC, or SM
Clod Size	-----	Maximum = ¾ inch
Gradation	ASTM D 422	≥ 20% Passing No. 200 U.S. Standard Sieve Max. = ½ inch (finished CSL surface) Max. = 1½ inches (below finished CSL surface)
Coefficient of Permeability - Lab Remolded	ASTM D 5084[3]	$\leq 1 \times 10^{-5}$ cm/s at a density of ≥ 95% Maximum Standard dry density and a moisture content ≥ optimum moisture content[4]

TABLE 2: IN-PLACE COMPACTED SOIL LINER REQUIREMENTS

PROPERTY	TEST METHOD	VALUE
Density	ASTM D 2922[1]	≥ 95% Maximum Standard dry density
Moisture Content	ASTM D 3017[2]	≥ optimum moisture content[4]
In-Place Coefficient of Permeability (Shelby Tube)	ASTM D 5084[3]	≤ 1 x 10^{-5} cm/s
Thickness	Survey	12 inches minimum (0.15 foot overbuild allowed)

Notes:

1. Optionally use ASTM D 1556, ASTM D 2167, or ASTM D 2937.
2. Optionally use ASTM D 2216, ASTM D 4643, or ASTM D 4959.
3. Maximum Effective Confining Pressure of 10 psi, backpressure as recommended by ASTM D 5084, and maximum hydraulic gradient of 15.
4. Or as otherwise determined by remolded samples to achieve permeability criteria.

END OF SECTION

SECTION 02256

PROTECTIVE COVER

Protective Cover: The Protective Cover consists of clean 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 (Leachate Management)	02710
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
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/ft^3).
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.

   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 tracked equipment. On slopes $\geq$ 6H:1V, low ground pressure (6 psi or less) tracked equipment shall be used. On slopes < 6H:1V, tracked equipment shall have a ground pressure of 12 psi or less. The CQA Engineer shall approve the equipment used to place Protective Cover.

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

   c. On slopes $\geq$ 6H:1V, Protective Cover shall be placed and spread 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. Protective Cover shall be compacted by tracking the final lift with tracked equipment.

4. The Protective Cover shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Protective Cover shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, Protective Cover shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   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 over geosynthetics 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(s) without a protective 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. Surveying:

   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 02258

VEGETATIVE SOIL LAYER

Vegetative Soil Layer (VSL): The Vegetative Soil Layer (VSL) is placed in the final cover system in order to support permanent vegetative cover. This section includes the topsoil to be placed as the upper 6 inches of the VSL.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the VSL (including topsoil) for the landfill cover, including borrowing, hauling, spreading, and final grading and all necessary and incidental items as detailed or required to complete the VSL, 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
HDPE Pipe	02614
Drainage Aggregate (Final Cover)	02711
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
Revegetation	02930
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 422	Standard Test Method for Particle Size Analysis of Soils.
ASTM D 2487	Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System).

4. Quality Assurance:

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

B. MATERIALS

Soil that meets all of the following requirements shall be classified as select soil fill for use in construction of the VSL.

1. Soil shall be classified according to the Unified Soil Classification System (USCS) as SC or CL (ASTM D 2487) and shall have no more than 15% non-plastic fines (ASTM D 422). Alternatives to these requirements must be approved in advance by the Engineer.

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

3. Continuous and repeated visual inspection of the materials being used will be performed by the Contractor to ensure proper soils are being used. In addition, the CQA Engineer shall make frequent inspections of the placement operations and materials, and will consult with the Engineer.

4. The VSL shall be uniform, smooth, and free of debris, rock, plant materials, and other foreign material larger than 3 inches in diameter. The material should contain no sharp edges. This material must be capable of supporting growth of vegetative cover.

5. Topsoil: The upper 6 inches of VSL shall be natural or blended soil material capable of supporting the growth of vegetative cover.

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 placement equipment to be used in construction of the VSL.

2. Survey Results:

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

D. CONSTRUCTION

1. The VSL 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 VSL shall be performed only when the CQA Engineer is informed by the Contractor of intent to perform such work.

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

   a. The VSL, including topsoil, shall be placed and spread using low ground pressure (6 psi or less) tracked equipment. The CQA Engineer shall approve the equipment used to place the VSL.

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

   c. On slopes $\geq$ 6H:1V, VSL shall be placed and spread from the bottom up unless otherwise approved by the Engineer. No material shall be dumped down a slope.

   d. VSL 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 VSL.

   e. VSL shall be compacted by tracking the final lift with tracked equipment.

4. The VSL shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. VSL shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, VSL shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   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 VSL on the final cover shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating over geosynthetics shall have a minimum of 3 feet of separation between the vehicle wheels and the Geomembrane.

6. The CQA Engineer may require removal of VSL 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 of the VSL shall be repaired in accordance with the applicable section of these Specifications at the Contractor's sole expense.

7. After the specified thickness has been achieved and verified, the Contractor shall proceed immediately with seeding.

8. Surveying:

   After completion of a segment of VSL, the VSL 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. A hand auger or similar method may be used to check for thickness at each location.

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

   c. VSL 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 sole 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.

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
HDPE Pipe	02614
Storm Water Systems	02720
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 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 Sediment Basins:

   Permanent sediment basins shall be constructed as shown on the Contract Drawings.

2. Permanent Ditches, Swales, and Drainage Channels:

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

3. 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.

4. Geotextiles:

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

5. Down Pipes:

   Down pipes shall be constructed as shown on the Contract Drawings.

6. Rip Rap:

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

7. 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.

8. 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.

13. 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.

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. 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 or deposited sediments from basins, traps, barriers, filters, and/or drainage features/devices;

(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. The Contractor shall accept and maintain any existing sediments that are included in existing sediment traps or sediment basins that accept or will accept stormwater flow and or silt accumulation from all areas within the Contractor's limits of construction.

e. 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.

f. 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	ASTM D 3786	psi	265
Puncture Resistance	ASTM D 4833	lbs	55
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	80
Apparent Opening Size (AOS)	ASTM D 4751	U.S. Sieve	20 (Max.)/40 (Min.)
Permittivity	ASTM D 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 earthen slopes 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

3. Reference Standards:

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

   NCDOT Standard Specifications for Roads and Structures.

B. MATERIALS

1. Rip Rap: Rip Rap shall be of the size indicated on the Contract Drawings and shall conform to NCDOT Section 1042, Rip Rap Materials.

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 868, 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 mats (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 4355	Standard Test Method for Deterioration of Geotextiles from Exposure to Ultraviolet Light and Water (Xenon-Arc Type Apparatus).
ASTM D 6475	Standard Test Method for Measuring Mass per Unit Area of Erosion Control Blankets.
ASTM D 6524	Standard Test Method for Measuring the Resiliency of Turf Reinforcement Mats.
ASTM D 6525	Standard Test Method for Measuring Nominal Thickness of Permanent Erosion Control Products.

ASTM D 6566	Standard Test Method for Measuring Mass per Unit Area of Turf Reinforcement Mats.
ASTM D 6818	Standard Test Method for Ultimate Tensile Properties of Turf Reinforcement Mats.

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 straw or wood excelsior fiber covered on the top and bottom sides with photodegradable extruded plastic or woven biodegradable nettings and sewn together with degradable thread. ECB (double net) shall also conform to the properties listed in Table 1 of this section. ECB (double net) shall be S150, as manufactured by North American Green, CURLEX II, as manufactured by American Excelsior Company, LANDLOK S2, as manufactured by Synthetic Industries, or approved equal.

3. Turf Reinforcement Mat (TRM):

TRM (Type 1) shall consist of a dense web of crimped and interlocking polypropylene fibers positioned between two biaxially oriented nets and mechanically bound together by parallel stitching with polypropylene thread. TRM (Type 1) shall be designed to accelerate seedling emergence, exhibit high resiliency, and possess strength and elongation properties to limit stretching in a saturated condition. TRM (Type 1) shall be stabilized against chemical and UV degradation which are normally found in a natural soil environment and shall have no biodegradable components. TRM (Type 1) shall also conform to the properties listed in Table 1 of this section. TRM (Type 1) 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 gauge 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 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. Installation Guidelines/Instructions: The Manufacturer's guidelines/instructions for installation shall be submitted for review.

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 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 and/or the Manufacturer's installation guidelines/instructions 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 and/or the Manufacturer's installation guidelines/instructions 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	ASTM D 6475	lbs/yd^2	0.5 ± 10% (Straw) 0.7 ± 10% (Excelsior)
Maximum Permissible Shear Stress (Un-Vegetated)	-----	lb/ft^2	1.75
Functional Longevity	-----	months	12
Turf Reinforcement Mat (TRM)			
Mass per Unit Area	ASTM D 6566	oz/yd^2	8
Thickness	ASTM D 6525	inches	0.35
Tensile Strength[2]	ASTM D 6818	lbs/ft	225 x 175
Tensile Elongation	ASTM D 6818	%	50 (max.)
Resiliency	ASTM D 6524	%	80
UV Resistance (1,000 Hours)	ASTM D 4355	%	80
Maximum Permissible Shear Stress (Long-Term Vegetated)	Large Scale	lb/ft^2	5

Notes:

1. Typical for ECB; Minimum Average Roll Value (MARV) for TRM.
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) are hereby made a part of these Specifications:

NCDOT Standard Specifications for Roads and Structures.

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 520, Aggregate Base Course, except that Articles 520-7 (Contractor Furnished Laboratory), 520-12 (Method of Measurement), and 520-13

(Basis of Payment) shall be deleted. Type "A" or "B" aggregate will be acceptable for this project.

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 520.

END OF SECTION

SECTION 02608

PRECAST CONCRETE STRUCTURES

Precast Concrete Structures: Precast Concrete Structures are used in the stormwater and leachate management systems.

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
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, Strom Drains, and Sewers.
ASTM C 850	Standard Specification for Precast Reinforced Concrete Box Sections for Culverts, Strom 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. <u>Quality Control:</u>

   The Contractor shall perform leak testing of Precast Concrete Structures as described in this section.

5. <u>Quality Assurance:</u>

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

B. <u>MATERIALS</u>

1. <u>Precast Concrete Manholes:</u> 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. <u>Precast Concrete Boxes:</u> 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. <u>Precast Energy Dissipaters:</u> All precast energy dissipaters shall meet the requirements of NCDOT and 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.

4. <u>Joints:</u> All joints shall be sealed with preformed plastic gaskets in conformance with ASTM C 990 or rubber gaskets in conformance with ASTM C 443.

5. <u>Steps:</u> 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.

6. Frames and Covers: Frames and covers shall consist of cast iron frames and covers (Vulcan Foundry, or equal) equipped with steel 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.

7. Markings: All Precast Concrete Structures shall include markings clearly identifying the date of manufacture, the name of the manufacturer, and any other pertinent information.

8. Epoxy Coating: Where indicated on the Contract Drawings, an epoxy coating shall be applied. Epoxy coating shall be Targuard Coal Tar Epoxy 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 storm water and leachate management systems.

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
Precast Concrete Structures	02608
Drainage Aggregate (Leachate Management)	02710
Drainage Aggregate (Final Cover)	02711
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
Concrete Work	03310
Leachate Pumps and Controls	11314
Landfill Gas System	13255
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 (DR-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 shall 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. HDPE plate, to be placed at the base of the sump, shall be provided and installed under this section and shall have similar properties to that of HDPE Pipe.

8. Materials used as anchorage for pipe cleanouts shall be provided and installed under this section. Concrete shall be in accordance with Section 03310, Concrete Work, of these Specifications.

9. Locator Balls:

   Locator balls shall be provided and installed along all buried leachate piping (including leak detection piping) under this section. Locator balls shall have a self-leveling capability and be 4 inch diameter green ScotchMark ball markers, as manufactured by 3M, or approved equal.

10. Electrical Heat Tape and Insulation:

   Electrical heat tape and insulation shall be installed where shown on the Contract Drawings. Heat tape shall be Easy Heat Freeze Free Self Regulating Pipe Heating System by Easy Heat of New Carlisle, Indiana, or approved equal. Heat tape shall be installed per the Manufacturer's guidelines based on the pipe diameter and a temperature of -20° F. Insulation shall consist of premolded fiberglass or of closed cell flexible elastomeric material. Insulation thickness shall be as recommended by the Manufacturer for a temperature of -20° F. Insulation of interior service shall be jacketed with suitable moisture resistant fabric type material. Insulation for exterior service shall have aluminum or plastic jacketing.

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 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:

   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 the he may observe field location and installation activities.

   b. Excavation for 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. <u>Cleaning:</u>

a. 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.

b. <u>Final Flushing:</u> The Contractor shall flush all leachate collection piping accessible by cleanout ports with potable water at or near the completion of the work. Any sediment remaining at collection points (sumps, manholes, etc.) shall be removed and disposed of as directed by the Engineer.

4. Pressure Testing:

a. All solid piping where factory or field joints have been performed require pressure testing except as noted below.

(1) Any unjointed 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 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 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 leachate 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 leachate discharge line that does not meet the pressure test criteria shall be repaired and retested at the Contractor's expense. No leachate discharge line shall be approved until successful pressure testing is completed.

5. Surveying:

The Contractor shall survey all HDPE Pipe on 100 foot centers and at bends to ensure the proper location and grade of the piping.

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/10 min	0.1
Flexural Modulus	ASTM D 790	psi	130,000
Tensile Strength @ Yield	ASTM D 638	psi	3,200
SCG (PENT)	ASTM F 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 02640

VALVES

Valves: Swing check, air and vacuum release, and ball 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) are 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 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. Swing Check Valves:

Swing Check Valves shall be constructed of solid Class 12454-B PVC or Class 23447-B CPVC with EPDM or 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 ASAHI/AMERICA, Inc., or equal.

3. Air and Vacuum Release Valves:

Air and vacuum release valves 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 and vacuum release valves shall be as manufactured by Crispin, or equal.

4. Ball Valves:

Ball valves shall be constructed of PVC. Ball valves shall have two-way blocking capability and shall have flanged (ANSI) ends. Ball valves shall have Teflon seats with Viton backing cushions and Viton o-ring seals, and shall be designed for a maximum water working pressure of 150 psi at 120°F. Ball valves shall be furnished with ABS lever operating handles. Ball valves shall be as manufactured by Asahi/America, Inc., or equal.

5. 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.

6. 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 (LEACHATE MANAGEMENT)

<u>Drainage Aggregate:</u> Drainage Aggregate includes coarse aggregate which is placed around leachate collection pipes (gravel columns) and in the sump for the purpose of leachate collection and removal.

A. <u>DESCRIPTION</u>

1. <u>General:</u>

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. <u>Related Work:</u>

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

Work	Section
Geotextiles	02240
Protective Cover	02256
HDPE Pipe	02614
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
CQA Manual	Attached

3. <u>Reference Standards:</u>

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 Standard Specifications for Roads and Structures.

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. Coarse Aggregate:

a. Coarse aggregate (NCDOT No. 57 or alternate gradation if approved by the Engineer) from a non-carbonate source ($\leq$ 15% carbonate content by ASTM D 3042) shall be placed around the collection pipes and within the sumps 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 smoother 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 at the sole discretion of the Engineer.

c. Coarse aggregate shall meet the following gradation criteria.

Sieve Size	Percent Passing
1½ Inch	100
1 Inch	95-100
½ Inch	25-60
No. 4	0-10
No. 8	0-5
No. 200	0-2

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 leachate collection media and coarse aggregate from each material source for approval at least four weeks prior to beginning construction of the leachate 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. <u>CONSTRUCTION</u>

1. <u>Failing CQA Material Control Tests:</u>

   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. All placement of Drainage Aggregate shall be performed 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 and/or piping 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 using tracked equipment. On slopes $\geq$ 6H:1V, <u>low ground pressure</u> (6 psi or less) tracked equipment shall be used. On slopes < 6H:1V, tracked equipment shall have a ground pressure of 12 psi or less. The CQA Engineer shall approve the equipment used to place Drainage Aggregate. The Contractor shall place plastic traffic cones or other markers approved by the CQA Engineer on 100 foot centers to monitor thickness during placement.

b. Tracked equipment used to place and 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 slopes $\geq$ 6H:1V, Drainage Aggregate shall be placed and spread 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 except that a 0.15 foot overbuild at the Contractor's expense is allowed. 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 or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Drainage Aggregate shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, Drainage Aggregate shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

   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 02711

DRAINAGE AGGREGATE (FINAL COVER)

Drainage Aggregate: Drainage Aggregate includes coarse aggregate, which is placed in the final cover system for the purpose of surface and subsurface water 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
Vegetative Soil Layer	02258
HDPE Pipe	02614
Drainage Geocomposite	02712
LLDPE Geomembrane	02778
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 Standard Specifications for Roads and Structures.

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. Coarse Aggregate:

a. Coarse aggregate (Rain Gutters: 1½ to 3 inch or alternate gradation if approved by the Engineer) (Other Drains: NCDOT No. 78 and/or 57 Stone) shall be placed around the collection pipes 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 smoother 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 at the sole discretion of the Engineer.

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 of each type of coarse aggregate from each material source for approval at least four weeks prior to beginning construction of the final cover 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/or 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 final cover system.

3. All placement of Drainage Aggregate shall be performed 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 and/or piping 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 <u>low ground pressure</u> (6 psi or less) tracked equipment. The CQA Engineer shall approve the equipment used to place Drainage Aggregate.

   b. Tracked equipment used to spread Drainage Aggregate shall operate on <u>at least 1 foot</u> of material overlying geosynthetics and/or piping. Sharp turning of tracked equipment on the Drainage Aggregate will not be permitted.

   c. On slopes $\geq$ 6H:1V, Drainage Aggregate shall be placed and spread 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 final cover.

6. The Drainage Aggregate shall be spread in a manner that minimizes development of wrinkles or tension in the underlying geosynthetics. Any portion of the underlying geosynthetics that develops excessive wrinkles or crimp or is otherwise damaged shall be repaired by the Geosynthetics Installer at no expense to the Owner.

   a. Drainage Aggregate shall not be placed when conditions are warm enough to produce excessive wrinkles in the underlying geosynthetics. Likewise, Drainage Aggregate shall not be placed when conditions are cold enough to produce tension in the underlying geosynthetics.

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 final cover shall be subject to advance approval by the Engineer. Any hauling equipment (dump trucks, etc.) operating on the final cover 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

DRAINAGE GEOCOMPOSITE

Drainage Geocomposite (DGC): The Drainage Geocomposite consists of a geonet drainage core with a nonwoven geotextile bonded to each surface. The purpose of the DGC is to rapidly transmit flow to collection piping.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of DGC, 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
Protective Cover	02256
Vegetative Soil Layer	02258
HDPE Pipe	02614
Drainage Aggregate (Leachate Management)	02710
Drainage Aggregate (Final Cover)	02711
LLDPE Geomembrane	02778
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 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 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 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 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 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5261	Standard Test Method for Measuring Mass per Unit Area of Geotextiles.
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 6243	Standard Test Method for Determining the Internal and Interface Shear Resistance of Geosynthetic Clay Liner by the Direct Shear Method.
GRI GC7	Determination of Adhesion and Bond Strength of Geocomposites.

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

Quality Assurance during installation of DGC 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 DGC shall identify the length, width, lot and roll numbers, and name of Manufacturer.

2. The geonet drainage core shall be manufactured by extruding polyethylene strands to form a three dimensional structure to provide planer water flow.

3. A nonwoven needlepunched geotextile, consisting of polyester or polypropylene and manufactured in a manner approved by the Engineer, shall be heat bonded to both sides of the geonet drainage core. Roll edges shall have a maximum unbonded length of 6 inches, unless otherwise approved by the Engineer. Heat bonding shall be performed by the Manufacturer prior to shipping to the site.

4. The geonet drainage core shall contain UV inhibitors to prevent ultraviolet light degradation.

5. Physical properties of the DGC shall be as shown in Table 1 of this section.

C. SUBMITTALS

Prior to DGC installation, 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 a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the DGC attesting that the DGC meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the DGC 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. Seaming Procedures:

Submit proposed seaming procedures including proposed method and equipment.

4. Quality Control Certificates: For DGC delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of DGC. 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.

5. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

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

2. Failing CQA Material Control Tests:

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

3. Installation:

a. The DGC shall be placed only on Geomembrane that has been approved by the Geomembrane Installer and accepted by the CQA Engineer. The Contractor shall remove debris, including sediment to the degree possible, from the Geomembrane prior to placement of the DGC.

b. DGC shall be placed to the lines and grades shown on the Contract Drawings. At the time of installation, the DGC shall be rejected, if it has defects, rips, holes, flaws, evidence of deterioration, or other damage. Isolated areas of up to 1 square yard where the geotextile has become delaminated from the geonet drainage core may be allowed by the CQA Engineer as long as there appears to be a good bond between the geotextile and the geonet in surrounding areas. Rolls where the geotextile appears to be easily delaminated from the geonet such as by foot or ATV traffic shall be rejected.

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

d. The Contractor shall provide temporary anchorage of the DGC at the top of perimeter and interior berms during installation as necessary 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.

4. Seams:

a. All seams constructed on slopes ≥ 6H:1V or within 10 feet of the toe of a slope ≥ 6H:1V 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 ≥ 6H:1V shall be staggered a minimum of 5 feet between adjacent rolls.

b. Geonet Drainage Core: The geonet drainage core shall be laid with a 3 inch minimum overlap seam along roll edges and a 6 inch minimum overlap seam along roll ends and shall be secured using plastic ties. Ties shall be placed every 5 feet along roll edges; every 2 feet along roll ends; and every 6 inches in the anchor trench.

c. Geotextile Component(s): Where applicable, the bottom geotextile of the DGC shall be overlapped with the same of the adjacent rolls. The top geotextile of the DGC shall be continuously sewn or heat bonded to the same of the adjacent rolls with methods approved by the Engineer.

(1) 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.

(2) Seams to be heat bonded shall be bonded using hot plate, hot knife, ultrasonic, or other approved devices.

5. Repairs:

Any DGC that is torn, crushed, punctured, or otherwise damaged 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 material, placed over the damaged area and shall overlap the existing material a minimum of 12 inches from any point of the damage. The patch shall be connected to the geonet drainage core of the damaged material using plastic cable ties at a 6 inch spacing and the upper geotextile of the patch shall be spot sewn or heat bonded to the upper geotextile of the damaged material. A geotextile patch, spot sewn or heat bonded to the damaged material, may be used where damage is to only that portion of the DGC.

6. Cover Placement:

Placement of materials over DGC shall be performed in a manner as to ensure that DGC and the underlying geosynthetics are not damaged; minimal slippage of DGC on the underlying geosynthetics occurs; no excess tensile stresses occur in the DGC; and that no portion of the DGC develops excessive wrinkles or crimp. Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or DGC that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED DRAINAGE GEOCOMPOSITE PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Geonet:			
Thickness	ASTM D 5199	inches	0.25
Density	ASTM D 1505	g/cm^3	0.94
Carbon Black Content	ASTM D 1603/D 4218	%	2-3
Geotextile:			
Mass per Unit Area (Unit Wt.)	ASTM D 5261	oz/yd^2	6
Tensile Properties:	ASTM D 4632		
Grab Strength		lbs	160
Grab Elongation		%	$\geq$ 50
Puncture Resistance	ASTM D 4833	lbs	55
Apparent Opening Size (AOS)	ASTM D 4751	U.S. Sieve	70+
Permittivity	ASTM D 4491	sec^{-1}	1.0
Ultraviolet Resistance (500 hrs)	ASTM D 4355	%	70
Geocomposite:			
Ply Adhesion	ASTM D 413/ GRI GC7	lb/inch	2.0 Typ. 1.0 Min. Avg.
Transmissivity: (Base Liner) (Final Cover)	ASTM D 4716	$m^3/m/sec$	7.5×10^{-4} (See Note 1) 1.0×10^{-3} (See Note 1)
Interface Shear Strength (Peak)[2] (Base Liner) (Final Cover)	ASTM D 5321 ASTM D 6243 (GCL)	psf	125 psf (Load = 200 psf) 1,000 psf (2,500 psf) 2,000 psf (5,000 psf) 4,000 psf (10,000 psf) 70 psf (Load = 100 psf) 125 psf (200 psf) 250 psf (400 psf)

Notes:

1. Base Liner:
   Conduct test for transmissivity at a normal compressive load of 7,000 psf and at a hydraulic gradient of 0.02 after a seating period of at least 100 hours. Boundary conditions are soil (sand) interface on the upper geotextile and textured LLDPE geomembrane against the lower geotextile.

   Final Cover:
   Conduct test for transmissivity at a normal compressive load of 500 psf and at a hydraulic gradient of 0.25 after a seating period of at least 1 hour. Boundary conditions are soil (sand) interface on the upper geotextile and textured LLDPE geomembrane against the lower geotextile.

2. DGC 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 QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Geonet:		
Thickness	ASTM D 5199	50,000 ft^2
Density	ASTM D 1505	50,000 ft^2
Carbon Black Content	ASTM D 1603/D 4218	50,000 ft^2
Geotextile:		
Mass Per Unit Area	ASTM D 5261	200,000 ft^2
Tensile Properties	ASTM D 4632	200,000 ft^2
Puncture Resistance	ASTM D 4833	200,000 ft^2
Apparent Opening Size (AOS)	ASTM D 4751	600,000 ft^2
Permittivity	ASTM D 4491	600,000 ft^2
UV Resistance	ASTM D 4355	600,000 ft^2
Geocomposite:		
Ply Adhesion	ASTM D 413/ GRI GC7	100,000 ft^2
Transmissivity[1]	ASTM D 4716	100,000 ft^2 (See Note 2)

Notes:

1. Conduct transmissivity tests in accordance with the criteria given in Table 1.
2. The required Manufacturer's quality control testing for transmissivity may be reduced to one test per resin lot or one test per 500,000 ft^2 (whichever provides the larger number of tests) if the minimum measured transmissivity is at least 50% greater than specified.

TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 5321 ASTM D 6243 (GCL)	(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 - Type 1:

   A. Textured LLDPE-GM (40 mil) against Compacted Soil Liner;
   B. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
   C. Protective Cover against Drainage Geocomposite.

   Base Liner - Type 2:

   A. Geosynthetic Clay Liner against Subgrade;
   B. Textured LLDPE-GM (40 mil) against Geosynthetic Clay Liner;
   C. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
   D. Protective Cover against Drainage Geocomposite.

   Final Cover:

   A. Textured LLDPE-GM (30 mil) against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil); and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   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 GM12) for the material samples used in the actual direct shear tests.

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
HDPE Pipe	02614

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.
ASTM D 1248	Standard Specification for Polyethylene Plastics Molding and Extrusion Materials For Wire and Cable.

ASTM D 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.
NCDOT	Standard Specifications for Roads and Structures and Roadway Standard Drawings.

B. <u>MATERIALS</u>

1. <u>Reinforced Concrete Pipe (RCP):</u>

   a. All reinforced concrete pipe shall be manufactured in accordance with ASTM C 76, Wall Type B or C, and shall be of the class that equals or exceeds the pipe class as shown on the Contract Drawings. All pipe shall be aged at the manufacturing plant for at least fourteen (14) days before delivery to the job site.

   b. Minimum pipe laying lengths shall be four (4) feet.

   c. Joints for the reinforced concrete pipe shall have bell and spigot ends with flexible preformed plastic gaskets.

2. <u>Corrugated Metal Pipe (CMP):</u>

   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 2⅔ inch crest to crest and ½ 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.

3. 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.

4. 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 02776

GEOSYNTHETIC CLAY LINER (GCL)

Geosynthetic Clay Liner (GCL): The GCL is used as a secondary hydraulic barrier beneath the LLDPE Geomembrane.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of GCL 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
Drainage Geocomposite	02712
LLDPE Geomembrane	02775
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 5887	Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
ASTM D 5890	Standard Test Method for Swell Index of Clay Mineral Component of Geosynthetic Clay Liners.
ASTM D 5891	Standard Test Method 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 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.

4. Quality Control:

The Contractor shall perform Quality Control tests in accordance with Table 3 of this section.

5. Quality Assurance:

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

6. Manufacturer Qualifications:

The GCL shall be furnished by a Manufacturer that has previously produced a minimum of 10,000,000 square feet of the material for use in similar projects.

7. Installer Qualifications:

The GCL Installer shall have installed a minimum of 500,000 square feet of GCL in the past two (2) years in similar landfill installations.

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 GCL.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the GCL Installer 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 overlapped 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 GCL 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 date of shipment.

B. MATERIALS

1. General:

The GCL shall consist of bentonite encased, top and bottom, with 6 oz./square yard non-woven geotextiles needle-punched together for reinforcement. GCL with a lighter non-woven geotextile on one side may be considered by the Engineer as long as all other criteria are met. Needle-punched GCL shall be essentially free of broken needles and fragments of needles that would negatively effect the performance of the final product. The materials supplied under these Specifications shall be first quality products designed and manufactured specifically for the purposes of this work.

The GCL shall be supplied in rolls which have a minimum width of 14 feet. The roll length shall be maximized to provide the largest manageable sheet for the fewest overlaps. Labels on the roll shall identify the length, width, lot and roll numbers, name of Manufacturer, proper direction of unrolling, and minimum recommended overlap.

2. Needle Detection and Removal Procedures:

The GCL Manufacturer shall use continuous needle detection and removal devices (e.g. metal detectors and magnets) in the manufacture of needle-punched GCL.

3. Physical Properties:

Physical properties of GCL 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 GCL installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit 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 including needle detection and removal procedures. The Contractor shall also submit a sample of the GCL 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 recommendations for shipping, handling, and storage shall be submitted for review.

d. Delivery Date: Submit notification of the scheduled delivery date for the materials.

e. Installation Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work. Procedures addressed by the Contractor shall include but not be limited to material installation, repair, and protection to be provided in the event of rain. Submit drawings showing typical details including pipe penetrations (if applicable). Following review, these procedures and drawings will be used for installation of the GCL. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

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. Each certificate shall also include a certification that each roll of GCL has been continually checked by the Manufacturer for needles and that any needles detected have been removed.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. 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 GCL installation the Contractor shall submit the following:

a. 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.

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. Installation of GCL:

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

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

c. The GCL shall not be placed during precipitation. Any material that becomes hydrated shall be removed and replaced at Contractor expense.

d. The GCL shall be placed smooth and free of excessive wrinkles.

e. 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 slopes ≥ 6H:1V shall be vertical seams, except where slope lengths exceed standard roll lengths and elsewhere as approved in advance by the Engineer.

f. All vertical panels placed on slopes ≥ 6H:1V shall extend a minimum of 5 feet beyond the grade break with a slope < 6H:1V.

g. The GCL shall be laid with a 6 inch minimum overlap seam along roll edges and a 12 inch minimum overlap seam along roll ends. Granular sodium bentonite shall be added between all overlapped seams at a rate of approximately 0.25 lbs/linear foot. As an alternative to the addition of bentonite along roll edges, GCL with slits cut in one of the geotextiles may be used if approved in advance by the Engineer.

h. GCL shall be temporarily secured in a manner approved by the CQA Engineer prior to placement of overlying materials.

i. Any GCL that is torn, punctured, or otherwise damaged 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 GCL placed over the damaged areas and shall overlap the existing GCL a minimum of 12 inches from any point of the damage.

j. GCL shall be covered with the overlying LLDPE Geomembrane or otherwise protected from hydration due to rainfall (i.e. temporary tarps, scrap geomembrane, etc.) within 24 hours of GCL placement, or sooner if rain is imminent.

k. Penetrations: All penetrations of GCL shall be made in accordance with the Contract Drawings and/or as directed by the Engineer.

4. Cover Placement:

Placement of materials over GCL shall be performed in a manner as to ensure that GCL and the underlying geosynthetics are not damaged; minimal slippage of GCL on the underlying geosynthetics occurs; no excess tensile stresses occur in the GCL; and that no portion of the GCL develops excessive wrinkles or crimp.

Wrinkles that exceed approximately 6 inches in height and cannot be eliminated by amended placement and covering methods or GCL that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED GCL PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE
Clay:			
Bentonite Swell Index	ASTM D 5890	ml/2g	24
Bentonite Fluid Loss	ASTM D 5891	ml	≤ 18
GCL:			
Bentonite Content	ASTM D 5993	psf	0.75 (@ 0% moisture)
Tensile Strength	ASTM D 6768	lbs/in	40
Peel Strength[1]	ASTM D 6496	lbs/in	7.5 Typ. 2.5 Min.
Hydraulic Conductivity	ASTM D 5887	cm/sec	$\leq 5 \times 10^{-9}$
Internal Shear Strength[2] (Hydrated) (Peak)	ASTM D 6243	psf	500
Interface Shear Strength (Hydrated) (Peak)[3]	ASTM D 6243	psf	125 psf (Load = 200 psf) 1,000 psf (2,500 psf) 2,000 psf (5,000 psf) 4,000 psf (10,000 psf)

Notes:

1. Based on a 4 inch wide sample/4 inch grip width.
2. Peak value measured at a normal load of 200 psf after a minimum 24 hour hydration period.
3. GCL 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 QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Clay:		
Bentonite Swell Index	ASTM D 5890	50 tons
Bentonite Fluid Loss	ASTM D 5891	50 tons
GCL:		
Bentonite Content	ASTM D 5993	5,000 yd^2
Tensile Strength	ASTM D 6768	25,000 yd^2
Peel Strength[1]	ASTM D 6496	5,000 yd^2
Hydraulic Conductivity	ASTM D 5887	30,000 yd^2
Minimum Shear Strength[2] (Hydrated)	ASTM D 6243	Periodic

Notes:

1. Conduct peel strength tests in accordance with the criteria given in Table 1.
2. Conduct shear strength tests in accordance with the criteria given in Table 1.

TABLE 3: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 6243	(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 - Type 1:

A. Textured LLDPE-GM (40 mil) against Compacted Soil Liner;
B. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
C. Protective Cover against Drainage Geocomposite.

Base Liner - Type 2:

A. Geosynthetic Clay Liner against Subgrade;
B. Textured LLDPE-GM (40 mil) against Geosynthetic Clay Liner;
C. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
D. Protective Cover against Drainage Geocomposite.

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 GM12) for the material samples used in the actual direct shear tests.

END OF SECTION

SECTION 02778

LLDPE GEOMEMBRANE

<u>LLDPE Geomembrane (LLDPE-GM):</u> The LLDPE Geomembrane serves as the primary hydraulic barrier in the landfill base liner system and in the final cover. It is of great importance that the LLDPE-GM be free from defects and installed free from damage.

A. <u>DESCRIPTION</u>

1. <u>General:</u>

The Contractor shall furnish all labor, material, and equipment to complete installation of LLDPE-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. <u>Related Work:</u>

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

Work	Section
Compacted Soil Liner	02251
Vegetative Soil Layer	02258
Drainage Geocomposite	02712
Geosynthetic Clay Liner	02776
CQA Manual	Attached

3. <u>Reference Standards:</u>

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 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.
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 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 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.
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 6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
ASTM D 6693	Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes.
GRI GM9	Cold Weather Seaming of Geomembranes.
GRI GM12	Asperity Measurement of Textured Geomembranes Using a Depth Gage.
GRI GM17	Standard Specification for Test Properties, Testing Frequency and Recommended Warranty for Linear Low Density Polyethylene (LLDPE) Smooth and Textured Geomembranes.

4. Quality Control:

   a. The Contractor shall perform Quality Control tests in accordance with Table 2 of this section.

b. The Geomembrane Installer shall follow the procedures and requirements described in the accompanying Project CQA Manual during installation of LLDPE-GM including performing and documenting trial seams, nondestructive and destructive Quality Control tests, and repairs.

5. Quality Assurance:

Quality Assurance during installation of LLDPE-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 LLDPE-GM by having successfully manufactured a minimum of 5,000,000 ft^2 of LLDPE-GM for hydraulic containment purposes.

7. Installer Qualifications:

a. Installation of the LLDPE-GM shall be performed by an Installer that has installed a minimum of 5,000,000 ft^2 of LLDPE-GM (or similar 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 LLDPE-GM (or similar material) using the same techniques to be used on site.

c. All welding machine operators shall have shown proven performance on previous LLDPE-GM installations. All welding machine operators shall perform a demonstration of their welding technique and a test of the welds which they have performed prior to 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 LLDPE-GM.

b. Workmanship: The Contractor shall furnish the Owner a warranty from the Installer of the LLDPE-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 LLDPE-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 LLDPE-GM and LLDPE-GM Manufacturer shall be approved by the Engineer.

The LLDPE-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. Labels on the roll shall identify the thickness, length, width, lot and roll numbers, and name of Manufacturer.

2. LLDPE-GM Materials:

a. Textured LLDPE-GM shall be 40 mils thick for the base liner system and 30 mils thick for the final cover system. Resin and sheet properties of LLDPE-GM shall meet or exceed the requirements of GRI GM17 and Table 1 of this section.

b. Materials classified as Very Flexible Polyethylene (VFPE) which otherwise meet the requirements of this section are also acceptable.

3. Extrusion Resin/Typical Extrudate:

Extrusion resin/typical extrudate used for extrusion welding of LLDPE-GM shall be linear low density polyethylene (LLDPE). Physical properties shall be the same as the LLDPE-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 LLDPE-GM, where required, shall be fabricated using coextrusion or impingement methods and not by lamination or embossing methods. Texturing applied to LLDPE-GM using impingement methods shall be bonded securely to the parent LLDPE-GM. All texturing shall be uniform in appearance and coverage on the finished sheet. Textured LLDPE-GM shall be textured on both sides of the sheet.

C. SUBMITTALS

The Contractor shall submit the following to the CQA Engineer:

1. Pre-Installation Requirements:

Prior to LLDPE-GM installation, the Contractor shall submit the following:

a. Mill Certificate and Sample: Prior to shipping to the site, the Contractor shall submit a mill certificate or affidavit signed by a legally authorized official of the Manufacturer for the LLDPE-GM attesting that the LLDPE-GM meets the physical and manufacturing requirements stated in these Specifications. The Contractor shall also submit a sample of the LLDPE-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 Procedures and Drawings:

Submit installation procedures and (shop) drawings for carrying out the work.

(1) Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds.

(2) Shop drawings shall have LLDPE-GM sheet layout with proposed size, number, position, and sequence of placing all panels, and indicating the location of all field seams. Shop drawings shall also show complete details and/or methods for anchoring the LLDPE-GM, making field seams, and making seals around pipes and structures penetrating the LLDPE-GM (if applicable).

Following review, these procedures and drawings will be used for installation of the LLDPE-GM. Any deviations from these procedures and drawings must be approved by the Engineer and CQA Engineer.

f. Quality Control Certificates: For LLDPE-GM delivered to the site, quality control certificates, signed by the Manufacturer's quality assurance manager shall be provided which represent every roll of LLDPE-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 meet or exceed the requirements of GRI GM17.

g. Contractor Quality Control Test Results: The Contractor shall provide the results of required testing.

h. 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 LLDPE-GM installation, the Contractor shall submit the following:

a. Certificate stating that the LLDPE-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:

(1) CQC Documentation: Includes trial weld logs, panel placement logs, panel seaming logs, non-destructive seam testing report forms, field destructive seam testing report forms, and repair logs.

(2) As-Built Drawing: Includes the requirements listed in Paragraph D.8 (Surveying) of this Specification.

Finalization of payment for LLDPE-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 LLDPE-GM shall be shipped, handled, and stored in strict accordance with the Manufacturer's recommendations.

2. Failing CQA Material Control Tests:

LLDPE-GM that is rejected upon testing shall be removed from the project site and replaced at Contractor's cost. Sampling and CQA testing of LLDPE-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 ½ inch in size, debris, and deleterious materials. During actual placing and seaming of the LLDPE-GM, the subgrade shall be kept free of all standing water. If the subgrade below the LLDPE-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 LLDPE-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 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 LLDPE-GM installation until a complete report on all Compacted Soil Liner or GCL (as required) CQA testing has been submitted and approved by the CQA Engineer. If the Contractor proceeds with LLDPE-GM installation prior to completion of these tests, the Contractor will do so at his own risk. If any tests fail, the Contractor will be required to remove LLDPE-GM and reconstruct the underlying materials to specification requirements. All costs associated with such actions (including the costs of additional testing) will be paid for entirely by the Contractor.

4. <u>LLDPE-GM Placement:</u>

a. <u>Weather Conditions:</u>

LLDPE-GM placement shall not proceed at an ambient temperature below 32° F or above 100° F unless otherwise authorized, in writing, by the Engineer. Installation of LLDPE-GM at temperatures below 32° F, if authorized by the Engineer, shall follow GRI GM9. LLDPE-GM placement shall not be performed during precipitation, excessive moisture, in an area of ponded water, or in excessive winds. Any portion of LLDPE-GM or subgrade damaged due to weather conditions shall be repaired at the Contractor's cost.

b. <u>Method of Placement:</u>

(1) Each panel of the LLDPE-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 LLDPE-GM to a minimum and consistent with proper methods of LLDPE-GM installation.

(2) Panels shall be oriented perpendicular to the line of the slope crest (i.e., down and not across slope).

(3) The LLDPE-GM shall be placed smooth and free of excessive wrinkles.

(4) LLDPE-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 LLDPE-GM on rough soil subgrades.

(7) All LLDPE-GM shall be anchored as shown on the Contract Drawings and consistent with Manufacturer's recommendations.

(8) Personnel working on the LLDPE-GM shall not smoke, wear damaging shoes, or involve themselves in any activity that may damage the LLDPE-GM, in the opinion of the CQA Engineer.

(9) The LLDPE-GM shall be properly weighted to avoid uplift due to wind.

(10) Vehicular traffic across the LLDPE-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) The LLDPE-GM shall be kept free of debris, unnecessary tools, and materials. In general, the LLDPE-GM area shall remain neat in appearance.

c. Pipe Penetrations:

All pipe penetrations through the LLDPE-GM shall be as shown in the Contract Drawings. Alternative penetration details may be approved by the Engineer and CQA Engineer.

5. Field Seams:

a. Individual panels of LLDPE-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 ¼ 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 LLDPE-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 slopes ≥ 6H:1V 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 slopes ≥ 6H:1V shall extend a minimum of 5 feet beyond the grade break with a slope < 6H:1V.

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 LLDPE-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 shall be placed over the LLDPE-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 LLDPE-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 controlled fill 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 LLDPE-GM installation capacity.

7. Repair Procedures:

a. Any portion of the LLDPE-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 LLDPE-GM sheet over, and at least 6-inches beyond the limits of a defect. The patch shall be extrusion seamed to the underlying LLDPE-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 LLDPE-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 LLDPE-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 LLDPE-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;

(5) Extrusion welding of flaps of double track hot wedge fusion welded seams is not acceptable. A patch or cap strip shall be used; and

(6) Patches or caps will extend at least 6-inches beyond the edge of the defect, and all patch corners will be rounded.

8. Surveying:

a. After completion of a segment of LLDPE-GM, the Contractor shall survey LLDPE-GM to obtain the following information:

(1) Location and numbering of all panels/seams.

(2) Location of all repairs/patches;

(3) Location of all destructive test locations; and

(4) Location of all pipe penetrations and other appurtenances (if applicable).

b. No overlying materials shall be placed before survey information is obtained.

c. The Contractor shall provide the CQA Engineer with updated survey information when requested by the CQA Engineer to verify that the required information is being obtained.

9. Cover Placement:

Placement of materials over LLDPE-GM shall be performed in a manner as to ensure that LLDPE-GM and the underlying geosynthetics are not damaged; minimal slippage of LLDPE-GM on the underlying geosynthetics occurs; no excess tensile stresses occur in the LLDPE-GM; and that no portion of the LLDPE-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 LLDPE-GM that becomes crimped shall be cut and repaired by the Geosynthetics Installer in a method approved by the Engineer.

TABLE 1: REQUIRED LLDPE-GM PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE	
			30 mil Textured (Final Cover)	40 mil Textured (Base Liner)
Interface Shear Strength (Peak)[1,2]	ASTM D 5321 ASTM D 6243 (GCL)	psf	Base Liner: 125 psf 1,000 psf 2,000 psf 4,000 psf Final Cover: 70 psf 125 psf 250 psf	 (200 psf) (2,500 psf) (5,000 psf) (10,000 psf) (100 psf) (200 psf) (400 psf)

Notes:

1. Textured LLDPE-GM shall have adequate adhesion against adjacent materials under low normal loads to achieve the successful installation of overlying components without slippage.
2. Note that the required values for textured LLDPE-GM may require an aggressively textured sheet.

TABLE 2: REQUIRED CONTRACTOR QUALITY CONTROL TESTS

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
Interface Shear Strength	ASTM D 5321 ASTM D 6243 (GCL)	(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 - Type 1:

   A. Textured LLDPE-GM (40 mil) against Compacted Soil Liner;
   B. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
   C. Protective Cover against Drainage Geocomposite.

   Base Liner - Type 2:

   A. Geosynthetic Clay Liner against Subgrade;
   B. Textured LLDPE-GM (40 mil) against Geosynthetic Clay Liner;
   C. Drainage Geocomposite against textured LLDPE-GM (40 mil); and
   D. Protective Cover against Drainage Geocomposite.

   Final Cover:

   A. Textured LLDPE-GM (30 mil) against existing cover soils (intermediate cover);
   B. Drainage Geocomposite against textured LLDPE-GM (30 mil); and
   C. Vegetative Soil Layer against Drainage Geocomposite.

   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 GM12) for the material samples used in the actual direct shear tests.

TABLE 3: REQUIRED SEAM STRENGTH PROPERTIES

PROPERTY	TEST METHOD	MINIMUM VALUE	
		30 mil	40 mil
Bonded Shear Strength	ASTM D 6392	40 lb/inch and FTB[1]	56 lb/inch and FTB[1]
Seam Peel Adhesion	ASTM D 6392	36 lb/inch and FTB[1]	48 lb/inch and FTB[1]

Notes:

1. FTB = Film-Tear-Bond = Tearing in the membrane itself before ply separation of the seam.

END OF SECTION

SECTION 02782

GEOSYNTHETIC RAIN COVER

<u>Geosynthetic Rain Cover (GRC):</u> The Geosynthetic Rain Cover serves to minimize infiltration of precipitation within inactive portions of the landfill into the underlying leachate collection system. It is of great importance that the GRC be free from defects and installed free from damage.

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
Drainage Aggregate (Leachate Management)	02710
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 751	Standard Test Methods for Coated Fabrics.
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.

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 4833	Standard Test Method for Index Puncture Resistance of Geotextiles, Geomembranes, and Related Products
ASTM D 5199	Standard Test Method for Measuring Nominal Thickness of Geotextiles and Geomembranes.
ASTM D 5397	Standard Test Method for Evaluation of Stress Crack Resistance of Polyolefin 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 G 154	Standard Practice for Operating Fluorescent Light Apparatus for UV Exposure of Nonmetallic Materials.

4. Quality Assurance:

Quality Assurance during installation of GRC 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 GRC by having successfully manufactured a minimum of 5,000,000 ft^2 of GRC (or similar material) for hydraulic containment purposes.

6. Installer Qualifications:

The GRC Installer shall have installed a minimum of 500,000 ft^2 of GRC (or similar material) in similar landfill installations.

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 GRC.

b. Material Performance: The Contractor shall furnish the Owner a warranty from the Installer of the GRC which warrants the material performance on a non-prorata basis for one (1) year after the final acceptance of the Work. This warranty shall include but not be limited to defects related to workmanship and manufacturing and damage caused by exposure and wind.

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:

GRC shall be manufactured to meet the following requirements:

a. 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.

b. GRC shall be either a high density polyethylene (HDPE) unreinforced geomembrane, a reinforced geomembrane composed of a polyethylene, polypropylene, or polyvinyl chloride (PVC) based material, or a woven coated polyethylene material. GRC shall have the physical properties as shown in Table 1 of this section

c. GRC shall be impermeable, capable of repelling water with no absorption.

3. Seaming Materials:

Materials used for seaming GRC (if used) shall be as recommended by the Manufacturer and approved by the Engineer.

4. Ballast System:

In addition to anchoring the edges of the GRC within the Protective Cover (as shown on the Contract Drawings, or, if not shown, in a 1 foot by 1 foot min. anchor trench), the Contractor shall place tires (typical auto - off rim) (or other ballast as approved by the Owner and Engineer) on top of the GRC on 8 foot centers over the entire area covered by the GRC. Ballast shall have sufficient UV resistance to maintain its integrity over the Contractor's Performance Warranty period. The Owner anticipates receiving an adequate supply of used tires on-site (at convenience center) during the duration of the project which the Contractor may use as ballast. The Contractor shall coordinate with the Owner to collect and move these tires as required by the Owner.

For slopes ≥ 5H:1V, the Contractor shall tie bags together with ⅜ inch min. nylon rope on a horizontal and vertical grid with anchors at the top of the slope for the rope. Anchors shall be 1 inch by 1 inch (actual dimensions) by 2 foot long treated wood stakes, or approved equal.

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 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 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. Installation Procedures:

Submit installation procedures for carrying out the work. Installation procedures to be addressed shall include but not be limited to material installation, repair, and protection to be provided in the event of rain or strong winds. With regard to protection, the Contractor shall provide a plan of anchoring the GRC sufficient to satisfy the Contractor's Performance Warranty. At a minimum, this plan shall meet the criteria described in Paragraph B.4 above and shall indicate the selected spacing and weight of the ballast to be used. This plan shall be approved by the Engineer prior to construction.

d. 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 GRC installation, the Contractor shall submit the following:

a. Completed material performance warranty.

Finalization of payment for GRC installation shall not be made until the above submittals have been reviewed by the CQA Engineer.

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:

The surface of the subgrade shall be smooth, uniform, free from sudden changes in grade (such as vehicular ruts), rocks or stones greater than ½ 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 32° 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 subgrades.

(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.

c. Pipe Penetrations:

All pipe penetrations through the GRC shall be as shown in the Contract Drawings. Alternate penetration details may be approved by the Engineer.

4. Field Seams:

a. Field seams shall be made according to the Manufacturer's recommendations and may include fusion welding, taping, chemical fusion, or other methods as appropriate for the selected material and as approved by the Engineer.

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.

c. All seams constructed on sloped surfaces shall be vertical seams. Where horizontal seams are required and no other option is available 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.

5. Repair Procedures:

   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. Ballasting:

   The Contractor shall add ballasting in accordance with the approved plan.

7. No overlying material shall be placed over the GRC until approved by the CQA Engineer.

TABLE 1: REQUIRED GRC PROPERTIES

PROPERTY	TEST METHOD	UNITS	VALUE[6]
Unreinforced Geomembranes:			
Thickness (Nominal)[2]	ASTM D 5199	mils	20
Density	ASTM D 1505/D 792	g/cm³	≥ 0.940
Carbon Black Content[2]	ASTM D 1603	%	2.0-3.0
Carbon Black Dispersion[2]	ASTM D 5596	category	See Note 3
Tensile Properties:	ASTM D 638 Type IV (See Note 4)		
Tensile Strength at Yield		lb/inch	≥ 30
Tensile Strength at Break		lb/inch	≥ 60
Elongation at Yield		%	≥ 10
Elongation at Break		%	≥ 500
Tear Resistance	ASTM D 1004	lbs.	≥ 10
Puncture Resistance	ASTM D 4833	lbs.	≥ 36
Stress Crack Resistance	ASTM D 5397 (App.)	hrs.	≥ 400
Reinforced Geomembranes/Woven Coated Polyethylene Materials:			
Thickness (Nominal) (Measured Across Reinforcement)	ASTM D 5199	mils	12
Grab Tensile Strength	ASTM D 751 Proc. A	lbs.	≥ 200 MD ≥ 170 CD (See Note 5)
Mullen Burst	ASTM D 751	psi	≥ 300
Trapezoidal Tear	ASTM D 4533	lbs.	≥ 45 MD ≥ 35 CD (See Note 5)
Accelerated Weathering (2,000 Hours)	ASTM G 154	%	≥ 95% Strength Retained

Notes:

1. The lowest individual thickness of 10 values = -10%.
2. Carbon black content and carbon black dispersion are applicable to black HDPE sheet only. Where white HDPE is used or where a white HDPE layer is coextruded with a black HDPE layer, the white HDPE shall be UV stabilized.
3. Carbon black dispersion for 10 different views:
   - minimum 8 of 10 in Categories 1 or 2
   - all 10 in Categories 1, 2, or 3.
4. Yield elongation calculated with a gauge length of 1.3 inches. Break elongation calculated with a gauge length of 2.0 inches.
5. MD = Machine Direction; CD = Cross Direction.
6. The Engineer may allow alternates to these requirements.

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
Protective Cover	02256
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 Paragraph D.4 (Maintenance) 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. <u>Grass Seed:</u> 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. <u>Mulch:</u> 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. <u>Binder:</u> Supply emulsified asphalt or synthetic binder.

6. <u>Water:</u> Supply potable, free of substances harmful to growth.

C. <u>SUBMITTALS</u>

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. <u>CONSTRUCTION</u>

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 a 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. <u>Maintenance:</u>

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	APPLICATION RATE[1]
Lime	-----	4,000 lbs/acre
Fertilizer	-----	1,000 lbs/acre
Seed		
Permanent:	Kentucky 31 Tall Fescue	80 lbs/acre
	Pensacola Bahiagrass	50 lbs/acre
	Sericea Lespedeza[3]	30 lbs/acre
	Kobe Lespedeza	10 lbs/acre
	Seasonal Nurse Crop[2]	See Note 2
Temporary:	Seasonal Nurse Crop[2]	See Note 2
Mulch	-----	4,000 - 5,000 lbs/acre
Binder	-----	150 gallons/acre

Notes:

1. Application rates and/or chemical analysis shall be confirmed or established by a soil test.

2. Use seasonal nurse crop in accordance with seeding dates as stated below:

April 15 - August 15	10 lbs/acre German Millet or 15 lbs/acre Sudangrass
August 16 - April 14	25 lbs/acre Rye (grain).

3. From September 1 - March 1, use unscarified Sericea seed.

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 and valve footings.

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
HDPE Pipe	02614
Valves	02640

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.

4. Quality Control:

The Contractor will perform Quality Control testing on Concrete Work as described in this section.

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.

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.

D. CONSTRUCTION

1. Concrete shall be placed per the procedures specified in ACI 301.

2. 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.

3. 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.

4. Structures shall be formed, chamfered, and finished in a workman-like manner.

5. <u>Curing:</u>

   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

SECTION 11314

LEACHATE PUMPS AND CONTROLS

Leachate Pumps And Controls: Leachate pumps will be used to pump leachate from the landfill sump to the leachate storage lagoon.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of all Leachate Pumps And Controls, 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
Precast Concrete Structures	02608
HDPE Pipe	02614
Valves	02640
CQA Manual	Attached

3. Manufacturers Qualifications:

The manufacturer shall be a UL listed shop for industrial control systems and shall provide evidence of such on request from the Engineer or Owner.

4. Warranty:

All equipment shall be warranted by the manufacturer against defects in material, installation, and workmanship for a period of one year. Warranties shall become effective (initiate) upon field service/start-up by the manufacturer's representative as required in this section.

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.

2. Leachate Sump and Side Risers:

The leachate sump and side risers shall be fabricated to the dimensions shown on the Contract Drawings and the side risers shall be in accordance with Section 02614, HDPE Pipe, of these Specifications. The Contractor and pump supplier shall verify that the selected pumps will fit within the dimensions of the side risers with an adequate factor of safety to account for internal pipe diameter, bends, fusion beads, etc.

3. Leachate Forcemain Valve Box:

The leachate forcemain valve box shall be fabricated to the dimensions shown on the Contract Drawings and shall be in accordance with Section 02608, Precast Concrete Structures, of these Specifications.

4. Pumps:

a. General:

The pumps shall be capable of the pumping conditions listed in Table 1 of this section. The pumps shall be suitable for vertical or side slope riser installations as shown on the Contract Drawings.

b. Design:

Each pump shall be capable of pumping leachate. A transmitter mount shall be welded to the pump for liquid level control. The pump shall permit the unit to "pump down" to within 12 inches of the sump or wet well bottom without any loss of performance or damage to the pump. External "priming" or "pump down" systems shall not be allowed. The pump shall be equipped with a vent valve to assist with the evacuation of air from the pump.

c. Materials:

Major components shall be made of 300 series stainless steel, seal rings and bearings shall be made of Teflon. In addition, all fasteners shall be 300 series stainless steel.

d. Check Valve:

Each pump shall include a built-in check valve, with housing and disc of 300 series stainless steel and check valve seat of Teflon.

e. Shaft:

The shaft shall be of 300 series stainless steel and rotate on Teflon bearings which are product lubricated.

f. Diffuser Chamber:

The diffuser chambers for each impeller shall be of 300 series stainless steel and they shall be fitted with Teflon impeller seal rings.

g. Impellers:

The impeller(s) shall be closed and consist of 300 series stainless steel.

h. Motor:

The motor shall be a submersible, hermetically sealed Franklin (or approved equal) motor in 300 series stainless steel construction. The motor shall be designed for continuous duty, capable of sustaining up to 100 starts per day. The motor shall be connected to the pump via a motor adaptor and coupling in 300 series stainless steel. Single phase motors shall have thermal protection in the motor windings to protect the windings from over-load. The unit will restart automatically after the motor cools down. Three phase motors shall have thermal protection located in the control panel which is to be manually reset.

i. Motor Lead Wire:

The lead wire shall be no-splice with a waterproof and chemically resistant insulation and shall be of the length required for each pump to be installed.

5. Guide Rails and Brackets and Lifting Cables:

Guide rails and brackets for vertical installations shall be as recommended by the pump manufacturer and shall include a disconnect system for ease in installation and service. Lifting cables for side slope riser installations shall be stainless steel and of sufficient length and strength to raise the pump unit.

6. Electrical and Controls:

a. General:

The control system shall be designed to operate the required number of pumps specified on the Contract Drawings.

The control function shall provide for the operation of the pumps under normal conditions and shall alternate the pumps on each pump down cycle to equalize the run time. In the event the incoming flow exceeds the pumping capacity of the lead pump, subsequent pumps shall automatically start to handle the increased flow. As the flow decreases, the pumps shall cut off at the elevations as shown on the Contract Drawings.

The control system shall function as described below. The equipment listed below is a guide and does not relieve the supplier from supplying a system that will function as required.

b. Enclosure:

The enclosure shall be a NEMA 4X rated steel enclosure. The enclosure shall be a pole mount type with a minimum depth sized to adequately house all of the components. The door shall open a minimum of 180 degrees.

c. Inner Dead Front Door:

A polished aluminum dead front shall be mounted on a continuous aircraft type hinge and shall contain cutout for mounted equipment and provide protection of personnel from live internal wiring. Cutouts for breaker handles shall be provided to allow operation of breakers without entering the compartment. All control switches, indicator pilot lights, elapsed time meters, duplex receptacle, and other operational devices shall be mounted on the external surface of the dead front. The dead front shall open a minimum of 150 degrees to allow access to equipment for maintenance. A ¾ inch break shall be formed around the perimeter of the dead front to provide rigidity.

d. Back Plate:

The back plate shall be manufactured of 14 gauge steel and be finished with a primer coat and two (2) coats of baked on white enamel. All hardware mounted to the subpanel shall be accomplished with machine thread tapped holes. Sheet metal screws are not acceptable. All devices shall be permanently identified.

e. Power Distribution:

The panel power distribution shall include all necessary components and be completely wired with stranded copper conductors rated at 90° C. All conductor terminations shall be as recommended by the device manufacturer.

f. Circuit Breakers:

All circuit breakers shall be heavy duty thermal magnetic or motor circuit protectors similar and equal to Square D type FAL. Each motor breaker shall be adequately sized to meet the pump motor operating characteristics and shall have a minimum of 10,000 amps interrupting capacity for 230 VAC and 14,000 amps at 480 VAC. The control circuit and the duplex receptacle shall individually be controlled by heavy duty breakers.

Circuit breakers shall be indicating type, providing "On-Off-Trip" positions of the operating handle. When the breaker is tripped automatically, the handle shall assume a middle position indicating "Trip".

Thermal magnetic breakers shall be quick-make and quick-break on manual and automatic operation and have inverse time characteristics secured through the use of bimetallic tripping elements supplemented by a magnetic trip.

Breakers shall be designed so that an overload on one pole automatically trips and opens all legs. Field installed handle ties shall not be acceptable.

g. Motor Starters:

Motor starters shall be open frame, across the line, NEMA rated with individual overload protection in each leg. Motor starter contact and coil shall be replaceable from the front of the starter without removing from its mounted position. Overload heaters shall be block type, utilizing melting alloy spindlers and shall have visual trip indication. Overload shall be sized for the full load amperage draw of the pumps. Adjustable type overloads, definite purpose contactors, fractional size starters and horsepower rated contactors or relays shall not be acceptable.

h. Transformers:

Control Transformers shall be provided to provide the 120 VAC and/or 24 VAC for control circuits. Transformers shall be fused on the primary and secondary circuits. The secondaries shall be grounded.

i. Lightning-Transit Protection:

A lightning -transit protector with tell-tale warning lights on each phase to indicate loss of protection on the individual phases shall be provided. The device shall be solid state with a response time of less than 5 nanoseconds withstanding surge capacity of 6,500 amperes. Unit shall be instant recovery, long life, and have no holdover currents.

j. Phase Monitor:

A line voltage rated, adjustable phase monitor shall be installed to sense low voltage, loss of power, reversed phasing, and loss of a phase. Control circuit shall de-energize upon sensing any of the faults and shall automatically restore service upon return to normal power.

k. Alarm System:

The alarm light shall be a weatherproof-shatterproof red light fixture with a 40 watt bulb to indicate alarm conditions. The alarm light shall be turned on by the alarm level.

l. Level Controls:

Each pump shall be equipped with a liquid level control. The level control shall be as recommended by the pump manufacturer. A control meter shall be provided for each pump's level control and shall be mounted on the inner door of the control panel. Control meters shall provide digital read-out and have the capability to monitor and maintain pumping operations and at least two other level signals. Level controls shall be accurate to within 0.1 inch.

m. Control System Operation:

The control system shall provide for the automatic and manual control and alternation of the pumps to maintain a pumped down condition of the wet well. Levels shall be sensed by level controls adjusted to the levels depicted on the Contract Drawings. The level controls shall sense the "Off", "Lead", "Lag" and "Alarm" levels. As the level in the wet well or sump rises, the lead pump shall start and pump to the "Off" position. In the event the incoming flow exceeds the capacity of the lead pump, the lag pump shall start and both pumps shall run to the "Off" level. The alternator shall switch lead pumps when the "Off" level is reached. If the level continues to rise, alarm functions shall be excited and the alternate lag pump shall start. The control system shall include but not be limited to the ancillary equipment listed below.

n. Flow Meters:

Flow meters shall be installed where shown on the Contract Drawings. Each flow meter shall be the electromagnetic type capable of true volumetric measurement. Each flow meter shall register total product flow and record totalized flow rate and shall be integrated into the pump control system. Flow meters shall have flanged connections and be constructed of materials compatible with leachate. Flow meters shall have the following characteristics:

(1) Accuracy to $\pm$ 0.25% of Rate
(2) Intelligent Micro-processor Based Transmitter
(3) Pressure Limits from Full Vacuum to 200 psi
(4) Temperature Limits to 250° F
(5) NEMA 4X Environmental Rating
(6) Accidental and Total Submergence Protection

Flow meters shall be as manufactured by Foxboro, Badger, ABB, or approved equal.

Valve boxes for flow meters shall be as shown on the Contract Drawings. Valve boxes shall be approved by the Engineer prior to installation.

o. Intrinsic Safe Duplex Controller:

The duplex controller control system shall be a UL listed control unit consisting of a plug-in programmed solid state controller. The controller shall include the following listed functions:

(1) Alternator
(2) Hand-Off-Auto (HOA) Switches
(3) Time Delay Relays
(4) Alternator Selector Switch
(5) Float Indicating Led's
(6) Output Led's
(7) Alternator Test Switch

All AC inputs and outputs shall be transient protected to eliminate introduced transients by inductive loads. The controller shall be UL listed as a control device with intrinsically safe output level of 630 microwatts at 5 VDC applied to the float regulators assuring adherence to UL 913 publication for Division 1, Class 1, intrinsically safe apparatus.

p. Ancillary Equipment:

The Ancillary equipment listed below will be provided unless otherwise indicated:

(1) HOA Switches: A three position HOA Switch shall be provided for each pump. The switch shall be NEMA 4X rated with 10 Amp contacts. A position indicating legend plate shall be provided. The HOA switches shall be mounted on the inner dead front door.

(2) Run Indicators: A green LED run pilot indicator shall be mounted on the dead front door for each pump.

(3) Elapsed Time Meter: An elapsed time meter shall be mounted on the dead front door for each pump. The meter shall operate on 120 VAC, shall indicate in hours (6 digits) and tenths and shall be non-resetable.

(4) Drawings: A final as-built drawing encapsulated in mylar shall be attached to the inside of the front door. A list of all legends shall be included.

(5) Panel Markings: All component parts in the control panel shall be permanently marked and identified as they are indicated on the drawing. Marking shall be on the back plate adjacent to the component. All control conductors shall be identified with wire markers at each end as close as practical to the end of conductor termination.

(6) Testing: All panels shall be tested to the necessary power requirements to assure proper operation of all the components. Each control function shall be activated to check for proper indication.

7. Gauges:

Gauges shall be furnished and installed under this section. All gauges shall be the Bourdon tube type with a black phenolic case conforming to NEMA 4 requirements and a 2½ inch diameter dial face. Gauge windows shall be constructed of a shatterproof glass. The gauge dial shall have black scale markings on a white background evenly spaced over a 270 degree arc. Gauges shall be provided on the discharge of the submersible pumps in a location as directed by the Engineer.

Each gauge installation shall include a diaphragm seal with flushing connection and a ½ inch 300 series stainless steel shutoff cock. The diaphragm seal shall be designed for continuous duty and the diaphragm shall be constructed of 316 stainless steel with a silicone fill liquid. The diaphragm seal body shall be constructed of carbon steel with a ½ inch, minimum, threaded connection on the process side and a ¼ inch, minimum, threaded connection on the gauge side.

Discharge gauges shall be graduated in psi from zero to approximately 25% above the respective pump shutoff head.

The Contractor shall coordinate with the various pump manufacturers so that all gauges are supplied by one gauge manufacturer. Gauges shall be as manufactured by Ashcroft Gauge, Division of Dresser Industries, U.S. Gauge Division of Ametek, or equal.

C. <u>SUBMITTALS</u>

The Contractor shall submit the following to the Engineer:

1. The Contractor shall submit shop drawings for the Leachate Pumps And Controls for approval at least 4 weeks prior to construction.

2. Operation and maintenance manuals shall be provided for all the equipment specified in this section.

3. The pump supplier shall submit documentation that the pumps will work with this application and provide certified performance curves.

4. The Contractor shall submit the manufacturer's warranty for each pump supplied.

D. <u>CONSTRUCTION</u>

1. <u>Installation:</u>

The Leachate Pumps And Controls shall be constructed as shown on the Contract Drawings and with the manufacturer's standard dimensions and tolerances for the pumps specified.

2. Field Tests:

The Contractor shall provide the services of the pump, control, and alarm system manufacturer's representatives to check the installation, make adjustments, and place the equipment in operation. Provide a minimum of one eight hour day on-site for start-up and checks of the system.

3. Equipment Identification:

The pumps shall be provided with a substantial stainless steel nameplate, securely fastened in a conspicuous place and clearly inscribed with the manufacturer's name, year of manufacture, serial number, and principal rating data. Nameplate data shall include the rating in gallons per minute, rated head, speed, and efficiency.

TABLE 1: PUMP REQUIREMENTS

PROPERTY	LEACHATE PUMPS
Quantity	2
Model	Leachator LPS150MSTG12075-04, or equal
Capacity (gpm)	100
Total Head (feet)	205
Shutoff Head (feet)	250
Horsepower	7.5
Voltage	230
Phase	3

END OF SECTION

SECTION 13255

LANDFILL GAS SYSTEM

Landfill Gas System: The Landfill Gas System includes a network of surface collector trenches and landfill gas flares installed under the piggyback liner system in order to collect and vent/burn landfill gas, which builds up due to the decomposition of waste.

A. DESCRIPTION

1. General:

The Contractor shall furnish all labor, material, and equipment to complete installation of the Landfill Gas System 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
Geotextiles	02240
HDPE Pipe	02614
Drainage Geocomposite	02712

3. Reference Standards:

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

NCDOT Standard Specifications for Roads and Structures.

B. MATERIALS

1. All pipe used for construction of Landfill Gas System shall be either solid (riser pipe) or perforated (collector pipe) HDPE Pipe in accordance with Section 02614, HDPE Pipe, of these Specifications. The pipe SDR and diameter shall be as shown on the Contract Drawings.

2. Backfill for collector trenches shall be NCDOT #57 stone.

3. Geotextiles used for collector trenches shall conform to the requirements outlined in Section 02240, Geotextiles, of these Specifications.

4. Drainage Geocomposite used for collector trenches shall conform to the requirements outlined in Section 02712, Drainage Geocomposite, of these Specifications.

5. Landfill Gas Utility Flares: Landfill gas utility flares shall be solar ignited. Utility flares shall be Model CF-5 as manufactured by Landfill Technologies, Inc., or approved equal.

C. SUBMITTALS

1. Submit a certification and summary of all required test results, prior to installation, that all Landfill Gas System components manufactured for the project have been produced in accordance with these Specifications.

2. Submit Shop Drawings for all components 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, 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 utility flares and accessories. The Manufacturer(s) shall delete all information which does not apply to the equipment being furnished.

D. CONSTRUCTION

1. All Landfill Gas System components shall be constructed at the locations and according to the details shown on the Contract Drawings. Care shall be taken to ensure that these locations are not in areas which are prone to pond water.

2. The depth of surface collector trenches shall be adjusted such that the perforated HDPE piping and stone backfill breaches the existing final/intermediate cover or to a maximum depth of four feet if no waste is encountered.

3. The Contractor shall exercise caution as excavations will extend into existing municipal solid waste. The Contractor shall construct surface collector trenches such that Contractor personnel are not required to enter the excavation.

4. All waste materials removed during construction of Landfill Gas System components shall be disposed of on site in the active lined landfill as directed by the Owner and Engineer. The Contractor shall weigh waste materials at the facility scales prior to disposal. No tipping fee will be charged to the Contractor for disposal of these wastes.

END OF SECTION

Construction Quality Assurance Manual

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

October 2005

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JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

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, the leachate management system, and the final cover system. The liner system, as referenced herein, consists of a soil subgrade and a composite liner (consisting of a compacted soil liner and/or GCL and LLDPE geomembrane). The leachate management system consists of a leachate collection system (LCS) and a leachate discharge and storage system. The final cover system consists of a LLDPE geomembrane, overlying granular and geosynthetic drainage material with collection piping, and overlying vegetative soil layer.

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 Compacted Soil Liner CQA
- Section 5.0 Geomembrane CQA
- Section 6.0 Leachate Management System CQA
- Section 7.0 Geotextile CQA
- Section 8.0 Drainage Geocomposite CQA
- Section 9.0 Geosynthetic Clay Liner CQA
- Section 10.0 Final Cover System 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, leachate management, and final cover 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 State Solid Waste Regulators. The certification report will include all QC testing performed by the Geosynthetics Manufacturers, all CQC testing performed by the Geosynthetic Installers, and all CQA 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 Johnston County, 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, leachate management, and final cover 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 G.N. Richardson & Associates, Inc.

1.3.1.3 <u>Contractor</u>

The Contractor is responsible for the construction of the subgrade, earthwork, and for placement of the liner, leachate management, and final cover systems. 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 <u>Geosynthetics Manufacturer</u>

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 <u>Geosynthetics Installer</u>

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 <u>CQA Engineer</u>

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, leachate management, and final cover 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 <u>Geosynthetics CQA Laboratory</u>

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, leachate management, and final cover 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, that is responsible for conducting geotechnical tests on conformance samples of soils and aggregates used in structural fills and the liner, leachate management, and final cover 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, leachate management, and final cover systems. Where applicable, these qualifications must be submitted by the Contractor to the Owner and Engineer for review and approval.

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, leachate management, and final cover systems. Each Geosynthetics Installer must meet the requirements of the project specifications and be approved 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, leachate management, and final cover 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 should be certified by the Geosynthetics Accreditation Institute, 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, leachate management, and final cover systems for 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 Soil Liner CQA Meeting

Prior to the start of the soil liner system construction a CQA Meeting will be held. This meeting will include all parties then involved, including the Engineer, the CQA Engineer, and the Contractor.

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. The Soil Liner CQA Meeting and the Geosynthetics CQA Meeting may be held as one meeting or separate meetings, depending on the direction of the Engineer.

1.7.2 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. The Soil Liner CQA Meeting and the Geosynthetics CQA Meeting may be held as one meeting or separate meetings, depending on the direction of the Engineer.

1.7.3 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 or, at a minimum, once per month during active construction. 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 or periodic reports. 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.

1.7.4 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.

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 plan 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. As 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 nonconformance 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 approved 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. Note that some items may not be applicable to all projects.

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 2.1A: FINAL CQA REPORT GENERAL OUTLINE (LINER SYSTEM)

1.0 Introduction
2.0 Project Description
3.0 CQA Program
- 3.1 Scope of Services
- 3.2 Personnel

4.0 Earthwork CQA
5.0 Compacted Soil Liner CQA
6.0 GCL CQA
7.0 Geomembrane CQA
8.0 Leachate Management System CQA
9.0 Geotextile CQA
10.0 Drainage Geocomposite CQA
11.0 Summary and Conclusions
12.0 Project Certification

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Appendix G	Compacted Soil Liner CQA Data	
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	I1.	Manufacturer's Product Data Submittals and Quality Control Certificates
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TABLE 2.1A (CONTINUED):

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	J5.	Trial Weld Logs
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	K4.	CQC Test Results - Pressure Testing of HDPE Discharge Piping
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1.0 Introduction
2.0 Project Description
3.0 CQA Program
  3.1 Scope of Services
  3.2 Personnel
4.0 Earthwork CQA
5.0 Final Cover System CQA
6.0 Geomembrane CQA
7.0 Geotextile CQA
8.0 Drainage Geocomposite CQA
9.0 Summary and Conclusions
10.0 Project Certification

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	G8. CQC Test Results - Nondestructive Seam Testing Report Forms
	G9. CQC Test Results - Destructive Seam Testing Report Forms (Field)
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TABLE 2.1B (CONTINUED):

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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 approval, subgrade approval, field control and record tests, and resolution of problems.

3.2 EMBANKMENT MATERIAL APPROVAL

All material to be used as compacted embankment shall be approved in advance by the CQA Engineer. Approval 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 APPROVAL

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 approved 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 3.2**, 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 APPROVAL

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:		
Visual Classification	ASTM D 2488	Each Soil
Moisture-Density Relationship	ASTM D 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]	20,000 ft^2 per lift & 1 per 500 LF/lift of Berms (< 200 ft. base width)
Moisture Content	ASTM D 3017[2]	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
COMPACTED SOIL LINER CQA

4.1 INTRODUCTION

This section of the CQA Manual addresses the compacted soil liner component of the liner system and outlines the soils CQA program to be implemented with regard to material approval, subgrade approval, test fill construction, field and laboratory control and record tests, and resolution of problems.

4.2 COMPACTED SOIL LINER MATERIAL APPROVAL

All material to be used as compacted soil liner shall be approved in advance by the CQA Engineer. Approval 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.

4.2.1 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 4.1**, will be performed by the CQA Engineer prior to placement of any compacted soil liner material.

4.3 SUBGRADE APPROVAL

The CQA Engineer shall verify that the soil liner subgrade is constructed in accordance with the project specifications.

4.4 TEST FILL CONSTRUCTION

A test fill meeting the requirements of the project specifications will be constructed using the same construction methods, equipment, and material to be used for the compacted soil liner component. The test fill construction will be conducted prior to or coincide with the beginning of construction of the soil liner component.

Construction equipment and methods shall be reviewed by the CQA Engineer prior to test fill placement.

4.4.1 Control Tests

The control tests, as shown on **Table 4.2**, will be performed by the CQA Engineer prior to placement of compacted soil liner material in the test fill.

4.4.2 Record Tests

The record tests, as shown on **Table 4.2**, will be performed by the CQA Engineer during placement of compacted soil liner material in the test fill.

4.4.3 Test Fill Completion

The test fill program is completed when the Contractor has shown that the soil liner constructed using the same construction methods, equipment, and material to be used in construction of the compacted soil liner will satisfy project specifications. No compacted soil liner can be placed until the test fill program is completed.

4.5 COMPACTED SOIL LINER CONSTRUCTION

4.5.1 Construction Monitoring

A. Compacted soil liner shall be placed as described in the project specifications using the construction methods, equipment, and material demonstrated in the test fill construction.

B. Only soil previously approved by the CQA Engineer (see **Section 4.2**) shall be used in construction of the compacted soil liner. 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 soil liner during and after construction.

E. The liner surface shall be sprinkled with water as needed to prevent desiccation. Should desiccation occur, the last lift shall be reconstructed in accordance with the project specifications. Standing water should not be present on the compacted soil liner.

F. Frost heave or other damage due to freezing shall require lift reconstruction in accordance with the project specifications.

G. The CQA Engineer shall inspect the compacted soil liner and certify that it is in accordance with the project specifications and approved plans prior to the Contractor beginning installation of overlying geosynthetics.

H. The finished compacted soil liner shall be free of all rock protrusions. All cracks and voids shall be filled and the surface made uniform. This shall be accomplished by final dressing of the soil liner with smooth-drum rollers and hand raking. No rubber tired vehicles are permitted on the final dressed surface unless authorized by the CQA Engineer.

I. The surface on which the overlying geosynthetics are to be placed shall be maintained in a firm, clean, and smooth condition and shall be within the acceptable moisture range before and during the geosynthetics installation.

4.5.2 Control Tests

The control tests, as shown on **Table 4.3**, will be performed by the CQA Engineer prior to placement of compacted soil liner material.

4.5.3 Record Tests

The record tests, as shown on **Table 4.3** and as described below, will be performed by the CQA Engineer during placement of compacted soil liner material.

A. Each lift shall be checked visually for soil clods, rocks, debris, plant materials and other foreign material. Any such material which will not pass through a ½ inch screen shall be identified and removed prior to and during the compaction process, if such material is part of the finished compacted soil liner surface. The remaining portion of compacted soil liner (below the finished surface) shall be free of material which will not pass through a 1½ inch screen.

B. The thickness of the loose lift shall be measured at random locations after spreading and leveling is completed. Loose lift thickness should not exceed the depth of penetration of the compaction feet.

C. Moisture content will be monitored by the CQA Engineer prior to compaction. If the soil is drier than the specified minimum moisture content, water will be added and the lift will be disced to distribute the moisture evenly.

Results of testing shall be certified within 7 days of compacted soil liner placement.

4.5.3.1 Record Test Failure

The following procedures shall be used in the event of density or permeability test failure:

A. Failed Density Test: Recompaction of the failed area shall be performed and retested until the area meets or exceeds requirements outlined in the specifications.

B. Failed Permeability Test: The area of failure shall be localized and reconstructed in accordance with the project specifications. This area shall be retested as outlined within the plan by the CQA Engineer. Optionally, at least five replicate samples shall be obtained and tested by the Contractor in the immediate vicinity of the failed test. If all five samples pass, then the initial failing test will be discounted. However, should the replicate samples confirm the failure of the soil to meet specifications, the area of failure shall be localized, reconstructed, and retested as described above.

4.5.4 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.

4.5.5 Perforations In Compacted Soil Liner

All holes shall be patched with compacted soil liner or sodium bentonite compacted and hydrated in the holes.

4.6 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 COMPACTED SOIL LINER MATERIAL APPROVAL

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:		
Visual Classification	ASTM D 2488	Each Soil
Moisture Content	ASTM D 2216	2,000 CY per Each Soil
Grain Size Analysis	ASTM D 422	2,000 CY per Each Soil
Atterberg Limits	ASTM D 4318	2,000 CY per Each Soil
Moisture-Density Relationship	ASTM D 698	5,000 CY per Each Soil
Permeability - Lab Remolded	ASTM D 5084[3]	10,000 CY per Each Soil

TABLE 4.2: CQA TESTING PROGRAM FOR COMPACTED SOIL LINER TEST FILL

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS: (See **Table 4.1**)		
Moisture-Density Relationship	ASTM D 698[4]	1 per lift
Permeability - Lab Remolded	ASTM D 5084[3,4]	1 per lift
RECORD TESTS:		
Lift Thickness	-----	Each Lift
Atterberg Limits	ASTM D 4318	1 per lift
Grain Size Analysis	ASTM D 422	1 per lift
In-Place Density	ASTM D 2922[1]	3 per lift
Moisture Content	ASTM D 3017[2]	3 per lift
Permeability - Undisturbed (Shelby Tube)	ASTM D 5084[3]	1 per lift

TABLE 4.3: CQA TESTING PROGRAM FOR COMPACTED SOIL LINER

PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS: (See **Table 4.1**)		
RECORD TESTS:		
Lift Thickness	-----	Each Lift
In-Place Density	ASTM D 2922[1]	10,000 ft^2 per lift
Moisture Content	ASTM D 3017[2]	10,000 ft^2 per lift
Permeability - Undisturbed (Shelby Tube)	ASTM D 5084[3]	80,000 ft^2 per lift

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.
3. Maximum Effective Confining Pressure of 10 psi, backpressure as recommended by ASTM D 5084, and maximum hydraulic gradient of 15.
4. These tests performed on the test fill may count toward the minimum frequencies established in **Table 4.1**.

SECTION 5.0
GEOMEMBRANE CQA

5.1 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 approval, material approval, subgrade approval, field and laboratory control and record tests, repairs, and resolution of problems.

5.2 GEOMEMBRANE MANUFACTURER AND INSTALLER APPROVAL

The Contractor shall submit the qualifications of the Geomembrane Manufacturer and the Geomembrane Installer, as described in the specifications, to the CQA Engineer for approval.

5.3 GEOMEMBRANE MATERIAL APPROVAL

5.3.1 Geomembrane Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

5.3.2 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.

5.3.3 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.

5.3.4 Material Control Tests

Samples for material control tests, as shown on **Table 5.1**, 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 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.

5.3.4.1 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 conformance samples for testing 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.

5.4 GEOMEMBRANE INSTALLATION

5.4.1 Handling

The Geosynthetic Installer will handle all geomembrane in such a manner as required by the project specifications.

5.4.2 Earthwork

5.4.2.1 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 soil liner 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.

5.4.2.2 Anchorage System

The CQA Engineer will verify that anchor trenches have been constructed and backfilled according to project specifications and design drawings.

5.4.3 Geomembrane Placement

5.4.3.1 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 1.7.2**).

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.

5.4.3.2 Field Panel Placement

5.4.3.2.1 Location: The CQA Engineer will verify that field panels are installed at the location indicated in the Geomembrane Installer's layout plan, as approved or modified in **Section 5.4.3.1**.

5.4.3.2.2 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.

5.4.3.2.3 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.

5.4.3.2.4 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.

5.4.4 Field Seaming

5.4.4.1 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 accepted state 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 approval.

A seam numbering system compatible with the panel numbering system will be agreed upon at the Geosynthetics CQA Meeting (see **Section 1.7.2**). 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.

5.4.4.2 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.

5.4.4.3 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 approval. Only seaming apparatus which have been specifically approved by make and model will be used. The CQA Engineer will submit all documentation to the Engineer for his concurrence.

5.4.5 Field Seam Control Tests

5.4.5.1 Trial Seams

A. Prior to production seaming, after four (4) hours of continuous seaming, and/or when significant changes in geomembrane or ambient temperature occurs, the Geomembrane Installer shall perform passing trial seams for each welder to be used 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 fusion welder.

B. Trial seams shall be made on appropriate sized pieces of identical or equivalent geomembrane material.

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. 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 seams and compile all trial seam logs.

5.4.6 Field Seam Record Tests

5.4.6.1 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 deployment as the work progresses and not at the completion of all field seaming.

A. Vacuum Testing shall conform to ASTM D 5641 requirements.

B. Air Pressure Testing (for double seam with an enclosed space) shall conform to ASTM D 5820 requirements and the requirements listed in **Table 5.2**.

The CQA Engineer shall observe the nondestructive testing on a full time basis to ensure conformance with this CQA Manual and the project specifications.

5.4.6.2 Field Destructive Seam Testing

A. The Geomembrane Installer will obtain 12" x 24" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an average frequency of one sample per 500 linear feet of weld. The sample shall be cut into two equal-length pieces, one for field destructive seam testing by the Geosynthetics Installer 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. The Geomembrane Installer will perform and document field destructive seam testing using a field tensiometer. A minimum of five coupons each will be tested in peel and shear (ASTM D 6392). 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 and not in accordance with 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.

5.4.6.3 Geosynthetics CQA Laboratory Destructive Testing

A. The Geomembrane Installer will obtain 12" x 24" (or longer as needed) samples of field seams with the seam centered lengthwise, suitable for testing, at an 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 shear (ASTM D 6392) by the Geosynthetics CQA Laboratory. Four of five coupons shall meet the minimum seam strength requirements as shown in 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.

5.4.6.4 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 the record 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.

5.4.6.5 Defining Extent of Field Seam Record Test Failure

All defective seam test failures must be bounded by acceptable destructive tests. The CQA Engineer will document repair actions taken in conjunction with all seam test failures.

5.4.7 Repairs & Verification

5.4.7.1 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 ¼ inch of abrasion shall be visible beyond the weld.

5.4.7.2 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.

5.5 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 test documentation, 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.

5.6 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.

5.6.1 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 5.4.2**. All soil materials shall be placed and compacted in accordance with project specifications.

5.6.2 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.

5.7 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 5.1: CQA TESTING PROGRAM FOR GEOMEMBRANE MATERIAL APPROVAL

PROPERTY	TEST METHOD	TEST FREQUENCY
Thickness	ASTM D 5199/D 5994	100,000 ft^2 or 1 per Lot[1]
Density	ASTM D 1505/D 792	100,000 ft^2 or 1 per Lot[1]
Carbon Black Content	ASTM D 1603	100,000 ft^2 or 1 per Lot[1]
Carbon Black Dispersion	ASTM D 5596	100,000 ft^2 or 1 per Lot[1]
Tensile Properties: Tensile Strength at Break Elongation at Break	ASTM D 6693 (Type IV)	100,000 ft^2 or 1 per Lot[1]
Tear Resistance	ASTM D 1004	100,000 ft^2 or 1 per Lot[1]

Notes:

1. Whichever provides the larger number of tests.

TABLE 5.2 AIR PRESSURE TEST REQUIREMENTS

MATERIAL	MIN. PRESSURE (PSI)	MAX. PRESSURE DROP (PSI) AFTER 5 MINUTES
30 Mil LLDPE	15	3
40 Mil LLDPE	20	3

SECTION 6.0
LEACHATE MANAGEMENT SYSTEM CQA

6.1 INTRODUCTION

This section of the CQA Manual addresses the components of the leachate management system including components of the leachate collection system (LCS) (drainage aggregate, collection pipe, protective cover, and geosynthetic rain cover) and the leachate discharge and storage system (sumps, discharge piping, manholes, valves, and storage tanks). By reference to **Sections 7.0 and 8.0** of this CQA Manual, this section also addresses the geotextiles and drainage geocomposite that are components of the LCS. This section outlines the CQA program to be implemented with regard to material approval, construction monitoring, and resolution of problems.

6.2 LEACHATE MANAGEMENT SYSTEM MATERIAL APPROVAL

The CQA Engineer shall verify that the following are provided and installed in accordance with the project drawings, specifications, and this CQA Manual.

6.2.1 Coarse Aggregate (Drainage Aggregate)

A. Receipt of Contractor's submittals on coarse aggregate.

B. Review of submittals for coarse aggregate for conformity to the project specifications.

C. Verify that coarse aggregate in stockpiles or at borrow sources conforms to the project specifications.

D. Conduct material control tests in accordance with **Table 6.1**.

6.2.2 High Density Polyethylene (HDPE) Pipe

A. Receipt of Contractor's submittals on HDPE pipe.

B. Review of submittals for HDPE pipe for conformity to the project specifications.

6.2.3 Geotextiles (Verify for each type of Geotextile)

The CQA program for geotextiles is presented in **Section 7.0** of this CQA Manual.

6.2.4 Drainage Geocomposite

The CQA program for drainage geocomposite is presented in **Section 8.0** of this CQA Manual.

6.2.5 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 6.1**.

6.2.6 Geosynthetic Rain Cover

A. Receipt of Contractor's submittals on Geosynthetic Rain Cover.

B. Review of submittals for Geosynthetic Rain Cover for conformity to the project specifications.

6.2.7 Sumps

A. Receipt of Contractor's submittals on sumps.

B. Review of submittals for sumps for conformity to the project specifications.

6.2.8 Valves

A. Receipt of Contractor's submittals on valves.

B. Review of submittals for valves for conformity to the project specifications.

6.3 LEACHATE MANAGEMENT SYSTEM INSTALLATION

6.3.1 Leachate Collection System (LCS)

The CQA Engineer will allow installation of the LCS to proceed only after he has been provided certification of the installed HDPE geomembrane.

The CQA Engineer will monitor and document the construction of all LCS components for compliance with the project specifications. Monitoring the construction work includes the following:

- monitoring the minimum vertical buffer maintained between field equipment and the geomembrane;
- monitoring that the placement of the LCS components does not fold or damage the geomembrane or other underlying layers; and
- witness and verify the installation of collection piping and gravel columns.

6.3.2 Leachate Discharge and Storage System

The CQA Engineer will monitor and document the construction of all leachate discharge and storage system components for compliance with the project specifications. Monitoring the construction work includes the following:

- witness and verify the installation of discharge piping; and
- witness and verify the leak testing of discharge piping.

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 LEACHATE MANAGEMENT SYSTEM

COMPONENT	PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:			
Coarse Aggregate:	Gradation	ASTM C 136	5,000 CY
	Carbonate Content	ASTM D 3042	1 per source
Protective Cover:	Visual Classification	ASTM D 2488	Each Load

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 approval, material control tests, repairs, and resolution of problems.

7.2 GEOTEXTILE MATERIAL APPROVAL

7.2.1 Geotextile Product Data

For 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 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.

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 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.

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 approved 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 APPROVAL

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Grab Tensile Strength	ASTM D 4632	100,000 ft^2 or 1 per Lot[1]
Puncture Resistance	ASTM D 4833	100,000 ft^2 or 1 per Lot[1]
Trapezoidal Tear Strength	ASTM D 4533	100,000 ft^2 or 1 per Lot[1]
Apparent Opening Size (AOS) (Type GT-S Geotextile Only)	ASTM D 4751	100,000 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
DRAINAGE GEOCOMPOSITE CQA

8.1 INTRODUCTION

This section of the CQA Manual addresses drainage geocomposite (DGC) and outlines the CQA program to be implemented with regard to material approval, material control tests, repairs, and resolution of problems.

8.2 DGC MATERIAL APPROVAL

8.2.1 DGC Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

8.2.2 Shipment And Storage

During shipment and storage, all DGC will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

8.2.3 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.

8.2.4 DGC 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 DGC. 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 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 DGC. The CQA

Engineer will examine all results from laboratory testing.

8.2.4.1 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 DGC 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 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.

8.3 DGC INSTALLATION

8.3.1 Handling And Placement

The Geosynthetic Installer will handle and place all DGC in such a manner as required by the project specifications.

8.3.2 Stacking And Joining

When several layers of DGC are stacked, care should be taken to ensure that stacked DGC are placed in the same direction. Stacked DGC will never be laid in perpendicular directions to the underlying DGC (unless otherwise specified by the Engineer). The CQA Engineer will observe the stacking of DGC.

Adjacent rolls of DGC will be joined according to construction drawings and project specifications.

8.3.3 Repairs

Any holes or tears in the DGC will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

8.3.4 Placement Of Overlying Materials

All soil materials located on top of DGC shall be placed in accordance with the project specifications.

8.4 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 8.1: CQA TESTING PROGRAM FOR DGC MATERIAL APPROVAL

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Thickness (geonet only)	ASTM D 5199	100,000 ft^2 or 1 per Lot[1]
Density (geonet only)	ASTM D 1505	100,000 ft^2 or 1 per Lot[1]
Ply Adhesion	ASTM D 413/ GRI GC7	100,000 ft^2 or 1 per Lot[1]
Transmissivity	ASTM D 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 9.0
GEOSYNTHETIC CLAY LINER (GCL) CQA

9.1 INTRODUCTION

This section of the CQA Manual addresses geosynthetic clay liner (GCL) and outlines the CQA program to be implemented with regard to material approval, material control tests, repairs, and resolution of problems.

9.2 GCL MANUFACTURER AND INSTALLER APPROVAL

The Contractor shall submit the qualifications of the GCL Manufacturer and the GCL Installer, as described in the specifications, to the CQA Engineer for approval.

9.3 GCL MATERIAL APPROVAL

9.3.1 GCL Product Data

The CQA Engineer will review the Contractor's submittals for conformance with the project specifications.

9.3.2 Shipment And Storage

During shipment and storage, GCL will be protected as required by the project specifications. The CQA Engineer will observe rolls upon delivery at the site.

9.3.3 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.

9.3.4 GCL Material Control Tests

Samples for material control tests, as shown on **Table 9.1**, 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 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.

9.3.4.1 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 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.

9.4 GCL INSTALLATION

9.4.1 Handling And Placement

The Geosynthetic Installer will handle and place all GCL in such a manner as required by the project specifications.

9.4.2 Seams And Overlaps

All GCL will be seamed or overlapped in accordance with project specifications or as approved by the CQA Engineer and Engineer.

9.4.3 Repairs

Any holes or tears in the GCL will be repaired in accordance with the project specifications. The CQA Engineer will observe any repair.

9.4.4 Placement Of Overlying Materials

All soil materials located on top of the GCL shall be placed in accordance with the project specifications.

9.5 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 9.1: CQA TESTING PROGRAM FOR GCL MATERIAL APPROVAL

PROPERTY	TEST METHOD	TEST FREQUENCY
CONTROL TESTS:		
Hydraulic Conductivity	ASTM D 5887	100,000 ft^2 or 1 per Lot[1]
Bentonite Content	ASTM D 5993 (@ 0% moisture)	100,000 ft^2 or 1 per Lot[1]
Tensile Strength	ASTM D 6768	100,000 ft^2 or 1 per Lot[1]

Notes:

1. Whichever provides the larger number of tests.

SECTION 10.0
FINAL COVER SYSTEM CQA

10.1 INTRODUCTION

This section of the CQA Manual addresses the drainage aggregate and piping and the vegetative soil layer of the final cover system. By reference to **Sections 5.0, 7.0, and 8.0** of this CQA Manual, this section also addresses the geomembrane, geotextiles, and drainage geocomposite that are included in the final cover system. This section outlines the CQA program to be implemented with regard to material approval, construction monitoring, and resolution of problems.

10.2 FINAL COVER SYSTEM MATERIAL APPROVAL

The CQA Engineer shall verify that the following are provided and installed in accordance with the project drawings, specifications, and this CQA Manual.

10.2.1 High Density Polyethylene (HDPE) Pipe

A. Receipt of Contractor's submittals on HDPE pipe.

B. Review of submittals for HDPE pipe for conformity to the project specifications.

10.2.2 Aggregates (Verify for each type of aggregate)

A. Receipt of Contractor's submittals on aggregates.

B. Review of submittals for aggregates for conformity to the project specifications.

C. Verify that aggregates in stockpiles or at borrow sources conform to the project specifications.

D. Conduct material control tests in accordance with **Table 10.1**.

10.2.3 Geomembrane

The CQA program for geomembranes is presented in **Section 5.0** of this CQA Manual.

10.2.4 Geotextiles

The CQA program for geotextiles is presented in **Section 7.0** of this CQA Manual.

10.2.5 Drainage Geocomposite

The CQA program for drainage geocomposite is presented in **Section 8.0** of this CQA

Manual.

10.2.6 Vegetative Soil Layer

A. Review the proposed source of vegetative soil layer for conformance with the project specifications.

B. Conduct material control tests in accordance with **Table 10.1**.

10.3 FINAL COVER SYSTEM INSTALLATION

The CQA Engineer will monitor and document the construction of all final cover system components for compliance with the project specifications. Monitoring the construction work for the components of the final cover system includes the following:

- verify location and depth of LFG wells;
- verify location of all piping;
- monitoring the minimum vertical buffer maintained between field equipment and geosynthetics/piping; and
- monitoring that the placement of the final cover system components does not fold or damage the geosynthetics or other underlying layers.

10.4 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 10.1: CQA TESTING PROGRAM FOR FINAL COVER SYSTEM

COMPONENT	PROPERTY	TEST METHOD	MINIMUM TEST FREQUENCY
CONTROL TESTS:			
Coarse Aggregate:	Gradation	ASTM C 136	5,000 CY
Vegetative Soil Layer:	Visual Classification	ASTM D 2488	Each Load
	Grain Size Analysis	ASTM D 422	5,000 CY
	Atterberg Limits	ASTM D 4318	5,000 CY

Appendix A

Reference List of Test Methods

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

CQA MANUAL
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.
ASTM D 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 698	Test Method for Laboratory Compaction Characteristics of Soil Using Standard Effort (12,400 ft-lbf/ft^3).
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.
ASTM D 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.
ASTM D 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.
ASTM D 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.
ASTM D 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.
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 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.
ASTM D 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.
ASTM D 5820	Standard Practice for Pressurized Air Channel Evaluation of Dual Seamed Geomembranes.
ASTM D 5887	Standard Test Method for Measurement of Index Flux Through Saturated Geosynthetic Clay Liner Specimens Using a Flexible Wall Permeameter.
ASTM D 5993	Standard Test Method for Measuring Mass per Unit of Geosynthetic Clay Liners.
ASTM D 5994	Standard Test Method for Measuring Core Thickness of Textured Geomembrane.
ASTM D 6392	Standard Test Method for Determining the Integrity of Nonreinforced Geomembrane Seams Produced Using Thermo-Fusion Methods.
ASTM D 6693	Standard Test Method for Determining Tensile Properties of Nonreinforced Flexible Polyethylene and Nonreinforced Polypropylene Geomembranes.
ASTM D 6768	Standard Test Method for Tensile Strength of Geosynthetic Clay Liners.

Geosynthetic Research Institute (GRI):

GRI GC7	Determination of Adhesion and Bond Strength of Geocomposites.

Operations Manual

Johnston County Landfill Facility
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

October 2005
Revised: May 2006

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY LANDFILL FACILITY

OPERATIONS MANUAL

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SECTION 1.0
GENERAL FACILITY OPERATIONS

1.1 OVERVIEW

This Operations Manual was prepared for operations of the Johnston County Landfill facility (Permit No. 51-03) located off of Highway 210 on County Home Road near Smithfield. This document discusses the operation of the following:

- Phase 4A (Lined Subtitle D MSW Landfill Unit - Existing);
- Area 1 (C&D Vertical Expansion - Existing);
- Area 2 (Lined C&D Landfill Unit - Proposed);
- Yard Waste Processing Area (Existing); and
- Convenience Center.

A companion Facility and Engineering Plan (**Attachment A** of the Permit Amendment Application for the Area 2 C&D landfill unit) presents a detailed discussion and calculations for the individual components of the landfill. The information contained herein was prepared to provide landfill personnel with a clear understanding of how the Design Engineer assumed that the completed facility would be operated. While deviations from the operations outlined here may be acceptable, they should be reviewed and approved by the Design Engineer.

1.2 CONTACT INFORMATION

All correspondence and questions concerning the operation of the Johnston County Landfill should be directed to the appropriate County and State personnel listed below. For fire or police emergencies dial 911.

1.2.1 <u>Johnston County</u>

Johnston County Department of Public Utilities
309 E. Market Street
P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 209-8333
Fax: (919) 934-7174

Contacts: Haywood Phthisic, Public Utilities Director
Tim Broome, P.E., Director of Engineering and Infrastructure

Johnston County Solid Waste Management Department
680 County Home Road
P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 938-4750

Fax: (919) 989-7152

Contact: Rick Proctor, Solid Waste Manager

1.2.2 North Carolina Department of Environment and Natural Resources

North Carolina Department of Environment and Natural Resources
3800 Barrett Drive
Raleigh, NC 27609
Phone: (919) 571-4700
Fax: (919) 571-4718

Division of Waste Management (DWM) - Solid Waste Section:

Waste Management Specialist: Ben Barnes

Division of Land Resources - Land Quality Section:

Regional Engineer: John Holley, P.E.

1.3 ACCESS CONTROL

Limiting access to the landfill facility is important for the following reasons:

- Unauthorized and illegal dumping of waste materials is prevented.
- Trespassing, and injury resulting therefrom, is discouraged.
- The risk of vandalism is greatly reduced.

Access to active areas of the landfill will be controlled by a combination of fences and natural barriers, and strictly enforced operating hours. A landfill attendant will be on duty at all times when the facility is open for public use to enforce access restrictions.

1.3.1 Physical Restraints

The site will be accessed by the existing entrance on County Home Road. Scales and a scale house and office are provided at the entrance. All waste will have been weighed prior to being placed in the landfill. The entrances have gates which will be securely locked during non-operating hours.

1.3.2 Security

Frequent inspections of gates and fences will be performed by landfill personnel. The County will arrange for a random security patrol of the main gate to further discourage trespassing. Evidence of trespassing, vandalism, or illegal operation will be reported to the County Solid Waste Manager.

1.4 SIGNAGE

A prominent sign(s) containing the information required by the DWM will be placed at the landfill entrance. This sign(s) will provide information on operating hours, operating procedures, and acceptable wastes. Additional signage will be provided within the landfill complex to distinctly distinguish the roadway to the active landfill unit(s). Service and maintenance roads for use by operations personnel will be clearly marked and barriers (e.g., traffic cones, barrels, etc.) will be provided as required.

1.5 COMMUNICATIONS

Two way radio communication will be maintained between the active landfill unit(s) and the landfill scale house and office. The scale house and office have telephones in case of emergency and for the conduct of day-to-day business. Emergency telephone numbers are displayed in the scale house and office.

1.6 FIRE AND SAFETY

1.6.1 Fire Control

The possibility of fire within the landfill or a piece of equipment must be anticipated in the daily operation of the landfill. A combination of factory installed fire suppression systems and/or portable fire extinguishers will be operational on all heavy pieces of equipment at all times. For larger or more serious outbreaks, the local fire department will respond.

Fires within the landfill will be limited by the use of daily and intermediate cover as a fire break and control of "hot" loads entering the landfill. Landfill personnel at the scale house will turn away all trucks containing waste that is suspected to be hot. If a hot load is placed on the working face, then the load will be spread as thin as possible and daily cover soil will be immediately placed on the waste to extinguish the fire.

In general, fires that break out close to the surface of the disposal area should be excavated and smothered with cover material. Deep fires should be smothered out by placing moist soil on the surface and by constructing soil barriers around the fire. Where the smothering technique fails, the burning material must be excavated and smothered or quenched with water once the burning material is brought to the surface. Water is usually not effective unless it can be directly applied to the burning material.

For the lined landfill unit(s), in the event a fire occurs in the first lift of waste immediately above the protective cover layer, the possibility of damage to geosynthetics and collection piping exists. Once the fire is extinguished, the residue must be removed to allow limited inspection of the geosynthetics and piping. Damaged sections of geosynthetics, piping, etc. must be removed and replaced with new items of the same or equal material. The new materials must be placed in accordance with the technical specifications and construction quality assurance (CQA) documents prepared for this facility.

The County will verbally notify the DWM (see **Section 1.2.2**) within 24 hours of discovery of a fire within any landfill disposal area. In addition, written documentation describing the fire, the actions carried out to extinguish the fire, and a strategy for preventing future occurrences will be provided to the DWM within 15 days following any such occurrence.

1.6.2 Safety

All aspects of the operation of the landfill facility were developed with the health and safety of the landfill's operating staff, customers, and neighbors in mind. Prior to commencement of operations in the new landfill phase/area, a member of the landfill operating staff will be designated site safety officer. This individual, together with the facility's management will modify the site safety and emergency response program to remain consistent with National Solid Waste Management Association and Occupational Safety and Health Administration (OSHA) guidance.

Safety equipment provided includes equipment rollover protective cabs, seat belts, audible reverse warning devices, hard hats, safety shoes, and first aid kits. Landfill personnel will be encouraged to complete the American Red Cross Basic First Aid Course. Other safety requirements as designated by the County will also be implemented.

1.7 SEVERE WEATHER CONDITIONS

Unusual weather conditions can directly affect the operation of the landfill facility. Some of these weather conditions and recommended operational responses are as follows.

1.7.1 Ice Storms

An ice storm can make access to the landfill dangerous, prevent movement or placement of daily cover, and, thus, may require closure of the landfill until the ice is removed or has melted.

1.7.2 Heavy Rains

Exposed soil surfaces can create a muddy situation in some portions of the landfill during rainy periods. The control of drainage and use of crushed stone on unpaved roads should provide all-weather access for the site and promote drainage away from critical areas. In areas where the aggregate surface is washed away or otherwise damaged, new aggregate should be used for repair.

Intense rains can affect newly constructed drainage structures such as swales, diversions, cover soils, and vegetation. After such a rain event, inspection by landfill personnel will be initiated and corrective measures taken to repair any damage found before the next rainfall.

1.7.3 Electrical Storms

The open area of a landfill is susceptible to the hazards of an electrical storm. If necessary, landfilling activities will be temporarily suspended during such an event. To guarantee the safety of all field personnel, refuge will be taken in the on-site buildings or in rubber-tired vehicles.

1.7.4 Windy Conditions

The proposed operational sequence minimizes the occurrence of unsheltered operations relative to prevailing winds. If this is not adequate during a particularly windy period, work will be temporarily shifted to a more sheltered area. When this is done, the previously exposed face will be immediately covered with daily cover.

1.7.5 Violent Storms

In the event of hurricane, tornado, or severe winter storm warning issued by the National Weather Service, landfill operations may be temporarily suspended until the warning is lifted. Daily cover will be placed on exposed waste and buildings and equipment will be properly secured.

1.8 EQUIPMENT REQUIREMENTS

The County will maintain on-site equipment required to perform the necessary landfill activities. Periodic maintenance of all landfilling equipment, and minor and major repair work will be performed at designated maintenance zones outside of the landfill.

1.9 PERSONNEL REQUIREMENTS

At least one member of the landfill supervisory staff will be certified as a Manager of Landfill Operations (MOLO) by the Solid Waste Association of North America (SWANA). Each landfill employee will go through an annual training course (led by supervisory staff) and is certified by SWANA as Landfill Operations personnel. As part of this training, personnel learn to recognize loads which may contain regulated hazardous waste or wastes containing PCB's.

1.10 UTILITIES

Electrical power, water, telephone, and restrooms are provided at the landfill scale house and/or office.

1.11 RECORD KEEPING PROGRAM

The County shall maintain the following records in an operating record at the landfill:

A. Waste inspection records (see **Section 2.4**);
B. Daily tonnage records - including source of generation;
C. Waste determination records;
D. Quantity, location of disposal, generator, and special handling procedures for all special wastes disposed of at the site;
E. List of generators and haulers that have attempted to dispose of restricted wastes;
F. Employee training procedures and records of training completed;
G. Documentation of cell activation (see **Section 2.5.2.2**)
H. Leachate records (see **Section 3.3.3**);
I. Gas monitoring results and remediation measures as required (see **Section 3.4.2**);
J. All ground water monitoring and surface water quality information (See the current **Ground Water Sampling and Analysis Plan**) including:
   1. Monitoring well construction records;
   2. Sampling dates and results;
   3. Statistical analyses; and
   4. Results of inspections, repairs, etc.
K. Annual landfill reports;
L. All closure and post-closure information, where applicable, including:
   1. Testing;
   2. Certification; and
   3. Recording.
M. Cost estimates or financial assurance documentation.

The operating record will be kept up to date by the Solid Waste Manager or his designee. It will be presented upon request to the DWM for inspection. A copy of this Operations Manual will be kept at the landfill and will be available for use at all times.

SECTION 2.0
WASTE HANDLING OPERATIONS

2.1 OVERVIEW

This section describes the required waste handling operations for the Johnston County Landfill facility. In addition to the MSW and C&D waste disposed of at this facility, the County also processes recyclables, scrap tires, and white goods. These materials are stored at the landfill facility until there are sufficient quantities for pick up by various recycling contractors.

2.2 ACCEPTABLE WASTES

2.2.1 MSW Landfill Units

The Johnston County MSW Landfill will only accept for disposal solid waste as defined by 15A NCAC 13A .0101(36) generated within approved areas of service. In addition, the special wastes described in **Section 2.5.4** may also be accepted at this facility.

2.2.2 C&D Landfill Units

The Johnston County C&D landfill units will only accept for disposal the following wastes generated within approved areas of service:

- Construction and Demolition Debris Waste: (Waste or debris from construction, remodeling, repair, or demolition operations on pavement or other structures)
- Inert Debris Waste: (Concrete, brick, concrete block, uncontaminated soils and rock, untreated and unpainted wood, etc.)
- Land Clearing Debris: as defined by G.S. 120A-290, specifically, waste that is generated solely from land-clearing activities, such as stumps, trees, etc.
- Asphalt: in accordance with G.S. 130-294 (m)
- Other Wastes as Approved by the Solid Waste Section of the Division of Waste Management.

In addition, the special wastes (asbestos only) described in **Section 2.5.4** may also be accepted at this facility.

2.3 PROHIBITED WASTES

2.3.1 MSW Landfill Units

The following wastes are prohibited from disposal within the MSW landfill:

- Whole Scrap Tires
- Used Oil
- White Goods

- Lead Acid Batteries
- Yard Waste
- Construction and Demolition Debris (C&D) (Except when allowed by the County)
- Aluminum Cans

In addition, operating criteria prohibit other materials from disposal at the MSW landfill unit. These materials include:

- Hazardous waste as defined by 15A NCAC 13A .0101(11), including hazardous waste from conditionally exempt small quantity generators.
- Polychlorinated biphenyls (PCB) wastes as defined in 40 CFR 761 with the exception of trace amounts found in materials such as consumer electronics.
- Bulk or non-containerized liquid wastes unless the waste is household waste other than septic waste and waste oil; or the waste is leachate or gas condensate derived from the MSW landfill unit. A liquid determination will be performed by the paint filter test (see **Appendix A** for apparatus and procedure).
- Containers holding liquid wastes unless the waste is household waste.

2.3.2 C&D Landfill Units

Only wastes, as defined in **Section 2.2.2** above will be accepted. No other wastes will be accepted.

2.4 WASTE SCREENING PROGRAMS

In order to assure that prohibited wastes are not entering the landfill facility, screening programs have been implemented at the landfill. Waste received at both the scale house entrance and waste taken to the working face is inspected by trained personnel. These individuals have been trained to spot indications of suspicious wastes, including: hazardous placarding or markings, liquids, powders or dusts, sludges, bright or unusual colors, drums or commercial size containers, and "chemical" odors. Screening programs for visual and olfactory characteristics of prohibited wastes are an ongoing part of the landfill operation.

2.4.1 Waste Receiving and Inspection

All vehicles must stop at the scale house located at the entrance of the facility and visitors are required to sign-in. All waste transportation vehicles are weighed and the content of the load assessed. The scale attendant(s) requests from the driver of the vehicle a description of the waste it is carrying to ensure that unacceptable waste is not allowed into the landfill. The attendant(s) then visually checks the vehicle as it crosses the scale. Signs informing users of the acceptable and unacceptable types of waste are posted at the scale house. Once passing the scales, the vehicles are routed to the appropriate landfill unit or to the citizen's convenience center in the case of small loads, recyclables, white goods, and/or tires.

Vehicles are randomly selected for screening at a rate of approximately 1% of industrial, commercial, and institutional vehicles entering the landfill. However, if something looks suspicious is spotted in any waste load, that load is inspected further. The number of loads inspected is determined by the total vehicle count as per scales tickets. Each calendar year the number is recalculated (For example, for 2001, 1% was equal to 252 vehicles; 264 vehicles were actually inspected.

Vehicles selected for inspection are directed to an area of intermediate cover adjacent to the working face where the vehicle will be unloaded. Waste is carefully spread using suitable equipment. An attendant trained to identify wastes that are unacceptable at the landfill inspects the waste discharged at the screening site. If unacceptable waste is found, including wastes generated from outside of the service area, the load will be isolated and secured by berming off the area. For unacceptable wastes that are non-hazardous, the Solid Waste Manager will then notify officials of the DWM (see **Section 1.2.2**) within 24 hours of attempted disposal of any waste the landfill is not permitted to receive in order to determine the proper course of action. For unacceptable wastes that are hazardous, the Hazardous Waste Contingency Plan outlined in **Section 2.4.2** will be followed. The hauler is responsible for removing unacceptable waste from the landfill property.

If no unacceptable waste is found, the load will be pushed to the working face and incorporated into the daily waste cell. All random waste inspections will be documented by landfill staff using the waste screening form provided in **Appendix B**.

In addition to random waste screening described above, waste unloaded on the active face will be inspected by the equipment operators, trained to spot unacceptable wastes, before and during spreading and compaction. Any suspicious looking waste is reported immediately to the designated primary inspector for further evaluation.

2.4.2 Hazardous Waste Contingency Plan

In the event that identifiable hazardous waste or waste of questionable character is detected at the landfill, appropriate equipment, protective gear, personnel, and materials as necessary will be employed to isolate the wastes. The DWM will be notified immediately (see **Section 1.2.2**) that an attempt was made to dispose of hazardous waste at the landfill. If the vehicle attempting disposal of such waste is known, all attempts will be made to prevent that vehicle from leaving the site or, if the vehicle has left the site, immediate notice will be served on the owner of the vehicle that hazardous waste, for which they have responsibility, has been disposed of at the landfill.

The County will assist the DWM as necessary and appropriate in the removal and disposition of the hazardous waste and in the prosecution of responsible parties. If needed, the hazardous waste will be covered with either on-site soils or other tarping material until such time when an appropriate method can be implemented to properly handle the waste. The cost of the removal and disposing of the hazardous waste will be charged to the owner of the vehicle involved. Any vehicle owner or operator who knowingly dumps hazardous waste in the landfill may be barred from using the landfill.

Should an incident where hazardous waste is found at the landfill occur, the event will be documented by landfill staff using the waste screening form provided in **Appendix B**.

Records of information gathered as part of the waste screening programs will be maintained at the landfill site during its active life and as long as required by the County and the DWM.

2.5 WASTE DISPOSAL

2.5.1 Access

Traffic will be clearly directed to the appropriate active access road. For the active lined disposal unit(s), all vehicles entering the unit will use the active ramp to avoid damaging the liner system. Traffic speed on the ramp should be less than 10 MPH. Rutting of gravel roadway surfaces must be repaired by placement of additional gravel on the roadway and not solely by grading the rut. This will maintain the separator geotextile placed below most gravel roadway surfaces.

The location of access roads during waste placement will be determined by operations personnel in order to reflect waste placement strategy.

2.5.2 Waste Disposal - Lined (MSW or C&D) Landfill Units

2.5.2.1 Cell Operations and Phasing

Each lined landfill unit is divided into cells. Each cell will be filled in sequence until the entire footprint is covered with waste. Phasing drawings for the landfill units are presented on **Drawings P1-P2** (C&D and MSW Landfill Phasing Plans).

It is advantageous to begin to establish final cover grades along the perimeter berms as soon as is possible. This will allow earlier construction of intermediate or final cover to promote "clean" runoff and to spread out final cover construction costs.

2.5.2.2 Cell Activation

Waste placement will begin in Cell 1. Before placing waste in a subsequent cell, that cell (or portion thereof) must be connected to the leachate collection system (LCS) by removing (or suitably perforating) geosynthetic rain cover (and/or making any required piping changes) such that all liquid collected in the cell will flow to the sump. Next, just ahead of waste placement operations, the Type GT-S geotextile placed over the gravel columns is to be cut and removed such that waste will be placed in direct contact with the coarse aggregate. Waste placement will generally be from the topographic high end to the topographic low end of each cell.

Once a cell has reached its effective capacity, operations will move to the next scheduled cell. Prior to placing waste in a new cell, it must be connected to the LCS as described above.

See **Appendix C** for cell activation forms to be used in the documentation of cell activation activities.

2.5.2.3 Placement of Initial Lift

During waste placement operations, the landfill liner systems are most vulnerable during the placement of the first lift of waste. In addition to the protective cover layer, the first lift of waste should be comprised of select loads spread on top of the protective cover layer. These select loads must be free of long or large pieces of waste that may push through the protective cover layer and damage the liner system. Workers will be positioned near the working face to check for any waste which could possibly penetrate the protective cover layer. The first lift should be a minimum of four (4) feet thick and provide sufficient area for at least one day's operation without placing other areas of the liner in jeopardy.

Another area of the liner system that is vulnerable during placement of the first lift of waste is the perimeter berms. As with the bottom liner, the first lift of waste against the liner side walls should be comprised of select loads.

In the event that the landfill staff identifies any damage to any part of the landfill's liner system, they should immediately initiate its repair. Additionally, they should document the damage and the repair as a part of the operating record.

2.5.2.4 General Procedures

Waste transportation vehicles will arrive at the working face at random intervals. There may be a number of vehicles unloading waste at the same time, while other vehicles are waiting. In order to maintain control over the unloading of waste, a certain number of vehicles will be allowed on the working face at a time. The actual number will be determined by the truck spotter. This procedure will be used in order to minimize the potential of unloading unacceptable waste and to control disposal activity. Operations at the working face will be conducted in a manner which will encourage the efficient movement of transportation vehicles to and from the working face, and to expedite the unloading of waste.

The approach to the working face will be maintained such that two or more vehicles may safely unload side by side. A vehicle turn-around area large enough to enable vehicles to arrive and turn around safely with reasonable speed will be provided adjacent to the unloading area. The vehicles will back to a vacant area near the working face to unload. Upon completion of the unloading operation, the transportation vehicles will immediately leave the working face area. Personnel will direct traffic necessary to expedite safe movement of vehicles.

Waste unloading at the landfill will be controlled to prevent disposal in locations other than those specified by site management. Such control will also be used to confine the working face to a minimum width, yet allow safe and efficient operations. The width and length of the working face will be maintained as small as practical in order to maintain the appearance of the site, control windblown waste, and minimize the amount of cover required each day. Normally, only one working face will be active on any given day, with all deposited waste in other areas covered by either daily, intermediate, or final cover, as appropriate. Within the active working face area, appropriate size berms (approximately 2 feet high) will be constructed as necessary to control surface water from entering the working face area and coming into contact with the waste. These berms will be relocated as waste cell development continues.

The procedures for placement and compaction of solid waste include: unloading of vehicles, spreading of waste into 2 foot lifts, and compaction on relatively flat slopes (i.e. 5H:1V max.) using a landfill compactor and a minimum number of three full passes.

Wind screens adjacent to the working face may be used as required to control windblown waste.

The use of portable signs with directional arrows and portable traffic barricades will facilitate the unloading of wastes to the designated disposal locations. These signs and barricades will be placed along the access route to the working face of the landfill or other designated disposal areas which may be established.

2.5.2.5 Equipment Operations Within the Landfill

Both the facility's operational vehicles and waste transportation vehicles must be restricted as follows within the lined landfill:

- Equipment operation directly on the protective cover will be limited to rubber-tired vehicles having a maximum ground contact, i.e., tire pressure, of less than 32 psi.
- A minimum vertical separation of 3 feet will be maintained between the geomembrane liner and all waste transportation vehicles.
- A minimum vertical separation of 5 feet will be maintained between the

geomembrane liner and waste compactors.

The operation of vehicles within those portions of the landfill not actively receiving waste should be restricted to activities associated with erosion and sedimentation control.

2.5.3 Waste Disposal - Unlined (C&D) Landfill Units

Waste will be placed in such a manner that the active face is minimized. The waste lift should be relatively thick in order to minimize the active face and the distance waste is spread by the compactor.

C & D waste will be unloaded at the upper limit of the working face and inspected (according to **Section 2.4.1**) prior to being spread on the face and compacted.

The active working face for each day shall be less than 1/4 acre in size and have a slope no greater than 5H:1V. The surface of the active area must be graded to drain.

Waste spread over the working face will be placed in lifts at least 5-ft thick and will receive a minimum of five passes of the compaction equipment over each lift. The 5 foot thick lift layer will be placed over the entire active area to be used that day. Once the area has received a full lift layer, subsequent lift layers that day will be placed above the previous lift. Each lift layer will be no more than 3 feet thick in compacted thickness. The entire day's lift should be approximately 8-10 feet thick at the end of a given working day.

2.5.4 Special Waste Management

2.5.4.1 Asbestos Management (MSW or C&D Landfill Units)

The County may dispose of asbestos within either the MSW or C&D landfill units. Asbestos will only be accepted if it has been processed and packaged in accordance with State and Federal (40 CFR 61) regulations. Asbestos will arrive at the site in vehicles that contain only the asbestos waste and only after advance notification by the generator.

Once the hauler brings the asbestos to the landfill, the hauler will be directed to the designated asbestos disposal area by operations personnel. The designated disposal area will be prepared by operations personnel by leveling a small area using a dozer or loader. Prior to disposal, the landfill operators will stockpile cover soil near the designated asbestos disposal area. The volume of soil stockpiled will be sufficient to cover the waste and to provide any berms, etc. to maintain temporary separation from other landfill traffic.

Once placed in the prepared area, the asbestos waste will be covered with a minimum of 18 inches of cover soil placed in a single lift. The surface of the cover soil will be compacted and graded using a tracked dozer or loader. The landfill compactor will be prohibited from operating over asbestos disposal areas until at least 18 inches of cover are in-place.

The landfill staff will record the approximate location and elevation of the asbestos waste once cover is in-place. The Solid Waste Manager will then review pertinent disposal and location information to assure compliance with regulatory requirements and enter the information into the Operating Record.

Once disposal and recording for asbestos waste is completed, the disposal area may be covered with waste. No excavation into designated asbestos disposal areas will be permitted.

In general, for the lined landfill unit(s), no asbestos will be stored over gravel columns or over sump areas in order to minimize the potential for future disturbance.

2.5.4.2 Sewage Sludge Management (MSW Landfill Units)

Sewage sludge may be accepted for disposal within the MSW landfill units in accordance with Federal and State requirements. Sewage sludge will be co-disposed along with other wastes if the sludge passes the liquids restriction criteria (i.e., the Paint Filter Test) and has an acceptable Toxicity Characteristic Leaching Procedure (TCLP) test. Such testing will be the responsibility of the generator, but landfill staff may conduct spot testing.

In order to minimize the potential for clogging of the leachate collection and removal system, sewage sludge will not be placed within the first lift of waste. Sewage sludge may also be used as a soil conditioner incorporated into the vegetative soil layer of the final cover.

2.5.4.3 Spoiled Food and Animal Waste (MSW Landfill Units)

The disposal of spoiled foods, animal carcasses, and other animal wastes within the MSW landfill units will be handled as follows. The generator of the material must call in advance to the landfill, and a determination will be made as to whether or not the waste will be accepted. If the waste is approved, the generator will present the waste at a predetermined time. An area for disposal will already have been prepared and the waste will be covered immediately.

2.5.5 Daily Cover

2.5.5.1 MSW Landfill Units

At the completion of waste placement each day, a 6 inch layer of earthen material or approved alternate daily cover (i.e. tarps, etc.) will be placed over the working face. This daily cover is intended to control vectors, fire, odors, and blowing litter. If the County should desire to use an alternate daily cover, a formal request and an appropriate demonstration will be made to the DWM.

2.5.5.2 C&D Landfill Units

At the completion of waste placement each week, or sooner if the area of exposed waste exceeds one acre in size, a 6-inch layer of earthen material will be placed over the exposed waste. This periodic cover is intended to control vectors, fire, odors, and blowing debris.

2.5.6 Intermediate Cover

A 12 inch layer of soil cover should be placed on all waste surfaces that have not received waste in 30 days but are below final elevation. This intermediate cover should be seeded immediately and graded such that all precipitation run-off is channeled to the surface water systems.

2.5.7 Height Monitoring

Approximately every month, the landfill staff will monitor landfill top and side slope elevations with a level. When such elevations approach design grades, the final top-of-waste grades will be staked to limit over-placement of waste.

2.6 YARD WASTE PROCESSING AREA OPERATIONS

The operation of the yard waste processing area is as follows:

Acceptable wood and yard wastes are stockpiled to an approximate height of 10 feet over an area of approximately 1 acre (approximate weight of 1,500 to 2,000 lbs.). At that time a contractor is brought in to grind the waste. Once the waste is ground and becomes mulch, it is used either around the site, primarily for surface stabilization, or placed in windrows to be given to the public or otherwise used in the future. A full time attendant looks over both the yard waste processing area and the convenience center operations.

2.7 CONVENIENCE CENTER OPERATIONS

The operation of the citizen's convenience center is as follows:

The convenience center is set up with up to eight 40 yard roll-off containers for the collection of MSW (small loads) and recyclables. The County currently typically separately collects aluminum cans, newspaper, cardboard, mixed no. 1 and no. 2 plastics, and brown, green, and clear glass. The convenience center also includes collection facilities for white goods, used tires, waste oil, and batteries.

The white goods area currently occupies approximately a 50 foot by 100 foot area. County personnel remove the Freon, as necessary, and load the white goods into three to four 40 yard roll-off containers. Typically, every Wednesday, the County hauls the full containers to a local salvage yard, where the white goods can be recycled.

Used tires are collected at the convenience center in up to three tire trailers. Once one or more trailers are full, the used tires are taken to a tire recycler for recycling.

A full time attendant looks over both the convenience center and yard waste processing area operations.

SECTION 3.0
ENVIRONMENTAL MANAGEMENT

3.1 OVERVIEW

This section reviews the overall environmental management tasks required for the successful operation of the landfill. Emphasis is given to the supplemental tasks required for the Area 2 - C&D landfill unit.

3.2 SURFACE WATER CONTROL

As used herein, the definition of "surface water" is water which results from precipitation or site run-on that has not contacted the waste.

Proper control of surface water at the landfill will accomplish the following goals:

- Prevent the run-on of surface water into the lined landfill unit(s) or the active face(s),
- Prevent the run-off of surface water that has come into contact with the waste (i.e. leachate),
- Limit the erosion caused by surface waters,
- Limit sediments carried off-site by surface waters, and
- Maximize the SEPARATION of SURFACE water from LEACHATE.

Separate erosion and sedimentation control plans have been provided for the various landfill units. These plans describe both short and long term engineered features and practices for preventing erosion and controlling sedimentation at this site. The following is a brief discussion of some of these features and practices, focusing more on the landfill units.

3.2.1 Surface Water Run-On Control

The perimeter berms and/or perimeter channels around the landfill unit(s) are designed to prevent the run-on of surface water from adjacent land into the landfill. Additional structures such as diversion berms, channels, down pipes, etc. carry surface water away from the landfill.

3.2.2 Active Face Run-Off Control - MSW Landfill Units

Particular care is required to ensure that surface water coming from the active face, e.g. having potential contact with the waste, is captured by the leachate collection system (LCS). Only run-off from waste surfaces that have received adequate cover is not considered leachate and should be directed to the stormwater drainage system where practical.

3.2.3 Erosion Control

The serviceability of the landfill relies heavily on soil berms, barrier layers, and agricultural layers that are readily eroded by flowing water. Erosion control provisions incorporated in the landfill include the following:

- The slope of the working face must be no steeper than 5H:1V where practical to limit erosion of the daily cover,
- Intermediate cover placed over daily cover that has been exposed for more than 30 days must be seeded immediately and repaired when erosion features are identified,
- Drainage breaks (diversion berms, rain gutters, etc.) are provided on the final cover to limit the flow length of run-off,
- Water collected by each drainage break is routed to stormwater drainage channels or down pipes so that the run-off volume does not accumulate going down the slope.
- The vegetative soil layer placed over the final cover must be seeded immediately.

Additional erosion control measures have been taken within the drainage channels and at points of stormwater discharge. All final cover should be inspected regularly for erosion damage and promptly repaired.

3.2.4 Sedimentation Control

Stormwater run-off from the landfill unit(s) is conveyed to one of the on site sediment basins and/or traps. These basins and/or traps should be inspected regularly for sediment build-up or erosion damage. The basins and/or traps should be cleaned out when sediments fill the lower half of the basin.

3.2.5 Separation of Stormwater/Leachate - Lined (MSW and C&D) Landfill Units

The stormwater separation system is accomplished by dividing the line landfill units into separate cells to reduce the volume of leachate generated and minimize the impoundment of stormwater within the landfill. The separation system allows stormwater in cells which have not yet received waste to be pumped out of the landfill to perimeter drainage features. During activation of a cell, the Owner will connect the cell to the LCS as discussed in **Section 2.5.2.2**.

3.3 LEACHATE MANAGEMENT - LINED (MSW AND C&D) LANDFILL UNITS

The leachate management system for the existing and proposed lined landfill units consists of the LCS, the leachate discharge piping, pumps, valve boxes, valves, and the existing leachate storage lagoon.

Leachate from the lined landfill units is collected in the leachate sumps at the low end of each disposal area. Leachate collected in each sump is pumped to the leachate storage lagoon via a HDPE force main. See **Drawing S7** (Leachate Forcemain Plan and Profile) for system features. From the storage lagoon, the leachate is pumped via force main to a County-owned wastewater treatment plant (WWTP) or back into the Phase 5 MSW landfill unit as part of an approved leachate recirculation plan (See **Appendix C**).

3.3.1 Leachate Collection System (LCS)

A blanket drainage layer (either natural or geosynthetic drainage media) covers the liner system to collect and remove leachate draining from the waste. In addition, a large flow capacity network of perforated pipe and gravel drains is constructed in the blanket drain. For the Area 2 C&D landfill unit, this perforated pipe and gravel drainage system is shown on **Drawing S5** (Area 2 - Composite Liner Grading and Leachate Collection System Plan) of the Project Drawings. The LCS is designed to remove inflow from a 25-year, 24-hour rainstorm. As such, its capacity is very large compared to that required to accommodate routine leachate generation rates once waste covers the landfill footprint.

The LCS has been designed to minimize the impact of long-term biological clogging as follows:

- Cleanouts are provided on the major perforated leachate collection pipes,
- No geotextiles will be used between the waste and the gravel columns, and
- The use of No. 57 stone around collection pipes allows hydro-washing of the pipe and gravel to remove biological growth.

3.3.1.1 Gravel Column Maintenance

The exposed surface of the gravel columns should be inspected monthly and after each large rain storm to check for buildup of sediment on the aggregate or on the adjacent leachate collection system on the sidewall. Sediment buildup must be periodically removed carefully with a backhoe. Aggregate that is removed must be replaced with new clean material. Per **Section 2.5.2.2**, the Type GT-S geotextile must be removed just prior to the placement of waste over that portion of gravel column.

3.3.1.2 Collection Pipe Cleanout

If an abnormal reduction in leachate production is observed, a remote camera inspection of the major leachate collection pipes will be performed. Based on the results of remote camera inspection, those locations of the major perforated pipe system that have sediment or biological growth buildup will be cleaned using high pressure water jetting equipment. The water jetting system should generate greater than 2,000 psi water pressure. Use of the high pressure water jetting equipment should be limited to only those portions of the piping system with buildup.

3.3.1.3 Leachate Removal

As constructed, leachate is collected in sumps at the low points of the landfill and is removed from the landfill via a side riser pump and HDPE discharge pipe. The leachate is routed to the leachate storage lagoon via a force main.

Under normal conditions, the County will remove (via forcemain) leachate from the storage lagoon at a rate to maintain a typical volume of 3,000,000 gallons (approximate 6 foot depth), or less, of leachate in the lagoon. This allows ample volume in the lagoon to handle the anticipated "surge" event caused by a design storm and minimizes the potential for ponding within the landfill. Additional draw-down of the lagoon will be performed in advance of predicted heavy rainfall (tropical storm, hurricane, etc.).

3.3.1.4 Operation and Maintenance of Leachate Pumps and Storage Lagoon

Operation and maintenance of leachate pumps shall be in accordance with the appropriate manufacturer's recommendations. If required, the leachate storage lagoon may require cleanout of sediment and/or maintenance of aerators. The County Solid Waste Director or his designee will be responsible for following and documenting, as required, these activities.

3.3.2 Leak Detection System - Phase 4A MSW Landfill Unit

A leak detection system (LDS) is part of the Phase 4A MSW landfill unit. The purpose of the LDS is to provide rapid detection of a major breach in the primary liner system and to limit the head on the secondary liner to less than the thickness of the LDS.

For Phase 4A, the LDS consists of a layer of drainage geocomposite directly overlying the secondary LLDPE geomembrane and a series of four leak detection trenches. Flow that is collected in the leak detection trenches is routed through 4 inch diameter HDPE piping to a pump station. The LDS pump station consists of a prefabricated HDPE manhole, valving, and submersible pumps. Leachate collected in the LDS pump station is pumped to the existing leachate storage lagoon via the same force main as leachate collected in the

LCS described above.

The LDS has been designed with an Action Leakage Rate (ALR) of 3,000 gallons per day. Should leakage collected in the LDS exceed the ALR based on routine flowmeter readings from the LDS pump station, the County will take steps (placement of soil cover, tarps, etc.) to limit leachate generation from in-place waste.

3.3.3 Leachate Quality Sampling

Semi-annual leachate quality sampling and analysis will be performed during operation of the lined landfill units. Samples will be recovered as grab samples from the following locations:

- MSW Phase 5: Sample from existing gravity line in leachate manhole;
- MSW Phase 4A (Leachate Collection System): Sample from side risers;
- MSW Phase 4A (Leak Detection System): Sample from leak detection pump station; and
- C&D Area 2: Sample from side risers.

The parameters to be analyzed will include BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, Appendix I constituents, sulfates, and nitrates.

3.3.4 Record Keeping

Accurate records for the following will be maintained at the landfill in accordance with **Section 1.11**.

Leachate Generation (Monthly):

- Phase 5 (Leachate storage lagoon pump station flowmeters minus flow from Phase 4A);
- Phase 4A (Leachate collection system flowmeter); and
- Phase 4A (Leak detection system pump station flowmeter).

Leachate Quality (Quarterly and/or Semi-Annual):

- Phase 5 (Quarterly during active leachate recirculation);
- Phase 4A (Leachate Collection System); and
- Phase 4A (Leak Detection System).

3.3.5 Leachate Contingency Plan

In the unlikely event that leachate levels within the existing leachate storage lagoon approach the freeboard capacity, due to unforeseen events, the DWM will be verbally notified (see **Section 1.2.2**) and the leachate flow will be valved off and temporarily stored in the landfill until the level of leachate in the lagoon can be lowered by direct pumping. Written documentation describing the unforeseen events, the actions carried out to remove the stored leachate, and a strategy for preventing future occurrences will be provided to the DWM within 30 days following any such occurrence.

3.4 LANDFILL GAS (LFG) MANAGEMENT - MSW LANDFILL UNITS

A landfill gas (LFG) management system is included as part of the design of the MSW landfill units. Refer to the design plans of each landfill unit for landfill gas control devices.

3.4.1 Methane Monitoring Program

The County will implement a routine methane monitoring program to ensure that methane concentrations do not exceed 25 percent of the lower explosive limit (LEL) in facility structures, or 100 percent of the LEL at property boundaries. Gas monitoring wells will be sampled on a quarterly basis. Monitoring of facility structures will be performed continually.

3.4.2 Record Keeping

Results of the methane monitoring program will be placed in the facility operating record as described in **Section 1.11**.

3.4.3 LFG Contingency Plan

In the event methane concentrations exceed allowable limits, the emergency response plan will be as follows:

Open Air Areas

1. For 100% LEL at distances less than 250 feet from structures:

    a. Recalibrate equipment and recheck reading.
    b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
    c. Call Fire Department.
    d. Notify the DWM (see **Section 1.2.2**).
    e. Notify the Consulting Engineer.
    f. Note the current weather and ground moisture conditions.
    g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
    h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will

describe the nature and extent of the problem and the proposed remedy.

2. For 100% LEL at distances greater than 250 feet from structures:

   a. Recalibrate equipment and recheck reading.
   b. Immediately take all necessary steps to ensure protection of human health (i.e. remove sources of ignition and limit access to the area).
   c. Notify the DWM.
   d. Notify the Consulting Engineer.
   e. Note the current weather and ground moisture conditions.

Structures

1. For structures with greater than 25% LEL:

   a. Recalibrate equipment and recheck reading.
   b. Immediately take all necessary steps to ensure protection of human health as above - including immediate evacuation leaving all doors open.
   c. Call Fire Department.
   d. Notify the DWM.
   e. Notify the Consulting Engineer.
   f. Note the current weather and ground moisture conditions.
   g. Within seven days of detection, place in the operating record the methane gas levels detected and a description of the steps taken to protect human health.
   h. Within 60 days of detection, implement a remediation plan for the methane gas releases, place a copy of the plan in the operating record, and notify the DWM that the plan has been implemented. The plan will describe the nature and extent of the problem and the proposed remedy.

2. For structures with 0-25% LEL:

   a. Recalibrate equipment and recheck reading.
   b. Discuss with the Consulting Engineer.

3.5 LANDFILL GAS (LFG) MANAGEMENT - C&D LANDFILL UNITS

Due to the nature of the waste disposed in the C&D landfill units, landfill gas control is not anticipated to be of concern. As such, the only LFG management devices are those associated with underlying MSW waste. Refer to the design plans of each landfill unit for landfill gas control devices.

3.6 VECTOR CONTROL

3.6.1 MSW Landfill Units

Control of insects, rodents, and birds will be accomplished by compaction of the waste and the use of daily cover. Spilled or wind-blown debris along the access road will be cleaned up daily and placed in the landfill. If vector control becomes a problem, additional measures will be taken to ensure the protection of human health.

3.6.2 C&D Landfill Units

Due to the nature of the waste disposed in the C&D landfill units, vector control is not anticipated to be of concern. Note that the use of periodic cover will discourage animals from nesting in the waste.

3.7 ODOR CONTROL

3.7.1 MSW Landfill Units

Odorous or potentially odorous materials will be covered as soon as possible to avoid odor problems. If odor control becomes a problem, additional measures will be taken to ensure odor control.

3.7.2 C&D Landfill Units

Due to the nature of the waste disposed in the C&D landfill units, odor control is not anticipated to be of concern.

3.8 DUST CONTROL

Dust related to waste hauler traffic on the access roads will be minimized by using a water truck to limit dust on the gravel portion of the road. Dust generated by excavation of cover soil will be limited by watering the cut soil areas if accessible to the water truck.

Appendix A

EPA Method 9095

Paint Filter Liquids Test

METHOD 9095
PAINT FILTER LIQUIDS TEST
From EPA SW-846

1.0 SCOPE AND APPLICATION

1.1 This method is used to determine the presence of free liquids in a representative sample of waste.

1.2 The method is used to determine compliance with 40 CFR 264.314 and 265.314.

2.0 SUMMARY OF METHOD

2.1 A predetermined amount of material is placed in a paint filter. If any portion of the material passes through and drops from the filter within the 5 minute test period, the material is deemed to contain free liquids.

3.0 INTERFERENCES

3.1 Filter media were observed to separate from the filter cone on exposure to alkaline materials. This development causes no problem if the sample is not disturbed.

4.0 APPARATUS AND MATERIALS

4.1 Conical paint filter: Mesh number 60 (fine meshed size). Available at local paint stores such as Sherwin-Williams and Glidden for an approximate cost of $0.07 each.

4.2 Glass funnel: If the paint filter, with the waste, cannot sustain its weight on the ring stand, then a fluted glass funnel or glass funnel with a mouth large enough to allow at least 1 inch of the filter mesh to protrude should be used to support the filter. The funnel is to be fluted or have a large open mouth in order to support the paint filter yet not interfere with the movement, to the graduated cylinder, of the liquid that passes through the filter mesh.

4.3 Ring stand and ring or tripod.

4.4 Graduated cylinder or beaker: 100-mL.

5.0 REAGENTS

5.1 None.

6.0 SAMPLE COLLECTION, PRESERVATION, AND HANDLING

6.1 All samples must be collected according to the directions in Chapter Nine of EPA SW-846.

6.2 A 100 mL or 100 g representative sample is required for the test. If it is not possible to obtain a sample of 100 mL or 100 g that is sufficiently representative of the waste, the analyst may use larger size samples in multiples of 100 mL or 100 g, i.e., 200, 300, 400 mL or g. However, when larger samples are used, analysts shall divide the sample into 100-mL or 100-g portions and test each portion separately. If any portion contains free liquids, the entire sample is considered to have free liquids.

7.0 PROCEDURE

7.1 Assemble test apparatus as shown in Figure 1.

7.2 Place sample in the filter. A funnel may be used to provide support for the paint filter.

7.3 Allow sample to drain for 5 minutes into the graduated cylinder.

7.4 If any portion of the test material collects in the graduated cylinder in the 5-min. period, then the material is deemed to contain free liquids for purposes of 40 CFR 264.314 and 265.314.

8.0 QUALITY CONTROL

8.1 Duplicate samples should be analyzed on a routine basis.

9.0 METHOD PERFORMANCE

9.1 No data provided.

10.0 REFERENCES

10.1 None required.

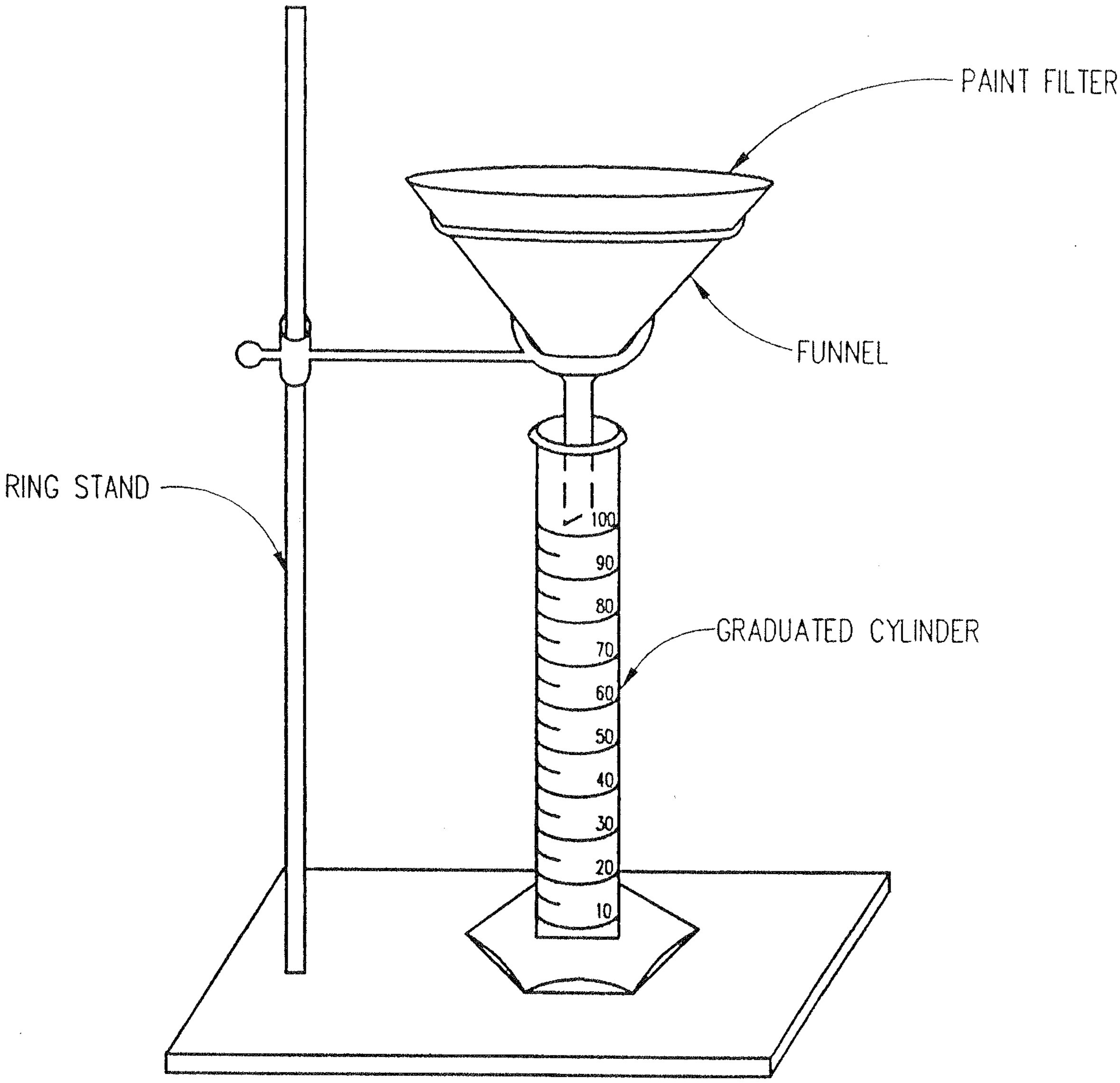


FIGURE 1. PAINT FILTER TEST APPARATUS.

Appendix B

Waste Screening Form

Johnston County Department of Public Utilities
Johnston County Landfill Facility
(919) 938-4750

WASTE SCREENING FORM

Day / Date: ____________________ Time Weighed in: ____________________
Truck Owner: ____________________ Driver Name: ____________________
Truck Type: ____________________ Vehicle ID / Tag No: ____________________
Weight ____________________ Tare: ____________________
Waste Generator / Source: ____

Reason Load Inspected: Random Inspection ______ Staff Initials ______
Detained at Scales ______ Staff Initials ______
Detained by Operating Staff ______ Staff Initials ______

Inspection Location: ____

Approved Waste Determination Form Present? Yes ______ No ______ N/A ______

Description of Load: ____

____

____

Load Accepted (signature) ____________________ Date __________
Load Not Accepted (signature) ____________________ Date __________

Reason Load Not Accepted (complete only if load not accepted)

Description of Suspicious Contents: Color ________ Haz. Waste Markings ________
Texture ________ ____________________
Drums Present ________ Smell ____________________
Est. Cu. Yds. Present in Load ________
Est. Tons Present in Load ________

Johnston County Emergency Management Contacted? Yes ______ No ______

Company or Authority Contacted? ____
Hazardous Materials Present: ____

____

Hauler Notified (if waste not accepted) Phone: Time Contacted:
Other Observations: ____

____

Final Disposition
Signed ______________________________ Date ____________________
Waste Screening Inspector or Solid Waste Manager

Attach related correspondence to this form.
File completed form in Operating Record.

Appendix C

Cell Activation Forms

JOHNSTON COUNTY MSW LANDFILL - PHASE 4A
CELL ACTIVATION FORM

Date: ____________________

Cell: ____________________

Size of Geosynthetic Rain Cover Removed (Length/Width): ____________________

Length of Type GT-S Geotextile Removed from Gravel Column(s): ____________________

Remarks: ____

____

____

____

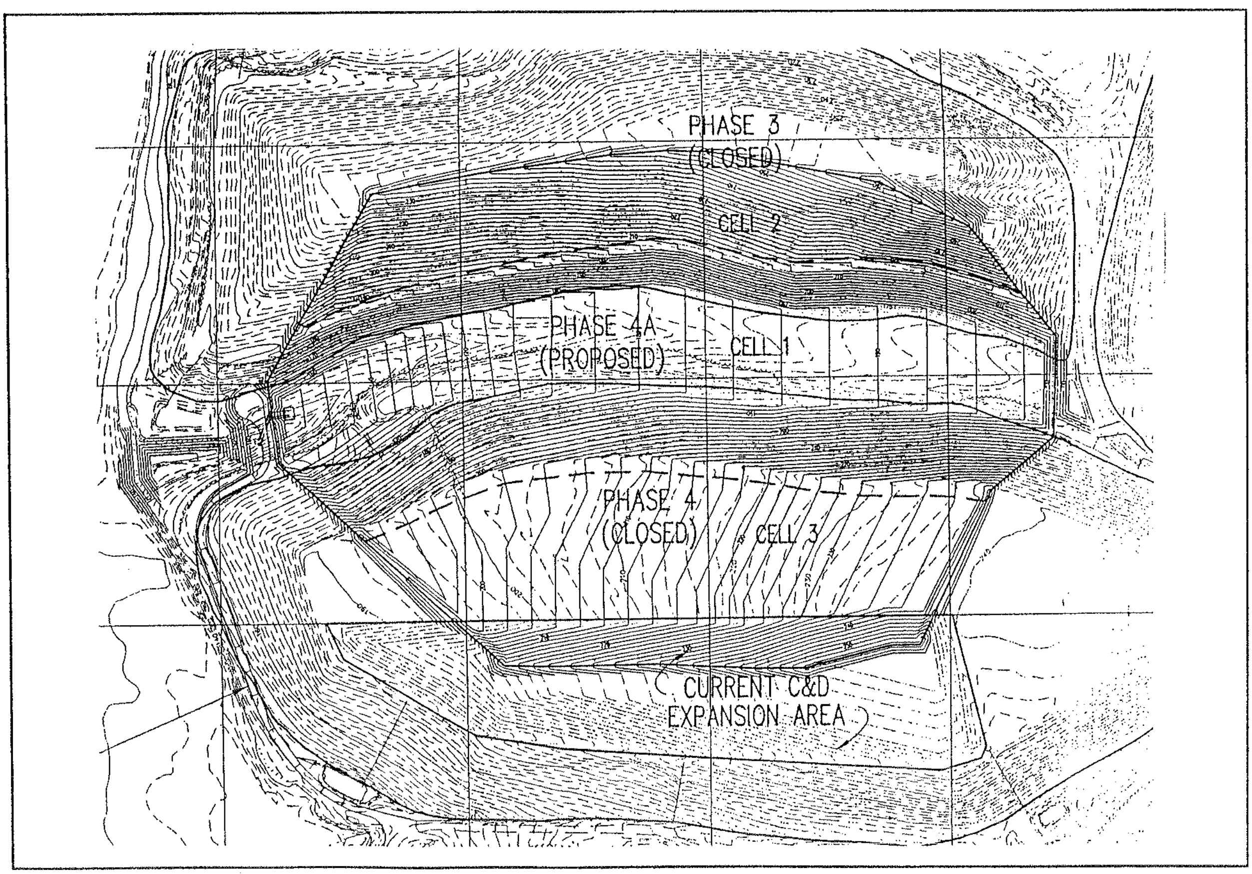
____

____

____

Signed: ________________________________

Sketch:



JOHNSTON COUNTY C&D LANDFILL - AREA 2
CELL ACTIVATION FORM

Date: ____________________

Cell: ____________________

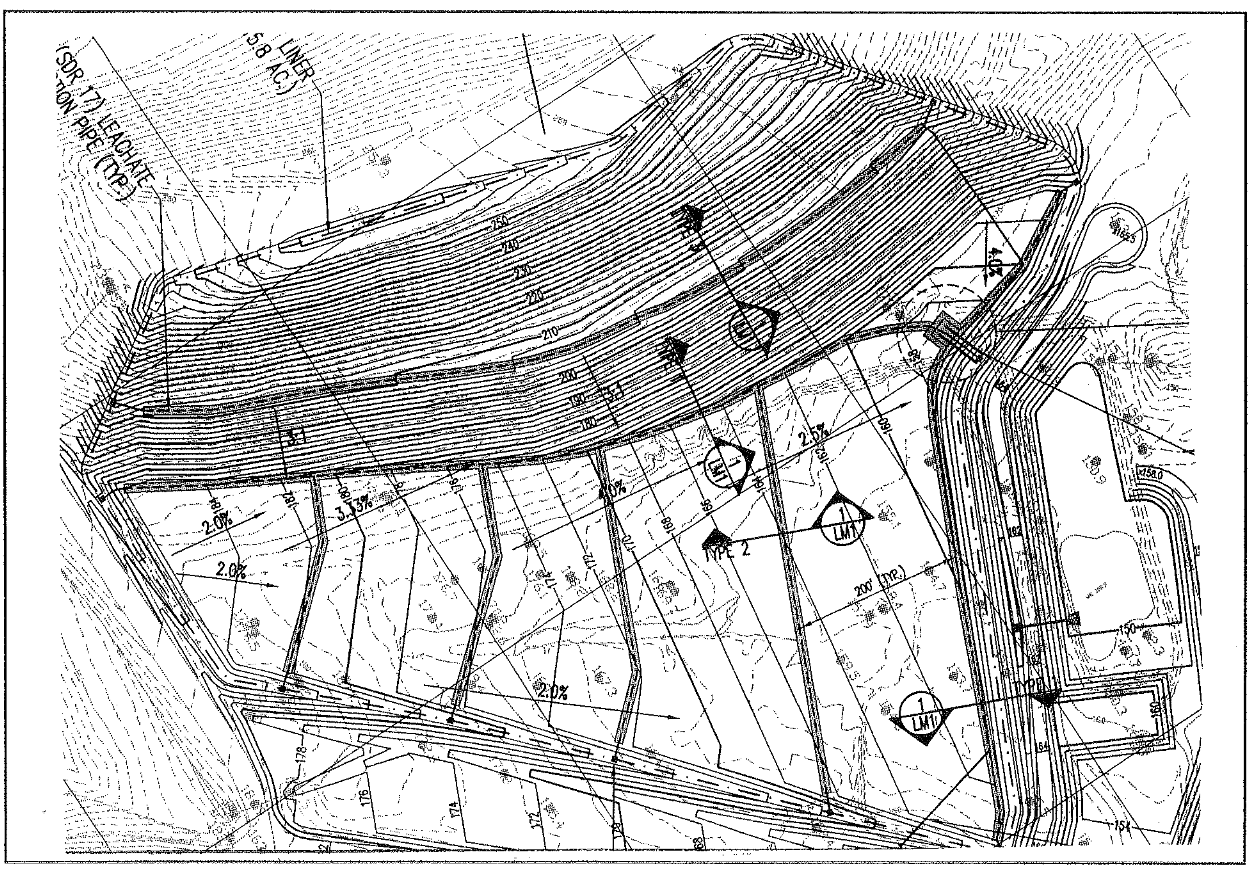
Size of Geosynthetic Rain Cover Removed (Length/Width): ____________________

Length of Type GT-S Geotextile Removed from Gravel Column(s): ____________________

Remarks: ____
____
____
____
____
____
____

Signed: ____

Sketch:



Appendix D

Leachate Recirculation Plan

Operations Manual
Appendix D: Leachate Recirculation Plan

Johnston County Landfill Facility
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

January 2002

PERMIT ISSUE DOCUMENTS

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
425 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY LANDFILL FACILITY

OPERATIONS MANUAL
APPENDIX D: LEACHATE RECIRCULATION PLAN

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JOHNSTON COUNTY
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1.0 OVERVIEW

Water is the most significant factor influencing waste stabilization and leachate quality. Moisture addition has been demonstrated repeatedly to have a stimulating effect on methanogenesis (Barlaz et al, 1990), although some researchers indicate that it is the movement of moisture through the waste as much as it is water addition that is important (Klink and Ham, 1982). Moisture within the landfill serves as a reactant in the hydrolysis reactions, transports nutrients and enzymes, dissolves metabolites, provides pH buffering, dilutes inhibitory compounds, exposes surface area to microbial attack, and controls microbial cell swelling (Noble, et al, 1991). Lu, et at, (1985) stated that high moisture flow rates can flush soluble organics and microbial cells out of the landfill and in such cases microbial activity plays a lesser role in determining leachate quality. Also, high moisture application rates can remove the majority of waste contaminants early in the life of the fill. Under low flow rate conditions, anaerobic microbial activity is the significant factor governing leachate organic strength (McBean et al, 1995). The quantity of moisture is important because it directly affects stabilization rates within the landfill. Sulfita et al, (1992) and Miller, et al, (1994) both noted the important role of moisture in supporting methanogenic fermentation of solid waste when examining samples removed from operating landfills. Relatively dry landfills (i.e. 20-40% water) have very slow stabilization rates because there is only a small quantity of moisture for biological degradation. Recommended moisture content reported in the literature ranges from a minimum of 25 percent (wet basis) to optimum levels of 40 to 70 percent (Barlaz, et al, 1990; Chen and Bowerman, 1974).

Leachate is recirculated in MSW landfills for one or more of the following reasons:

- as an alternative to leachate treatment,
- to promote biodegradation of the waste as detailed above to produce a smaller and more stable waste mass, and
- to accelerate the production of landfill gas (LFG).

Johnston County's plan to recirculate leachate within the Phase 5 area of their Subtitle D landfill is based on a desire to stabilize the waste and associated contaminants prior to placement of the final cover. The County facility is presently equipped with a leachate force main to a County owned and operated wastewater treatment plant (WWTP) so that disposal of leachate is not a concern. As such, this recirculation plan is developed with the goal of maximizing the rate of degradation of the waste and not for the purpose of leachate disposal.

2.0 REGULATORY REQUIREMENTS

The recirculation of leachate within lined MSW landfills is provided for in Federal RCRA Subtitle D regulations and not prohibited in North Carolina regulations. It is anticipated that design and operational requirements for recirculation will evolve from guidance provided by the Solid Waste Section of the North Carolina Division of Waste Management (DWM).

2.1 40 CFR 258 RCRA Subtitle D

Federal regulations provide both specific and implied requirements that must be met by landfills recirculating leachate. Relevant sections of the Federal regulations are as follows:

§258.28 (a): Bulk or non-containerized liquid waste may not be placed in the MSWLF units unless: (1) The waste is household waste other than septic waste; or (2) The waste is leachate or gas condensate from the MSWLF unit and the MSWLF unit, whether it is a new or existing MSWLF, or lateral expansion, is designed with a composite liner and leachate collection system as described in §258.40(a)(2) of this part...

§258.40(a)(2): With a composite liner, as defined in paragraph (b) of this section and a leachate collection system that is designed and constructed to maintain less than a 30-cm depth of leachate over the liner. (b) For purposes of this section, *composite liner* means a system consisting of two components: the upper component must consist of a minimum 30-mil flexible membrane liner (FML), and the lower component must consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than $1x10^{-7}$ cm/sec...

2.2 North Carolina Rule NCAC T15A: 13B.1600

North Carolina regulations mirror the above referenced Federal regulations in Rule .1624(b)(1) related to design and construction, Rule .1624(b)(2)(A) related to maximum head, and Rule .1626(9)(a)(ii) related to recirculation of leachate. Currently, however, implementation of leachate recirculation is administered using policy established in DWM guidance for leachate recirculation. This guidance establishes basic elements that must be incorporated into a leachate recirculation plan prior to implementation of a 120-day trial period and eventual long-term operation. Key elements of this guidance are listed on **Table 1** along with the location in this manual where the element is addressed.

3.0 FACILITY LIQUIDS CONTROL - ENGINEERED PERFORMANCE

Significant engineering effort has been expended to ensure that the maximum head acting on the liner system during routine recirculation does not exceed 30 cm and that the recirculation system itself does not adversely affect the integrity or stability of the landfill. This section provides a general description of these systems and the technical evaluation performed to ensure adequate performance.

3.1 Leachate Recirculation System

The leachate recirculation system uses a network of horizontal porous galleries to both inject leachate into the waste and to vent landfill gas (LFG) generated by the degradation of the waste. The galleries are designed to minimize leachate short circuiting of the waste and the potential for landfill fires in the LFG collection system. Each gallery consists of a family of parallel trench drains that are individually fitted with a leachate injection pipe. The **Project Drawings** show the general geometry and placement of the injection/LFG galleries and details for their construction. The galleries are placed at an approximate 30 foot vertical spacing and a maximum 80 foot horizontal spacing. Each successive vertical gallery is staggered to provide for more uniform leachate distribution and gas collection. The porous LFG collection and leachate distribution media can be constructed using gravel, tire chips, or other relatively inert media having a permeability greater than 1×10^{-2} cm/sec. The leachate injection and LFG collection pipes are high density polyethylene (HDPE) fusion welded pipe having a maximum SDR of 11. Leachate is injected under a minimum 10 psi pressure through a series of 1/8 inch holes spaced 10 feet apart. Field tests by GNRA have confirmed that this hole size and spacing allows for a very uniform release of leachate from each hole for pipe lengths up to 800 feet in length. For this project, lengths were designed up to ±400 feet in length. Installation details for each injection/LFG gallery are recorded using the form provided in **Appendix D1**.

Significant settlement of the waste is anticipated during the service life of the recirculation system. HDPE was selected for use in the injection/LFG pipes due to both its chemical resistance and its low coefficient of friction which minimizes potential tensile forces caused by differential settlement of the waste. The selected SDR of the pipes is based on anticipated maximum tensile forces related to differential settlement and not the stresses generated by the leachate pressure.

3.2 Leachate Collection and Recovery (LCR) System

The leachate collection and recovery (LCR) system for Phase 5 was modified by the County as follows. The modification consisted of removal of 12 inches of sand and a geotextile that had originally been placed between the primary leachate collection pipes and the waste. This material was replaced with a NC DOT #57 stone that provides a significant increase in the transmissivity of the pipe/stone drain and resistance to bioclogging of the drain. This conversion of the primary collection pipe system is performed just in advance of the placement of waste immediately on the #57 stone to ensure that the stone remains free of fines from the protective cover.

The HELP (v. 3.07) Model was used to evaluate the impact of leachate recirculation on the head acting on the composite liner system. This analysis indicates that the average head acting on the liner system is less than 12 inches when a minimum of 30 feet of waste is in place prior to initiating recirculation. The short-term HELP evaluations are conservative in that only a single 30 foot lift of waste is modeled for a 5 year period. As the height of waste is increased, the storage capacity within the waste increases and the resulting head on the liner system decreases. For example, modeling a 60 foot layer of waste under intermediate cover reduces the short term head from 10.2 inches to 5.4 inches.

4.0 FACILITY EQUIPMENT AND OPERATING PRACTICES

Leachate recirculation must be performed in a manner that does not create odor or stability problems and produces heads on the liner system less than 30 cm. Odor problems are minimized in the proposed system by the use of leachate injection galleries such that raw leachate is not applied to the surface of the waste. The permanent system for injection of leachate is shown in the **Project Drawings** and requires operational steps as follows:

- Leachate to be recirculated is collected in the existing leachate pump station located adjacent to the existing leachate storage lagoon.
- Leachate is pumped from the pump station to the injection galleries using a submersible high-head pump capable of maintaining a minimum 10 psi pressure at the inlet of the injection gallery. Each injection gallery is provided with a positive on-off ball valve as shown in the **Project Drawings**.
- Leachate is pumped into individual injection galleries in metered $\pm$6,000 gallon slugs designed to prevent localized saturation of the waste and stability problems. Injection is sequenced between the galleries and recorded using the form provided in **Appendix D1**.
- A backup system can be provided using a water truck that receives leachate from the leachate lagoon and then transports it back to the top of Phase 5 and injects it directly from the truck to one of the injection galleries. This system may be utilized in the event of a shutdown of the recirculation pump.

The general recirculation philosophy is to avoid visible discharge of leachate, e.g., spraying into the air by truck, sprinklers, or hoses, to minimize the potential for odor problems and excessive discharge in one zone of waste to minimize stability and seep related problems. This section discusses the facility hardware and operational procedures employed to successfully recirculate leachate to the waste.

4.1 Leachate Injection Gallery

Each injection gallery extends horizontally from the face of the final cover into the waste a distance of no more than about 400 ($\pm$10%) feet in length. Each injection gallery consists of a granular windrow or trench drain containing a HDPE leachate injection pipe. The details of this system are discussed in **Section 3.1**. Each leachate injection gallery pipe is fitted at its exposed end with a positive on-off valve connected to the supply line. A check valve and cleanout are also provided for each injection gallery pipe.

The injection pipe diameter and pressure are selected to ensure that leachate flow velocities are sufficient to prevent fouling of the injection pipe and the perforations. It is not anticipated that the leachate injection pipes will require servicing during their estimated 5-8 year service life. The granular drain surrounding the injection pipe is designed to both allow a more uniform distribution of the leachate and for the collection of LFG within the waste. The size and permeability of the granular trench drain is based on the desire to maintain internal LFG pressures less than 6-inches H_2O (0.22 psi). All injection gallery installation details will be recorded using the form provided in **Appendix D1**.

4.2 Leachate Injection Equipment

One submersible pump will be provided in the existing pump station for recirculating leachate. This pump is rated for a flow of 50 gpm at a head of 210 feet. This pump was selected to provide the required minimum inlet pressure to the leachate injection gallery of 10 psi and approximately 2 hours pumping time to inject 6,000 gallons of leachate. The injection pump is equipped with on-off controls within the pump station.

4.3 Leachate Amendment

With time it is anticipated that the leachate draining from Phase 5 will become increasingly acidic. Research by Barlaz (1990) has shown that the rate of waste decomposition actually decreases with increasing acidity. Therefore it may be necessary to buffer the leachate prior to future recirculation. This will be accomplished using a liquid lime injector as needed. Currently there are no plans for leachate amendment other than buffering.

5.0 FACILITY MONITORING PRACTICES

The facility must be monitored to ensure that the combination of leachate recirculation and natural precipitation does not produce excessive head on the liner system, side slope seeps, or stability problems. This section reviews a monitoring system to be installed at Phase 5 to monitor both weather and leachate quantities.

5.1 Weather Monitoring

Daily weather monitoring will be obtained using a rain gauge and tell-tale equipped thermometer located at the landfill office. Daily readings would be obtained for the maximum temperature, total rainfall, and general weather conditions. This information would be recorded on the form provided in **Appendix D1**. This data allows an accurate evaluation of the water-balance over time within the waste.

5.2 Leachate Monitoring

Leachate from Phase 5 gravity drains to the leachate lagoon. The cumulative flow through the gravity drain line will be monitored via flowmeters for all pumps. Calculations commonly performed to determine action leakage rates (ALR) for leak detection systems show that the flow rate will be 130,600 gallons per day when the maximum head acting on the liner is 30 cm. The cumulative flow monitoring will provide verification that the head acting on the liner system is less than 30 cm.

Landfill personnel will pay particular attention to sudden increases in leachate generation during or immediately after recirculation activities. Sudden increases in rate of leachate generation from the facility not accompanied by precipitation indicates that injected leachate is moving through the waste faster than normal. This may imply either saturation of the waste due to over injection of leachate or short circuiting (via voids in the waste) of the waste by a single injection. Both situations require a cessation of injection to the injection gallery in question and a modification of the injection sequence.

6.0 REPORTS

The following reports will be prepared:

- Pre-Operational Report;
- 120-Day Trial Period Reporting (Progress and Final Reports); and
- Quarterly Operational Reports.

Reporting forms proposed in this pre-operational report will be revised with experience.

6.1 Pre-Operational Report

The pre-operational report provides sufficient information to justify the 120-day trial recirculation period. This Leachate Recirculation Plan is the pre-operational report for the Johnston County Phase 5 leachate recirculation program.

6.1.1 Weather Monitoring

A daily rain gauge and thermometer will be installed at the landfill office to allow daily recording of total rainfall and maximum temperature. This data will be recorded at the end of each working day.

6.1.2 Baseline Leachate Sampling

Baseline leachate quality data for Phase 5 will be provided within the last 30 days prior to the initiation of leachate recirculation. This data will include test results for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and volatiles.

6.1.3 Operational Procedures

Johnston County plans on proceeding with the installation of the recirculation pump and force main. Thus, the operational procedures during the 120-day trial recirculation period will be the same as for long-term operations as previously described in **Section 4**.

6.1.4 Operational Equipment

The operational equipment during the 120-day trial will include the recirculation pump and force main and a portion of the first level of injection galleries as shown in the **Project Drawings** and installed at a nominal elevation of 30 feet of waste.

6.1.5 Record Keeping

Daily readings for rainfall, maximum temperature, quantity of leachate generated/recirculated, and leachate injection galleries used will be maintained using the form provided in **Appendix D1**. This form provides for a week of data and allows comments on the daily weather conditions and unusual operating conditions, e.g., odor or seeps. These data sheets will be provided to the State as part of the technical report submitted to DWM in support of implementation of the long-term leachate recirculation program.

6.2 120-Day Trial Period Reporting

6.2.1 Progress Report

After a minimum of 60 days, a progress report will be prepared which describes and documents the monitoring activities since initiation of the 120-day trial period, presents observed difficulties and/or operational modifications, and presents leachate quality data. Leachate quality data will include test results for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and volatiles.

6.2.2 Final Report

At the completion of the 120-day trial period, a final report will be prepared which describes and documents the monitoring activities for the entire trial period, presents observed difficulties and/or operational modifications, and presents leachate quality data. Leachate quality data will include test results for BOD, COD, temperature, conductivity, pH, ammonia, suspended solids, metals, and volatiles. The most critical aspect of this report is confirmation that the proposed leachate injection sequence results in acceptable performance. Final drawings and specifications for the facility modifications will also be submitted with this report. Based on this report, Johnston County will request approval by DWM to implement the long-term leachate recirculation program.

6.3 Quarterly Operational Reports

Quarterly leachate recirculation operational reports will be submitted to DWM after the 120-day trial period. These reports will provide the daily log sheets provided in **Appendix D1**, identify all leachate injection galleries in service, and provide updated leachate quality data.

7.0 REFERENCES

1- Barlaz, M.A., R.K. Ham, and D.M. Schaefer, 1990. "Methane Production from Municipal Refuse: A review of Enhancement Techniques and Microbial Dynamics," Critical Reviews in Environmental Control, 19(6): 557.

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7- Noble, J.J. and A.E. Arnold, 1991. "Experimental and Mathematical Modeling of Moisture Transport in Landfills," Chemical Eng. Comm., 100: 95-111.

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TABLE 1: NC DWM POLICY ELEMENTS FOR LEACHATE RECIRCULATION

Conditions	Policy Element	Section(s)
Preoperative Conditions	A rain gauge and thermometer shall be placed on the site.	6.1.1
	A Baseline sampling of leachate shall be performed.	6.1.2
	An outline of expected operational procedures shall be submitted.	4.0
	A brief description of the equipment and its' associated specifications shall be submitted.	4.0 & Specs.
	A brief description of record-keeping forms shall be submitted including: • daily/weekly record of leachate generated • daily/weekly record of leachate recirculated • weather conditions and other pertinent daily information • a log for reporting operating or other unusual problems, and their subsequent rectification • any other forms or procedures, etc., that the owner/operator will use.	5.0/6.0
	An estimation of height of waste in the cell where leachate is anticipated to be applied.	Project Drawings
	An analysis of the field capacity of the waste where leachate is to be applied, such that the gallons per unit area does not exceed the field capacity of the waste volume.	3.2
Operating Conditions	Records shall be kept or a daily/weekly basis as outlined.	6.0
	No leachate shall be applied on less than one lift (10 feet) of waste.	3.1
	No leachate shall be spray applied or surface circulated when it is raining, or when the waste is too wet.	4.0
	No run-off or side seepage will be allowed.	4.0
	Odors will be controlled.	4.0
	Leachate depth shall be monitored in the manhole to ensure that the head on the liner does not exceed one foot for more than 24 hours.	5.2
	Leachate will be spray applied or surface circulated during daylight hours only.	N/A
	The application system will be properly maintained and documented.	5.0/6.0
	Subsurface distribution systems will be outlined.	4.1
	Operation and maintenance of subsurface systems will be proposed.	4.0

Appendix D1

Reporting Forms and Logs

JOHNSTON COUNTY MSW LANDFILL - PHASE 5
LEACHATE RECIRCULATION
120-DAY TRIAL PERIOD MONTHLY REPORTING FORM

Start Date (Day 1): ______________________

Day	Rain (Inch)	Max. Temp.	Leachate Generated	Leachate Recirculated	Injection Galleries Used	Problems/Weather (Use Extra Sheet if Required)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
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26						
27						
28						
29						
30						
31						

JOHNSTON COUNTY MSW LANDFILL - PHASE 5
LEACHATE RECIRCULATION
LEACHATE RECIRCULATION MONTHLY REPORTING FORM

Start Date (Day 1): ______________________

Day	Rain (Inch)	Max. Temp.	Leachate Generated	Leachate Recirculated	Injection Galleries Used	Problems/Weather (Use Extra Sheet if Required)
1						
2						
3						
4						
5						
6						
7						
8						
9						
10						
11						
12						
13						
14						
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30						
31						

JOHNSTON COUNTY MSW LANDFILL - PHASE 5
LEACHATE RECIRCULATION
LEACHATE RECIRCULATION DAILY LOG

Date: ______________			
Time	Injection Gallery	Volume Pumped	Remarks

JOHNSTON COUNTY MSW LANDFILL - PHASE 5
LEACHATE RECIRCULATION
HORIZONTAL WELL INSTALLATION LOG

Well Number: ______________

Date(s) Installed: ____________________

Length Installed: ____________________

Elevation: ____________________

Number of Holes/Spacing: ____________________

Hole Size: ____________________

Coordinates:

Point #: ______________ X: ______________ Y: ______________ Z: ______________

Point #: ______________ X: ______________ Y: ______________ Z: ______________

Point #: ______________ X: ______________ Y: ______________ Z: ______________

Remarks: ____

Installation Sketch:

Appendix E

Irrigation of Reclaimed Wastewater

Operations Manual
Appendix E: Irrigation of Reclaimed Wastewater

Johnston County Landfill Facility
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

January 2002
Revised: August 2005

PERMIT ISSUE DOCUMENTS

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY LANDFILL FACILITY

OPERATIONS MANUAL
APPENDIX E: IRRIGATION OF RECLAIMED WASTEWATER

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JOHNSTON COUNTY
JOHNSTON COUNTY LANDFILL FACILITY

OPERATIONS MANUAL
APPENDIX E: IRRIGATION OF RECLAIMED WASTEWATER

1.0 OVERVIEW

This Operations Manual Addendum was prepared for the Johnston County MSW Landfill located off of Highway 210 on County Home Road for the purpose of describing the operation of an irrigation system for reclaimed wastewater, which is proposed for the site. The system will be owned and operated by Johnston County.

2.0 CONTACT INFORMATION

All correspondence and questions concerning the operation of the reclaimed wastewater irrigation system should be directed to the appropriate County personnel listed below:

Johnston County Department of Public Utilities
309 E. Market Street, P.O. Box 2263
Smithfield, NC 27577
Phone: (919) 209-8333 (Downtown); (919) 938-4750 (Landfill)
Fax: (919) 934-7174 (Downtown); (919) 989-7152 (Landfill)

Solid Waste Manager:	Rick Proctor
Public Utilities Director:	Haywood Phthisic
Director of Engineering:	Tim Broome, P.E.

3.0 IRRIGATION SYSTEM OPERATION

3.1 Areas to be Irrigated

Areas to be irrigated and order of priority (1 being the highest) include the following:

Priority 1:

- Wooded area behind (south and east of) NC Forest Service building (Field 1) (Not on Solid Waste Permit Site);
- Agricultural fields to the south and west of the landfill office (Field 2) (majority not on Solid Waste Permit Site);
- Area behind (west of) landfill office (Fields 3 & 4 - future Phases 6, 9, and 10); and
- Wooded area south of the leachate storage lagoon (Fields 6, 7, & 8 - future Phases 7 and 8).

Priority 2:

- Closed landfill areas on Phase 1 & 2, 3, 4, and 5 (LF Cap 1 & 2, LF Cap 3, LF Cap 4, and LF Cap 5).

Priority 3:

- Inactive borrow areas (Field 5 - future Phases 6 and 7) (Fields 9, 10, & 11).

In addition to these areas, the County plans to use reclaimed wastewater for the control of dust within the facility and around the County livestock arena (not on Solid Waste Permit Site). **Figure 1** presents the location of the various planned irrigation areas.

3.2 Periods of Operation

The irrigation system will be operated during the months of April through October with the exception of Fields 1, 2, and 3. In addition, irrigation will be discontinued on any day that rainfall exceeds 0.2 inches.

For Fields 1, 2, and 3, irrigation will be year-round. A winter cover crop, such as annual rye, will be used as required. No irrigation will take place during freezing temperatures. Equipment will be drained as required to prevent problems due to freezing temperatures.

3.3 Irrigation Amounts

Irrigation amounts off the landfills will be in accordance with the agronomic rates determined for the landfill site (based on "wettest" year amounts) in an analysis performed by Robert Evans, Ph.D., P.E. of N.C. State University and entitled "Hydrologic Wastewater Reuse Irrigation Analysis for Johnston County". Irrigation amounts on the landfill final covers will be in accordance with HELP model evaluations performed by G.N. Richardson & Associates. A tabulation of amounts to be irrigated is given in **Table 1**. Restrictions to these amounts are as stated herein. Note that based on site monitoring of the irrigation program (see **Section 3.5**), future increases to these amounts may be allowed.

3.4 Irrigation Restrictions

3.4.1 Monitoring Wells

No irrigation will occur within 100 feet of an actively monitored site monitoring well.

3.4.2 <u>Closed Landfill Areas</u>

Irrigation over closed landfill areas shall only take place over closed areas which have at least 2 feet of soil cover or at least 1.5 feet of soil cover and a synthetic barrier.

3.4.3 <u>Future Landfill Areas</u>

Irrigation over areas designated as future landfill areas (or areas within 300 feet of future landfill areas) will be discontinued within 2 years before the anticipated start of construction for that area unless it is demonstrated by use of piezometers, monitoring wells, or other method (see **Section 3.5**) that irrigation rates are not creating an artificial rise in groundwater levels. Closed landfill areas, if to be lined over as part of a future landfill area may be irrigated in accordance with **Section 3.4.2**.

3.4.4 <u>Borrow Areas</u>

No irrigation will be performed in active borrow areas. Irrigation may be performed in inactive borrow areas as long as the ground surface is prepared to promote vegetation (soil type, nutrients, etc.).

3.5 Site Monitoring of Irrigation Program

In order to monitor the effect of the irrigation program both to ground water quality and to the ground water table a monitoring program will be implemented. This program will consist of two elements. One will be the addition of sampling and testing of the treated irrigation water as part of the regular Spring and Fall ground water sampling/testing events already performed as part of site operations. After sampling, the irrigation water will be tested for the same detection monitoring parameters as for the other site samples.

In addition, the second element of the monitoring program will be the installation of piezometers in each future landfill area to be irrigated (i.e. Phases 6-10). At a minimum, one piezometer will be installed roughly in the central portion of the proposed future landfill phase before irrigation can begin over that area. The water elevations in these piezometers will be measured and recorded both during the spring and fall, concurrent with regular site ground water monitoring, and in the mid-summer. These levels will be evaluated in order to determine if there appears to be a rise in ground water elevations due to the irrigation activities. Should ground water elevations be maintained within a couple of feet of initial levels or levels that might otherwise be considered normal considering other factors such as weather, etc., the irrigation amounts for that area may be increased. Likewise, if there appears to be a significant (more than a couple of feet) increase in ground water elevation, which cannot be otherwise explained, irrigation activities in this area will be reduced or suspended. Also, as stated in **Section 3.4.3**, irrigation in future landfill areas will be halted at least two years prior to planned construction activities in that area.

3.6 System Maintenance and Inspections

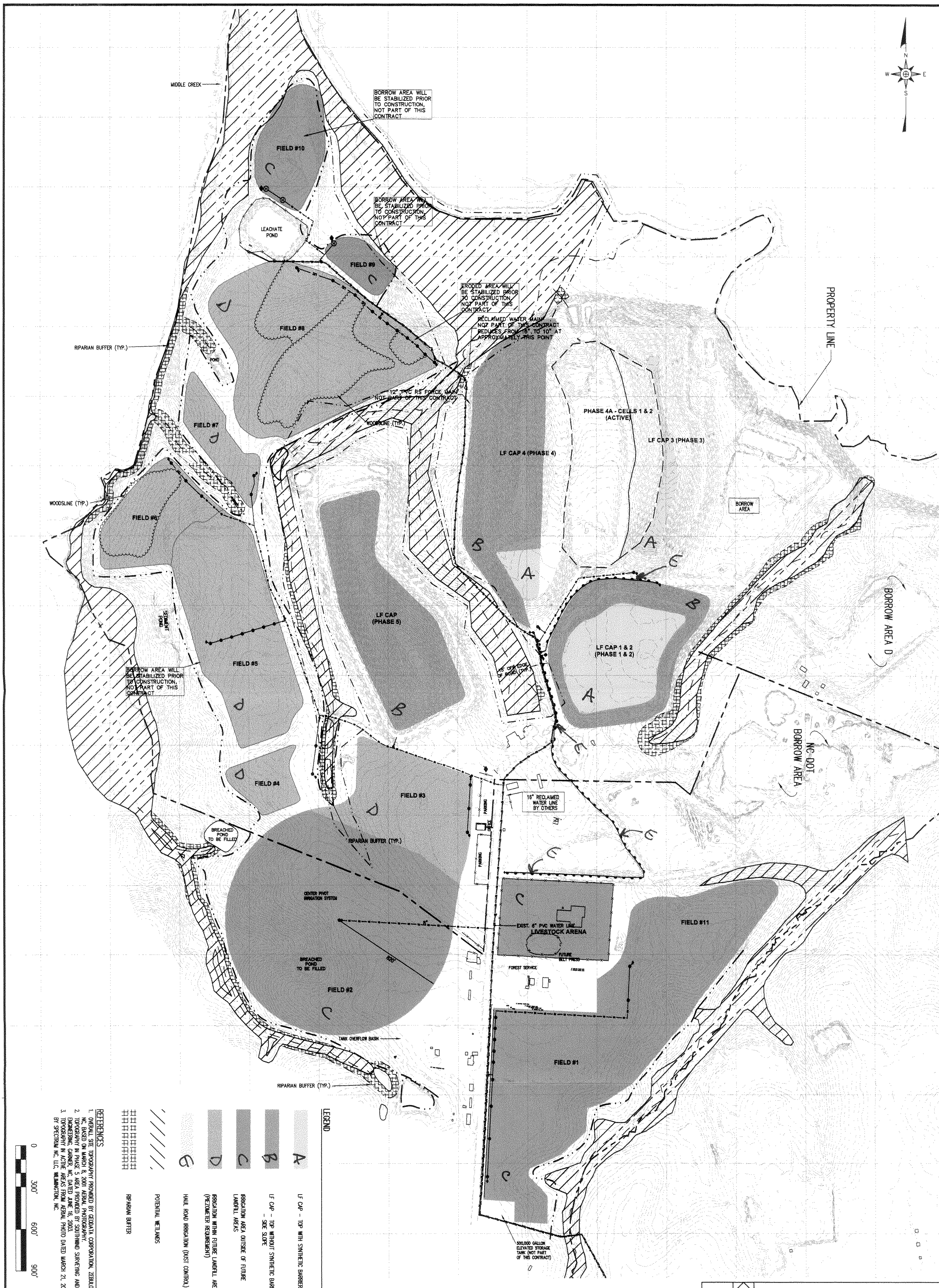
Inspection of the irrigation system during periods of operation will be performed by landfill staff on a weekly basis for the closed landfill areas. Other areas may be inspected less frequently, but not less than once per month. As much of the proposed system will be above ground, inspection for damaged piping, valves, sprinklers, etc. will be done on a mostly visual basis. Should maintenance be required to any portion of the irrigation system, that part of the system will be shut off until adequate repairs are made.

Table 1: Irrigation Amounts

Field	Max. Daily Application Rate cm/day (inch/day)	Annual Application Rate cm/year (inch/year)
Fields 1 and 2	0.60 (0.25)	70 (28)
Fields 3, 4, and 5	0.60 (0.25)	62 (25)
Fields 6, 7, and 8	0.60 (0.25)	42 (17)
Fields 9 and 10 Livestock Arena	0.60 (0.25)	50 (20)
Dust Control	0.60 (0.25)	45 (18)
Field 11	0.60 (0.25)	40 (16)
Landfill Final Cover[1]	0.25 (0.1)	12 (5)

Note:

1) At a rate less than that which would cause saturation of the upper 9 inches of soil cover. This will be controlled by the use of soil moisture devices, which will automatically shut off the irrigation system if the upper 9 inches becomes saturated.



DATE	NO.	REVISION
2/06	3	REMOVED SIDE SLOPE LFG CAP 3 (PHASE 3)
8/05	2	GENERAL MAP UPDATES
3/04	1	ADDED FIELD 11 AND LF CAP 5

DESIGNED BY: P.K.S.
DRAWN BY: J.A.L.
CHECKED BY:
PROJECT NO.: JOHN-2
SCALE: AS SHOWN
DATE: OCT 2001
FILE NAME: JOHN-D0212C
SHEET NO.
DRAWING NO.: FIG. 1

DRAWING TITLE: LANDFILL SITE IRRIGATION PLAN

PROJECT TITLE: JOHNSTON COUNTY LANDFILL IRRIGATION OF RECLAIMED WASTEWATER

SEAL

SEAL

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Erosion And Sedimentation Control Plan

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

October 2005

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

EROSION AND SEDIMENTATION CONTROL PLAN

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JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

EROSION AND SEDIMENTATION CONTROL PLAN

1.0 NARRATIVE

1.1 Project Description

Johnston County plans to construct a lined expansion (Area 2 C&D landfill unit) of their existing landfill facility located off of Highway 210 on County Home Road near Smithfield. Much of this landfill expansion is to be located in a old soil borrow area. The construction and operation of the landfill expansion will require the disturbance of approximately 25.9 acres. This plan discusses both the initial and long term (final) erosion and sedimentation control measures used on this project.

1.2 Contact Information

1.2.1 Engineer: For questions regarding this erosion and sedimentation control plan, please contact the following:

G.N. Richardson & Associates, Inc.
Attn.: Pieter K. Scheer, P.E.
14 N. Boylan Ave.
Raleigh, NC 27607
Phone: (919) 828-0577
Fax: (919) 828-3899.

1.2.2 Owner: The owner of the site and the person to contact should sediment control issues arise during the land-disturbing activity is as follows:

Johnston County Department of Public Utilities
Attn.: Haywood Phthisic, Director
309 E. Market Street
Smithfield, NC 27577
Phone: (919) 209-8333
Fax: (919) 934-7174.

1.3 Existing Site Conditions

The proposed site is located adjacent to and partially overlying the east side of the closed Phase 3 MSW landfill unit. Existing ground surface elevations vary from El. 260 (feet) to the west at the top of the Phase 3 unit to El. 150 in existing Sediment Basin No. 6. Currently, the majority of the site is part of an existing borrow site. The Phase 3 landfill unit is vegetated with grass.

1.4 Adjacent Areas

The proposed site lies within County-owned property on all sides. Middle Creek, a tributary to the Neuse River, lies to the north of the proposed site.

1.5 Site Soils Information

Within much of the proposed site, the soils within the upper 10 to 20 feet of the surface are generally classified as silty and clayey sands (SM and SC). These soils overlie a stiff clay layer typically about 10 feet thick. Below this layer is bedrock (Mudstone).

For the portion of the site which overlies the closed Phase 3 landfill unit, there exists a cover consisting of a minimum of 24 inches of silty and clayey sands (SM and SC).

2.0 DESIGN GUIDELINES AND PROCEDURES

The erosion and sediment control design for the landfill was conducted based on guidelines and procedures as set forth in the following references:

1. North Carolina Erosion & Sediment Control Planning & Design Manual, (E&SCP&DM), North Carolina Division of Land Resources, 1988; and

2. Malcom, H. Rooney, Elements of Urban Stormwater Design, (EOUSD), NC State Univ., Raleigh, NC, 1989.

All stormwater flow volumes were calculated using the Rational Method based on the maximum rate of runoff from a 25-year storm event which exceeds the 10-year event required by current North Carolina Sediment Control regulations. Note that the maximum rate of runoff from a 25-year storm exceeds the rate of runoff from a 25-year, 24-hour storm as required by current North Carolina Solid Waste regulations. Runoff coefficients for various ground cover conditions are referenced to Exhibit 1 of EOUSD. Rainfall intensities used in the Rational Method were derived from an analysis of design storms for the site. Times of concentration were calculated with the Kirpich Equation. Drainage areas were determined using a planimeter and/or AutoCAD on topographic sheets of the project area.

3.0 EROSION AND SEDIMENTATION CONTROL MEASURES - INITIAL

The following erosion and sedimentation control measures are to be constructed as part of the initial construction of the landfill. Appendices A, B, and C to this plan include calculations, technical specifications, and plans and details for each of these measures, respectively.

In most cases, the following erosion and sedimentation control measures were designed using the final drainage areas which were found to represent a worst case for design.

3.1 Sediment Basins

There are two permanent sediment basins (Sediment Basins 4 and 6) which will serve the site. Existing Sediment Basin 6 is located on the northeast side of the project area and will be expanded to handle an the design flow. Existing Sediment Basin No. 4 is located to the north west of the project area. In that existing Sediment Basin No. 4 will receive flow from less disturbed area than originally designed, the basin was not analyzed in the calculations.

Sediment basin design is subject to several requirements. The sediment basins must provide a basin volume of 1,800 ft^3/acre of disturbed area. Other E&SCP&DM requirements for permanent basins include riser/barrel principal spillways and emergency weir-type spillways. The principal spillways must have a capacity of 0.2 ft^3 /second/acre of drainage area. This flow must be met with one foot of driving head. The crest of the emergency spillways is set one foot above the invert of the riser and must pass the peak run-off from the 25-year storm event with one foot of freeboard to crest of berm. The principal and emergency spillways were designed using a spreadsheet based on methods provided in EOUSD. These methods provide a more detailed design than provided in E&SCP&DM while meeting the above requirements. The riser/barrel assemblies must be provided with an anchor displacing a buoyant weight of at least 1.1 times the weight of water displaced by the riser. The risers must also be provided with a method of dewatering the basin. This design was carried out in accordance with criteria from E&SCP&DM.

3.2 Drainage Channels

Drainage channel calculations were conducted using a reformulation of Manning's Equation to calculate normal depth of flow, as set forth in EOUSD, for given conditions to establish ditch capacity and velocity of flow. For conservatism, the channel calculations assume peak flow over maximum slope of channel reach in determining velocity. Channels were first checked assuming just constructed, bare earth, conditions. The maximum allowable velocity for bare earth was assumed to be 2.5 feet per second (Table 8.05d E&SCP&DM). If the velocity exceeded this value, a temporary liner was chosen if appropriate. Normal depth and velocity was then calculated assuming grass lining as a minimum constructed condition. The allowable velocity for grass lining was assumed to be 4.5 feet per second (Table 8.05a, E&SCP&DM). If the velocity exceeded this, a permanent liner was designed. Both temporary and permanent channel linings were designed using the Tractive Force Procedure as outlined in E&SCP&DM.

3.3 Culverts

There are two culverts which will be used at the site to convey flow beneath roadways and embankments. Culverts were designed based on an analysis of inlet and outlet control under the influence of the design storm to determine the governing headwater condition. Where required, culvert outlets were designed for outlet stabilization based on criteria set forth in E&SCP&DM, Section 6.41.

3.4 Drop Inlets

One weir-type drop inlet will be used in the perimeter drainage channel to route flow into the Sediment Basin No. 6. This drop inlets was designed based on an analysis of the flow capacity of the open sides (weirs) of the drop inlet compared to the maximum flow from the design storm. Prior to vegetative stabilization of the perimeter channel, the drop inlet will be protected from sedimentation by a placing a wire mesh and coarse aggregate filter around all sides of the drop inlet.

3.5 Silt Fence

Silt fencing design was based on criteria set forth in E&SCP&DM, Section 6.62 including the limitation of 100 feet of fencing for each ¼ acre of drainage area.

3.6 Vegetative Stabilization

Vegetative stabilization will be in accordance with the seeding schedule in the project specifications (provided as an attachment to this plan). The seeding schedule was based on Table 6.11k of E&SCP&DM which is applicable to this site.

4.0 EROSION AND SEDIMENTATION CONTROL MEASURES - FINAL

The following erosion and sedimentation control measures are to be constructed as part of final cover construction. Appendices A, B, and C to this plan include calculations, technical specifications, and plans and details for each of these measures, respectively.

4.1 Cap Diversion Berms

Cap diversion berms will be placed near the slope break of the final cover where the 4H:1V side slopes break to a flatter grade. Flow from the cap diversion berms is directed to the down pipes. The capacity and erosion potential of these berms was checked using the reformulation of Manning's Equation from EOUSD as stated above for design flows.

4.2 Rain Gutters

Rain gutters will be placed along final cover side slopes at a maximum spacing of approximately 140 feet. Flow from the rain gutters will be directed to the down pipes. The capacity of the rain gutters was checked based on partial flow to determine flow depth and velocity then compared with the full flow capacity of each pipe size with the calculated peak flow rate to verify the desired factor of safety. Rain gutter drop inlets (inlet to down pipes) were analyzed as orifices.

4.3 Down Pipes

Down pipes will be used to carry flows from diversion berms and/or rain gutters to the bottom of final cover slopes. Down pipes were designed based on the same procedures as rain gutters. Down pipes will be adequately anchored to the landfill side slopes by use of a soil cover and each will be outleted either directly to perimeter sediment basins (with rip rap apron at outlet) or to energy dissipating structures (precast energy dissipators, drop inlets, stone structures, etc.) at the base of each slope.

5.0 SCHEDULE FOR IMPLEMENTATION

All erosion control measures will be placed before any land disturbance or waste placement may begin in that portion of the site which drains to the erosion control measures. All areas reaching final elevations will be vegetated.

6.0 MAINTENANCE AND SEDIMENT DISPOSAL

All erosion and sedimentation control devices will be inspected at regular intervals and immediately following any significant rainfall event. Repairs will then be made as needed and accumulated sediment removed if necessary. In the case of both the sediment basins, sediments will be removed when one half of the basin volume is filled with sediment.

All sediments which are removed from erosion and sedimentation control measures will be disposed of in an approved manner at a location to be designated by the Engineer in such a manner that further erosion and sedimentation will not occur.

Appendix A

Erosion & Sedimentation Control Calculations

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

EROSION AND SEDIMENTATION CONTROL PLAN
APPENDIX A: EROSION AND SEDIMENTATION CONTROL CALCULATIONS

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PROJECT Johnston County C&D Landfill - Area 2	SHEET 1 OF 2
	JOB NO. JOHNSTON-22
	DATE 9/22/05
SUBJECT Erosion & Sedimentation Control - Overview	COMPUTED BY PKS
	CHECKED BY

Objective To design erosion and sedimentation control structures to remove and contain storm water flow from the design storm at the proposed facility.

Calculations will be based on:

- Rational Method
- Rainfall Frequencies for the Site

Analysis The main design criteria will be to ensure that all storm water conveyance and retention structures will be able to accommodate the peak rate of run off from the design storm without erosion.

The erosion control measures will be designed to control sedimentation from time of construction until the site is stabilized.

References North Carolina Erosion & Sediment Control Planning & Design Manual, North Carolina Division of Land Resources, 1988.

Malcom, H. Rooney, Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC, 1989.

Calculations

- Rational Method (Flow Rate, Q):

$Q = CIA$ (cfs) (Malcom Eq. I -1)

where: C = Rational Runoff Coefficient

I = Applicable Rainfall Intensity (in/hr) of storm event (Based on Time of Concentration)

A = Drainage Area (Acres)

E&SC.WPD

- Time of Concentration (t_c) (Kirpich Equation):

$$t_c = \frac{\left(\frac{L^3}{H}\right)^{0.385}}{128}$$ (minutes) (Malcom Eq. I-2)

where: L = Hydraulic Length of Watershed to Point of Interest (ft)
H = Fall Along L (ft)

Note: I is found by calculating t_c and using a rainfall intensity - duration - frequency graph or table suitable to the site. t_c (minimum) = 5 minutes.

Objective To compile the expected design storm depths and intensities over various return periods. These design storm values will be used in various calculations.

References Rainfall data was obtained from the following references:

Frederick, R.H., V.A. Myers, and E.P. Anciello, "Five to 60-Minute Precipitation Frequency for the Eastern and Central United States," NOAA Technical Memo. NWS HYDRO-35, National Weather Service, NOAA, U.S. Dept. Of Commerce, Silver Spring, MD, 1977.

U.S. Weather Bureau, "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years," U.S. Weather Bureau Technical Paper 40, 1961.

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14 N. Boylan Avenue Tel: 919-828-0577
Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 2/2
JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Analysis of Design Storms

LOCATION: **Smithfield, NC**

DURATION	RETURN PERIOD 2-YR P (in)	100-YR P (in)	SOURCE
5 min	0.48	0.81	NOAA HYDRO-35
15 min	1.03	1.81	NOAA HYDRO-35
60 min	1.80	3.75	NOAA HYDRO-35

2 hr to 24 hr Rainfall Events = **USER INPUT** USWB TP-40

DEPTH-DURATION-FREQUENCY TABLE

DURATION	2-YR (in)	5-YR (in)	10-YR (in)	25-YR (in)	50-YR (in)	100-YR (in)
5 min	0.48	0.55	0.60	0.68	0.75	0.81
10 min	0.80	0.93	1.03	1.17	1.29	1.40
15 min	1.03	1.20	1.32	1.51	1.66	1.81
30 min	1.41	1.72	1.94	2.26	2.51	2.76
60 min	1.80	2.26	2.58	3.04	3.39	3.75
2 hr	2.20	2.80	3.25	3.70	4.20	4.60
3 hr	2.40	3.10	3.60	4.10	4.55	5.10
6 hr	2.85	3.60	4.20	4.90	5.50	6.10
12 hr	3.35	4.20	5.00	5.80	6.40	7.20
24 hr	3.70	4.85	5.80	6.60	7.40	8.20

INTENSITY-DURATION-FREQUENCY TABLE

DURATION	2-YR (in/hr)	5-YR (in/hr)	10-YR (in/hr)	25-YR (in/hr)	50-YR (in/hr)	100-YR (in/hr)
5 min	5.76	6.58	7.22	8.19	8.96	9.72
10 min	4.83	5.59	6.17	7.03	7.72	8.40
15 min	4.12	4.79	5.29	6.05	6.65	7.24
30 min	2.81	3.43	3.88	4.52	5.02	5.52
60 min	1.80	2.26	2.58	3.04	3.39	3.75
2 hr	1.10	1.40	1.63	1.85	2.10	2.30
3 hr	0.80	1.03	1.20	1.37	1.52	1.70
6 hr	0.48	0.60	0.70	0.82	0.92	1.02
12 hr	0.28	0.35	0.42	0.48	0.53	0.60
24 hr	0.15	0.20	0.24	0.28	0.31	0.34

PROJECT Johnston County C&D Landfill - Area 2

JOB NO. JOHNSTON-22

DATE 9/29/05

SUBJECT Drainage Areas

COMPUTED BY PKS

CHECKED BY

Objective To breakout drainage areas for each erosion control measure. Areas were measured by planimeter or AutoCAD on the attached plan drawings. Below is a summary of drainage areas used in erosion control calculations. Plan sheets with delineations of drainage areas are attached.

Analysis

Area	Area (Acres)
A	25.6
1	3.3
2	3.5
3	2.9
4	2.8
5	3.5
6	1.5
7	2.2
8	2.4
9	0.9
10	2.4

DRAINAGE AREAS.WPD

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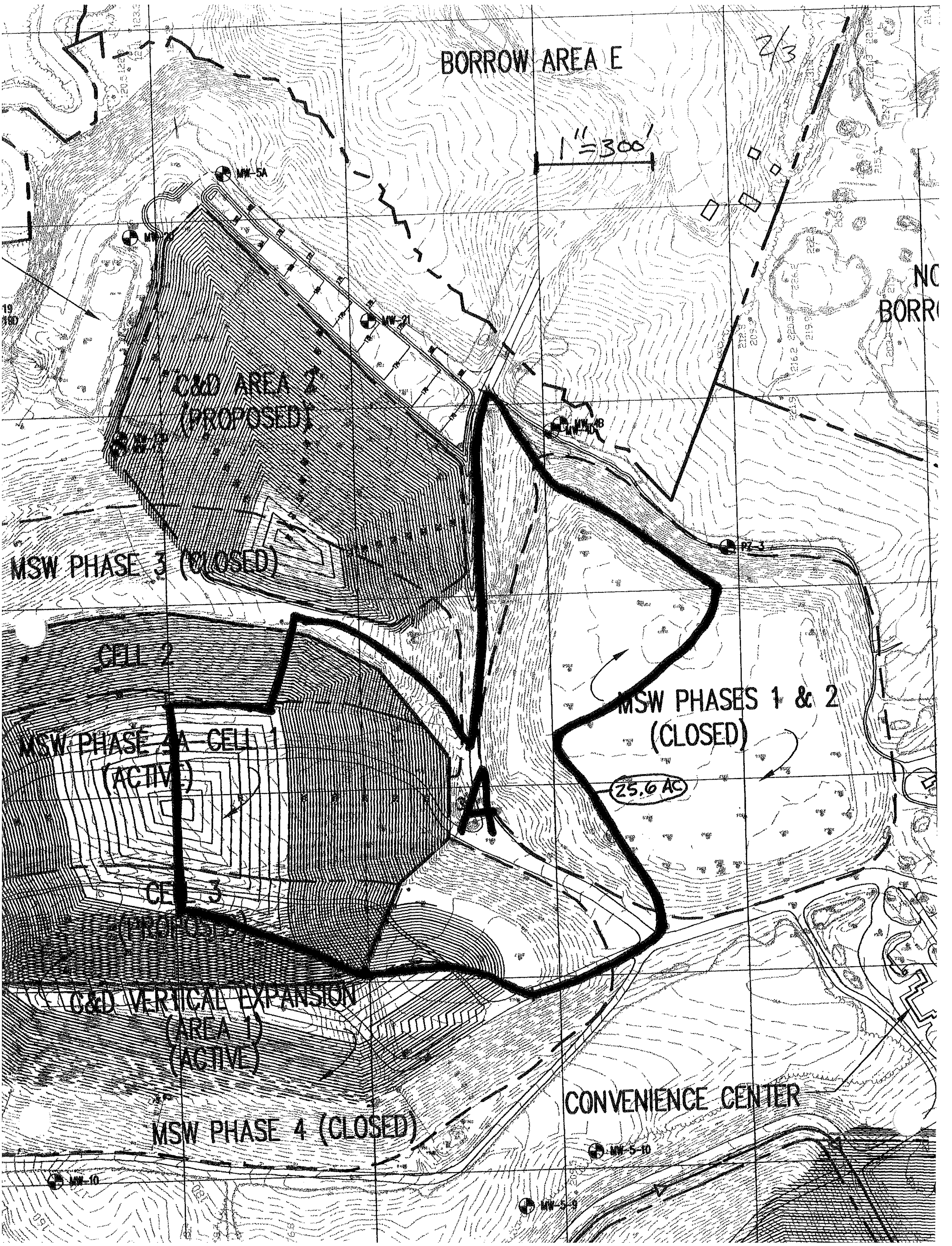
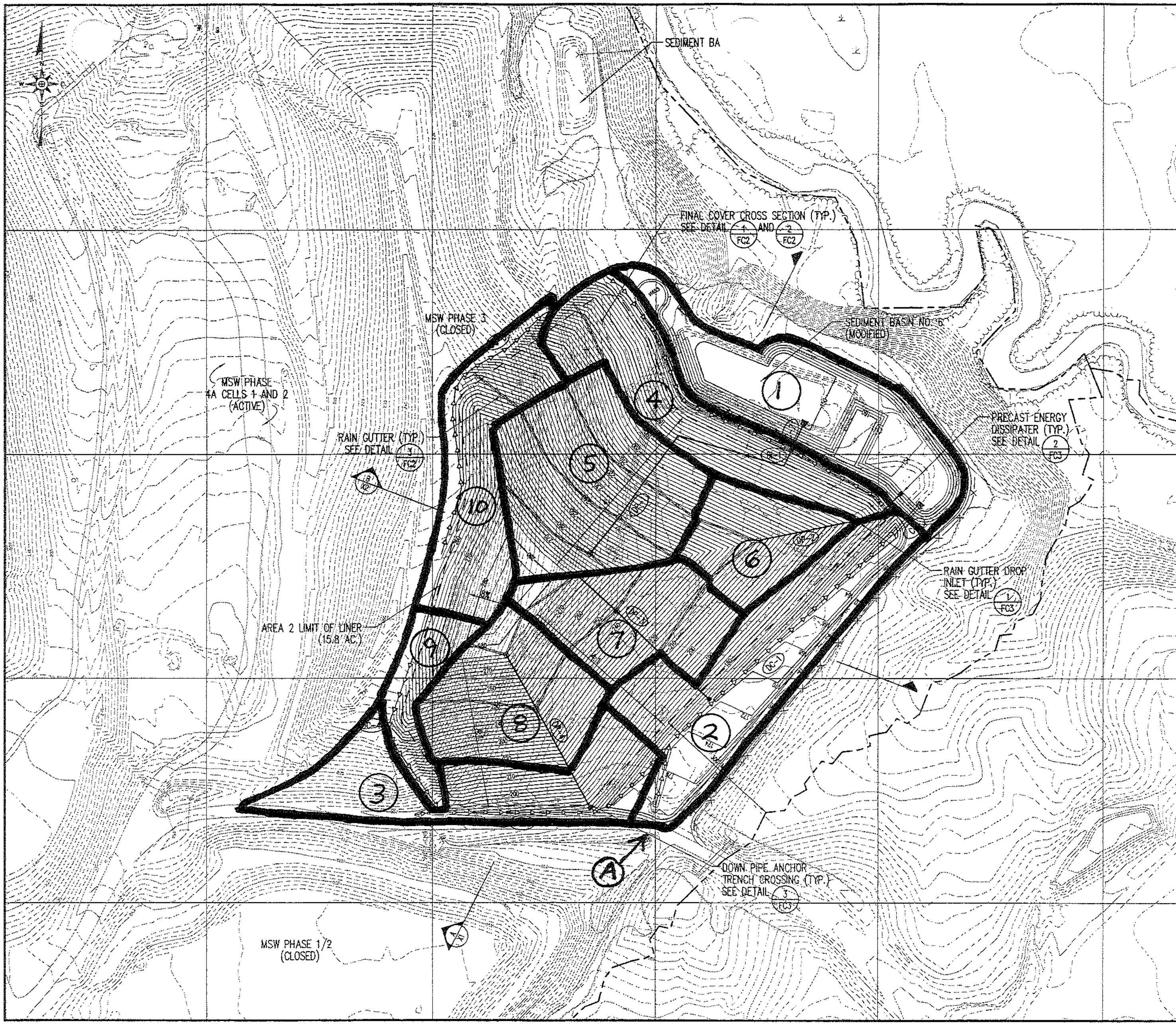

2/3
BORROW AREA E
1" = 300'
MW-5A
MW-20
MW-21
C&D AREA 2
(PROPOSED)
MW-4B
NO
BORRO
MSW PHASE 3 (CLOSED)
PZ-3
CELL 2
MSW PHASE 4A CELL 1
(ACTIVE)
MSW PHASES 1 & 2
(CLOSED)
25.6 AC
A
CELL 3
(PROPOSED)
C&D VERTICAL EXPANSION
(AREA 1)
(ACTIVE)
CONVENIENCE CENTER
MSW PHASE 4 (CLOSED)
MW-5-10
MW-10
MW-5-9



PIPING SCHEDULE	
RAIN GUTTERS	
PIPE DIAMETER (INCHES)	MAX. DRAINAGE AREA (AC.)
6	0.32
8	0.67
10	1.18
12	1.89
DOWN PIPE DROP INLETS	
PIPE DIAMETER (INCHES)	MAX. DRAINAGE AREA (AC.)
8	0.52
10	0.80
12	1.14
14	1.37
16	1.80
18	2.27
DOWN PIPES	
PIPE DIAMETER (INCHES)	MAX. DRAINAGE AREA (AC.)
8	0.77
10	1.36
12	2.18
14	2.76
16	3.99
18	5.42

LEGEND

150	EXISTING 10' CONTOUR (SEE REFERENCE 1)
	EXISTING 2' CONTOUR
	APPROXIMATE PROPERTY LINE
150	PROPOSED 10' CONTOUR
	PROPOSED 2' CONTOUR
DP-3	DOWN PIPE
DC-1	DRAINAGE CHANNEL
C-1	CULVERT NUMBER
DI-1	DROP INLET NUMBER
□	DOWN PIPE DROP INLET
■	PRECAST ENERGY DISSIPATER
	RAIN GUTTER

NOTES

1. GRADES SHOWN REPRESENT APPROXIMATE TOP OF FINAL COVER GRADES.
2. THE RAIN GUTTERS AND DOWN PIPES SHOWN ARE CONCEPTUAL LOCATIONS ONLY. THE DESIGN OF THESE DEVICES IS TO BE EVALUATED PRIOR TO THE PLACEMENT OF FINAL COVER.

REFERENCES

1. OVERALL SITE TOPOGRAPHY PROVIDED BY GEODATA CORPORATION, BASED ON MAY 21, 2004 AERIAL PHOTOGRAPHY. TOPOGRAPHY IN ACTIVE AREAS PROVIDED BY SPECTRUM NC, LLC, BASED ON MARCH 21, 2005 AERIAL PHOTOGRAPHY. TOPOGRAPHY OF PHASE 4 CELL 2 PROVIDED BY 4D SITE SOLUTIONS INC., DATED JUNE 2, 2005. TOPOGRAPHY IN PHASE 5 AREA PROVIDED BY SOUTHWIND SURVEYING AND ENGINEERING, GARNER, NC, DATED JUNE 16, 2003.

0 100' 200' 300'

DATE	NO.	REVISION

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SEAL

SEAL

PROJECT TITLE:
JOHNSTON COUNTY C&D LANDFILL
AREA 2
PERMIT DRAWINGS

DRAWING TITLE:
AREA 2
FINAL COVER GRADING
AND DRAINAGE PLAN

DESIGNED BY: P.K.S.	DRAWN BY: C.T.J.
CHECKED BY:	PROJECT NO.: JOHN-22
SCALE: AS SHOWN	DATE: OCT. 2005
FILE NAME: JOHN-D0386	
SHEET NO. 17	DRAWING NO. FC1

3/3

PROJECT	Johnston County C&D Landfill - Area 2	SHEET 1 OF 9	
		JOB NO.	JOHNSTON-22
		DATE	9/22/05
SUBJECT	Normal Depth Analysis	COMPUTED BY	PKS
		CHECKED BY	

Objective To design ditches and channels to remove storm water flow from the design storm at the proposed facility.

Analysis The main design criteria will be to ensure that all ditches and channels will be able to accommodate the peak rate of run off from the design storm without erosion.

References North Carolina Erosion & Sediment Control Planning & Design Manual, North Carolina Division of Land Resources, 1988.

Malcom, H. Rooney, Elements of Urban Stormwater Design, NC State Univ., Raleigh, NC, 1989.

Virginia Erosion & Sediment Control Handbook, Virginia Department of Conservation and Recreation, Third Edition, 1992.

Calculations

- Determine Peak Flow Rate to Ditch/Channel:

Use Rational Method ($Q_P = CIA$)

- Manning's Equation:

$$Q = \frac{1.49\,AR^{2/3}S^{1/2}}{n} = AV$$ (Malcom Eq. I-8)

where:
- Q = Discharge/Flow Rate (cfs)
- n = Manning's Roughness Coefficient (See Below)
- A = Cross Sectional Area of Flow (ft^2)
- R = Hydraulic Radius (ft) = A/Wetted Perimeter
- S = Slope of Channel (ft/ft)
- V = Average Channel Velocity (ft/sec)

- Tractive Force Procedure:

$$T = yds$$

where:
T = Shear Stress on Channel Lining (lb/ft^2)
y = Unit Weight of Water (62.4 lb/ft^3)
d = Depth of Flow (ft)
s = Channel slope (ft/ft)

- Froude Number:

$$Fr = \frac{v}{\sqrt{\frac{gA}{T}}}$$

where:
Fr = Froude Number (dimensionless)
v = Flow Velocity (ft/sec)
g = Acceleration of Gravity (32.2 ft/sec^2)
A = Cross-sectional Area of Flow (ft^2)
T = Top Width of Flow (ft)

If Fr is greater than 1.0, flow is supercritical; if it is under 1.0, flow is subcritical. Fr is 1.0 for critical flow conditions.

- Manning's Roughness Coefficient (n):

Rip Rap:

$n = 0.0395\ (d_{50})^{1/6}$ (Ref: VA E&SC Handbook p. V-101)

where: d_{50} = Median Size of Rip Rap (ft)

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SHEET: 3/9
JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Normal Depth Analysis **Channel No. DC-1**

Peak Flow Rate:

Drainage Area (Ac.) =	37.5	Areas A, 2, 3, 7, 8, & 9
Hydraulic Length (ft) =	2,700	Head of Area A to End of DC-1
Fall Along Length (ft) =	171	EL. 330 - EL. 159
Time of Conc. (min.) =	9.9	
Intensity (in/hr) =	7.05	(25 Year Storm)
Runoff Coefficient =	0.425	(Assume 1/2 at 0.5 and 1/2 at 0.35)
Q (cfs) =	112.4	

Ditch/Channel Parameters:

Lining:	9" RipRap
Maximum Slope (ft/ft) =	0.03
Minimum Slope (ft/ft) =	0.02
n =	0.038
B (ft) =	8
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	16.5442093
y (ft) =	1.37 **(Iterate)**
accuracy =	0.1
f(M,y,B) =	16.54158847
Normal Depth (ft) =	1.37

Velocity:

V (ft/s) = 6.77

Liner Shear Stress:

T (lb/ft^2) = 2.56

Froude Number:

Fr = 1.18

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	20.26243549
y (ft) =	1.53 **(Iterate)**
accuracy =	0.1
f(M,y,B) =	20.27135773
Normal Depth (ft) =	1.53

Velocity:

V (ft/s) = 5.86

Liner Shear Stress:

T (lb/ft^2) = 1.90

Froude Number:

Fr = 0.98

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JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Normal Depth Analysis

Channel No. DC-2

Peak Flow Rate:

Drainage Area (Ac.) =	6.2	Areas 3, 8, & 9
Hydraulic Length (ft) =	1,200	Head of Area 9 to End of DC-2
Fall Along Length (ft) =	109	EL. 282 - EL. 173
Time of Conc. (min.) =	4.6	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	25.4	

Ditch/Channel Parameters:

Lining:	6" RipRap
Maximum Slope (ft/ft) =	0.133
Minimum Slope (ft/ft) =	0.025
n =	0.035
B (ft) =	6
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 1.635315492

y (ft) = 0.44 **(Iterate)**

accuracy = 0.1

f(M,y,B) = 1.650126778

Normal Depth (ft) = 0.44

Velocity:

V (ft/s) = 7.95

Liner Shear Stress:

T (lb/ft^2) = 3.65

Froude Number:

Fr = 2.30

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 3.771875655

y (ft) = 0.70 **(Iterate)**

accuracy = 0.1

f(M,y,B) = 3.777404737

Normal Depth (ft) = 0.70

Velocity:

V (ft/s) = 4.48

Liner Shear Stress:

T (lb/ft^2) = 1.09

Froude Number:

Fr = 1.06

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JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Normal Depth Analysis **Channel No. DC-3**

Peak Flow Rate:

Drainage Area (Ac.) =	6.3	Areas 4 & 5 (Short-Term - Worst Case)
Hydraulic Length (ft) =	820	Head of Area 5 to DI-1
Fall Along Length (ft) =	125	EL. 284 - EL. 159
Time of Conc. (min.) =	2.8	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	25.8	

Ditch/Channel Parameters:

Lining:	TRM
Maximum Slope (ft/ft) =	0.02
Minimum Slope (ft/ft) =	0.01
n =	0.035
B (ft) =	6
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 4.285102687

y (ft) = 0.75 **(Iterate)**

accuracy = 0.1

f(M,y,B) = 4.283153758

Normal Depth (ft) = 0.75

Velocity:

V (ft/s) = 4.17

Liner Shear Stress:

T (lb/ft^2) = 0.94

Froude Number:

Fr = 0.96

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 6.060050336

y (ft) = 0.91 **(Iterate)**

accuracy = 0.1

f(M,y,B) = 6.117900488

Normal Depth (ft) = 0.91

Velocity:

V (ft/s) = 3.28

Liner Shear Stress:

T (lb/ft^2) = 0.57

Froude Number:

Fr = 0.69

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Johnston County C&D Landfill - Area 2
Normal Depth Analysis **Channel No. DC-4A**

Peak Flow Rate:

Drainage Area (Ac.) =	0.6	Portion of Area 9
Hydraulic Length (ft) =	400	Head of Area 9 to End of DC-4A
Fall Along Length (ft) =	42	EL. 282 - EL. 240
Time of Conc. (min.) =	1.9	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	2.5	

Ditch/Channel Parameters:

Lining:	TRM
Maximum Slope (ft/ft) =	0.15
Minimum Slope (ft/ft) =	0.04
n =	0.035
B (ft) =	4
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	0.149018883
y (ft) =	0.13 **(Iterate)**
accuracy =	0.1
f(M,y,B) =	0.137567697
Normal Depth (ft) =	0.13

Velocity:

V (ft/s) = 3.97

Liner Shear Stress:

T (lb/ft^2) = 1.22

Froude Number:

Fr = 2.03

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	0.288573826
y (ft) =	0.20 **(Iterate)**
accuracy =	0.1
f(M,y,B) =	0.287553572
Normal Depth (ft) =	0.20

Velocity:

V (ft/s) = 2.66

Liner Shear Stress:

T (lb/ft^2) = 0.50

Froude Number:

Fr = 1.11

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JOB #: JOHNSTON-22
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Johnston County C&D Landfill - Area 2
Normal Depth Analysis **Channel No. DC-4B**

Peak Flow Rate:

Drainage Area (Ac.) =	0.9	Area 9
Hydraulic Length (ft) =	650	Head of Area 9 to End of DC-4B
Fall Along Length (ft) =	88	EL. 282 - EL. 194
Time of Conc. (min.) =	2.5	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	3.7	

Ditch/Channel Parameters:

Lining:	9" Rip Rap
Maximum Slope (ft/ft) =	0.25
Minimum Slope (ft/ft) =	0.15
n =	0.038
B (ft) =	4
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	0.187985235
y (ft) =	0.16 (Iterate)
accuracy =	0.1
f(M,y,B) =	0.196031764
Normal Depth (ft) =	0.16

Velocity:

V (ft/s) = 5.36

Liner Shear Stress:

T (lb/ft^2) = 2.50

Froude Number:

Fr = 2.49

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	0.242687895
y (ft) =	0.19 (Iterate)
accuracy =	0.1
f(M,y,B) =	0.263241563
Normal Depth (ft) =	0.19

Velocity:

V (ft/s) = 4.60

Liner Shear Stress:

T (lb/ft^2) = 1.78

Froude Number:

Fr = 1.97

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Johnston County C&D Landfill - Area 2
Normal Depth Analysis

Channel No. DC-5A

Peak Flow Rate:

Drainage Area (Ac.) =	1.6	Portion of Area 10
Hydraulic Length (ft) =	640	Head of Area 10 to End of DC-5A
Fall Along Length (ft) =	38	EL. 282 - EL. 244
Time of Conc. (min.) =	3.4	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	6.6	

Ditch/Channel Parameters:

Lining:	TRM
Maximum Slope (ft/ft) =	0.04
Minimum Slope (ft/ft) =	0.02
n =	0.035
B (ft) =	4
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	0.769530201	
y (ft) =	0.35	(Iterate)
accuracy =	0.1	
f(M,y,B) =	0.764487268	
Normal Depth (ft) =	0.35	

Velocity:

V (ft/s) = 3.68

Liner Shear Stress:

T (lb/ft^2) = 0.87

Froude Number:

Fr = 1.21

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) =	1.088280047	
y (ft) =	0.43	(Iterate)
accuracy =	0.1	
f(M,y,B) =	1.104874331	
Normal Depth (ft) =	0.43	

Velocity:

V (ft/s) = 2.92

Liner Shear Stress:

T (lb/ft^2) = 0.54

Froude Number:

Fr = 0.88

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Johnston County C&D Landfill - Area 2
Normal Depth Analysis

Channel No. DC-5B

Peak Flow Rate:

Drainage Area (Ac.) =	2.4	Area 10
Hydraulic Length (ft) =	900	Head of Area 10 to End of DC-5B
Fall Along Length (ft) =	89	EL. 282 - EL. 193
Time of Conc. (min.) =	3.6	
Intensity (in/hr) =	8.19	(25 Year Storm)
Runoff Coefficient =	0.5	(Assume)
Q (cfs) =	9.8	

Ditch/Channel Parameters:

Lining:	12" Rip Rap
Maximum Slope (ft/ft) =	0.25
Minimum Slope (ft/ft) =	0.15
n =	0.04
B (ft) =	6
M =	3

MAXIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 0.527677852

y (ft) = 0.23 (Iterate)

accuracy = 0.1

f(M,y,B) = 0.537409011

Normal Depth (ft) = 0.23

Velocity:

V (ft/s) = 6.50

Liner Shear Stress:

T (lb/ft^2) = 3.59

Froude Number:

Fr = 2.51

MINIMUM SLOPE

Normal Depth Calculations:

nQ/(1.49s^0.5) = 0.681229178

y (ft) = 0.27 (Iterate)

accuracy = 0.1

f(M,y,B) = 0.707246298

Normal Depth (ft) = 0.27

Velocity:

V (ft/s) = 5.55

Liner Shear Stress:

T (lb/ft^2) = 2.53

Froude Number:

Fr = 1.99

PROJECT	Johnston County C&D Landfill - Area 2	SHEET 1 OF 2	
		JOB NO.	JOHNSTON-22
		DATE	9/22/05
SUBJECT	Drop Inlet Analysis	COMPUTED BY	PKS
		CHECKED BY	

Objective To design the inlet structure for a drop inlet. Either a weir or grated inlet will be used. Check the appropriate inlet type(s) for proper flow capacity. Analyze outlet for drop inlet separately by evaluating its behavior as a culvert.

Analysis

- Determine Peak Flow Rate to Drop Inlet:

Use Rational Method (Q_P = CIA)

- Weir-Type Inlet ⇒ Use the Weir Equation:

$$Q = C_w L H^{3/2}$$

where:
Q = Discharge (cfs)
C_w = Weir Coefficient (=3.0 for Free Overfall)
L = Length of Weir (ft)
H = Driving Head (ft) (=Allowable Height of Water above Crest of Weir)

- Grated Inlet ⇒ Use the Orifice Equation:

$$Q = C_d A \sqrt{2gh}$$

where:
Q=Discharge (cfs)
C_d = Coefficient of Discharge (0.6 = Typical Value)
A = Cross-Sectional Area of Flow at Orifice Entrance (ft^2)
g = Acceleration of Gravity (32.2 ft/sec^2)
h = Driving Head (ft) (=Allowable Height of Water above Grate)

DROPINLET.WPD

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SHEET:	2/2
JOB #:	JOHNSTON-22
DATE:	10/3/05
BY:	PKS
CHKD BY:	

Johnston County C&D Landfill - Area 2
Drop Inlet Analysis — Drop Inlet No.: DI-1

Peak Flow Rate:

Drainage Area (Ac.) =	6.3	**Areas 4 & 5**
Hydraulic Length (ft) =	820	**Head of Area 5 to DI-1**
Fall Along Length (ft) =	125	**EL. 284 - EL. 159**
Time of Conc. (min.) =	2.8	
Intensity (in/hr) =	8.19	**(25 Year Storm)**
Runoff Coefficient =	0.50	**(Assume)**
Q (cfs) =	25.8	

Drop Inlet Parameters:

Weir Coefficient =	3.0
Coefficient of Discharge (Orifice) =	0.6
Allowable Driving Head (ft) =	1.0

Weir-Type Inlet:

L (ft) =	12	← Assumes 1 side is Blocked
Q (cfs) =	36.0	← Use Weir Type

Grated Inlet:

A (in^2) =	1,500
Q (cfs) =	50.2

PROJECT Johnston County C&D Landfill - Area 2

SUBJECT Culvert Analysis

Objective To analyze culverts for inlet and outlet control. Verify that the allowable headwater depth is not exceeded.

Reference Debo, T.N., and Reese, A.J., Municipal Storm Water Management, Lewis Publishers, Boca Raton, FL, 1995, pp.438-442.

Analysis

- Determine Peak Flow Rate to Culvert:

  Use Rational Method (Q_P = CIA)

- Determine Input Parameters:

  - HW_{ALLOW} = Allowable Headwater Depth (ft)
  - N = Number of Pipes Used
  - $Q_{PIPE} = Q_P / N$ (cfs)
  - D = Culvert Diameter (in)
  - Type of Culvert (i.e., Concrete, CMP, etc.)
  - L = Culvert Length (ft)
  - s = Culvert Slope (ft/ft)
  - n = Manning's Number
  - k_e = Entrance Loss Coefficient
  - d_c = Critical Depth (Use Critical Depth Figures) (ft)

- Find actual HW for the culvert for both inlet & outlet control: (The condition with the greatest HW governs.)

  - For Inlet Control:

    - Enter Inlet Control Nomograph with D & Q_{PIPE} and find HW/D for the proper entrance type.

    - Compute HW. If HW exceeds HW_{ALLOW}, try larger culvert.

CULVERT.WPD

- For Outlet Control:

- Enter Outlet Control Nomograph with L, K_e, & D.

- To compute HW, connect the length scale for the type of entrance condition and culvert diameter scale with a straight line, pivot on the turning line, and draw a straight line from the design discharge through the turning point to the head loss scale H. Compute HW from the following equation:

$$HW = H + h_o - LS$$

where: $h_o = \left(\frac{d_c + D}{2} \right)$ or tailwater depth, whichever is greater.

- If HW exceeds HW_{ALLOW}, try larger culvert.

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SHEET: 3,7
JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Culvert Analysis Culvert No.: C-1

Peak Flow Rate:

Drainage Area (Ac.) =	37.5	**Areas A, 2, 3, 7, 8, & 9**
Hydraulic Length (ft) =	2,700	**Head of Area A to End of DC-1**
Fall Along Length (ft) =	171	**EL. 330 - EL. 159**
Time of Conc. (min.) =	9.9	
Intensity (in/hr) =	7.05	**(25 Year Storm)**
Runoff Coefficient =	0.425	**(Assume 1/2 at 0.5 and 1/2 at 0.35)**
Q (cfs) =	112.4	

Culvert Parameters: (User Input)

Allowable HW Depth (ft) =	5		
Number of Pipes, N =	2	Qpipe (cfs) =	56.2
Culvert Diameter, D (in) =	42		
Type of Culvert =	RCP		
Invert In Elev. (ft) =	159.0	Invert Out Elev. (ft) =	156.0
Culvert Length, L (ft) =	72		
Culvert Slope, S (ft/ft) =	0.042		
Manning's Number, n =	0.012		
Entrance Loss Coef., ke =	0.5		
Critical Depth (ft) =	2.4		

Case 1: Inlet Control

HW/D = 1.0 **(From Inlet Control Nomograph)**
HW (ft) = 3.5

INLET CONTROL GOVERNS!

Case 2: Outlet Control

ho (ft) = 3.0
H (ft) = 1.0 **(From Outlet Control Nomograph)**
HW (ft) = 0.9

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SHEET: 47
JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Culvert Analysis **Culvert No.: C-2**

Peak Flow Rate:

Drainage Area (Ac.) =	6.3	**Areas 4 & 5**
Hydraulic Length (ft) =	820	**Head of Area 5 to DI-1**
Fall Along Length (ft) =	125	**EL. 284 - EL. 159**
Time of Conc. (min.) =	2.8	
Intensity (in/hr) =	8.19	**(25 Year Storm)**
Runoff Coefficient =	0.5	**(Assume)**
Q (cfs) =	25.8	

Culvert Parameters: (User Input)

Allowable HW Depth (ft) =	4		
Number of Pipes, N =	1	Qpipe (cfs) =	25.8
Culvert Diameter, D (in) =	30		
Type of Culvert =	RCP		
Invert In Elev. (ft) =	154.2	Invert Out Elev. (ft) =	152.0
Culvert Length, L (ft) =	48		
Culvert Slope, S (ft/ft) =	0.046		
Manning's Number, n =	0.012		
Entrance Loss Coef., ke =	0.5		
Critical Depth (ft) =	1.8		

Case 1: Inlet Control

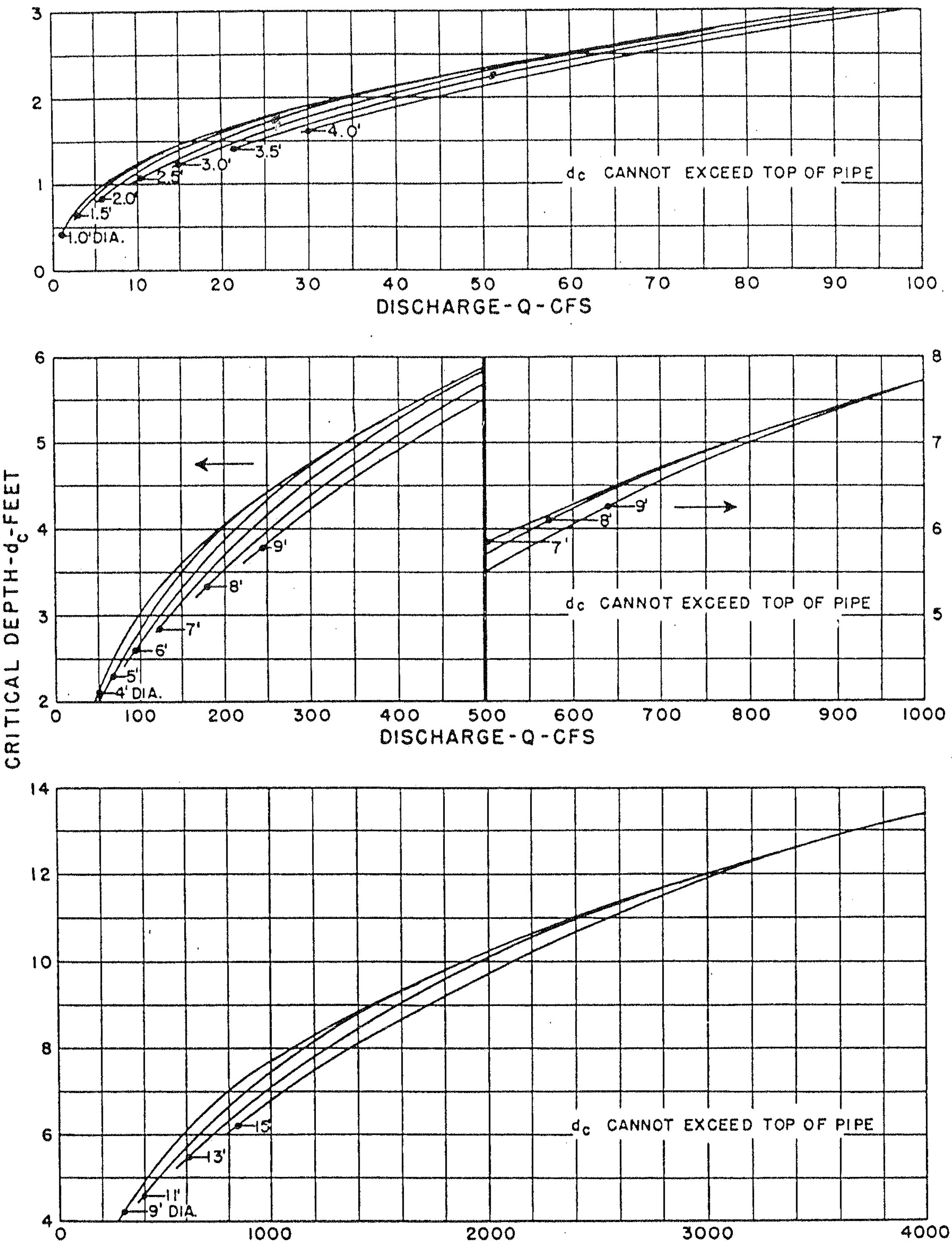
HW/D = 1.1 **(From Inlet Control Nomograph)**
HW (ft) = 2.8

INLET CONTROL GOVERNS!

Case 2: Outlet Control

ho (ft) = 2.2
H (ft) = 0.8 **(From Outlet Control Nomograph)**
HW (ft) = 0.7

5/7



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JAN. 1964

CRITICAL DEPTH
CIRCULAR PIPE

FIGURE 3-6.1M(1)

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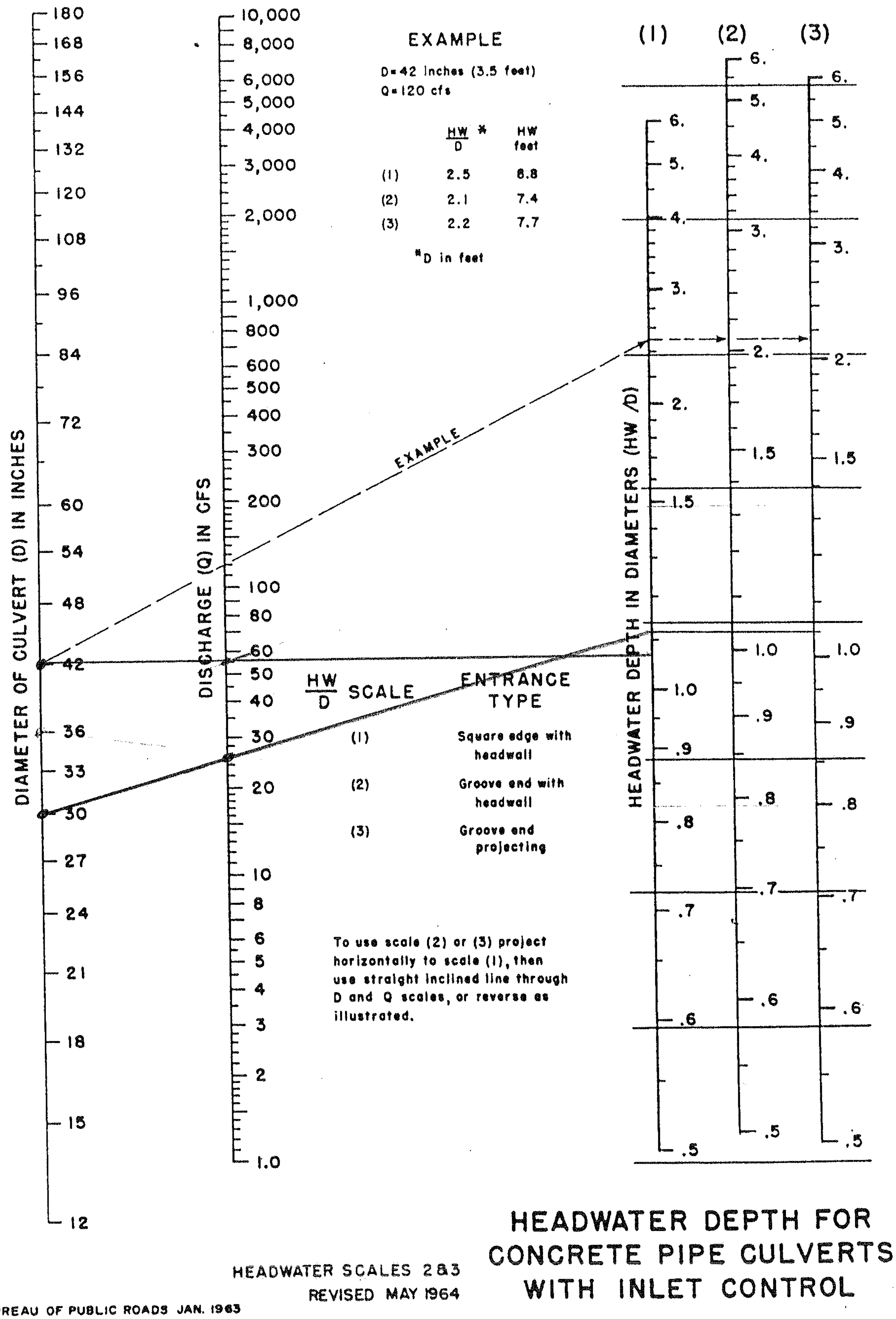

HEADWATER DEPTH FOR CONCRETE PIPE CULVERTS WITH INLET CONTROL

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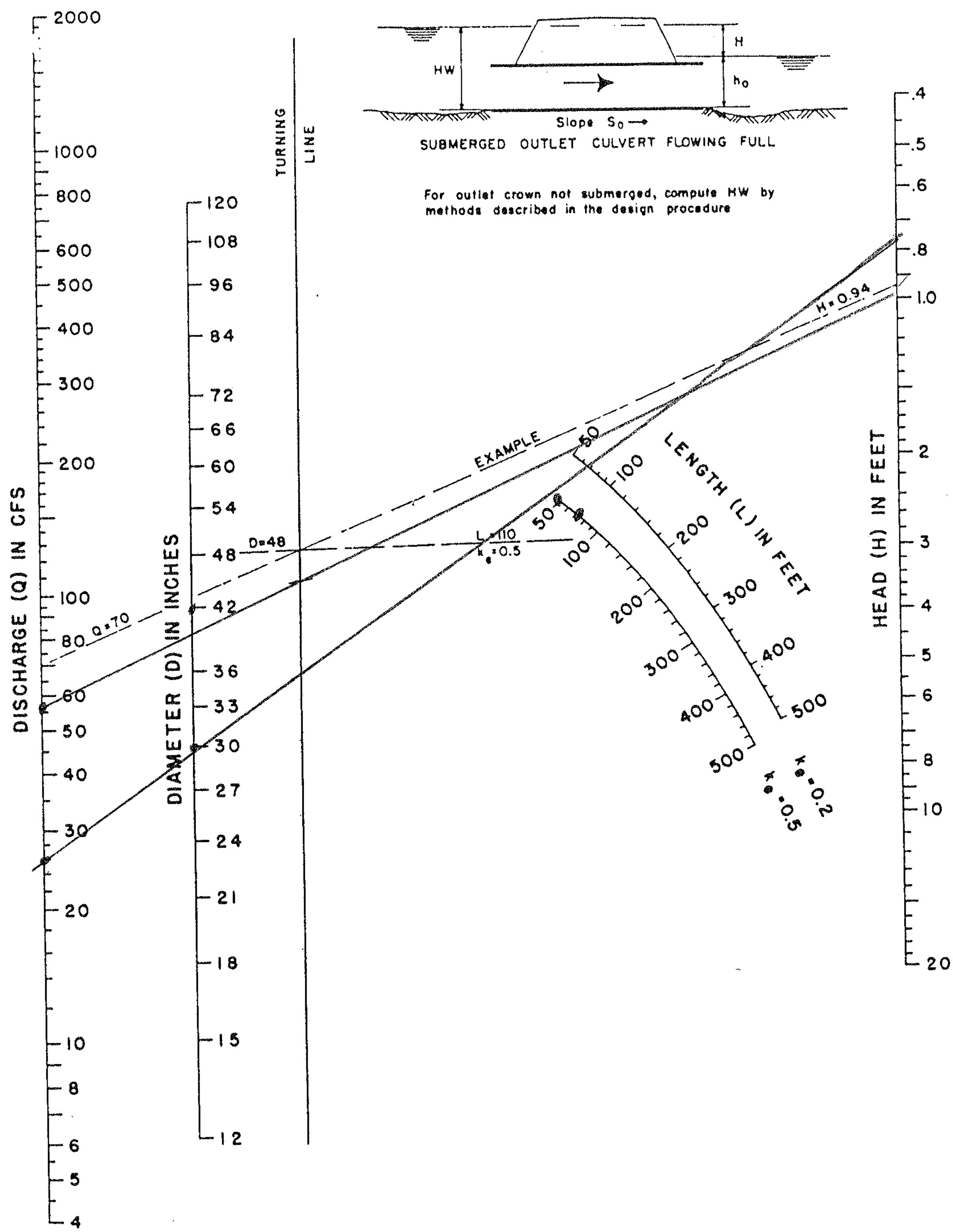

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HEAD FOR
CONCRETE PIPE CULVERTS
FLOWING FULL
n = 0.012

Objective Evaluate the required pipe strength for concrete pipe and select the appropriate class of pipe to satisfy the strength requirement.

Reference Concrete Pipe Design Manual, American Concrete Pipe Association, Vienna, VA, 1992.

"Design Data 40 - Standard Installations and Bedding Factors for the Indirect Design Method", American Concrete Pipe Association, Vienna, VA, September 1994.

ASTM C 76, "Standard Specification for Reinforced Concrete Culvert, Storm Drain, & Sewer Pipe", American Society for Testing and Materials, Philadelphia.

Analysis The analysis is based on the following procedure recommended by the American Concrete Pipe Association (ACPA):

1. Determination of Earth Load
2. Determination of Live Load
3. Selection of Standard Installation
4. Determination of Bedding Factors
5. Application of Factor of Safety
6. Selection of Pipe Strength/Class.

The design parameters will vary depending on the type of installation (trench, embankment, etc.).

Equations

- Determination of Earth Load, W_E:

Based on the assumed concrete pipe parameters (size, backfill, etc.) use the tables and figures in the Concrete Pipe Design Manual to determine the earth load acting on the pipe. Note that the values determined in the tables and figures are based on a backfill unit weight of 100 lbs/ft^3. This value must be adjusted for the anticipated backfill unit weight. Also, for non-trench installations, values for projection ratio, p (vertical distance between the top of the pipe and natural ground divided by the outside vertical height of the pipe), and settlement ratio, r_{sd}, must be determined in order to use the figures. Table 43 of the Design Manual gives suggested values for r_{sd} based on the known or assumed value of p.

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- Determination of Live Load, W_L:

Based on the concrete pipe parameters (size, backfill, etc.) use the tables in the Concrete Pipe Design Manual to determine the live load acting on the pipe. Note that the values for backfill heights of 10 feet or more and considered insignificant to the design of the pipe.

-Selection of Standard Installation:

Select the Standard Installation based on the guidance given in Design Data 40. Note that a Type 1 Standard Installation requires the highest construction quality and degree of inspection while a Type 4 Standard Installation requires virtually no construction quality or inspection.

-Determination of Bedding Factors:

Determine the bedding factors based on the guidance given in Design Data 40. For embankment installations, the bedding factor, B_{fe}, is found from Table 4 of Design Data 40 depending on the selected Standard Installation. For trench installations the bedding factor is based on the following equation:

$$B_{fv} = \frac{(B_{fe} - B_{fo}) \cdot (B_d - B_c)}{(B_{dt} - B_c)} + B_{fo} \qquad \text{(Design Data 40 Eqn. 5)}$$

Where:
- B_{fv} = Variable Bedding Factor, Trench
- B_{fe} = Bedding Factor, Embankment (Design Data 40 Table 4)
- B_{fo} = Minimum Bedding Factor, Trench (Design Data 40 Table 6)
- B_d = Trench Width at Top of Pipe (ft)
- B_c = Outside Horizontal Span of Pipe (ft)
- B_{dt} = Transition Width at Top of Pipe (ft) (Given in Design Manual Tables for Earth Load).

Use Table 7A of Design Data 40 to determine the live load bedding factor, B_{fLL}.

-Application of Factor of Safety, FS:

According to the ACPA, a factor of safety of 1.0 should be applied if the 0.01-inch crack strength is used as the design criterion rather than the ultimate strength.

-Selection of Pipe Strength/Class:

The required three-edge bearing strength of circular reinforced concrete pipe is expressed as D-load in the following equation:

$$D\text{-}load = \left[\frac{W_E}{BF} + \frac{W_L}{B_{fLL}}\right] \times \frac{FS}{D} \qquad \text{(Design Data 40 Eqn. 6)}$$

Where:

W_E = Earth Load on Pipe (lbs/linear ft)
W_L = Live Load on Pipe (lbs/linear ft)
BF = Bedding Factor
= B_{fe} for Embankment Installations
= B_{fv} for Trench Installations
B_{fLL} = Live Load Bedding Factor
FS = Factor of Safety
D = Pipe Diameter (ft)

Note that if B_{fLL} is greater than B_{fe} for embankment installations or B_{fv} for trench installations, use B_{fe} or B_{fv} in place of B_{fLL}.

Select class of reinforced concrete pipe based on the following ASTM C-76 guidelines:

Pipe Class	Maximum D-Load For 0.01-inch Crack (lbs/lf/ft of diameter)
I	800
II	1,000
III	1,350
IV	2,000
V	3,000

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SHEET: 49
JOB #: JOHNSTON-22
DATE: 9/22/05
BY: PKS
CHKD BY:

Johnston County Landfill - Area 2
Concrete Pipe Strength Analysis
(Positive Projecting Embankment Installation)

Culvert No.: C-1

Concrete Pipe Parameters:

Type of Pipe =	Circular, Concrete
Pipe Diameter, D (in) =	42
Outside Horzontal Span, Bc (ft) =	4.25 (From Concrete Pipe Design Manual Table 45)
Height of Backfill, H (ft) =	6
Backfill Type =	Sand
Backfill Unit Wt. (lbs/ft^3) =	120
Standard Installation =	Type 2

Determine Earth Load:

Projection Ratio, p =	0.7 (Known or Assumed)
Settlement Ratio, rsd =	0.7 (From Concrete Pipe Design Manual Table 43)
rsd x p =	0.49
WE (lbs/LF) (@ 100 pcf) =	3,450 (From Concrete Pipe Design Manual - Figure 166)
WE (lbs/LF) (Adjusted) =	4,140

Determine Live Load:

WL (lbs/LF) =	610 (From Concrete Pipe Design Manual Table 45)

Determine Bedding Factors:

Embankment Bedding Factor, Bfe =	2.8 (From ACPA Design Data 40 Table 4)
Live Load Bedding Factor, Bfll =	2.2 (From ACPA Design Data 40 Table 7A)

Factor of Safety:

Factor of Safety, FS =	1.0 (Use 1.0 for Reinforced and 1.25 to 1.5 for Non-Reinforced Pipe)

Selection of Required Pipe Strength/Class:

D-Load (lbs/LF/ft) = 502

Pipe Class	Max. D-Load
I	800
II	1,000
III	1,350
IV	2,000
V	3,000

(Table per ASTM C 76)

Use Class I RCP

USE CLASS II

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SHEET: 5 / 9
JOB #: JOHNSTON-22
DATE: 9/22/05
BY: PKS
CHKD BY:

Johnston County Landfill - Area 2
Concrete Pipe Strength Analysis
(Positive Projecting Embankment Installation)

Culvert No.: C-2

Concrete Pipe Parameters:

Type of Pipe =	Circular, Concrete
Pipe Diameter, D (in) =	30
Outside Horzontal Span, Bc (ft) =	3.08 (From Concrete Pipe Design Manual Table 45)
Height of Backfill, H (ft) =	5
Backfill Type =	Sand
Backfill Unit Wt. (lbs/ft^3) =	120
Standard Installation =	Type 2

Determine Earth Load:

Projection Ratio, p =	0.7 (Known or Assumed)
Settlement Ratio, rsd =	0.7 (From Concrete Pipe Design Manual Table 43)
rsd x p =	0.49
WE (lbs/LF) (@ 100 pcf) =	2,200 (From Concrete Pipe Design Manual - Figure 166)
WE (lbs/LF) (Adjusted) =	2,640

Determine Live Load:

WL (lbs/LF) =	590 (From Concrete Pipe Design Manual Table 45)

Determine Bedding Factors:

Embankment Bedding Factor, Bfe =	2.9 (From ACPA Design Data 40 Table 4)
Live Load Bedding Factor, Bfll =	2.2 (From ACPA Design Data 40 Table 7A)

Factor of Safety:

Factor of Safety, FS =	1.0 (Use 1.0 for Reinforced and 1.25 to 1.5 for Non-Reinforced Pipe)

Selection of Required Pipe Strength/Class:

D-Load (lbs/LF/ft) = $\boxed{471}$

Pipe Class	Max. D-Load
I	800
II	1,000
III	1,350
IV	2,000
V	3,000

(Table per ASTM C 76)

Use Class I RCP

Use Class II

TABLE 43

DESIGN VALUES OF SETTLEMENT RATIO

Installation and Foundation Condition	Settlement Ratio r_{sd} Usual Range	Settlement Ratio r_{sd} Design Value
Positive Projecting	0.0 to +1.0	
Rock or Unyielding Soil	+1.0	+1.0
*Ordinary Soil	+0.5 to +0.8	+0.7
Yielding Soil	0.0 to +0.5	+0.3
Zero Projecting		0.0
Negative Projecting	−1.0 to 0.0	
p′ = 0.5		−0.1
p′ = 1.0		−0.3
p′ = 1.5		−0.5
p′ = 2.0		−1.0
Induced Trench	−2.0 to 0.0	
p′ = 0.5		−0.5
p′ = 1.0		−0.7
p′ = 1.5		−1.0
p′ = 2.0		−2.0

**The value of the settlement ratio depends on the degree of compaction of the fill material adjacent to the sides of the pipe. With good construction methods resulting in proper compaction of bedding and sidefill materials, a settlement ratio design value of +0.5 is recommended.*

TABLE 44

DESIGN VALUES OF COEFFICIENT OF COHESION

Type of Soil	Values of c
Clay	
Soft	40
Medium	250
Hard	1000
Sand	
Loose Dry	0
Silty	100
Dense	300
Top Soil	
Saturated	100

TABLE 45

HIGHWAY LOADS ON CIRCULAR PIPE

POUNDS PER LINEAR FOOT

PIPE SIZE D IN INCHES	B_c (ft.)	HEIGHT OF FILL H ABOVE TOP OF PIPE IN FEET 0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0	6.0	7.0	8.0	9.0	PIPE SIZE D IN INCHES
12	1.33	3780	2080	1470	1080	760	550	450	380	290	230	190	160	130	12
15	1.63	4240	2360	1740	1280	900	660	540	450	350	280	230	190	160	15
18	1.92	4110	2610	1970	1460	1030	750	620	520	400	320	260	220	190	18
21	2.21	3920	2820	2190	1620	1150	840	690	580	450	360	300	250	210	21
24	2.50	4100	3010	2400	1780	1270	930	760	640	500	400	330	280	240	24
27	2.79	3880	2940	2590	1930	1380	1010	830	700	560	440	360	300	260	27
30	3.08	3620	2830	2770	2070	1480	1080	890	750	590	480	390	330	280	30
33	3.38	3390	2930	2950	2200	1580	1160	960	810	630	510	420	360	300	33
36	3.67	3190	2810	2930	2330	1670	1230	1020	860	670	550	450	380	330	36
39	3.96	3010	2670	2850	2440	1760	1290	1070	910	710	580	480	410	350	39
42	4.25	2860	2550	2770	2560	1840	1360	1130	950	750	610	510	430	370	42
48	4.83	2590	2330	2620	2480	1990	1470	1230	1040	820	670	560	470	410	48
54	5.42	2360	2150	2490	2360	2050	1580	1320	1120	890	730	610	520	440	54
60	6.00	2170	1990	2450	2250	1960	1680	1400	1190	950	780	650	560	480	60
66	6.58	2010	1850	2520	2160	1880	1640	1480	1260	1010	830	700	590	510	66
72	7.17	1870	1730	2580	2190	1810	1570	1510	1330	1060	880	740	630	540	72
78	7.75	1750	1630	2630	2240	1770	1520	1460	1390	1110	920	780	660	570	78
84	8.33	1650	1540	2730	2290	1810	1460	1410	1360	1160	960	810	690	600	84
90	8.92	1550	1460	2530	2330	1850	1470	1360	1310	1210	1000	850	720	630	90
96	9.50	1470	1380	2410	2290	1880	1500	1330	1270	1250	1040	880	750	650	96
102	10.08	1390	1320	2300	2190	1910	1530	1350	1240	1290	1070	910	780	680	102
108	10.67	1320	1260	2200	2090	1830	1560	1380	1230	1330	1110	940	810	700	108
114	11.25	1260	1200	2110	2010	1760	1540	1410	1260	1362	1140	970	830	730	114
120	11.83	1210	1150	2020	1930	1700	1480	1420	1280	1400	1170	990	860	750	120
126	12.42	1160	1100	1940	1860	1640	1430	1380	1300	1430	1200	1020	880	770	126
132	13.00	1110	1060	1870	1800	1580	1380	1330	1290	1460	1220	1040	900	790	132
138	13.58	1070	1020	1800	1730	1530	1340	1290	1250	1490	1250	1070	920	810	138
144	14.17	1020	980	1740	1670	1480	1300	1250	1210	1470	1280	1090	940	830	144

DATA:
1. Unsurfaced roadway.
2. Loads — AASHTO HS 20, two 16,000 lb. dual-tired wheels, 4 ft. on centers, or alternate loading, four 12,000 lb. dual-tired wheels, 4 ft. on centers with impact included.

NOTES:
1. Interpolate for intermediate pipe sizes and/or fill heights.
2. Critical loads.
   a. For H = 0.5 and 1.0 ft., a single 16,000 lb. dual tired wheel.
   b. For H = 1.5 through 4.0 ft., two 16,000 lb. dual tired wheels, 4 ft. on centers.
   c. For H > 4.0 ft. alternate loading.
3. Truck live loads for H = 10.0 ft. or more are insignificant.

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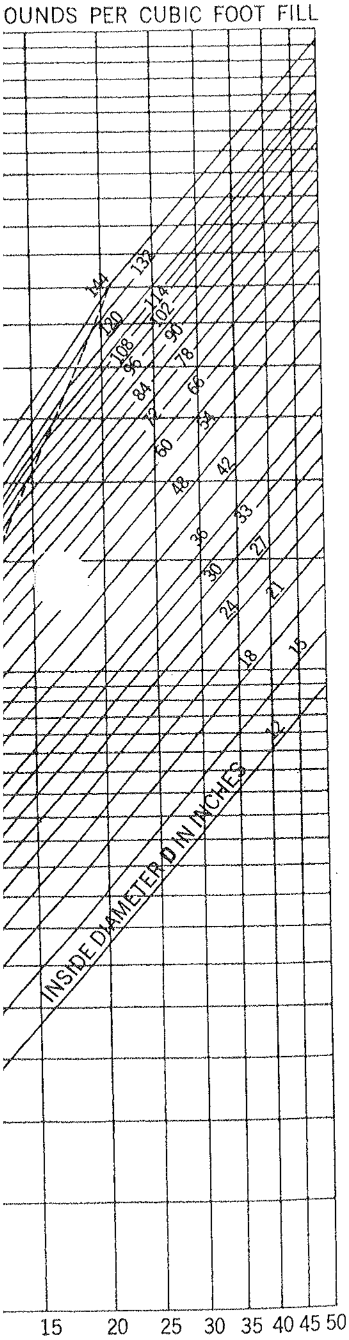
N CIRCULAR PIPE
OUNDS PER CUBIC FOOT FILL

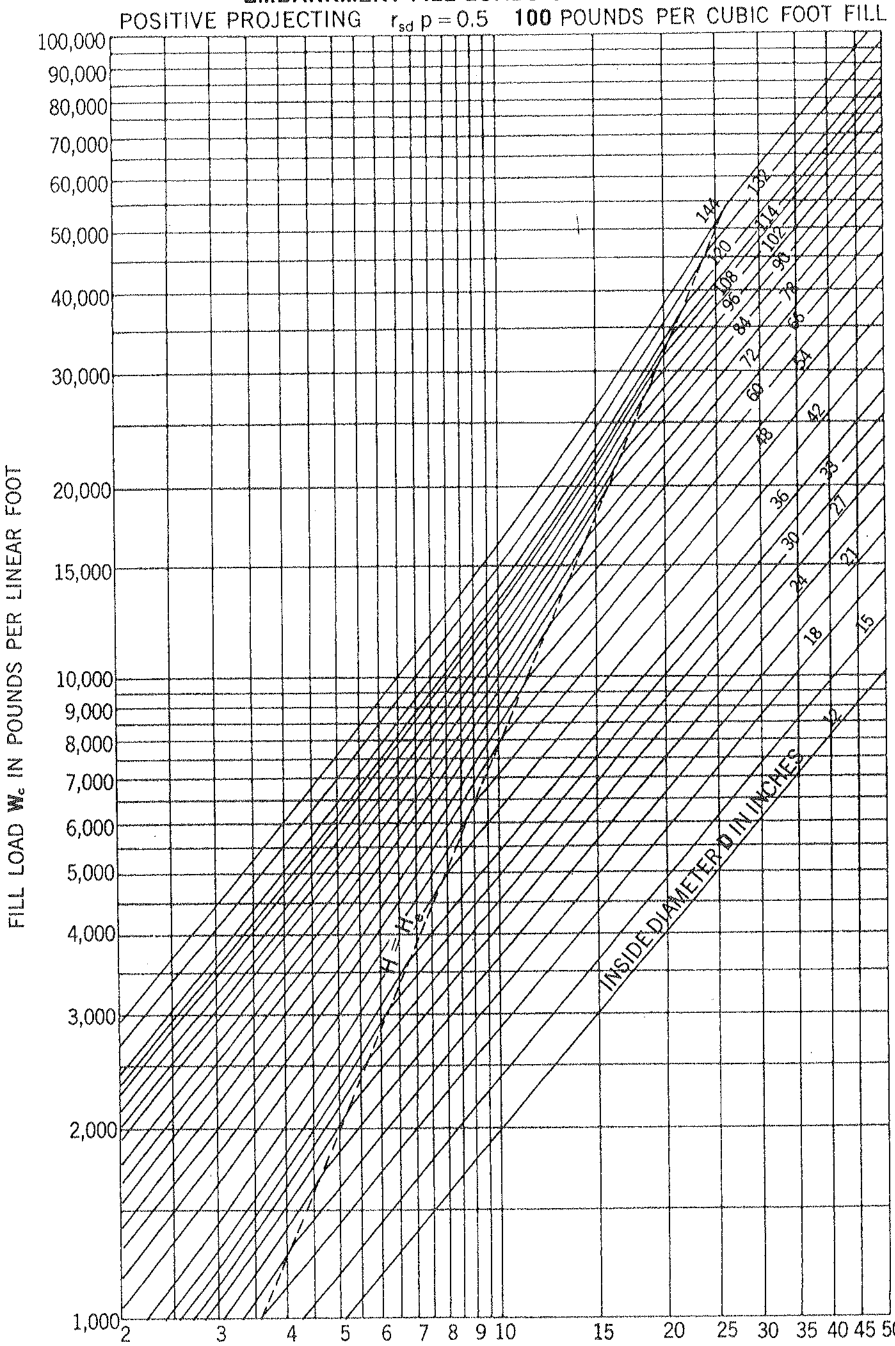


; fo pounds increase 20%, etc.

FIGURE 166

EMBANKMENT FILL LOADS ON CIRCULAR PIPE

POSITIVE PROJECTING $r_{sd}\,p = 0.5$ **100** POUNDS PER CUBIC FOOT FILL



For fill weighing 110 pounds per cubic foot, increase loads 10%; for 120 pounds increase 20%, etc. Interpolate for intermediate pipe sizes.

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TABLE 4 BEDDING FACTORS, EMBANKEMENT CONDITION, B_{fe}				
PIPE DIAMETER, IN.	STANDARD INSTALLATION			
	Type 1	Type 2	Type 3	Type 4
12 (300mm)	4.6	3.2	2.5	1.7
24 (600mm)	4.4	3.0	2.4	1.7
36 (900mm)	4.2	2.9	2.3	1.7
72 (1800mm)	4.0	2.8	2.2	1.7
144 (3600mm)	3.8	2.8	2.2	1.7

NOTES:

1. For pipe diameters other than listed in Table 4, embankment condition factors, B_{fe}, can be obtained by interpolation.

2. Bedding factors are based on the soils being placed with the minimum compaction specified in Tables 2 and 3 for each standard installation.

Determination Of Earth Load

The Design Manual tables and graphs can be used to determine the earth loads on a buried pipe. These tables and graphs refer to soils by common names, while SIDD soils are referred to by generic soil types. Table 5 presents the relationship between these two different methods of soil designations:

One of the informative calculations output by SPIDA is the arching factor, which is defined as the ratio of the calculated vertical load on the pipe to the weight of the prism of earth directly above the outside diameter of the pipe. Evaluation of the arching factor from the SPIDA studies shows that the factor approaches a value of 1.45 as an upper limit for any of the four standard installations.

For positive projection embankment installations, since the arching factor will not exceed 1.45, the appropriate earth load can be obtained from Design Manual graphs (Figures 163, 164, 165 and 166)for embankment earth load for the range of $r_{sd}p$ values from zero to 0.5. When the product of r_{sd}, settlement ratio, and p, projection ratio, is zero, the earth load on the pipe is equal to the weight of the prism of soil above the pipe. For positive values of $r_{sd}p$, the load on the pipe will be greater than the weight of the prism of soil above the pipe, and for negative values of $r_{sd}p$, the load on the pipe will be less than the weight of the prism of soil above the pipe.

For trench installations, Design Manual tables (Tables 13 through 42) and graphs (Figures 147, 148, 149 and I 50) for earth load can be used as is to determine the load on the pipe. These tables and graphs take into account the beneficial effects of upward frictional forces on the trench wall in reducing the load on the pipe to less than the prism load.

Determination Of Live Load

Design Manual Table 45 can be used as is to determine the live load for both the trench and embankment conditions.

Selection Of Standard Installation

The selection of a Standard Installation for a project should be based on an evaluation ofthe quality of construction and inspection anticipated. A Type 1 Standard Installation requires the highest construction quality and degree of inspection. Required construction quality is reduced for a Type 2 Standard Installation, and reduced further for a Type 3 Standard Installation. A Type 4 Standard Installation requires virtually no construction orquality inspection. Consequently, a Type 4 Standard Installation will require a higher strength pipe, and a Type I Standard Installation will require a lower strength pipe for the same depth of installation.

Determination Of Bedding Factor

Table 4 presents bedding factors, B_{fe}, for each of the Standard Installations.

For trench installations as discussed in C.P. Info No. 12 and in the Design Manual,

TABLE 7A BEDDING FACTORS, B_{fLL}, FOR HS20 LIVE LOADINGS											
FILL HEIGHT, FT.	PIPE DIAMETER, INCHES										
	12	24	36	48	60	72	84	96	108	120	144
0.5	2.2	1.7	1.4	1.3	1.3	1.1	1.1	1.1	1.1	1.1	1.1
1.0	2.2	2.2	1.7	1.5	1.4	1.3	1.3	1.3	1.1	1.1	1.1
1.5	2.2	2.2	2.1	1.8	1.5	1.4	1.4	1.3	1.3	1.3	1.1
2.0	2.2	2.2	2.2	2.0	1.8	1.5	1.5	1.4	1.4	1.3	1.3
2.5	2.2	2.2	2.2	2.2	2.0	1.8	1.7	1.5	1.4	1.4	1.3
3.0	2.2	2.2	2.2	2.2	2.2	2.2	1.8	1.7	1.5	1.5	1.4
3.5	2.2	2.2	2.2	2.2	2.2	2.2	1.9	1.8	1.7	1.5	1.4
4.0	2.2	2.2	2.2	2.2	2.2	2.2	2.1	1.9	1.8	1.7	1.5
4.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9	1.8	1.7
5.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9	1.8
5.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.0	1.9
6.0	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.1	2.0
6.5	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2

NOTE:

1. For pipe diameters other than listed in Table 7A, B_{fLL}l values can be obtained by interpolation.

The Design Manual tables (Tables 13 through 42) for trench earth loads present transition width values which are sufficiently accurate for use as values for B_{dt} in the preceding equation.

For pipe installed with six feet (1.98m), or less, of overfill and subjected to truck loads, the controlling maximum moment may be at the crown rather than the invert. Consequently, the use of an earth load bedding factor may produce unconservative designs. Crown and invert moments of pipe for a range of diameters and burial depths subjected to HS20 truck live loadings were evaluated. Evaluated also, was the effect of bedding angle and live load angle (width of loading on the pipe). When HS20 live loadings are encountered to a significant value, the live load bedding factors, B_{fLL}, presented in Table 7A or B are satisfactory for a Type 4 Standard Installation, and become increasingly conservative for Types 3, 2 and 1. Limitations on B_{fLL} are discussed in the Section on Selection of Pipe Strength.

Application Of Factor Of Safety

The indirect design method for concrete pipe is similar to the comnion working stress method of steel design, which employs a factor of safety between yield stress and the desired working stress. In the indirect method, the factor of safety is defined as the relationship between the ultimate strength D-load and the 0.01 -inch(0.3mm) crack D-load. This relationship is specified in the ASTM Standards C76 and C655 on concrete pipe. The relationship between ultimate D-load and 0.01 -inch(0.3mm) crack D-load is 1.5 for 0.0 1 -inch(0.3mm) crack D-loads of 2000 or less; 1.25 for 0.0 1 -inch(0.3mm) crack D-loads of 3000 or more; and a linear reduction from 1.5 to 1.25 for 0.01 -inch(0.3mm) crack D-loads between more than 2000 and less than 3000. Therefore, a factor of safety of 1.0 should be applied if the 0.01-inch(0.3mm) crack strength is used as the design criterion rather than the ultimate strength. The 0.01-inch (0.3mm) crack width is an arbitrary chosen test criterion and not a criteria for field performance or service limit.

Objective To design a sediment basin to handle the maximum flow from the design storm.

References North Carolina Erosion & Sediment Control Planning & Design Manual, North Carolina Division of Land Resources, 1988.

Malcom, H. Rooney, Elements of Urban Stormwater Design, N. C. State University, Raleigh, NC, 1989.

Analysis The following approach is used to properly size and evaluate the sediment basin:

1. Determine Peak Flow Rate into Basin
2. Formulate Design Hydrograph.
3. Size Basin & Determine Stage-Storage Function.
4 Route for Flow Check and Desired Settling Efficiency.

Calculations

- Determine Peak Flow Rate Into Basin:

Use Rational Method (Q_P=CIA)

- Formulate Design Hydrograph:

Estimate Volume of Runoff from 6 hour storm for the design return period (i.e. 6 hr. 10 yr., or 6 hr. 25 yr. storm). The six hour storm for the return period of interest is typically included in the design hydrograph (Malcom).

$$Q^* = \frac{(P-0.2\underline{S})^2}{(P+0.8\underline{S})}$$ (Malcom Equation III-6)

SEDBASIN.WPD

Where: Q^* = Volume of Runoff from 6 hr, x year storm (in.)

$\underline{S}$ = $\frac{1000}{CN} - 10$

CN = Runoff Curve Number

P = 6 hr, x year Storm Depth (in.)

Set Time to Peak Using Step Function as Pattern Hydrograph

$$Tp = \frac{Q^* A}{1.39 Qp}$$ (Malcom Eq. III-4)

Where: T_p = Time to Peak (min)

Q^* = Volume of Runoff (in.)

A = Area Flowing to Basin (Ac)

Qp = Peak Flow into Basin (cfs)

Design Hydrograph

$$Q = \frac{Qp}{2}\left[1 - COS\left(\frac{\pi t}{Tp}\right)\right]$$ (Malcom Eq. III-1)

for $0 \leq t \leq 1.25$ Tp

$$Q = 4.34\, Qp \exp\left[-1.30\left(\frac{t}{Tp}\right)\right]$$ (Malcom Eq. III-2)

for $t > 1.25$ Tp

Where: Q = Flow into Basin at Time t (cfs)

- Size Basin & Determine Stage-Storage Function:

Size Basin based on minimum storage volume and desired surface area.

Determine Stage-Storage Function

$$S = K_S Z^b \qquad \text{(Malcom Eq. III-7)}$$

Where:
- S = Storage Volume (ft^3)
- K_S&b = Linear Regression Constants Describing the Stage-Storage Relationship
- Z = Stage Referenced to the Bottom of the Basin (ft)

- Route for Flow Check and Desired Settling Efficiency:

Route design hydrograph through the sediment basin to determine peak stage and outflow and settling efficiency.

Settling Velocity of Design Particle

$$V_o = \frac{g}{18}\left[(S_s - 1)/\upsilon\right] d^2 \qquad \text{(Malcom Eq. IV-3)}$$

Where:
- V_o = Settling Velocity (ft/s) - convert from (m/s)
- g = Gravitational Acceleration (m/s^2)
- S_s = Specific Gravity of Design Particle
- υ = Kinematic Viscosity of the Fluid (m^2/s) (= 1.14×10^{-6} m^2/s @ 15°C Rf. Streeter, 1975)
- d = Diameter of Design Particle (m)

Settling Constant

$$C_s = \frac{bK_s(V_o)}{N\left[(1-E)^{-1/N}-1\right]}$$ (Malcom Eq. IV-10)

Where: N = Number of Effective Cells (N=2=>Conservative)
E = Settling Efficiency (Decimal Fraction)

Settling Envelope

$$Q = C_S Z^{(b-1)}$$ (Malcom Eq. IV-9)

Where: Q = Discharge Limit at Given Stage Z (ft)

Surface Area

$$A_s = bK_s Z^{(b-1)}$$ (Malcom Eq. IV-7)

Settling Efficiency

$$E = 1 - \left[1 + \frac{V_o A_s}{NQ}\right]^{-N}$$ (Malcom Eq. IV-1)

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SHEET: 5 / 7
JOB #: JOHNSTON-22
DATE: 10/3/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Sedimentation Basin Analysis Basin No.: 6

AREAS DRAINING INTO BASIN:

Hydraulic Length (ft) = 3,200 Head of Area to End of Area
Fall Along Length (ft) = 180 EL. 330 - EL. 150

Drainage Area	Area (Ac.)	C	
Area A	25.6	0.425	(Assume 1/2 at 0.5 and 1/2 at 0.35)
Areas 1-9	23.0	0.50	

Total = 48.6 Acres

Avg. C = 0.46

PEAK FLOW RATE:

Time of Conc. = 11.8
Intensity (in/hr) = 6.68 (25 yr Storm)
Qp (cfs) = 149.5

ESTIMATE VOLUME OF RUNOFF:

P6,X (in) = 4.9 (6 hr, 25 yr Storm)

Runoff Curve # (CN) = 79 (NC Sed. & Erosion Control Man., Fair Condition Soil Type C)

Q* (in) = 2.72

SET TIME TO PEAK:

Tp (min) = 38.4

SHEET:	6 / 7
JOB #:	JOHNSTON-22
DATE:	10/3/05
BY:	PKS
CHKD BY:	

BASIN REQUIREMENTS:

Required Storage Capacity (ft^3/Ac.) =	1,800	**(North Carolina)**
Required Storage Capacity (ft^3) =	87,480	
Multipier (X) for Desired Surface Area (Qp x X) =	0.01	**(North Carolina)**
Desired Surface Area (Ac) =	1.49	

DETERMINE STAGE-STORAGE FUNCTION:

Contour	Area (sq ft)	Incr Vol (cu ft)	Accum Vol (cu ft)	Stage (ft)	ln S	ln Z	Z est
150	31,950		0	0			
152	43,550	64,175	64,175	1.7	11.07	0.53	1.70
154	62,000	105,550	169,725	3.7	12.04	1.31	3.70
156	82,950	144,950	314,675	5.7	12.66	1.74	5.70

Linear Regression Constants:

Ks = 31,716 Storage = 31716 z^1.307

b = 1.31

***CAUTION: CHECK INPUT FOR REGRESSION ANALYSIS!**

SHEET:	7/7
JOB #:	JOHNSTON-22
DATE:	10/3/05
BY:	PKS
CHKD BY:	

RISER BARREL ROUTING:

General:

Qp (cfs) = 149.5
Tp (min) = 38.4
dT (min) = 3

Ks = 31,716
b = 1.31
Zo (ft) = 150.0
Zinitial (ft) = 150.0

Riser (Principal Spillway):

Dr (in) = 48
Cw = 3.3
Zcr (ft) = 154.0
Surf. Area at P. Spillway (Ac.)= 1.46
Note: Spreadsheet Assumes Riser Acts As A Weir.

Barrel:

Db (in) = 24
Zi (ft) = 150.0
Cd = 0.59

Emergency Spillway:

Crest Elevation (ft) = 156.1
Width at Crest (ft) = 20
Cw = 3.0

Particle Data:

Diam. (microns) = 40
Specific Gravity = 2.65
Settling Veloc. (ft/s) = 0.004140
Reynolds No. (<0.5) = 0.044284 O.K.

Efficiency Data:

Desired Efficiency (%) = 70
No. of Effective Cells = 2
Settling Constant (Cs) = 103.8765

BASIN PERFORMANCE O.K.

Peak Outflow = 37.5 cfs
Peak Stage = 156.1 ft
Min. Settling Efficiency = 96.0 %
Settling Efficiency O.K.

TIME (min)	INFLOW (cfs)	RISER (cfs)	BARREL (cfs)	E. SPILLWAY (cfs)	OUTFLOW (cfs)	STORAGE (cu ft)	STAGE (ft)	SURF. AREA (ft^2)	SET ENV. (cfs)	SET EFF. (%)
0	0.0	NA	NA	NA	0.0	0	150.0	0	na	NA
3	2.2	0.0	0.0	0.0	0.0	0	150.0	0	0.0	NA
6	8.8	0.0	0.0	0.0	0.0	403	150.0	14,875	37.3	NA
9	19.3	0.0	0.2	0.0	0.0	1,989	150.1	21,639	54.2	NA
12	33.2	0.0	0.7	0.0	0.0	5,470	150.3	27,436	68.8	NA
15	49.5	0.0	1.6	0.0	0.0	11,442	150.5	32,623	81.8	NA
18	67.3	0.0	3.2	0.0	0.0	20,354	150.7	37,344	93.6	NA
21	85.6	0.0	5.4	0.0	0.0	32,476	151.0	41,671	104.5	NA
24	103.3	0.0	8.5	0.0	0.0	47,889	151.4	45,647	114.4	NA
27	119.2	0.0	12.3	0.0	0.0	66,476	151.8	49,298	123.6	NA
30	132.5	0.0	16.1	0.0	0.0	87,929	152.2	52,642	132.0	NA
33	142.3	0.0	18.9	0.0	0.0	111,771	152.6	55,691	139.6	NA
36	148.0	0.0	21.4	0.0	0.0	137,378	153.1	58,453	146.5	NA
39	149.4	0.0	23.6	0.0	0.0	164,024	153.5	60,936	152.7	NA
42	146.3	0.0	25.5	0.0	0.0	190,918	154.0	63,146	158.3	NA
45	139.0	9.0	27.2	0.0	9.0	217,258	154.4	65,090	163.2	99.6
48	127.7	25.1	28.6	0.0	25.1	240,651	154.7	66,671	167.1	97.6
51	115.6	40.9	29.7	0.0	29.7	259,122	155.0	67,838	170.0	97.0
54	104.4	55.7	30.5	0.0	30.5	274,582	155.2	68,767	172.4	96.9
57	94.3	69.4	31.2	0.0	31.2	287,886	155.4	69,534	174.3	96.8
60	85.2	81.8	31.8	0.0	31.8	299,252	155.6	70,169	175.9	96.8
63	77.0	92.6	32.2	0.0	32.2	308,877	155.7	70,692	177.2	96.7
66	69.6	102.0	32.6	0.0	32.6	316,937	155.8	71,121	178.3	96.7
69	62.9	110.0	32.9	0.0	32.9	323,589	155.9	71,468	179.1	96.7
72	56.8	116.5	33.2	0.0	33.2	328,976	156.0	71,745	179.8	96.7
75	51.3	121.7	33.4	0.0	33.4	333,226	156.1	71,962	180.4	96.6
78	46.4	125.8	33.5	0.0	33.5	336,454	156.1	72,125	180.8	96.6
81	41.9	128.6	33.6	1.8	35.4	338,764	156.1	72,241	181.1	96.3
84	37.8	130.1	33.7	3.6	37.3	339,929	156.1	72,299	181.2	96.0
87	34.2	130.2	33.7	3.8	37.5	340,032	156.1	72,304	181.2	96.0
90	30.9	129.5	33.7	2.8	36.4	339,444	156.1	72,275	181.2	96.2
93	27.9	128.2	33.6	1.4	35.0	338,444	156.1	72,225	181.0	96.4
96	25.2	126.7	33.6	0.1	33.7	337,172	156.1	72,161	180.9	96.6
99	22.8	124.7	33.5	0.0	33.5	335,645	156.1	72,084	180.7	96.6
102	20.6	122.4	33.4	0.0	33.4	333,718	156.1	71,987	180.4	96.6
105	18.6	119.5	33.3	0.0	33.3	331,412	156.0	71,870	180.2	96.7
108	16.8	116.3	33.2	0.0	33.2	328,767	156.0	71,735	179.8	96.7
111	15.2	112.7	33.0	0.0	33.0	325,820	155.9	71,583	179.4	96.7
114	13.7	108.8	32.9	0.0	32.9	322,607	155.9	71,417	179.0	96.7
117	12.4	104.7	32.7	0.0	32.7	319,157	155.9	71,237	178.6	96.7
120	11.2	100.3	32.5	0.0	32.5	315,498	155.8	71,045	178.1	96.7

PROJECT Johnston County C&D Landfill - Area 2
JOB NO. JOHNSTON-22
DATE 9/22/05
SUBJECT Outlet Protection Analysis
COMPUTED BY PKS
CHECKED BY

Objective To design rip-rap aprons at the outlet of facility culverts and sediment basin barrel pipes to handle the maximum flow from the design storm. The maximum flow for each pipe was calculated in culvert and/or sedimentation basin calculations.

Reference North Carolina Erosion & Sediment Control Planning & Design Manual, North Carolina Division of Land Resources, 1988.

Analysis The following approach, based on Section 8.06 of the NC Erosion & Sediment Control Planning and Design Manual, is used to properly size rip-rap aprons:

1. Determine the tailwater condition and select the appropriate design chart.

2. Using the appropriate design chart, determine the d_{50} rip-rap size and minimum apron length (La) based on the maximum design flow.

3. Using the same chart, determine apron dimensions.

4. Determine the maximum stone diameter: $d_{max} = 1.5 \times d_{50}$

5. Determine the apron thickness:

   Thickness = 1.5 x d_{max} (No Filter Geotextile)
   Thickness = 1.5 x d_{50} (With Filter Geotextile)

OUTLETPROTECT.WPD

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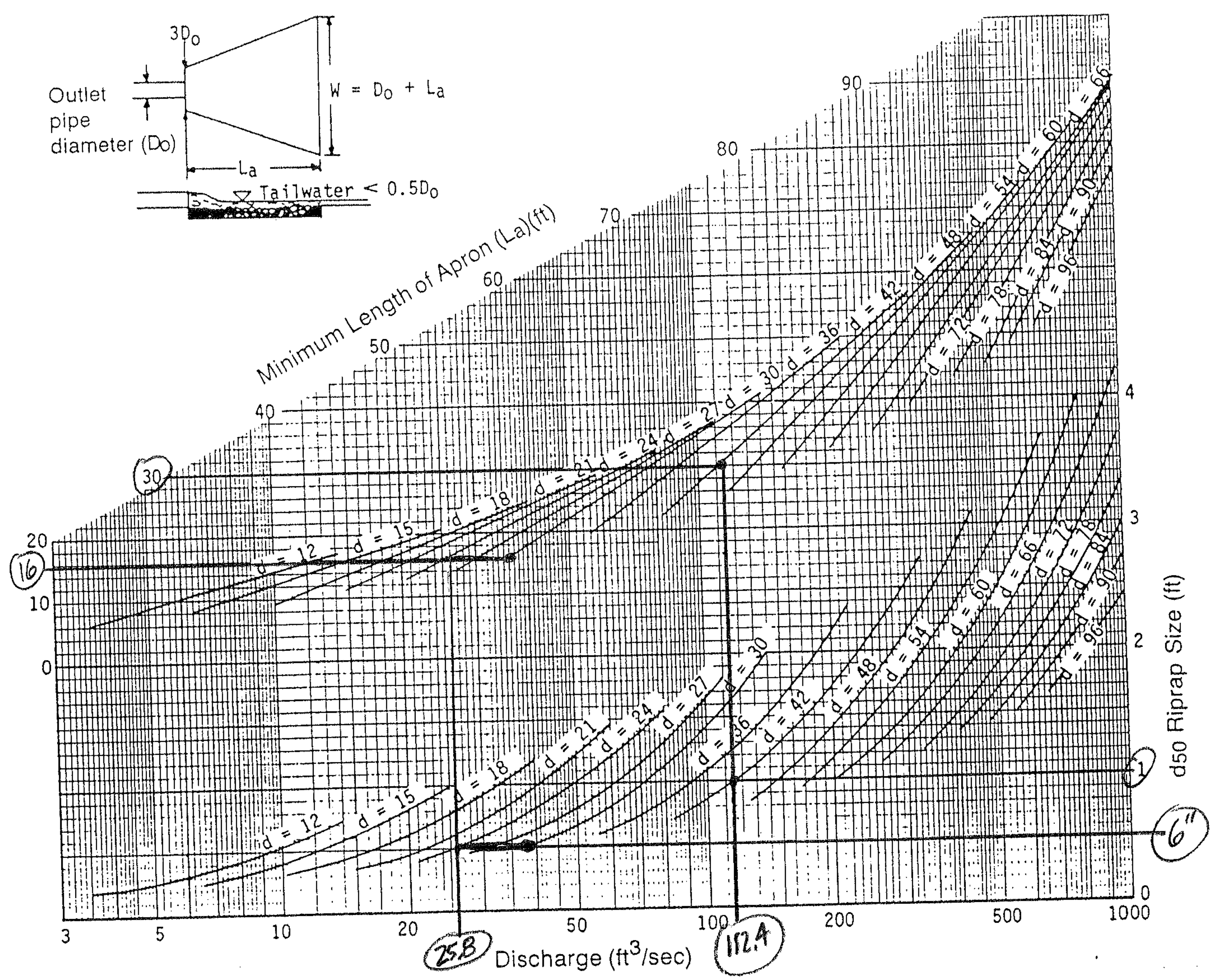
SHEET: 2 / 3
JOB #: JOHNSTON-22
DATE: 10/4/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Outlet Protection Analysis

Rip-Rap Apron Design:

Outlet	Diameter (inches)	Design Flow (cfs)	Tailwater Condition	d50 (feet)	dmax (feet)	Thickness (feet) (No Geotextile)	Thickness (feet) (w/ Geotextile)	La (feet)	W (feet)
C-1	42	112.4	Tw < 0.5Do	1.0	1.5	2.3	1.5	30	~~34~~ 37 = 2 Pipes
C-2	30	25.8	Tw < 0.5Do	0.5	0.8	1.1	0.8	16	19

3/3



Curves may not be extrapolated.

Figure 8.06a Design of outlet protection protection from a round pipe flowing full, minimum tailwater condition (T_w < 0.5 diameter).

Slope Stability, Settlement, and Bearing Capacity Evaluation

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:

Johnston County
Department of Public Utilities

October 2005

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

SLOPE STABILITY, SETTLEMENT, AND BEARING CAPACITY EVALUATION

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JOHNSTON COUNTY
JOHNSTON COUNTY C&D LANDFILL - AREA 2

SLOPE STABILITY, SETTLEMENT, AND BEARING CAPACITY EVALUATION

1.0 OVERVIEW

The slope stability of the overall waste mass and perimeter berms, the protective cover veneer stability, and the final cover veneer stability are addressed herein in addition to evaluations of foundation settlement and bearing capacity. In that the project site lies outside a seismic impact zone ($a_{max} \leq 0.10$ g according to USGS (Frankel et. al)), seismic slope stability analyses were not required (see **Figure 1**).

2.0 SLOPE STABILITY

EPA guidance (EPA/600/R-95/051) requires that the completed landfill have minimum static factor of safety against slope failures of 1.5.

2.1 Global Slope Stability

The slope stability analyses for the landfill were obtained using the computer program STABL5M, a computer program developed by Purdue University. Both block (along liner) and circular failure surfaces were assumed for the evaluation. The block failure surfaces were assumed for the analysis since the lowest interface shear strength values are related to the liner system geosynthetics. The circular failure surfaces were checked to verify stability of the perimeter berms and landfill subgrade.

Slope stability analyses were performed for the final geometry sections shown in **Figure 2** and **Appendix A**. A summary of results for the STABL5M studies is presented in **Table 1**. Complete output for these analyses are presented in **Appendix A**. The minimum static factor of safety is 1.6, which satisties EPA guidelines.

A summary of material properties assumed in the slope stability analyses is presented in **Table 2**. The shear strength values used for the waste in these evaluations were cohesion (c) = 500 psf and phi = 25 degrees; which is believed to be conservative for C&D wastes. Although construction and demolition waste has not been thoroughly studied as municipal solid waste (MSW), it is believed to have a shear strength similar to MSW. Kavazanjian et. al. (1995) and Eid et. al. (2000) have summarized shear strength data for MSW. These data came from published lab and field tests on MSW wastes and from values back figured from steep landfill slopes. Kavazanjian et. al. (1995) recommend a bilinear strength envelope (c = 100 psf; phi = 33 degrees) for MSW materials as shown on **Figure 3**. This envelope represents a lower bound to the MSW strength data collected in that study. Also shown on **Figure 3** is the strength envelope recommended by Eid et. al. (c = 500 psf; phi = 35 degrees). Note that the strength envelope used in this analysis is conservatively below the Kavazanjian and Eid values for MSW. Note that, based on typical soil strength properties for sands (Das), the shear strength values assumed for the landfill subgrade (shown in **Table 2**) are conservative considering actual subgrade conditions.

Also as shown in **Table 2**, the assumed shear strength for the liner system is defined by c = 0 psf and phi = 20 degrees. Note that based on performing a parametric analysis of the worst case slope stability cross section, an interface shear strength envelope defined by c = 0 psf and phi = 17 degrees is the minimum required for liner system components to satisfy minimum static factor of safety. The actual interface shear strength properties for the liner system interfaces should be confirmed prior to construction of the base liner system. Based on this evaluation, GNRA recommends the use of a textured geomembrane and reinforced GCL (if used) on this project to satisfy minimum slope stability factors of safety.

2.2 Protective Cover Veneer Stability

Stability of the protective cover layer on interior side slopes was modeled by a veneer approach. The critical interfaces are the ones on either side of the base geosynthetics.

The stability calculations, provided in **Appendix B**, show that an interface shear strength envelope defined by c = 0 psf and phi = 27 degrees is the minimum required for liner system components to satisfy minimum slope stability factors of safety. This envelope is conservative at low (≤ 500 psf) normal loads for each of the geosynthetic/soil or geosynthetic/geosynthetic interfaces to be used. The minimum factor of safety is 1.5 for static conditions. Note that the stability of the internal side slopes will increase as waste is placed in the landfill. The actual interface properties for the geosynthetic interfaces should be confirmed prior to construction of the interior side slopes.

2.3 Final Cover Veneer Stability

Stability of the final cover side slope was modeled by a veneer approach. The critical interfaces are the ones on either side of the final cover geosynthetics.

The final cover side slope has been designed with a drainage layer (drainage geocomposite) and will have adequate drains slope drains along its 4H:1V slope to relieve excess pore water pressure that may adversely affect stability of the cover soil overlying the geomembrane.

The stability calculations, provided in **Appendix C**, show that an interface shear strength envelope defined by c = 0 psf and phi = 24 degrees is the minimum required for liner system components to satisfy minimum slope stability factors of safety. This envelope is conservative at low (≤ 500 psf) normal loads for each of the geosynthetic/soil or geosynthetic/geosynthetic interfaces to be used. The minimum factor of safety is 1.5 for static conditions. The actual interface properties for the geosynthetic interfaces should be confirmed prior to construction of the final cover side slopes.

3.0 FOUNDATION SETTLEMENT

The anticipated total and differential settlements of the Area 2 foundation were estimated under maximum Area 2 loading. These values do not include subsidence of the waste itself, only settlement of the subgrade soils. The settlement analysis evaluated both elastic and consolidation settlement at various points in the landfill in predicting total and differential settlements.

Based upon site boring information, Area 2 is generally underlain by 5 to 20 feet of loose to medium dense silty and clayey sands (SM and SC), a stiff to very hard clay of varying thickness, and mudstone.

Settlement calculations were performed on the worst case cross section (see **Figure 4**) through the landfill (e.g. a section including the highest waste depths and along the slope of the base grades) to estimate the total and differential foundation settlements due to the weight of the planned waste and embankment loads. The resulting post-settlement slopes were evaluated to ensure that 1) positive drainage (2% min. post-settlement slope along base grades) is maintained toward collection piping and/or sumps and 2) the maximum tensile strains in the liner system do not exceed allowable values.

The settlement calculations show that maximum total foundation settlement will be approximately 0.7 feet and that a 2% min. post-settlement slope will be maintained along base grades. Additionally, strains resulting from differential settlements are expected to be negligible meaning that no adverse impacts on the function of the leachate collection or liner systems are anticipated.

Foundation settlement calculations are provided in **Appendix D.**

4.0 BEARING CAPACITY

Both the bearing capacity of the subgrade materials beneath the landfill footprint and the bearing capacity of the leachate collection system under anticipated construction and operations equipment loads were evaluated. Based on the anticipated conditions, the overall landfill and the leachate collection system have adequate bearing capacity. The evaluation of the equipment loads also demonstrates the required separation between equipment and the underlying geomembrane.

Bearing capacity calculations are provided in **Appendix E.**

5.0 REFERENCES

1- Frankel, A.D., Peterson, M.D., et. al (2002), "Documentation for the 2002 Update of the National Seismic Hazard Maps," U.S. Geological Survey Open-File Report 02-420.

2- Richardson, G.N., Kavazanjian, E., and Matasovic, N. (1995), RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities, EPA/600/R-

95/051, U.S. Environmental Protection Agency, Washington, D.C.

3- Kavazanjian, E., Bonaparte, R., and Schmertmann, G.R. (1995), "Evaluation of MSW Properties for Seismic Analysis," Proceedings of the *Geoenvironment 2000* Specialty Conference, ASCE, Vol. 2, pp. 1126-1141, New Orleans, LA, 24-26 February 1995.

4- Eid, H.T., Stark, T.D., Evans, W.D., and Sherry, P.E. (2000), "Municipal Solid Waste Slope Failure. I: Waste and Foundation Soil Properties," *Journal of Geotechnical and Geoenvironmental Engineering*, ASCE, Vol. 126, No. 5, pp. 397-407.

5- Das, B.M. (1990), Principles of Foundation Engineering, 2nd Ed., PWS-Kent Publishing Co., Boston, p. 89.

TABLE 1: RESULTS OF SLOPE STABILITY ANALYSES

CROSS SECTION	FAILURE TYPE	FACTOR OF SAFETY[1]
		STATIC
A	Block Along Liner	2.1
	Circular - Global	2.0
B	Block Along Liner	1.8
	Circular - Global	1.6
N/A	Protective Cover Veneer	1.5
N/A	Final Cover Veneer	1.5

Notes:

1. See **Table 2** for material properties used in each run.

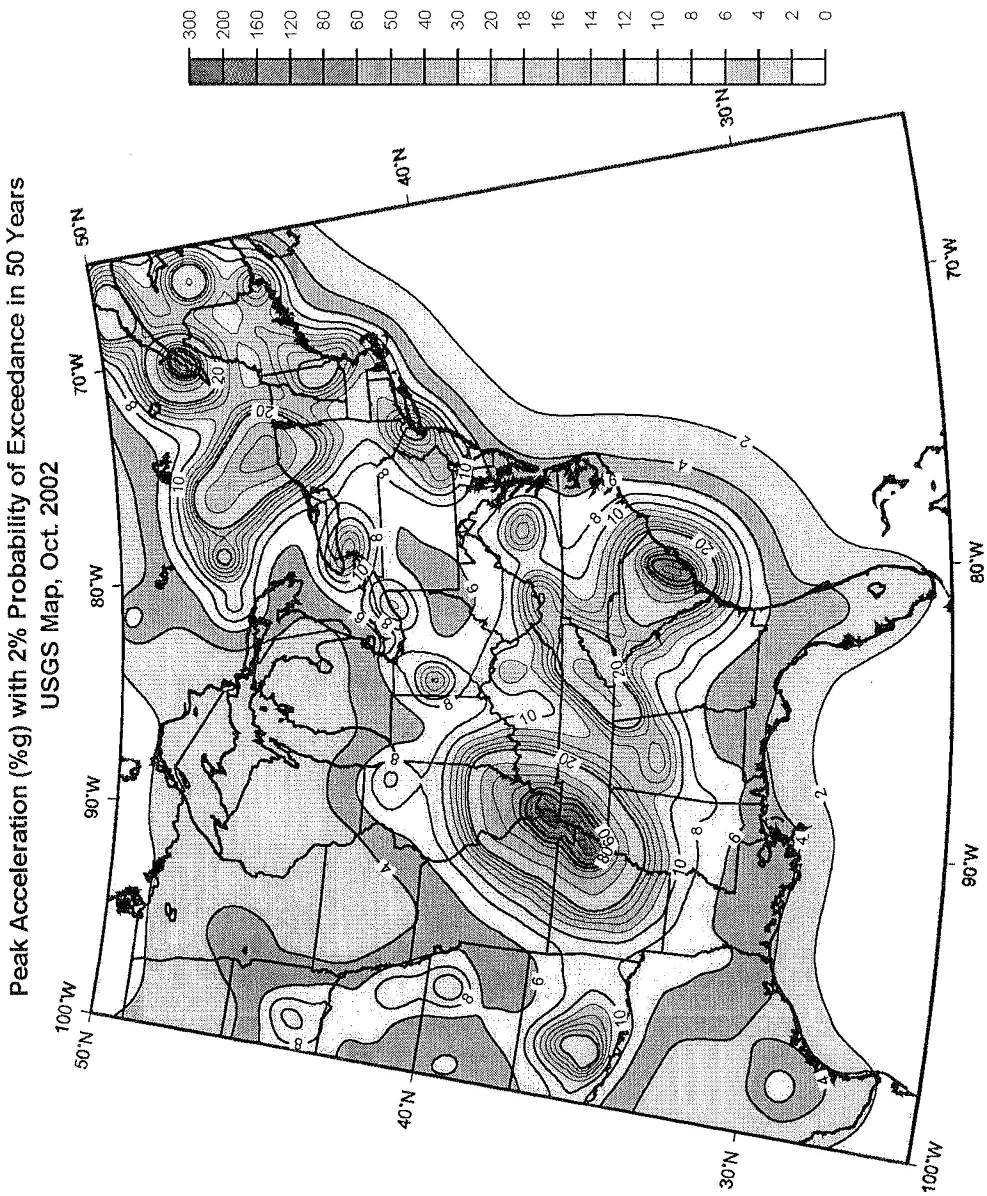
TABLE 2: MATERIAL PROPERTIES USED IN SLOPE STABILITY ANALYSES

MATERIAL TYPE	UNIT WEIGHT (pcf)	COHESION, *c* (psf)	PHI, ϕ (degrees)
C&D Waste	70	100	30
Liner: (Text. Geomembrane Interface)[1]	110	0	20
Subgrade	110	0	20
Protective Cover Veneer[2]	110	0	27
Final Cover Veneer[2]	110	0	24

Notes:

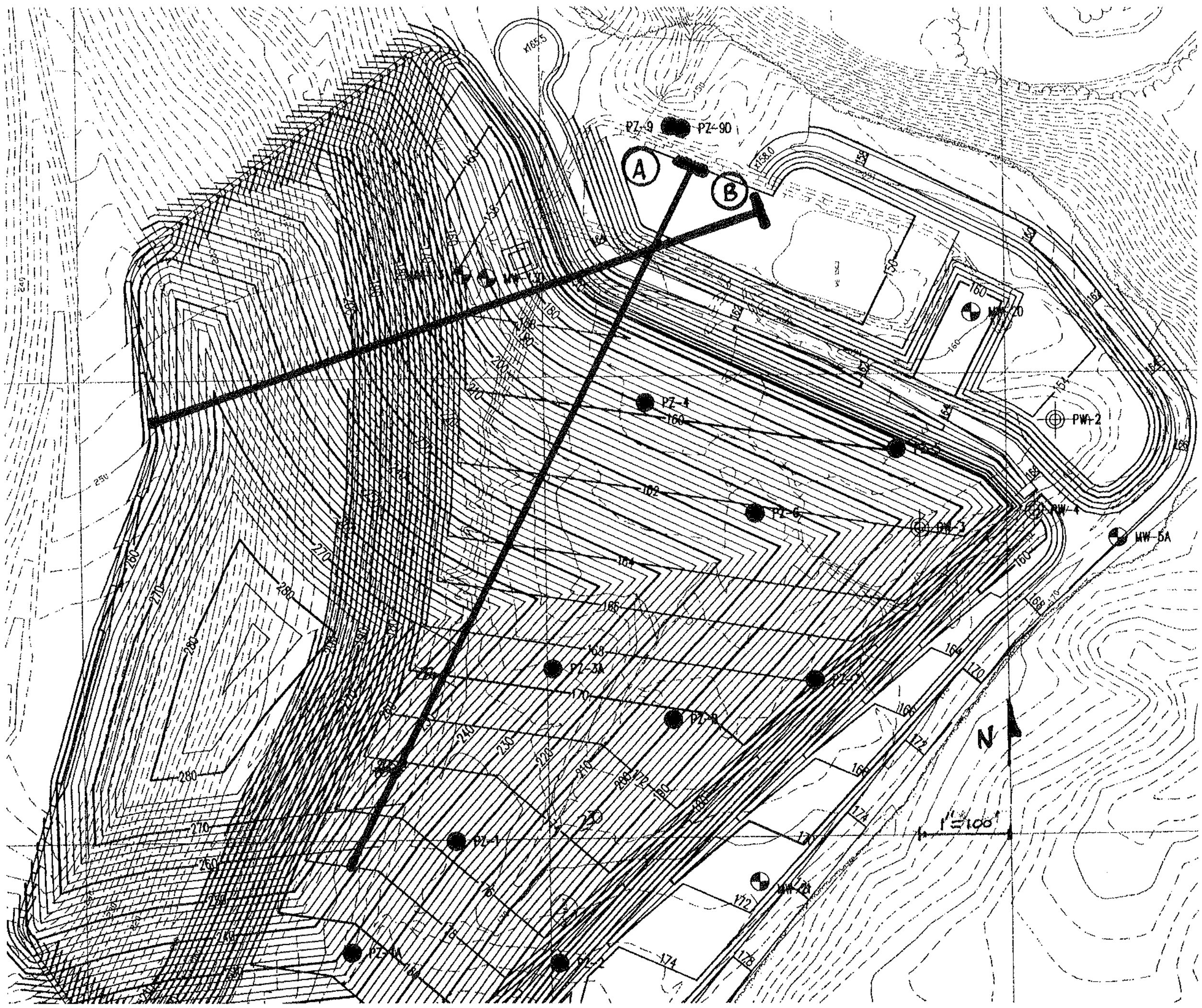
1. A parametric evaluation of the worst case slope stability run (Cross Section A - Static) revealed that an interface shear strength envelope defined by at least c = 0 psf and phi = 17 degrees would be required to satisfy the minimum required static FS value of 1.5.

2. Cohesion and phi angles given for protective cover and final cover veneer are minimum required to satisfy the required factors of safety under low ($\leq$ 500 psf) normal loads.



USGS SEISMIC HAZARD MAP	**G.N. RICHARDSON & ASSOCIATES** Engineering and Geological Services 14 N. Boylan Ave. ph: 919-828-0577 Raleigh, NC 27603 fax: 919-828-3899

SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
NOT TO SCALE	OTHERS	PKS	OCT. 2005	JOHNSTON-22	1



LOCATION OF SLOPE STABILITY
CROSS SECTIONS

G.N. RICHARDSON & ASSOCIATES
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fax: 919-828-3899

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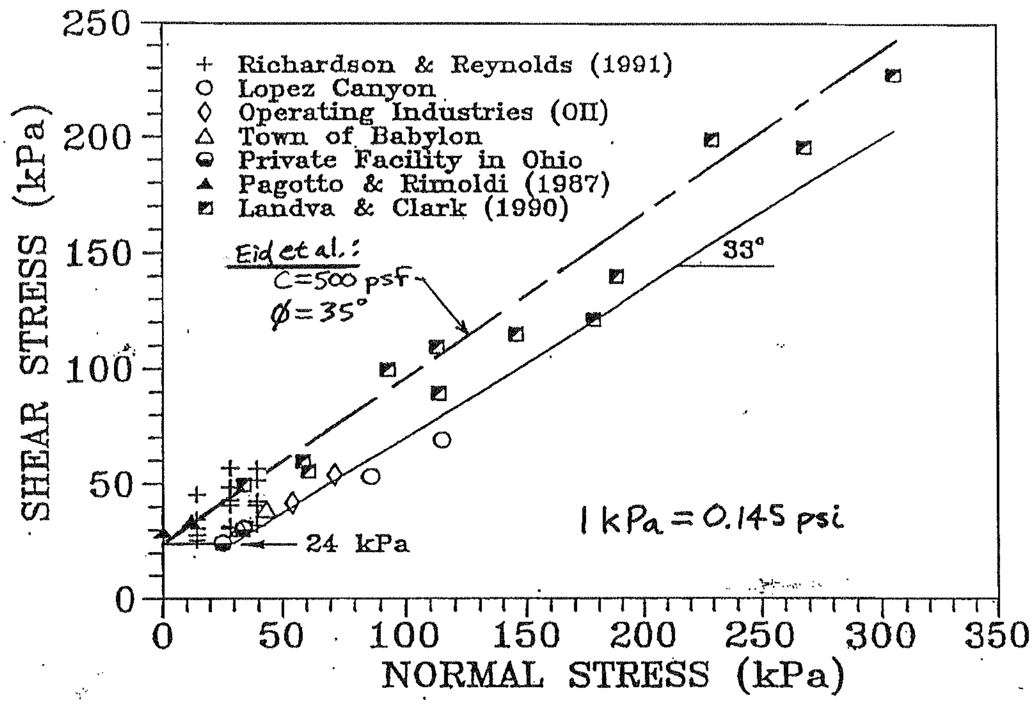
AS SHOWN	OTHERS	PKS	OCT. 2005	JOHNSTON-22	2



SHEAR STRENGTH OF MUNICIPAL SOLID WASTE	G.N. RICHARDSON & ASSOCIATES Engineering and Geological Services 14 N. Boylan Ave. ph: 919-828-0577 Raleigh, NC 27603 fax: 919-828-3899

SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
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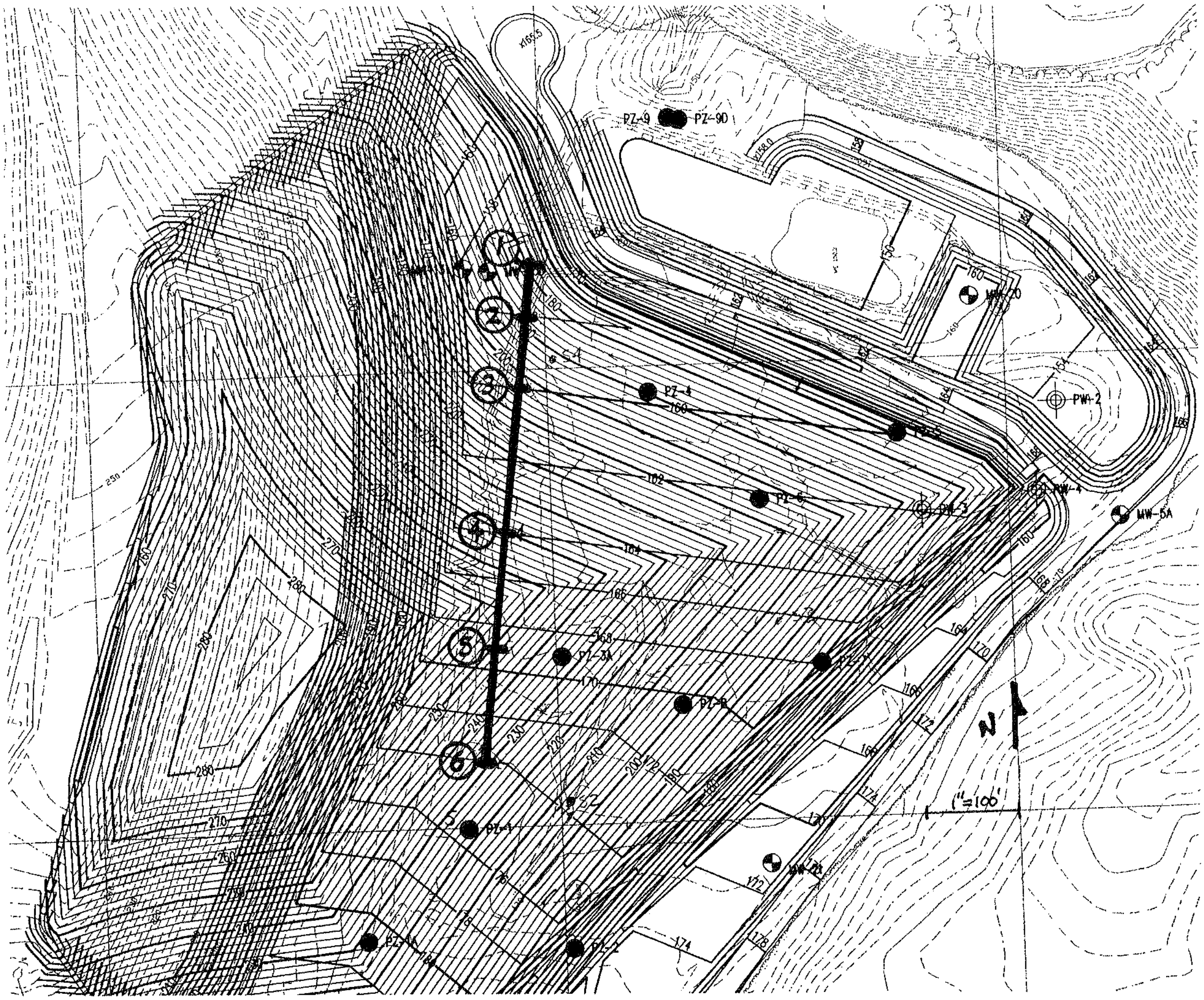

LOCATION OF SETTLEMENT CROSS SECTION

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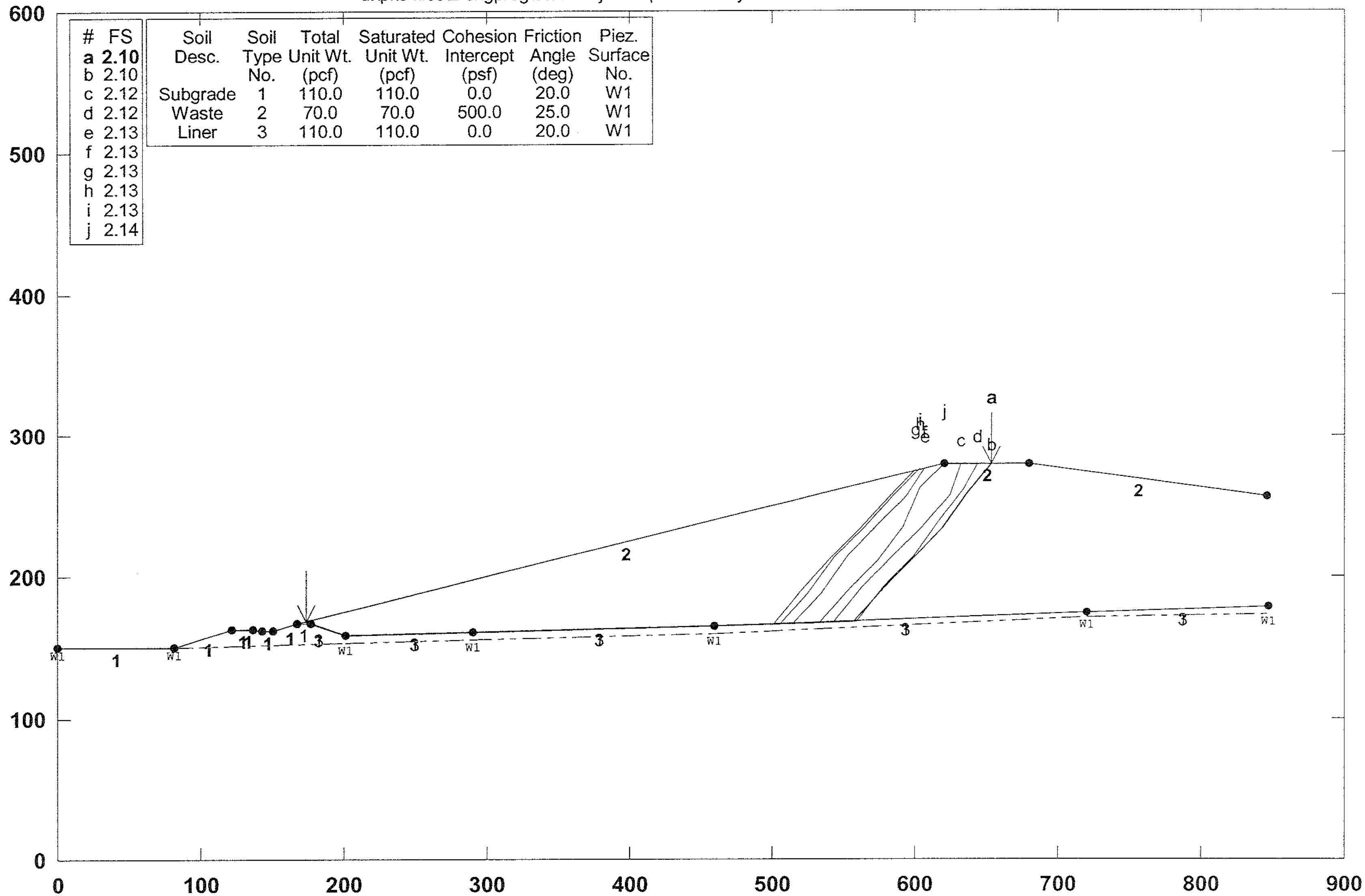
SCALE:	DRAWN BY:	CHECKED BY:	DATE:	PROJECT NO.	FIGURE NO.
AS SHOWN	OTHERS	PKS	OCT. 2005	JOHNSTON-22	4

Appendix A

Slope Stability Analyses

Johnston County C&DLF - Area 2 Section A - Block Liner Static

d:\pks files\2 engprog\stedwin\jcabls.pl2   Run By: Pieter Scheer   9/27/2005   05:58PM



PCSTABL5M/si FSmin=2.10

Safety Factors Are Calculated By The Modified Janbu Method

STED

1/28

2/28

** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 9/27/2005
Time of Run: 05:58PM
Run By: Pieter Scheer
Input Data Filename: D:jcabls.in
Output Filename: D:jcabls.OUT
Unit: ENGLISH
Plotted Output Filename: D:jcabls.PLT
PROBLEM DESCRIPTION Johnston County C&DLF - Area 2
Section A - Block Liner Static

BOUNDARY COORDINATES
9 Top Boundaries
20 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	150.00	82.00	150.00	1
2	82.00	150.00	122.00	163.50	1
3	122.00	163.50	137.00	163.50	1
4	137.00	163.50	143.00	161.50	1
5	143.00	161.50	150.00	161.50	1
6	150.00	161.50	167.00	167.00	1
7	167.00	167.00	620.00	280.00	2
8	620.00	280.00	680.00	280.00	2
9	680.00	280.00	846.00	256.00	2
10	167.00	167.00	177.00	167.00	1
11	177.00	167.00	201.00	159.00	3
12	201.00	159.00	290.00	161.00	3
13	290.00	161.00	460.00	165.00	3
14	460.00	165.00	720.00	175.00	3
15	720.00	175.00	847.00	179.00	3
16	177.00	166.80	201.00	158.80	1
17	201.00	158.80	290.00	160.80	1
18	290.00	160.80	460.00	164.80	1
19	460.00	164.80	720.00	174.80	1
20	720.00	174.80	847.00	178.80	1

ISOTROPIC SOIL PARAMETERS
3 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	110.0	110.0	.0	20.0	.00	.0	1
2	70.0	70.0	500.0	25.0	.00	.0	1
3	110.0	110.0	.0	20.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 7 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	150.00
2	82.00	150.00
3	201.00	154.00
4	290.00	156.00
5	460.00	160.00
6	720.00	171.00
7	847.00	174.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Sliding Block Surfaces, Has Been Specified.
500 Trial Surfaces Have Been Generated.
5 Boxes Specified For Generation Of Central Block Base
Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 30.0

3/28

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	177.00	166.90	177.00	166.90	.00
2	201.00	158.90	201.00	158.90	.00
3	290.00	160.90	290.00	160.90	.00
4	460.00	164.90	460.00	164.90	.00
5	460.01	164.90	720.00	174.90	.00

Factor Of Safety Calculation Has Gone Through Ten Iterations

The Trial Failure Surface In Question Is Defined
By The Following 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.88	168.72
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	488.49	166.00
7	488.59	196.00
8	501.91	222.88
9	523.11	244.09
10	527.02	256.81

Factor Of Safety For The Preceding Specified Surface = 5.242

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 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.96	168.74
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	556.54	168.61
7	577.51	190.06
8	598.58	211.42
9	618.90	233.49
10	636.38	257.87
11	652.85	280.00

*** 2.101 ***

Individual data on the 13 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	2.9	246.5	.0	.0	.0	.0	.0	.0	.0
2	.2	29.5	.0	.0	.0	.0	.0	.0	.0
3	24.0	16203.6	.0	.0	.0	.0	.0	.0	.0
4	89.0	166582.9	.0	.0	.0	.0	.0	.0	.0
5	170.0	666904.1	.0	.0	.0	.0	.0	.0	.0
6	96.5	577307.0	.0	.0	.0	.0	.0	.0	.0
7	.1	681.3	.0	.0	.0	.0	.0	.0	.0
8	20.9	127719.8	.0	.0	.0	.0	.0	.0	.0
9	21.1	105140.0	.0	.0	.0	.0	.0	.0	.0
10	20.3	77835.2	.0	.0	.0	.0	.0	.0	.0
11	1.1	3520.5	.0	.0	.0	.0	.0	.0	.0
12	16.4	38476.3	.0	.0	.0	.0	.0	.0	.0
13	16.5	12756.2	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.96	168.74
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90

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5	460.00	164.90
6	556.54	168.61
7	577.51	190.06
8	598.58	211.42
9	618.90	233.49
10	636.38	257.87
11	652.85	280.00

*** 2.101 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	174.64	168.91
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	543.65	168.12
7	562.71	191.29
8	583.66	212.76
9	604.87	233.98
10	624.15	256.96
11	632.05	280.00

*** 2.115 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.90	168.72
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	559.20	168.72
7	577.86	192.21
8	599.07	213.43
9	616.67	237.72
10	634.32	261.98
11	643.37	280.00

*** 2.123 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.53	168.63
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	514.58	167.00
7	535.07	188.91
8	552.22	213.53
9	573.30	234.87
10	594.47	256.13
11	607.18	276.80

*** 2.125 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.53	168.63
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	514.58	167.00
7	535.07	188.91
8	552.22	213.53
9	573.30	234.87
10	594.47	256.13
11	607.18	276.80

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*** 2.125 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	172.87	168.46
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	500.81	166.47
7	519.86	189.64
8	540.40	211.51
9	561.36	232.97
10	581.34	255.35
11	600.53	275.14

*** 2.126 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	174.53	168.88
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	504.87	166.63
7	525.54	188.37
8	542.87	212.86
9	563.98	234.17
10	584.77	255.80
11	603.38	275.85

*** 2.131 ***

Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	174.53	168.88
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	504.87	166.63
7	525.54	188.37
8	542.87	212.86
9	563.98	234.17
10	584.77	255.80
11	603.38	275.85

*** 2.131 ***

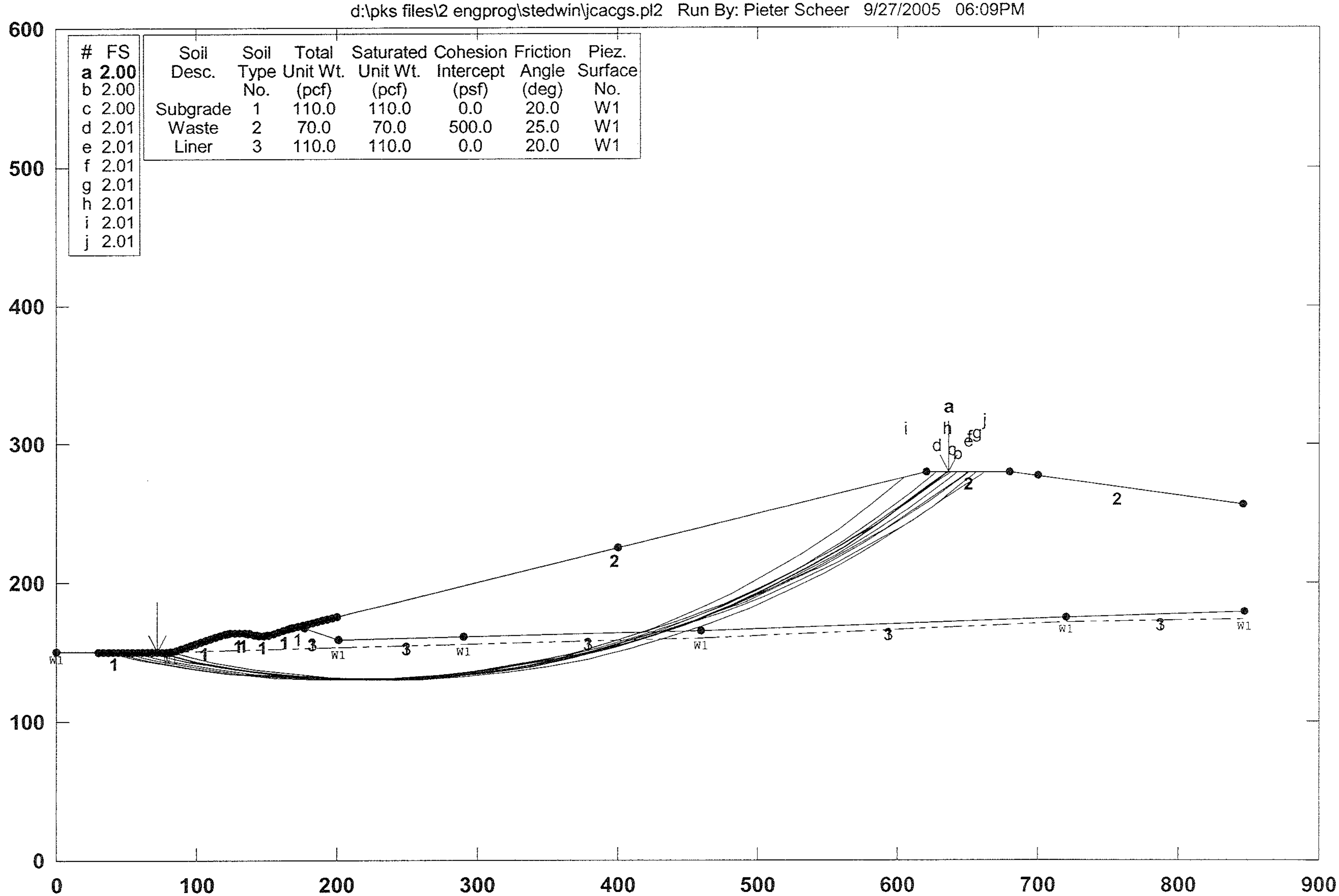
Failure Surface Specified By 11 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	173.80	168.70
2	177.00	166.90
3	201.00	158.90
4	290.00	160.90
5	460.00	164.90
6	532.10	167.67
7	552.53	189.65
8	573.50	211.10
9	592.08	234.65
10	603.55	262.37
11	620.15	280.00

*** 2.135 ***

Johnston County C&DLF - Area 2 Section A - Circular Global Static

d:\pks files\2 engprog\stedwin\jcacgs.pl2   Run By: Pieter Scheer   9/27/2005   06:09PM



PCSTABL5M/si FSmin=2.00
Safety Factors Are Calculated By The Modified Bishop Method

STED

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** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 9/27/2005
Time of Run: 06:09PM
Run By: Pieter Scheer
Input Data Filename: D:jcacgs.in
Output Filename: D:jcacgs.OUT
Unit: ENGLISH
Plotted Output Filename: D:jcacgs.PLT
PROBLEM DESCRIPTION Johnston County C&DLF - Area 2
Section A - Circular Global Static

BOUNDARY COORDINATES
9 Top Boundaries
20 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	150.00	82.00	150.00	1
2	82.00	150.00	122.00	163.50	1
3	122.00	163.50	137.00	163.50	1
4	137.00	163.50	143.00	161.50	1
5	143.00	161.50	150.00	161.50	1
6	150.00	161.50	167.00	167.00	1
7	167.00	167.00	620.00	280.00	2
8	620.00	280.00	680.00	280.00	2
9	680.00	280.00	846.00	256.00	2
10	167.00	167.00	177.00	167.00	1
11	177.00	167.00	201.00	159.00	3
12	201.00	159.00	290.00	161.00	3
13	290.00	161.00	460.00	165.00	3
14	460.00	165.00	720.00	175.00	3
15	720.00	175.00	847.00	179.00	3
16	177.00	166.80	201.00	158.80	1
17	201.00	158.80	290.00	160.80	1
18	290.00	160.80	460.00	164.80	1
19	460.00	164.80	720.00	174.80	1
20	720.00	174.80	847.00	178.80	1

ISOTROPIC SOIL PARAMETERS
3 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	110.0	110.0	.0	20.0	.00	.0	1
2	70.0	70.0	500.0	25.0	.00	.0	1
3	110.0	110.0	.0	20.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 7 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	150.00
2	82.00	150.00
3	201.00	154.00
4	290.00	156.00
5	460.00	160.00
6	720.00	171.00
7	847.00	174.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.
2500 Trial Surfaces Have Been Generated.
50 Surfaces Initiate From Each Of 50 Points Equally Spaced Along The Ground Surface Between X = 30.00 ft.
and X = 200.00 ft.
Each Surface Terminates Between X = 400.00 ft.

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and X = 700.00 ft.

Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is Y =130.00 ft.
30.00 ft. Line Segments Define Each Trial Failure Surface.

****** ERROR - RC11 ******

>>200 attempts to generate failure surface have failed. Revise limitations

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 Bishop Method * *

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	71.63	150.00
2	100.86	143.22
3	130.37	137.84
4	160.11	133.87
5	190.00	131.33
6	219.98	130.21
7	249.98	130.53
8	279.93	132.27
9	309.76	135.44
10	339.40	140.03
11	368.80	146.03
12	397.87	153.42
13	426.56	162.19
14	454.80	172.32
15	482.53	183.78
16	509.67	196.55
17	536.18	210.61
18	561.98	225.90
19	587.03	242.42
20	611.26	260.10
21	634.62	278.93
22	635.83	280.00

Circle Center At X = 228.4 ; Y = 759.0 and Radius, 628.9

*** 1.998 ***

Individual data on the 34 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	10.4	1371.5	.0	798.7	.0	.0	.0	.0	.0
2	18.9	16127.5	.0	5927.5	.0	.0	.0	.0	.0
3	21.1	43351.1	.0	12996.7	.0	.0	.0	.0	.0
4	8.4	22924.5	.0	6835.9	.0	.0	.0	.0	.0
5	6.6	19034.8	.0	5981.1	.0	.0	.0	.0	.0
6	6.0	17123.4	.0	5811.3	.0	.0	.0	.0	.0
7	7.0	19874.9	.0	7258.0	.0	.0	.0	.0	.0
8	10.1	31783.3	.0	11388.0	.0	.0	.0	.0	.0
9	6.9	24493.7	.0	8266.5	.0	.0	.0	.0	.0
10	10.0	38425.6	.0	12620.6	.0	.0	.0	.0	.0
11	13.0	52833.1	.0	17516.5	.0	.0	.0	.0	.0
12	11.0	46173.4	.0	15577.9	.0	.0	.0	.0	.0
13	19.0	84559.4	.0	28015.7	.0	.0	.0	.0	.0
14	30.0	147793.6	.0	45651.5	.0	.0	.0	.0	.0
15	29.9	160641.3	.0	44985.1	.0	.0	.0	.0	.0
16	10.1	56176.5	.0	14585.7	.0	.0	.0	.0	.0
17	19.8	112151.5	.0	27069.4	.0	.0	.0	.0	.0
18	29.6	170853.8	.0	35699.8	.0	.0	.0	.0	.0
19	29.4	168251.5	.0	27093.2	.0	.0	.0	.0	.0
20	29.1	160653.5	.0	15851.2	.0	.0	.0	.0	.0
21	18.1	95159.5	.0	3025.3	.0	.0	.0	.0	.0
22	10.6	53109.8	.0	.0	.0	.0	.0	.0	.0
23	5.4	26582.6	.0	.0	.0	.0	.0	.0	.0
24	.6	2881.8	.0	.0	.0	.0	.0	.0	.0
25	22.2	105221.9	.0	.0	.0	.0	.0	.0	.0

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26	27.7	124586.2	.0	.0	.0	.0	.0	.0	.0
27	27.1	111967.6	.0	.0	.0	.0	.0	.0	.0
28	26.5	96860.7	.0	.0	.0	.0	.0	.0	.0
29	25.8	79579.1	.0	.0	.0	.0	.0	.0	.0
30	25.0	60472.5	.0	.0	.0	.0	.0	.0	.0
31	24.2	39923.7	.0	.0	.0	.0	.0	.0	.0
32	8.7	9349.7	.0	.0	.0	.0	.0	.0	.0
33	14.6	7127.9	.0	.0	.0	.0	.0	.0	.0
34	1.2	45.4	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 22 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	64.69	150.00
2	93.97	143.45
3	123.51	138.24
4	153.26	134.37
5	183.16	131.85
6	213.14	130.68
7	243.13	130.88
8	273.09	132.43
9	302.95	135.34
10	332.65	139.60
11	362.12	145.20
12	391.31	152.13
13	420.16	160.38
14	448.60	169.92
15	476.58	180.74
16	504.04	192.82
17	530.93	206.13
18	557.18	220.64
19	582.75	236.33
20	607.59	253.15
21	631.64	271.09
22	642.51	280.00

Circle Center At X = 223.8 ; Y = 792.0 and Radius, 661.4

*** 2.003 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	36.94	150.00
2	66.24	143.57
3	95.79	138.39
4	125.53	134.46
5	155.42	131.81
6	185.38	130.42
7	215.38	130.30
8	245.36	131.46
9	275.26	133.88
10	305.03	137.58
11	334.62	142.53
12	363.97	148.73
13	393.04	156.18
14	421.76	164.84
15	450.08	174.72
16	477.97	185.80
17	505.35	198.04
18	532.20	211.43
19	558.45	225.96
20	584.06	241.58
21	608.98	258.27
22	633.18	276.01
23	638.16	280.00

Circle Center At X = 203.1 ; Y = 837.3 and Radius, 707.1

*** 2.004 ***

Failure Surface Specified By 21 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)

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1	71.63	150.00
2	100.87	143.26
3	130.39	137.94
4	160.14	134.07
5	190.04	131.63
6	220.02	130.65
7	250.02	131.12
8	279.96	133.05
9	309.77	136.42
10	339.38	141.24
11	368.72	147.48
12	397.73	155.14
13	426.33	164.19
14	454.46	174.62
15	482.05	186.40
16	509.04	199.50
17	535.36	213.89
18	560.95	229.55
19	585.76	246.42
20	609.71	264.48
21	628.36	280.00

Circle Center At X = 225.3 ; Y = 749.6 and Radius, 619.0

*** 2.005 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	43.88	150.00
2	73.20	143.67
3	102.77	138.57
4	132.52	134.70
5	162.40	132.08
6	192.37	130.70
7	222.37	130.57
8	252.35	131.69
9	282.25	134.06
10	312.04	137.67
11	341.64	142.51
12	371.02	148.59
13	400.12	155.88
14	428.89	164.38
15	457.28	174.07
16	485.25	184.94
17	512.74	196.95
18	539.70	210.11
19	566.09	224.37
20	591.87	239.72
21	616.98	256.13
22	641.39	273.57
23	649.64	280.00

Circle Center At X = 210.5 ; Y = 850.8 and Radius, 720.4

*** 2.006 ***

Failure Surface Specified By 23 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	50.82	150.00
2	80.14	143.64
3	109.70	138.53
4	139.45	134.67
5	169.33	132.07
6	199.31	130.74
7	229.31	130.67
8	259.28	131.87
9	289.18	134.34
10	318.95	138.07
11	348.53	143.05
12	377.88	149.28
13	406.94	156.74

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     14          435.65       165.42
     15          463.98       175.30
     16          491.86       186.38
     17          519.25       198.62
     18          546.09       212.01
     19          572.35       226.52
     20          597.97       242.13
     21          622.91       258.80
     22          647.12       276.52
     23          651.48       280.00
 Circle Center At X =   215.9 ; Y =   840.6  and Radius,   710.0
        ***      2.006    ***
 Failure Surface Specified By 22 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
      1          82.04       150.01
      2         111.30       143.38
      3         140.83       138.10
      4         170.57       134.19
      5         200.47       131.64
      6         230.44       130.47
      7         260.44       130.67
      8         290.40       132.25
      9         320.25       135.21
     10         349.94       139.53
     11         379.40       145.22
     12         408.56       152.25
     13         437.37       160.61
     14         465.77       170.28
     15         493.69       181.25
     16         521.08       193.49
     17         547.88       206.97
     18         574.03       221.68
     19         599.48       237.56
     20         624.17       254.60
     21         648.06       272.75
     22         656.73       280.00
 Circle Center At X =   241.0 ; Y =   782.8  and Radius,   652.4
        ***      2.010    ***
 Failure Surface Specified By 22 Coordinate Points
   Point       X-Surf       Y-Surf
    No.         (ft)         (ft)
      1          61.22       150.00
      2          90.53       143.57
      3         120.09       138.48
      4         149.86       134.73
      5         179.76       132.34
      6         209.74       131.31
      7         239.74       131.64
      8         269.69       133.33
      9         299.54       136.37
     10         329.21       140.77
     11         358.66       146.51
     12         387.81       153.59
     13         416.62       161.98
     14         445.01       171.66
     15         472.94       182.63
     16         500.33       194.85
     17         527.15       208.30
     18         553.33       222.95
     19         578.81       238.78
     20         603.55       255.75
     21         627.50       273.82
     22         634.95       280.00
 Circle Center At X =   217.5 ; Y =   791.4  and Radius,   660.2
        ***      2.012    ***
 Failure Surface Specified By 21 Coordinate Points
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Point No.	X-Surf (ft)	Y-Surf (ft)
1	71.63	150.00
2	100.81	143.02
3	130.31	137.57
4	160.05	133.65
5	189.96	131.27
6	219.95	130.44
7	249.94	131.17
8	279.85	133.45
9	309.61	137.27
10	339.13	142.63
11	368.33	149.51
12	397.13	157.89
13	425.46	167.75
14	453.25	179.07
15	480.41	191.80
16	506.88	205.93
17	532.58	221.40
18	557.44	238.19
19	581.40	256.24
20	604.40	275.51
21	605.29	276.33

Circle Center At X = 220.9 ; Y = 709.9 and Radius, 579.5

*** 2.014 ***

Failure Surface Specified By 24 Coordinate Points

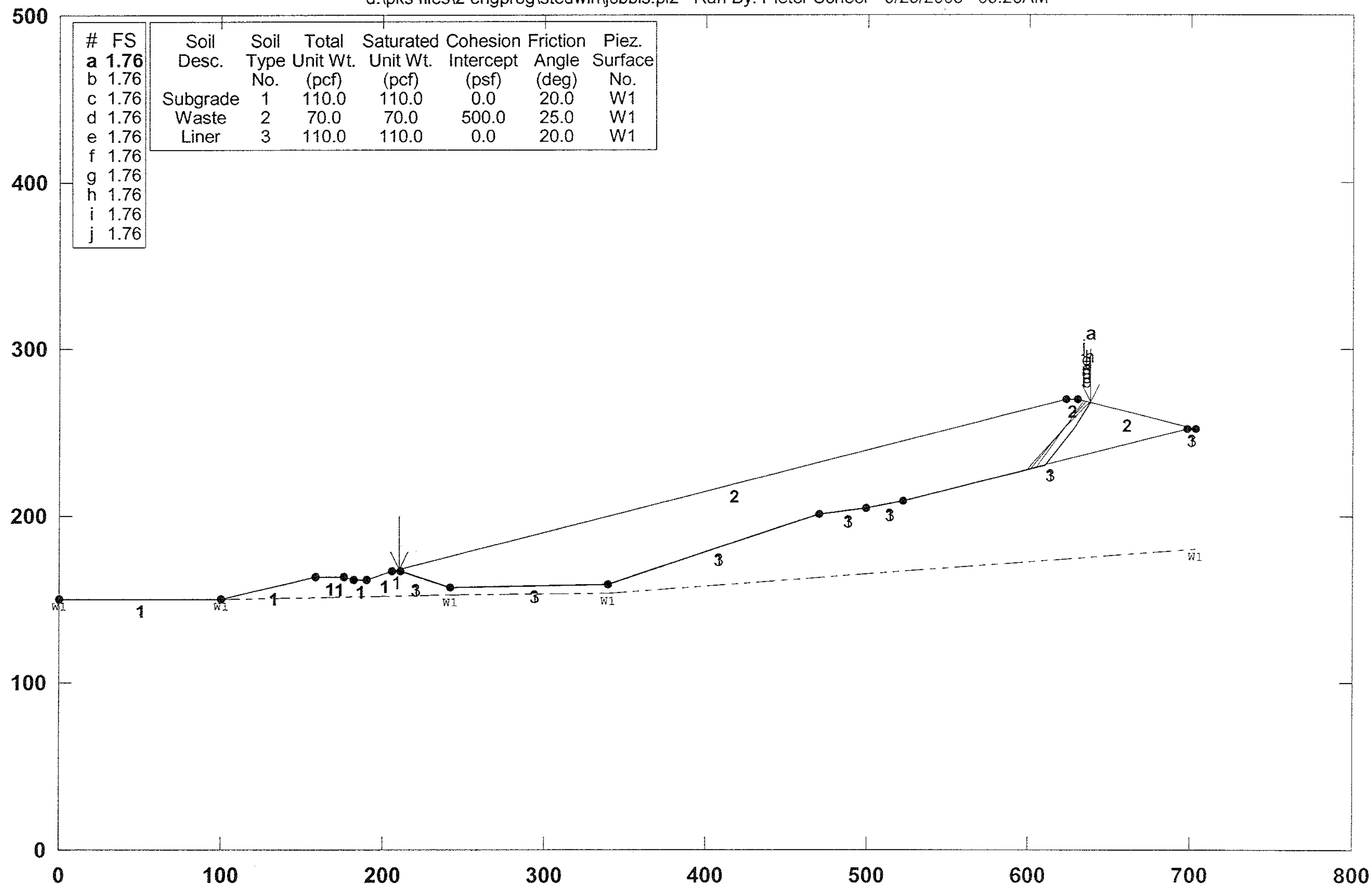
Point No.	X-Surf (ft)	Y-Surf (ft)
1	33.47	150.00
2	62.82	143.78
3	92.39	138.72
4	122.13	134.82
5	152.01	132.08
6	181.97	130.51
7	211.96	130.12
8	241.95	130.91
9	271.89	132.86
10	301.73	135.99
11	331.42	140.28
12	360.92	145.72
13	390.19	152.32
14	419.17	160.06
15	447.83	168.93
16	476.12	178.91
17	504.00	189.99
18	531.42	202.16
19	558.35	215.38
20	584.74	229.65
21	610.55	244.95
22	635.74	261.24
23	660.27	278.50
24	662.24	280.00

Circle Center At X = 207.0 ; Y = 896.4 and Radius, 766.3

*** 2.014 ***

Johnston County C&DLF - Area 2 Section B - Block Liner Static

d:\pks files\2 engprog\stedwin\jcbbls.pl2 Run By: Pieter Scheer 9/29/2005 09:26AM



PCSTABL5M/si FSmin=1.76
Safety Factors Are Calculated By The Modified Janbu Method

STED

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**** PCSTABL5M ****
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 9/29/2005
Time of Run: 09:26AM
Run By: Pieter Scheer
Input Data Filename: D:jcbbls.in
Output Filename: D:jcbbls.OUT
Unit: ENGLISH
Plotted Output Filename: D:jcbbls.PLT
PROBLEM DESCRIPTION Johnston County C&DLF - Area 2
Section B - Block Liner Static

BOUNDARY COORDINATES
9 Top Boundaries
24 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	150.00	100.00	150.00	1
2	100.00	150.00	158.00	163.50	1
3	158.00	163.50	176.00	163.50	1
4	176.00	163.50	182.00	161.50	1
5	182.00	161.50	190.00	161.50	1
6	190.00	161.50	206.00	167.00	1
7	206.00	167.00	623.00	270.00	2

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8	623.00	270.00	630.00	270.00	2
9	630.00	270.00	703.00	252.00	2
10	206.00	167.00	211.00	167.00	1
11	211.00	167.00	242.00	157.50	3
12	242.00	157.50	339.00	159.00	3
13	339.00	159.00	470.00	201.00	3
14	470.00	201.00	499.00	205.00	3
15	499.00	205.00	522.00	209.00	3
16	522.00	209.00	698.00	252.00	3
17	698.00	252.00	703.00	252.00	3
18	211.00	166.80	242.00	157.30	1
19	242.00	157.30	339.00	158.80	1
20	339.00	158.80	470.00	200.80	1
21	470.00	200.80	499.00	204.80	1
22	499.00	204.80	522.00	208.80	1
23	522.00	208.80	698.00	251.80	1
24	698.00	251.80	703.00	251.80	1

ISOTROPIC SOIL PARAMETERS

3 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	110.0	110.0	.0	20.0	.00	.0	1
2	70.0	70.0	500.0	25.0	.00	.0	1
3	110.0	110.0	.0	20.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED

Unit Weight of Water = 62.40

Piezometric Surface No. 1 Specified by 5 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	150.00
2	100.00	150.00
3	242.00	152.50
4	339.00	154.00
5	703.00	180.00

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

1500 Trial Surfaces Have Been Generated.

7 Boxes Specified For Generation Of Central Block Base

Length Of Line Segments For Active And Passive Portions Of Sliding Block Is 30.0

Box No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Height (ft)
1	211.00	166.90	211.00	166.90	.00
2	242.00	157.40	242.00	157.40	.00
3	339.00	158.90	339.00	158.90	.00
4	470.00	200.90	470.00	200.90	.00
5	499.00	204.90	499.00	204.90	.00
6	522.00	208.90	522.00	208.90	.00
7	522.01	208.90	698.00	251.90	.00

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 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.70	167.91
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	609.61	230.30
9	628.65	253.49

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10	638.41	267.93

*** 1.757 ***

Individual data on the 13 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	1.2	49.3	.0	.0	.0	.0	.0	.0	.0
2	.1	11.6	.0	.0	.0	.0	.0	.0	.0
3	31.0	21636.4	.0	.0	.0	.0	.0	.0	.0
4	97.0	202198.4	.0	.0	.0	.0	.0	.0	.0
5	131.0	331836.0	.0	.0	.0	.0	.0	.0	.0
6	29.0	66883.0	.0	.0	.0	.0	.0	.0	.0
7	23.0	56944.7	.0	.0	.0	.0	.0	.0	.0
8	87.6	222785.2	.0	.0	.0	.0	.0	.0	.0
9	.1	264.8	.0	.0	.0	.0	.0	.0	.0
10	13.3	27755.7	.0	.0	.0	.0	.0	.0	.0
11	5.6	7886.3	.0	.0	.0	.0	.0	.0	.0
12	1.4	1469.3	.0	.0	.0	.0	.0	.0	.0
13	8.4	4272.4	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90

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3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.58	167.89
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	598.48	227.58
9	618.74	249.70
10	635.33	268.69

*** 1.757 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.22	167.80
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	601.06	228.21
9	620.44	251.11
10	637.45	268.16

*** 1.758 ***

Failure Surface Specified By 10 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	209.34	167.83
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	604.28	229.00
9	622.10	253.13
10	633.23	269.20

*** 1.758 ***

Failure Surface Specified By 10 Coordinate Points

Point	X-Surf	Y-Surf

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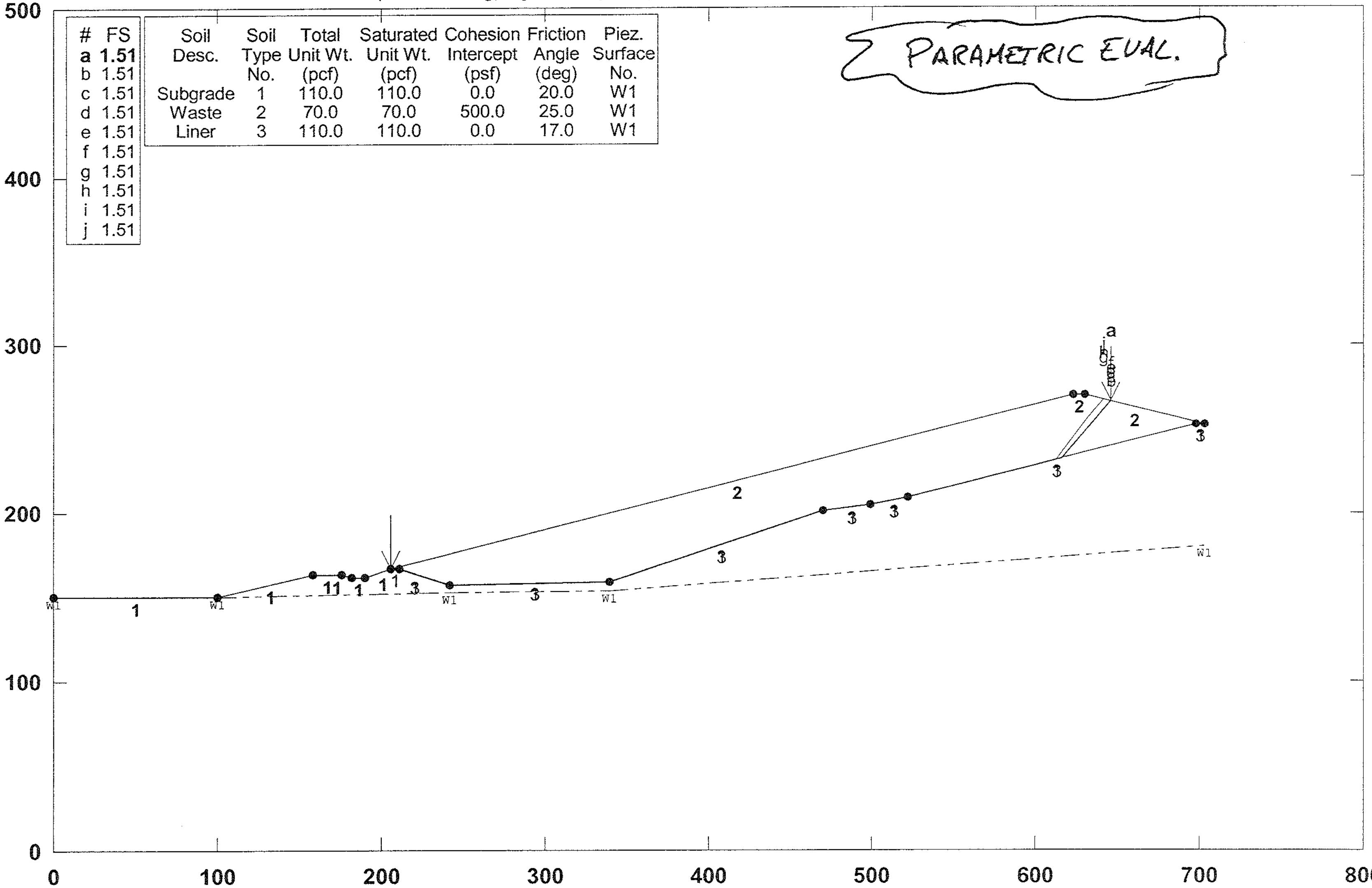
No.	(ft)	(ft)
1	209.34	167.83
2	211.00	166.90
3	242.00	157.40
4	339.00	158.90
5	470.00	200.90
6	499.00	204.90
7	522.00	208.90
8	604.28	229.00
9	622.10	253.13
10	633.23	269.20

*** 1.758 ***

Johnston County C&DLF - Area 2 Section B - Block Liner Static (PMetric)

d:\pks files\2 engprog\stedwin\jcbblsp.pl2 Run By: Pieter Scheer 9/29/2005 09:27AM



PCSTABL5M/si FSmin=1.51

Safety Factors Are Calculated By The Modified Janbu Method

STED

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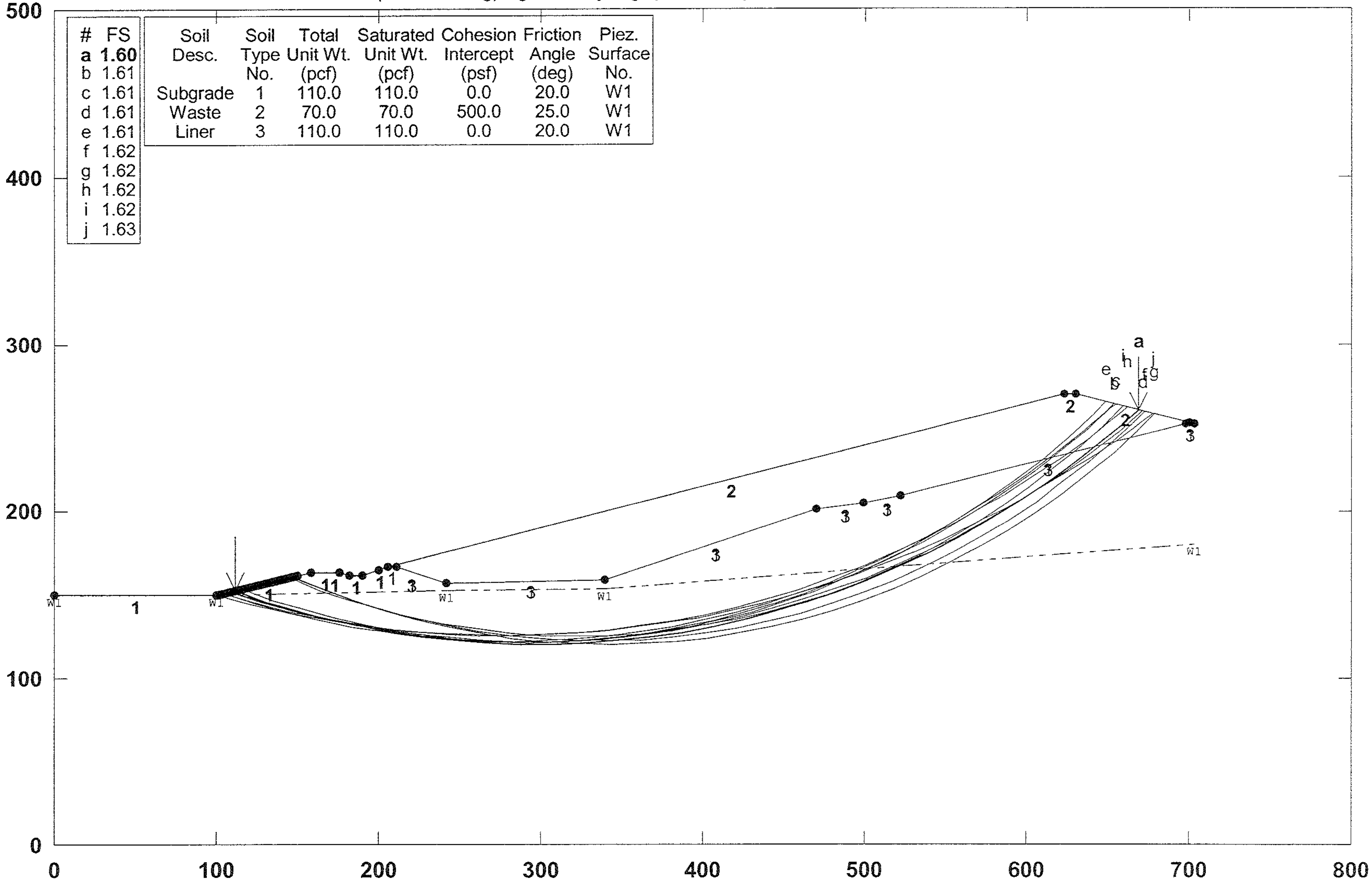
Johnston County C&DLF - Area 2 Section B - Circular Global Static

d:\pks files\2 engprog\stedwin\jcbcgs.pl2 Run By: Pieter Scheer 9/29/2005 09:36AM



#	FS
a	**1.60**
b	1.61
c	1.61
d	1.61
e	1.61
f	1.62
g	1.62
h	1.62
i	1.62
j	1.63

Soil Desc.	Soil Type No.	Total Unit Wt. (pcf)	Saturated Unit Wt. (pcf)	Cohesion Intercept (psf)	Friction Angle (deg)	Piez. Surface No.
Subgrade	1	110.0	110.0	0.0	20.0	W1
Waste	2	70.0	70.0	500.0	25.0	W1
Liner	3	110.0	110.0	0.0	20.0	W1

PCSTABL5M/si FSmin=1.60

Safety Factors Are Calculated By The Modified Bishop Method

STED

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** PCSTABL5M **
by
Purdue University
--Slope Stability Analysis--
Simplified Janbu, Simplified Bishop
or Spencer`s Method of Slices

Run Date: 9/29/2005
Time of Run: 09:36AM
Run By: Pieter Scheer
Input Data Filename: D:jcbcgs.in
Output Filename: D:jcbcgs.OUT
Unit: ENGLISH
Plotted Output Filename: D:jcbcgs.PLT
PROBLEM DESCRIPTION Johnston County C&DLF - Area 2
Section B - Circular Global Static

BOUNDARY COORDINATES
9 Top Boundaries
24 Total Boundaries

Boundary No.	X-Left (ft)	Y-Left (ft)	X-Right (ft)	Y-Right (ft)	Soil Type Below Bnd
1	.00	150.00	100.00	150.00	1
2	100.00	150.00	158.00	163.50	1
3	158.00	163.50	176.00	163.50	1
4	176.00	163.50	182.00	161.50	1
5	182.00	161.50	190.00	161.50	1
6	190.00	161.50	206.00	167.00	1
7	206.00	167.00	623.00	270.00	2
8	623.00	270.00	630.00	270.00	2
9	630.00	270.00	703.00	252.00	2
10	206.00	167.00	211.00	167.00	1
11	211.00	167.00	242.00	157.50	3
12	242.00	157.50	339.00	159.00	3
13	339.00	159.00	470.00	201.00	3
14	470.00	201.00	499.00	205.00	3
15	499.00	205.00	522.00	209.00	3
16	522.00	209.00	698.00	252.00	3
17	698.00	252.00	703.00	252.00	3
18	211.00	166.80	242.00	157.30	1
19	242.00	157.30	339.00	158.80	1
20	339.00	158.80	470.00	200.80	1
21	470.00	200.80	499.00	204.80	1
22	499.00	204.80	522.00	208.80	1
23	522.00	208.80	698.00	251.80	1
24	698.00	251.80	703.00	251.80	1

ISOTROPIC SOIL PARAMETERS
3 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	110.0	110.0	.0	20.0	.00	.0	1
2	70.0	70.0	500.0	25.0	.00	.0	1
3	110.0	110.0	.0	20.0	.00	.0	1

1 PIEZOMETRIC SURFACE(S) HAVE BEEN SPECIFIED
Unit Weight of Water = 62.40
Piezometric Surface No. 1 Specified by 5 Coordinate Points

Point No.	X-Water (ft)	Y-Water (ft)
1	.00	150.00
2	100.00	150.00
3	242.00	152.50
4	339.00	154.00
5	703.00	180.00

A Critical Failure Surface Searching Method, Using A Random Technique For Generating Circular Surfaces, Has Been Specified.
2500 Trial Surfaces Have Been Generated.
50 Surfaces Initiate From Each Of 50 Points Equally Spaced Along The Ground Surface Between X = 100.00 ft.

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                          and   X = 150.00 ft.
Each Surface Terminates Between   X = 200.00 ft.
                          and   X = 700.00 ft.
Unless Further Limitations Were Imposed, The Minimum Elevation
At Which A Surface Extends Is  Y =120.00 ft.
20.00 ft. Line Segments Define Each Trial Failure Surface.
The Factor Of Safety For The Trial Failure Surface Defined
By The Coordinates Listed Below Is Misleading.
Failure Surface Defined By  4 Coordinate Points
  Point       X-Surf       Y-Surf
   No.         (ft)         (ft)
    1         146.94       160.93
    2         165.47       153.41
    3         185.39       155.27
    4         200.88       165.24
Factor Of Safety For The Preceding Specified Surface =-78.325
The Factor Of Safety For The Trial Failure Surface Defined
By The Coordinates Listed Below Is Misleading.
Failure Surface Defined By  4 Coordinate Points
  Point       X-Surf       Y-Surf
   No.         (ft)         (ft)
    1         146.94       160.93
    2         166.36       156.16
    3         186.25       158.25
    4         200.20       165.01
Factor Of Safety For The Preceding Specified Surface =-80.811
The Factor Of Safety For The Trial Failure Surface Defined
By The Coordinates Listed Below Is Misleading.
Failure Surface Defined By  5 Coordinate Points
  Point       X-Surf       Y-Surf
   No.         (ft)         (ft)
    1         150.00       161.64
    2         165.41       148.89
    3         185.41       149.43
    4         200.11       162.99
    5         200.34       165.05
Factor Of Safety For The Preceding Specified Surface =-49.688
The Factor Of Safety For The Trial Failure Surface Defined
By The Coordinates Listed Below Is Misleading.
Failure Surface Defined By  5 Coordinate Points
  Point       X-Surf       Y-Surf
   No.         (ft)         (ft)
    1         150.00       161.64
    2         164.90       148.30
    3         184.90       148.22
    4         199.91       161.44
    5         200.35       165.06
Factor Of Safety For The Preceding Specified Surface =-71.835
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 Bishop Method * *
      Failure Surface Specified By 31 Coordinate Points
        Point       X-Surf       Y-Surf
         No.         (ft)         (ft)
          1         111.22       152.61
          2         130.20       146.29
          3         149.38       140.64
          4         168.76       135.68
          5         188.30       131.42
          6         207.98       127.85
          7         227.77       124.99
          8         247.66       122.84
          9         267.61       121.39
         10         287.59       120.66
         11         307.59       120.64
         12         327.58       121.33
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13	347.53	122.74
14	367.42	124.85
15	387.22	127.68
16	406.90	131.20
17	426.45	135.43
18	445.84	140.35
19	465.04	145.96
20	484.02	152.25
21	502.77	159.21
22	521.26	166.84
23	539.46	175.12
24	557.36	184.04
25	574.93	193.60
26	592.15	203.78
27	608.99	214.56
28	625.44	225.94
29	641.47	237.89
30	657.07	250.41
31	668.71	260.46

Circle Center At X = 298.1 ; Y = 681.6 and Radius, 561.0

*** 1.602 ***

Individual data on the 47 slices

Slice No.	Width (ft)	Weight (lbs)	Water Force Top (lbs)	Water Force Bot (lbs)	Tie Force Norm (lbs)	Tie Force Tan (lbs)	Earthquake Force Hor (lbs)	Earthquake Force Ver (lbs)	Surcharge Load (lbs)
1	6.9	1473.9	.0	.0	.0	.0	.0	.0	.0
2	12.1	9736.1	.0	1688.3	.0	.0	.0	.0	.0
3	19.2	33342.9	.0	9030.7	.0	.0	.0	.0	.0
4	8.6	21758.8	.0	6329.4	.0	.0	.0	.0	.0
5	10.8	31296.5	.0	9741.2	.0	.0	.0	.0	.0
6	7.2	22783.4	.0	7574.3	.0	.0	.0	.0	.0
7	6.0	19175.2	.0	6875.4	.0	.0	.0	.0	.0
8	6.3	20371.5	.0	7802.9	.0	.0	.0	.0	.0
9	1.7	5654.0	.0	2188.7	.0	.0	.0	.0	.0
10	16.0	60879.4	.0	22385.9	.0	.0	.0	.0	.0
11	2.0	8520.1	.0	2994.1	.0	.0	.0	.0	.0
12	3.0	13261.3	.0	4625.6	.0	.0	.0	.0	.0
13	16.8	77435.5	.0	27386.7	.0	.0	.0	.0	.0
14	14.2	69887.1	.0	25136.8	.0	.0	.0	.0	.0
15	5.7	28952.5	.0	10439.3	.0	.0	.0	.0	.0
16	19.9	108914.3	.0	38220.3	.0	.0	.0	.0	.0
17	20.0	118665.7	.0	39963.6	.0	.0	.0	.0	.0
18	20.0	126733.5	.0	40818.5	.0	.0	.0	.0	.0
19	20.0	133073.4	.0	40783.8	.0	.0	.0	.0	.0
20	11.4	78302.6	.0	22984.0	.0	.0	.0	.0	.0
21	8.5	59797.4	.0	16961.7	.0	.0	.0	.0	.0
22	19.9	144950.3	.0	39242.0	.0	.0	.0	.0	.0
23	19.8	150761.8	.0	37932.2	.0	.0	.0	.0	.0
24	19.7	154728.3	.0	35735.0	.0	.0	.0	.0	.0
25	19.5	156853.5	.0	32653.1	.0	.0	.0	.0	.0
26	19.4	157156.0	.0	28690.3	.0	.0	.0	.0	.0
27	19.2	155669.2	.0	23851.9	.0	.0	.0	.0	.0
28	5.0	40084.0	.0	5337.7	.0	.0	.0	.0	.0
29	14.0	111638.0	.0	12806.1	.0	.0	.0	.0	.0
30	15.0	115817.4	.0	9808.6	.0	.0	.0	.0	.0
31	3.8	28518.6	.0	1764.7	.0	.0	.0	.0	.0
32	18.5	135686.6	.0	4148.8	.0	.0	.0	.0	.0
33	.5	3352.6	.0	2.9	.0	.0	.0	.0	.0
34	.3	1936.4	.0	.0	.0	.0	.0	.0	.0
35	17.5	120917.5	.0	.0	.0	.0	.0	.0	.0
36	17.9	115887.5	.0	.0	.0	.0	.0	.0	.0
37	17.6	104328.7	.0	.0	.0	.0	.0	.0	.0
38	17.2	91657.9	.0	.0	.0	.0	.0	.0	.0
39	16.8	78014.0	.0	.0	.0	.0	.0	.0	.0
40	14.0	54951.4	.0	.0	.0	.0	.0	.0	.0
41	2.4	8542.7	.0	.0	.0	.0	.0	.0	.0

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42	4.6	14829.4	.0	.0	.0	.0	.0	.0	.0
43	11.5	29545.2	.0	.0	.0	.0	.0	.0	.0
44	.2	356.0	.0	.0	.0	.0	.0	.0	.0
45	.4	726.1	.0	.0	.0	.0	.0	.0	.0
46	15.1	21951.3	.0	.0	.0	.0	.0	.0	.0
47	11.6	5258.2	.0	.0	.0	.0	.0	.0	.0

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	105.10	151.19
2	124.18	145.19
3	143.46	139.87
4	162.92	135.25
5	182.53	131.33
6	202.27	128.12
7	222.11	125.61
8	242.03	123.81
9	262.00	122.73
10	282.00	122.36
11	302.00	122.71
12	321.97	123.78
13	341.89	125.56
14	361.73	128.05
15	381.48	131.25
16	401.09	135.16
17	420.56	139.76
18	439.84	145.06
19	458.92	151.04
20	477.78	157.71
21	496.39	165.04
22	514.72	173.04
23	532.75	181.69
24	550.47	190.97
25	567.84	200.89
26	584.84	211.42
27	601.45	222.55
28	617.66	234.27
29	633.44	246.57
30	648.76	259.42
31	653.95	264.09

Circle Center At X = 282.2 ; Y = 681.0 and Radius, 558.7

*** 1.607 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	110.20	152.38
2	129.21	146.13
3	148.42	140.60
4	167.83	135.77
5	187.41	131.67
6	207.12	128.29
7	226.94	125.64
8	246.85	123.73
9	266.82	122.54
10	286.81	122.10
11	306.81	122.40
12	326.78	123.43
13	346.71	125.20
14	366.55	127.70
15	386.29	130.93
16	405.89	134.89
17	425.34	139.56
18	444.59	144.96
19	463.64	151.06
20	482.45	157.85
21	501.00	165.34
22	519.25	173.51

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23	537.20	182.34
24	554.80	191.83
25	572.05	201.96
26	588.90	212.72
27	605.35	224.10
28	621.37	236.08
29	636.94	248.63
30	652.03	261.76
31	654.41	263.98

Circle Center At X = 288.8 ; Y = 664.2 and Radius, 542.1

*** 1.608 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	108.16	151.90
2	127.27	145.99
3	146.57	140.73
4	166.03	136.13
5	185.64	132.19
6	205.37	128.91
7	225.20	126.30
8	245.10	124.35
9	265.06	123.09
10	285.05	122.49
11	305.05	122.58
12	325.04	123.34
13	344.99	124.77
14	364.88	126.87
15	384.68	129.65
16	404.38	133.09
17	423.96	137.20
18	443.38	141.96
19	462.63	147.38
20	481.69	153.45
21	500.53	160.15
22	519.14	167.49
23	537.49	175.45
24	555.55	184.03
25	573.32	193.21
26	590.77	202.99
27	607.88	213.35
28	624.62	224.28
29	640.99	235.77
30	656.97	247.81
31	671.70	259.72

Circle Center At X = 292.6 ; Y = 714.6 and Radius, 592.2

*** 1.610 ***

Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	116.33	153.80
2	135.19	147.15
3	154.30	141.25
4	173.62	136.10
5	193.14	131.72
6	212.81	128.11
7	232.61	125.28
8	252.50	123.23
9	272.46	121.96
10	292.46	121.48
11	312.45	121.79
12	332.43	122.88
13	352.34	124.76
14	372.16	127.42
15	391.86	130.86
16	411.41	135.07
17	430.78	140.05

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18	449.94	145.79
19	468.86	152.27
20	487.51	159.50
21	505.86	167.45
22	523.88	176.13
23	541.55	185.50
24	558.83	195.56
25	575.71	206.29
26	592.15	217.68
27	608.13	229.71
28	623.62	242.36
29	638.61	255.61
30	648.80	265.36

Circle Center At X = 294.6 ; Y = 629.3 and Radius, 507.8
*** 1.610 ***
Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	146.94	160.93
2	165.51	153.49
3	184.36	146.83
4	203.48	140.96
5	222.83	135.88
6	242.37	131.62
7	262.07	128.16
8	281.89	125.53
9	301.81	123.72
10	321.79	122.74
11	341.79	122.59
12	361.78	123.27
13	381.72	124.78
14	401.58	127.11
15	421.33	130.26
16	440.93	134.24
17	460.35	139.02
18	479.56	144.60
19	498.52	150.97
20	517.19	158.13
21	535.56	166.05
22	553.57	174.73
23	571.22	184.15
24	588.46	194.29
25	605.26	205.14
26	621.60	216.67
27	637.44	228.88
28	652.77	241.73
29	667.55	255.20
30	672.02	259.64

Circle Center At X = 335.4 ; Y = 604.4 and Radius, 481.8
*** 1.620 ***
Failure Surface Specified By 30 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	147.96	161.16
2	166.43	153.50
3	185.21	146.61
4	204.26	140.51
5	223.54	135.20
6	243.02	130.70
7	262.68	127.01
8	282.47	124.13
9	302.37	122.08
10	322.33	120.86
11	342.33	120.47
12	362.32	120.90
13	382.28	122.17
14	402.17	124.26

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15	421.96	127.18
16	441.61	130.91
17	461.08	135.46
18	480.35	140.81
19	499.39	146.96
20	518.15	153.89
21	536.61	161.59
22	554.73	170.05
23	572.48	179.25
24	589.84	189.19
25	606.77	199.83
26	623.25	211.17
27	639.24	223.18
28	654.72	235.85
29	669.66	249.15
30	678.78	257.97

Circle Center At X = 341.8 ; Y = 602.2 and Radius, 481.7

*** 1.622 ***

Failure Surface Specified By 31 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	104.08	150.95
2	123.34	145.57
3	142.77	140.82
4	162.34	136.71
5	182.04	133.24
6	201.84	130.43
7	221.73	128.26
8	241.67	126.75
9	261.65	125.90
10	281.65	125.70
11	301.64	126.16
12	321.61	127.28
13	341.53	129.05
14	361.39	131.47
15	381.15	134.54
16	400.80	138.26
17	420.32	142.63
18	439.68	147.63
19	458.87	153.27
20	477.87	159.53
21	496.65	166.41
22	515.19	173.91
23	533.47	182.01
24	551.48	190.70
25	569.20	199.99
26	586.60	209.85
27	603.67	220.27
28	620.38	231.25
29	636.73	242.78
30	652.69	254.83
31	661.77	262.17

Circle Center At X = 277.7 ; Y = 734.8 and Radius, 609.1

*** 1.623 ***

Failure Surface Specified By 29 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	144.90	160.45
2	163.58	153.30
3	182.54	146.94
4	201.75	141.39
5	221.18	136.64
6	240.79	132.72
7	260.55	129.63
8	280.42	127.36
9	300.37	125.94
10	320.36	125.35

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11	340.36	125.60
12	360.33	126.70
13	380.24	128.63
14	400.05	131.39
15	419.72	134.99
16	439.23	139.41
17	458.53	144.64
18	477.60	150.69
19	496.39	157.52
20	514.88	165.14
21	533.04	173.53
22	550.82	182.68
23	568.21	192.56
24	585.17	203.17
25	601.66	214.48
26	617.67	226.47
27	633.16	239.12
28	648.10	252.42
29	658.90	262.87

Circle Center At X = 324.3 ; Y = 601.3 and Radius, 476.0

*** 1.623 ***

Failure Surface Specified By 32 Coordinate Points

Point No.	X-Surf (ft)	Y-Surf (ft)
1	100.00	150.00
2	119.36	144.97
3	138.86	140.52
4	158.48	136.66
5	178.21	133.38
6	198.03	130.69
7	217.92	128.60
8	237.86	127.11
9	257.84	126.21
10	277.84	125.91
11	297.84	126.21
12	317.82	127.10
13	337.76	128.59
14	357.65	130.68
15	377.47	133.36
16	397.20	136.64
17	416.83	140.50
18	436.33	144.95
19	455.68	149.97
20	474.88	155.58
21	493.90	161.75
22	512.73	168.49
23	531.35	175.80
24	549.75	183.65
25	567.90	192.05
26	585.79	200.99
27	603.40	210.46
28	620.73	220.46
29	637.74	230.97
30	654.44	241.98
31	670.80	253.48
32	677.28	258.34

Circle Center At X = 277.9 ; Y = 794.4 and Radius, 668.5

*** 1.627 ***

Appendix B

Protective Cover Veneer Stability Evaluation

Objective To evaluate the stability of the protective cover veneer against sliding.

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.

Requirements FS_{min}(Static) = 1.5
FS_{min}(Dynamic) = 1.0 (If Applicable)

Analysis Treat the protective cover as an infinite slope and use the following equation (Matasovic, 1991):

$$FS = \frac{\dfrac{c}{\gamma_c z_c \cos^2\beta} + \tan\phi\left[\dfrac{1-\gamma_w(z_c - d_w)}{\gamma_c z_c}\right] - k_s(\tan\beta)(\tan\phi)}{k_s + \tan\beta}$$

Where:

FS	=	factor of safety against shallow veneer failure
k_s	=	seismic coefficient (= peak horizontal acceleration) (= 0 for static stability)
γ_c	=	unit weight of protective cover material(s) (pcf)
γ_w	=	unit weight of water (pcf)
c	=	cohesion/adhesion along assumed failure surface (psf)
ϕ	=	interface friction angle along assumed failure surface (degrees)
z_c	=	depth of protective cover (depth to failure surface) (ft)
d_w	=	depth to seepage surface (assumed parallel to slope) (ft) (= z if slope is dry)
β	=	slope angle of protective cover (degrees).

Determine minimum interface shear strength as follows:

$$\tau = \sigma \tan\phi + c$$

Where:

τ	=	interface shear strength (lbs)
σ	=	normal load (psf)
ϕ	=	interface friction angle (min. value from analysis or greater)
c	=	cohesion/adhesion (min. value from analysis or greater)

PROCVR STABILITY.WPD

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SHEET: 2 / 2
JOB #: JOHNSTON-22
DATE: 9/7/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Protective Cover Veneer Stability Evaluation

Input Parameters:

	Side Slope Angle (β):	18.4 degrees	(3H:1V Slopes)
Protective Cover:	Thickness (z_c):	2 ft	
	Unit Weight (γ_c):	110 pcf	
	Cohesion (c):	0 psf	
	Depth to Seepage (d_w):	2 ft	(= z if Slope is Dry)
	Seismic Coefficient (k_s):	0 Static FS	
Required Factors of Safety:			
	Static:	1.5	

Calculate Static FS Against Sliding:

Interface Friction Angle (ϕ) (degrees)	Resisting Force	Driving Force	FS	Comment
22	0.40	0.33	1.21	**NO GOOD**
23	0.42	0.33	1.28	**NO GOOD**
24	0.45	0.33	1.34	**NO GOOD**
25	0.47	0.33	1.40	**NO GOOD**
26	0.49	0.33	1.47	**NO GOOD**
27	0.51	0.33	1.53	**OK**

Minimum Interface Shear Strength Requirements:

Cohesion (c) (From Above) = 0 psf
Interface Friction Angle (ϕ) = 27 degrees (Use Min. Value From Above or Greater)

Normal Load (psf)	Interface Shear Strength (psf)
100	51
200	102
400	204

Appendix C

Final Cover Veneer Stability Evaluation

Objective To evaluate the stability of the final cover veneer against sliding.

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.

Requirements FS_{min}(Static) = 1.5
FS_{min}(Dynamic) = 1.0 (If Applicable)

Analysis Treat the final cover as an infinite slope and use the following equation (Matasovic, 1991):

$$FS = \frac{\dfrac{c}{\gamma_c z_c \cos^2\beta} + \tan\phi\left[\dfrac{1-\gamma_w(z_c - d_w)}{\gamma_c z_c}\right] - k_s(\tan\beta)(\tan\phi)}{k_s + \tan\beta}$$

Where:
- FS = factor of safety against shallow veneer failure
- k_s = seismic coefficient (= peak horizontal acceleration) (= 0 for static stability)
- γ_c = unit weight of final cover material(s) (pcf)
- γ_w = unit weight of water (pcf)
- c = cohesion/adhesion along assumed failure surface (psf)
- ϕ = interface friction angle along assumed failure surface (degrees)
- z_c = depth of final cover (depth to failure surface) (ft)
- d_w = depth to seepage surface (assumed parallel to slope) (ft) (= z if slope is dry)
- β = slope angle of final cover (degrees)

$$u = \gamma_w(z_c - d_w)$$

Determine minimum interface shear strength as follows:

$$\tau = \sigma \tan\phi + c$$

Where:
- τ = interface shear strength (lbs)
- σ = normal load (psf)
- ϕ = interface friction angle (min. value from analysis or greater)
- c = cohesion/adhesion (min. value from analysis or greater)

FCS STABILITY.WPD

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SHEET: 2/2
JOB #: JOHNSTON-22
DATE: 7/15/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Final Cover Veneer Stability Evaluation

Input Parameters:

Side Slope Angle (β): 14.0 degrees (4H:1V Slopes)

Final Cover:
Thickness (z_c): 2 ft
Unit Weight (γ_c): 110 pcf
Cohesion (c): 0 psf
Depth to Seepage (d_w): 1.5 ft (= z if Slope is Dry)

Seismic Coefficient (k_s): 0 Static FS

Required Factors of Safety:
Static: 1.5

Calculate Static FS Against Sliding:

Interface Friction Angle (ϕ) (degrees)	Resisting Force	Driving Force	FS	Comment
22	0.35	0.25	1.39	**NO GOOD**
23	0.36	0.25	1.46	**NO GOOD**
24	0.38	0.25	1.53	**OK**
25	0.40	0.25	1.61	**OK**
26	0.42	0.25	1.68	**OK**
27	0.44	0.25	1.75	**OK**

Minimum Interface Shear Strength Requirements:

Cohesion (c) (From Above) = 0 psf
Interface Friction Angle (ϕ) = 24 degrees (Use Min. Value From Above or Greater)

Normal Load (psf)	Interface Shear Strength (psf)
100	45
200	89
400	178

Appendix D

Foundation Settlement Evaluation

Objective To estimate the total and differential foundation settlements due to the weight of the planned waste and embankment loads. The resulting post-settlement slopes are evaluated to ensure that 1) positive drainage is maintained toward collection piping and/or sumps and 2) the maximum tensile strains in the liner system do not exceed allowable values.

References

Holtz, R.D., & Kovacs, W.D. (1981), An Introduction To Geotechnical Engineering, Prentice-Hall, Englewood Cliffs, NJ, Chapters 8 and 9.

Koerner, R.M., Designing With Geosynthetics, Fourth Ed., Prentice Hall, Upper Saddle River, N.J., 1999, pp. 469-473.

Ohio EPA - Geotechnical Resource Group (2004), "Geotechnical and Stability Analyses for Ohio Waste Containment Facilities", Ohio EPA, Columbus, Ohio, Chapter 6.

Assumptions

1. Vertical stresses acting on the liner are assumed to be one-dimensional (1-D).
2. Assumptions for soil properties are listed in the attached spreadsheet.

Analysis The following approach is used to perform the evaluation:

1. Identify the critical cross section(s) to be evaluated (maximum waste fill, minimum liner slopes, etc.).
2. Select points along each cross section to perform calculations (points of grade breaks in final cover and/or liner system).
3. For each calculation point, determine the subsurface profile beneath the liner system and separate into distinct layers (thickness and material properties) (Include structural fill where applicable).
4. For each calculation point, determine the stresses acting on the midpoint of each layer both before and after liner construction.
5. For each calculation point, determine the stress change at the liner. Take into account the stress decrease due to excavation (where applicable) and the stress increase due to waste loads.
6. Calculate elastic settlements for each granular soil layer using the equations below.
7. Calculate consolidation (primary and secondary) settlements for each clay/silt soil layer using the equations below.
8. Calculate total settlements at each calculation point and resulting post-settlement slopes and liner strain between each point. Verify that slopes meet or exceed the minimum allowable slope. Verify that tensile strains do not exceed allowable values.

SETTLEMENT 1D.WPD

Calculations

- Elastic Settlement Equation:

$$S_e = \frac{\Delta p}{M_S} H$$

Where:

S_e = elastic settlement (ft)
Δp = net stress change acting on middle of soil layer (psf)
Ms = constrained modulus of soil (psf)

$$M_S = \frac{E_S(1-\upsilon_S)}{(1+\upsilon_S)(1-2\upsilon_S)}$$

Es = elastic modulus of soil (psf)
v_s = Poisson's ratio of soil
H = initial thickness of soil layer (ft).

- Primary Consolidation Settlement Equations:

$$for\ p'_O + \Delta p \geq p'_{mp}$$

$$S_C = H\left(C_{r\varepsilon} \log \frac{p'_{mp}}{p'_o} + C_{c\varepsilon} \log \frac{p'_o + \Delta p}{p'_{mp}} \right)$$

$$for\ p'_O + \Delta p < p'_{mp}$$

$$S_C = H\left(C_{r\varepsilon} \log \frac{p'_o + \Delta p}{p'_o} \right)$$

Where:

S_C = primary consolidation settlement (ft)
H = initial thickness of soil layer (ft)
p'_{mp} = maximum past consolidation pressure (psf)
p'_o = effective vertical stress in middle of soil layer afer excavation, but before loading (psf)
Δp = net stress change acting on middle of soil layer (psf).
$C_{r\varepsilon}$ = modified recompression index

$$C_{r\varepsilon} = \frac{C_r}{1+e_o}$$

$C_{c\varepsilon}$ = modified primary compression index

$$C_{c\varepsilon} = \frac{C_c}{1+e_o}$$

C_r = recompression index
C_c = primary compression index
e_O = initial void ratio

- Secondary Consolidation Settlement Equation:

$$S_s = C_{s\varepsilon} H \log \frac{t_s}{t_{pf}}$$

Where:
S_s = secondary consolidation settlement (ft)
$C_{s\varepsilon}$ = modified secondary compression index
H = initial thickness of soil layer (ft)
t_s = time over which secondary settlement is to be calculated (typ. this is a max. of 100 years plus the max. time to complete primary consolidation)
t_{pf} = time to complete primary consolidation

$$t_{pf} = \frac{T_V * H_t^2}{C_V}$$

T_V = dimensionless time factor associated with the time it takes for primary consolidation settlement to be completed

$$For U < 60\%: \; T_V = \frac{\pi}{4}\left(\frac{U\%}{100}\right)^2$$

$$For U \geq 60\%: \; T_V = 1.781 - 0.933\log(100 - U\%)$$

H_t = maximum length of drainage in the consolidating layer (= H for single-drained; = 0.5H for double-drained)
C_V = coefficient of consolidation (ft^2/year)
U = percent of primary consolidation (%) (typ. max. is 99.999; results in T_V = 4.58).

- Total Settlement Equation:

$$S_{Total} = S_e + S_c + S_s$$

Where: S_{Total} = total settlement (ft)
Se = elastic settlement (ft)
S_C = primary consolidation settlement (ft)
S_s = secondary consolidation settlement (ft).

- Liner Strain Equation:

$$E_T = \frac{L_f - L_o}{L_o} x100$$

Where: E_T = total strain (%) ("+" = tension; "-" = compression)
L_o = original distance separating two adjacent calculation points (ft)
L_f = final distance separating two adjacent calculation points after settlement is complete (ft).

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SHEET: 5/9
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DATE: 9/27/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Settlement Analysis Cross Section No.: 1

Soils Information: (Note: When elastic or consolidation settlement is not applicable to a particular layer, enter "NA" for requested parameters.)

Soil Layer	Description	Dry Unit Wt. (pcf)	Natural Moisture Content (%)	Wet Unit Wt. (pcf)	Elastic Settlement Parameters E_s (psf)	ν_s	M_s (psf)	Consolidation Settlement Parameters OCR	C_{cc}	C_{rc}	$C_{\alpha c}$
1	Structural Fill	110.0	15.0	126.5	NA		NA	NA	NA	NA	NA
2	Silty/Clayey Sands (Loose 4-7 bpf)	100.0	20.0	120.0	100,000	0.30	134,615	NA	NA	NA	NA
3	Silty/Clayey Sands (Medium 7-20 bpf)	100.0	20.0	120.0	150,000	0.30	201,923	NA	NA	NA	NA
4	Silts & Clays (V. Stiff 20-30 bpf)	120.0	20.0	144.0	NA		NA	2++	0.15	0.015	0.002
5	Clay (Hard >30 bpf) and Rock (Incompressible)										
6											
7											
8											
9											
10											

Waste Information:

Average Unit Weight, γ_{Waste} (pcf) = 70

Assumptions:

Sands:

Dry Unit Weight (pcf): 100.0 Estimated for Sands
Natural moisture content (%), w_n: 20.0 Estimated for Sands
E_s: Various Estimated for Sands - Based on Bowles - Foundation Analysis & Design - Table 2-7
ν_s: 0.30 Estimated for Sands

Clay:

Dry Unit Weight (pcf): 120.0 Estimated for V. Stiff Clay
Natural moisture content (%), w_n: 20.0 Estimated for V. Stiff Clay
OCR: 2.0 Estimated for V. Stiff Clay (p_{mp} is input by the user below based on 50'+ of overburden that has prev. been removed.)
Modified primary compression index (dimensionless), C_{cc}: 0.15 Estimated for V. Stiff Clay
Modified recompression Index (dimensionless), C_{rc}: 0.015 Estimated as 10% of Primary Comp. Index
Modified secondary compression index (dim'less), $C_{\alpha c}$: 0.002 (estimated as w_n x 0.0001)

SHEET:	6/9
JOB #:	JOHNSTON-22
DATE:	9/27/05
BY:	PKS
CHKD BY:	

Settlement Points - Location Information:

Parameter		Point 1	2	3	4	5	6	7	8	9	10	11	12
	Position:	0	59	140	300	425	550						
	Original Ground Surface Elevation (ft) =	166.0	160.0	161.0	165.0	167.5	170.5						
	Avg. Unit Wt. of Soil Excavated (pcf) =	100.0	100.0	100.0	100.0	100.0	100.0						
	Top of Landfill Elevation (ft) =	179.0	188.0	204.0	240.0	270.0	256.0						
	Top of Liner Elevation (ft) =	157.0	159.0	161.0	165.0	170.0	175.0						
	Top of Groundwater Elevation (ft) =	152.0	154.0	156.0	160.0	165.0	170.0						
Layer 1:	Thickness (ft) =	0.0	0.0	0.0	0.0	2.5	4.5						
	Elevation of Mid Point (ft) =	157.0	159.0	161.0	165.0	168.8	172.8						
	(Before Liner Construct.) p'_o at Mid Point (ft) =	900	100	0	0	-158	-285						
	p'_{mp} at Mid Point (ft) =	NA	NA	NA	NA	NA	NA						
	(After Liner Construct.) p'_o at Mid Point (ft) =	0	0	0	0	158	285						
Layer 2:	Thickness (ft) =	0.0	0.0	0.0	5.0	5.0	5.0						
	Elevation of Mid Point (ft) =	157.0	159.0	161.0	162.5	165.0	168.0						
	(Before Liner Construct.) p'_o at Mid Point (ft) =	900	100	0	300	300	175						
	p'_{mp} at Mid Point (ft) =	NA	NA	NA	NA	NA	NA						
	(After Liner Construct.) p'_o at Mid Point (ft) =	0	0	0	300	616	744						
Layer 3:	Thickness (ft) =	5.0	5.0	5.0	5.0	5.0	15.0						
	Elevation of Mid Point (ft) =	154.5	156.5	158.5	157.5	160.0	158.0						
	(Before Liner Construct.) p'_o at Mid Point (ft) =	1,200	400	300	744	588	751						
	p'_{mp} at Mid Point (ft) =	NA	NA	NA	NA	NA	NA						
	(After Liner Construct.) p'_o at Mid Point (ft) =	300	300	300	744	904	1,320						
Layer 4:	Thickness (ft) =	0.0	0.0	0.0	5.0	5.0	0.0						
	Elevation of Mid Point (ft) =	152.0	154.0	156.0	152.5	155.0	150.5						
	(Before Liner Construct.) p'_o at Mid Point (ft) =	1,500	700	600	1,092	936	1,183						
	p'_{mp} at Mid Point (ft) =	4,000	4,000	4,000	4,000	4,000	4,000						
	(After Liner Construct.) p'_o at Mid Point (ft) =	600	600	600	1,092	1,252	1,752						
Layer 5:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												
Layer 6:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												
Layer 7:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												
Layer 8:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												
Layer 9:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												
Layer 10:	Thickness (ft) =												
	Elevation of Mid Point (ft) =												
	(Before Liner Construct.) p'_o at Mid Point (ft) =												
	p'_{mp} at Mid Point (ft) =												
	(After Liner Construct.) p'_o at Mid Point (ft) =												

Acct. For Possible Vert. Expn. In Future

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BY:	PKS
CHKD BY:	

Stress Change, Δp, at Liner:

Parameter	Point 1	2	3	4	5	6	7	8	9	10	11	12
Stress Decrease From Excavation (psf) =	900	100	0	0	0	0						
Stress Increase From Waste Load (psf) =	1,540	2,030	3,010	5,250	7,000	5,670						
Net Stress Increase/Decrease, Δ_p (psf) =	640	1,930	3,010	5,250	7,000	5,670						

Elastic Settlement:

Parameter		Point 1	2	3	4	5	6	7	8	9	10	11	12
Elastic Settlement (ft):													
Layer 1:	**S_e =**	NA	NA	NA	NA	NA	NA						
Layer 2:	**S_e =**	NA	NA	NA	0.20	0.26	0.21						
Layer 3:	**S_e =**	0.02	0.05	0.07	0.13	0.17	0.42						
Layer 4:	**S_e =**	NA	NA	NA	NA	NA	NA						
Layer 5:	**S_e =**												
Layer 6:	**S_e =**												
Layer 7:	**S_e =**												
Layer 8:	**S_e =**												
Layer 9:	**S_e =**												
Layer 10:	**S_e =**												
Total Elastic Settlement (ft) =		**0.02**	**0.05**	**0.07**	**0.33**	**0.43**	**0.63**						

Elastic Settlement Equation:

$$\boxed{Se = \frac{\Delta p}{M_S} H}$$

Primary Consolidation Settlement:

Parameter		Point 1	2	3	4	5	6	7	8	9	10	11	12
Primary Consolidation Settlement (ft):													
Layer 1:	**S_c =**	NA	NA	NA	NA	NA	NA						
		---	---	---	---	---	---						
Layer 2:	**S_c =**	NA	NA	NA	NA	NA	NA						
		---	---	---	---	---	---						
Layer 3:	**S_c =**	NA	NA	NA	NA	NA	NA						
		---	---	---	---	---	---						
Layer 4:	**S_c =**	NA	NA	NA	0.19	0.27	NA						
		---	---	---	C	C	---						
Layer 5:	**S_c =**												
Layer 6:	**S_c =**												
Layer 7:	**S_c =**												
Layer 8:	**S_c =**												
Layer 9:	**S_c =**												
Layer 10:	**S_c =**												
Total Primary Consol. Settlement (ft) =		**0.00**	**0.00**	**0.00**	**0.19**	**0.27**	**0.00**						

Primary Consolidation Settlement Equations:

For primary recompression and compression (designated C):

$$\boxed{S_C = H\left(C_{r\varepsilon}\log\frac{p'_{mp}}{p'_o} + C_{c\varepsilon}\log\frac{p'_o+\Delta p}{p'_{mp}}\right)}$$

For primary recompression only (designated R):

$$\boxed{S_C = H\left(C_{r\varepsilon}\log\frac{p'_o+\Delta p}{p'_o}\right)}$$

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Secondary Consolidation Settlement:

Assumed % Primary Consolidation (U) = 99.999 (Max. = 99.999)
T_v (dimensionless) = 4.58
$t_s = t_{pf}$ + "X" (years) = 100

Parameter		Point 1	2	3	4	5	6	7	8	9	10	11	12
Secondary Consolidation Settlement (ft):													
Layer 1:	Drainage* =	1	1	1	1	1	1						
	H_t (ft) =	0.0	0.0	0.0	0.0	2.5	4.5						
	C_v (in²/min) =	0.000	0.000	0.000	0.000	0.000	0.000						
	t_{pf} (years) =	0.0	0.0	0.0	0.0	0.0	0.0						
	S_s =	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**						
Layer 2:	Drainage* =	1	1	1	1	1	1						
	H_t (ft) =	0.0	0.0	0.0	5.0	5.0	5.0						
	C_v (in²/min) =	0.000	0.000	0.000	0.000	0.000	0.000						
	t_{pf} (years) =	0.0	0.0	0.0	0.0	0.0	0.0						
	S_s =	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**						
Layer 3:	Drainage* =	1	1	1	1	1	1						
	H_t (ft) =	5.0	5.0	5.0	5.0	5.0	15.0						
	C_v (in²/min) =	0.000	0.000	0.000	0.000	0.000	0.000						
	t_{pf} (years) =	0.0	0.0	0.0	0.0	0.0	0.0						
	S_s =	**NA**	**NA**	**NA**	**NA**	**NA**	**NA**						
Layer 4:	Drainage* =	1	1	1	1	1	1						
	H_t (ft) =	0.0	0.0	0.0	5.0	5.0	0.0						
	C_v (in²/min) =	0.050	0.050	0.050	0.050	0.050	0.050						
	t_{pf} (years) =	0.0	0.0	0.0	0.6	0.6	0.0						
	S_s =	**NA**	**NA**	**NA**	**0.02**	**0.02**	**NA**						
Layer 5:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Layer 6:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Layer 7:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Layer 8:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Layer 9:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Layer 10:	Drainage* =												
	H_t (ft) =												
	C_v (in²/min) =												
	t_{pf} (years) =												
	S_s =												
Total Sec. Consol. Settlement (ft) =		**0.00**	**0.00**	**0.00**	**0.02**	**0.02**	**0.00**						

* Single-Drained = 1; Double-Drained = 2

Secondary Consolidation Settlement Equation:

$$\boxed{S_s = C_{se} H \log \frac{t_s}{t_{pf}}}$$

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BY:	PKS
CHKD BY:	

Total Settlement:

Parameter		Point 1	2	3	4	5	6	7	8	9	10	11	12
Total Settlement (ft):													
Layer 1:	S_{Total} =	0.00	0.00	0.00	0.00	0.00	0.00						
Layer 2:	S_{Total} =	0.00	0.00	0.00	0.20	0.26	0.21						
Layer 3:	S_{Total} =	0.02	0.05	0.07	0.13	0.17	0.42						
Layer 4:	S_{Total} =	0.00	0.00	0.00	0.21	0.30	0.00						
Layer 5:	S_{Total} =												
Layer 6:	S_{Total} =												
Layer 7:	S_{Total} =												
Layer 8:	S_{Total} =												
Layer 9:	S_{Total} =												
Layer 10:	S_{Total} =												
Total Settlement (ft) =		0.02	0.05	0.07	0.54	0.73	0.63						

MAX

Total Settlement Equation:

$$\boxed{S_{Total} = S_e + S_c + S_s}$$

Liner Slopes & Liner Strain:

Min. Post-Settlement Liner Slope (%) = 2.0
Max. Liner Strain (%) = 0.5 **(Assumed Max. Tensile Strain in Compacted Soil Liner)**

Parameter	Point 1	2	3	4	5	6	7	8	9	10	11	12
Position:	0	59	140	300	425	550						
Before Settlement:												
Top of Liner Elevation (ft) =	157.0	159.0	161.0	165.0	170.0	175.0						
Slope of Liner (%) (+ up;- down)=	-----	3.4	2.5	2.5	4.0	4.0						
Length Along Liner (L_o) Bet. Points (ft) =	-----	59.034	81.025	160.050	125.100	125.100						
After Settlement:												
Top of Liner Elevation (ft) =	157.0	159.0	160.9	164.5	169.3	174.4						
Slope of Liner (%) (+ up; - down)=	-----	**3.3**	**2.4**	**2.2**	**3.8**	**4.1**						
Slope Change (%) (+ steeper; - flatter)=	-----	-0.1	0.0	-0.3	-0.2	0.1						
Length Along Liner (L_f) Bet. Points (ft) =	-----	59.033	81.024	160.039	125.093	125.104						
Liner Strain (E_T) (%) (+ tension; - comp.)=	-----	**0.00**	**0.00**	**-0.01**	**-0.01**	**0.00**						
Comments:												
Liner Slope:	-----	O.K.	O.K.	O.K.	O.K.	O.K.						
Liner Strain:	-----	O.K.	O.K.	O.K.	O.K.	O.K.						

Liner Strain Equation:

$$\boxed{E_T = \frac{L_f - L_o}{L_o} \times 100}$$

Slopes/Strain = O.K.

Appendix E

Bearing Capacity Evaluation

PROJECT Johnston County C&D Landfill - Area 2
JOB NO. JOHNSTON-22
DATE 7/14/05
SUBJECT Bearing Capacity Analysis
COMPUTED BY PKS
CHECKED BY

Objective To evaluate the bearing capacity of the subgrade materials beneath the landfill footprint and the bearing capacity of the leachate collection system and the protective cover under anticipated construction and operations equipment loads. The evaluation of the equipment loads also demonstrates the required separation between equipment and the underlying geomembrane(s).

References Foundations & Earth Structures - Design Manual 7.02 (1986), NAVFAC, Alexandria, VA, Change 1, September 1986, p. 7.2-131.

Analysis Use FS_{min} (Overall) = 3.0, FS_{min} (Leach. Collection/Protective Cover) = 2.0.

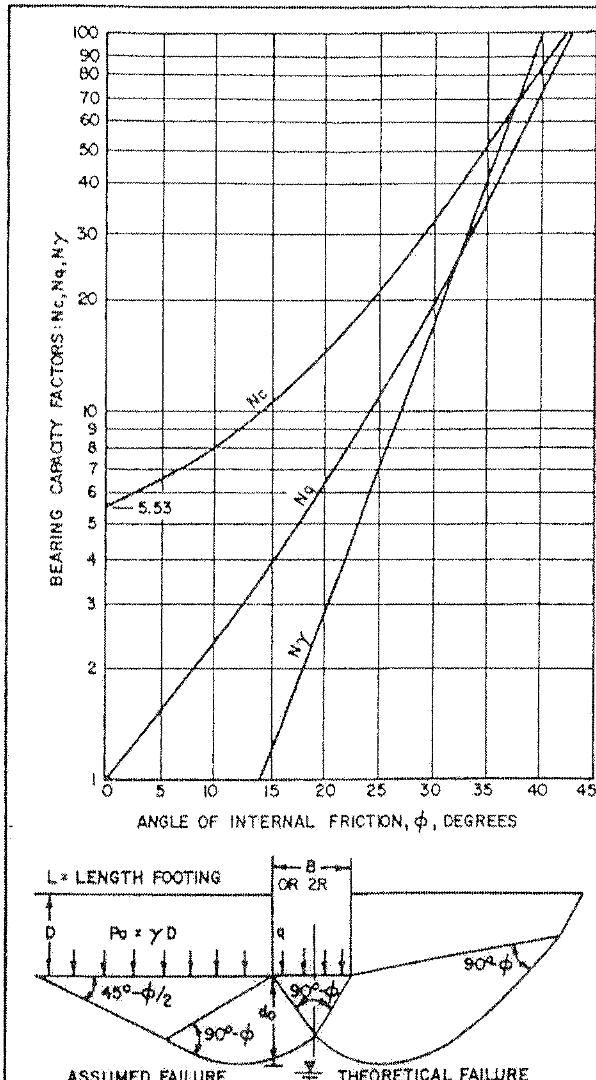
Assumptions

1. General shear failure mode controls.
2. For the overall bearing capacity of the landfill, the landfill footprint is simplified as a rectangle.
3. For the evaluation of equipment loads, the stress is distributed at depth based on 2V:1H (2:1 approximation).
4. Tracked equipment are modeled as rectangular loads; wheeled equipment are modeled as circular loads.

Equations See Attached from NAVFAC

BEARING CAPACITY.WPD

G.N. RICHARDSON & ASSOCIATES
Engineering and Geological Services
14 N. Boylan Avenue, Raleigh, NC 27603
Telephone: (919) 828-0577



ULTIMATE BEARING CAPACITY = q_{ult}

CONTINUOUS FOOTING; GENERAL CASE

$q_{ult} = q' + q''$

q' = PORTION OF BEARING CAPACITY ASSUMING WEIGHTLESS FOUNDATION SOIL

q'' = PORTION OF BEARING CAPACITY FROM WEIGHT OF FOUNDATION SOILS

$q' = cN_c + \gamma D N_q$

$q'' = \gamma \frac{B}{2} N_\gamma$

$q_{ult} = cN_c + \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING

$q_{ult} = cN_c\,(1 + .3\frac{B}{L}) + \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING: $R = B/2$

$q_{ult} = 1.3\,cN_c + \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIONLESS FOUNDATION SOILS ($c = 0$)

CONTINUOUS FOOTING:

$q_{ult} = \gamma D N_q + \frac{\gamma B}{2} N_\gamma$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.4\gamma B N_\gamma$

CIRCULAR FOOTING:

$q_{ult} = \gamma D N_q + 0.6\gamma R N_\gamma$

FOR COHESIVE FOUNDATION SOILS ($\phi = 0$)

CONTINUOUS FOOTING:

$q_{ult} = cN_c + \gamma D$

SQUARE OR RECTANGULAR FOOTING:

$q_{ult} = cN_c(1 + .3\frac{B}{L}) + \gamma D$

CIRCULAR FOOTING:

$q_{ult} = 1.3\,cN_c + \gamma D$

ASSUMED CONDITIONS:

1. $D \leq B$
2. SOIL IS UNIFORM TO DEPTH $d_o > B$.
3. WATER LEVEL LOWER THAN d_o BELOW BASE OF FOOTING.
4. VERTICAL LOAD CONCENTRIC.
5. FRACTION AND ADHESION ON VERTICAL SIDES OF FOOTING ARE NEGLECTED.
6. FOUNDATION SOIL WITH PROPERTIES c, ϕ, γ

FIGURE 1
Ultimate Bearing Capacity of Shallow Footings With Concentric Loads

7.2-131

NAVFAC DM7.2

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Engineering and Geological Services
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Raleigh, NC 27603 Fax: 919-828-3899

SHEET: 3/4
JOB #: JOHNSTON-22
DATE: 9/7/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Overall Bearing Capacity Analysis

Subsurface Bearing Soil & Load Information (USER INPUT):

Soil Parameters:

Friction Angle (ϕ) =	20	Degrees
Cohesion (c) =	0	psf
Unit Weight (γ) =	100	pcf
Eff. Unit Weight (γ_{eff})=	37.6	pcf

Soil Bearing Capacity Factors:

N_c =	15
N_q =	6.5
N_g =	2.8

Load Information:

Depth of Footing (D_f) =	0	ft	(Depth of Landfill Base Below Outside Ground Surface - Typ. Min.)
Foundation Width (B) =	650	ft	
Foundation Width (L) =	950	ft	
Waste Unit Weight (γ) =	70	pcf	
Waste Thickness =	90	ft	(Typ. Thickness)

Bearing Capacity:

Soil Surcharge (γ x D_f) =	0	psf	
Ultimate Bearing Cap. (q_{ult}) =	27,373	psf	
Allowable Bearing Cap. (q_{allow}) =	9,124	psf	(Ultimate Bearing Capacity/3)
Applied Load =	6,300	psf	
Bearing Capacity FS =	**4.3**		**OK - GREATER THAN 3**

G.N. Richardson & Associates
Engineering and Geological Services
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SHEET: 4/4
JOB #: JOHNSTON-22
DATE: 5/18/05
BY: PKS
CHKD BY:

Johnston County C&D Landfill - Area 2
Equipment Contact Stress & Bearing Capacity Analysis - Leachate Collection System/Protective Cover

Bearing Soil & Load Information (USER INPUT):

Soil Parameters:
Friction Angle (ϕ) = 30 Degrees
Cohesion (c) = 0 psf
Unit Weight (γ) = 110 pcf

Soil Bearing Capacity Factors:
N_c = 32
N_q = 20
N_g = 16

Equipment Contact Stress & Bearing Capacity:

LGP Dozer:

Max. Contact Stress = 6 psi
Typ. Track Width = 34 in
Typ. Track Length = 122 in
CAT D6N LGP DS

Depth (ft)	Contact Area (in^2)	Contact Stress (psi)	qult (psi)	FS		Comment
0	4,148	6.0	13.9	2.3		OK
0.5	5,120	4.9	21.5	4.4		OK
0.75	5,633	4.4	25.3	5.7		OK
1	6,164	4.0	29.1	7.2		OK
1.5	7,280	3.4	36.8	10.8		OK
2	8,468	2.9	44.4	15.1		OK

Non-LGP Dozer:

Max. Contact Stress = 12 psi
Typ. Track Width = 22 in
Typ. Track Length = 112 in
CAT D7R Series II

Depth (ft)	Contact Area (in^2)	Contact Stress (psi)	qult (psi)	FS		Comment
0	2,464	12.0	9.0	0.7	Expect Rutting	- More Separation Reqd.
0.5	3,304	8.9	16.6	1.9		- More Separation Reqd.
0.75	3,751	7.9	20.4	2.6		OK
1	4,216	7.0	24.2	3.5		OK
1.5	5,200	5.7	31.9	5.6		OK
2	6,256	4.7	39.5	8.4		OK

Truck (H_{20}):

Max. Contact Stress = 90 psi
Typ. Contact Diameter = 9 in

Depth (ft)	Contact Area (in^2)	Contact Stress (psi)	qult (psi)	FS		Comment
0	64	90.0	2.8	0.0	Expect Rutting	- More Separation Reqd.
0.5	177	32.4	10.4	0.3	Expect Rutting	- More Separation Reqd.
0.75	254	22.5	14.2	0.6	Expect Rutting	- More Separation Reqd.
1	346	16.5	18.0	1.1		- More Separation Reqd.
1.5	573	10.0	25.7	2.6		OK
2	855	6.7	33.3	5.0		OK
2.5	1,195	4.8	40.9	8.5		OK
3	1,590	3.6	48.6	13.5		OK

Truck (Off-Road):

Max. Contact Stress = 60 psi
Typ. Contact Diameter = 30 in

Depth (ft)	Contact Area (in^2)	Contact Stress (psi)	qult (psi)	FS		Comment
0	707	60.0	9.2	0.2	Expect Rutting	- More Separation Reqd.
0.5	1,018	41.7	16.8	0.4	Expect Rutting	- More Separation Reqd.
0.75	1,195	35.5	20.6	0.6	Expect Rutting	- More Separation Reqd.
1	1,385	30.6	24.4	0.8	Expect Rutting	- More Separation Reqd.
1.5	1,810	23.4	32.1	1.4		- More Separation Reqd.
2	2,290	18.5	39.7	2.1		OK
2.5	2,827	15.0	47.4	3.2		OK
3	3,421	12.4	55.0	4.4		OK

Waste Compactor:

Max. Contact Stress = 70 psi
Typ. Drum Contact Width = 12 in
Typ. Drum Length = 48 in
Typ. Drum - Large Compactor

Depth (ft)	Contact Area (in^2)	Contact Stress (psi)	qult (psi)	FS		Comment
0	576	70.0	4.9	0.1	Expect Rutting	- More Separation Reqd.
0.5	972	41.5	12.5	0.3	Expect Rutting	- More Separation Reqd.
0.75	1,197	33.7	16.3	0.5	Expect Rutting	- More Separation Reqd.
1	1,440	28.0	20.2	0.7	Expect Rutting	- More Separation Reqd.
1.5	1,980	20.4	27.8	1.4		- More Separation Reqd.
2	2,592	15.6	35.4	2.3		OK
2.5	3,276	12.3	43.1	3.5		OK
3	4,032	10.0	50.7	5.1		OK

ATTACHMENT G

PROJECT DRAWINGS

(Project Drawings are Provided as a Separate Attachment to this Application)

Permit to Construct Application (Design Hydrogeologic Report)

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared For:

Johnston County Department of Public Utilities
309 E. Market Street
Smithfield, North Carolina 27577

Prepared By:

G.N. Richardson & Associates, Inc.
Engineering and Geological Services
14 N. Boylan Avenue
Raleigh, North Carolina 27603

October 2005

PERMIT TO CONSTRUCT APPLICATION
(Design Hydrogeologic Report)

Johnston County C&D Landfill - Area 2
Johnston County, North Carolina

Prepared for:
Johnston County
Department of Public Utilities

To the Attention of:
Mr. Haywood M. Phthisic, III
Director

GNRA Project No. JOHNSTON-23

NORTH CAROLINA LICENSED SEAL 1369 GEOLOGIST JOAN A. SMYTH

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Design Hydrogeologic Report
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1.0 INTRODUCTION

The planned lined Construction and Demolition (C&D) Debris Landfill is to be developed at the existing Johnston County Landfill (Permit 51.02). The planned lined C&D landfill area is approximately 15.8 lined acres within the existing permitted facility boundary, located in the former borrow area east of the unlined Phase 3 MSW landfill. The lined C&D landfill will partially overlie the sideslope of the unlined Phase 3 MSW landfill. The geology and hydrogeology of the study area has been characterized, and a site design package has been prepared pursuant to applicable North Carolina Solid Waste Management Rules 15 NCAC 13B.0503 through 0505. The proposed lined C&D landfill is shown on **Figure 1**.

The proposed lined C&D landfill is designed to be part of the continued remediation strategy for the unlined Phase 3 MSW landfill. The liner of the C&D landfill will act as a cover barrier over a portion of the eastern sideslope of the unlined Phase 3 MSW landfill and will prevent rainwater infiltration and the generation of leachate from the unlined facility. The lined C&D landfill will work in conjunction with the double-lined Phase 4A MSW landfill in preventing rainwater infiltration over much of the unlined Phase 3 landfill.

The planned lined C&D site meets all applicable location requirements of Rule .0504 (1) through (6). The site vicinity is sparsely populated. There are no flood plains, or endangered species identified within the lined C&D footprint.

The lined C&D site has been used most recently as a borrow area for the MSW landfill. Ground water characteristics at the site are sufficiently well understood to design an effective ground water monitoring network.

The overall site contains a permanent stream (Middle Creek) that provides an on-site ground water discharge feature. There are no potable wells located between the planned lined C&D landfill and the ground water discharge feature. Depths to bedrock and/or ground water are such that the current grading plan will meet regulatory vertical separation requirements.

2.0 SITE REPORT - .0504 (1)

2.1 Regional and Local Characteristic Study - .0504 (1) (a) and (b)

The facility is located approximately seven (7) miles west of downtown Smithfield off Hwy. 210. **Figure 2** shows the site and vicinity with a 2000-foot radius on regional mapping (1 inch = equal 400 feet). The site is accessed via County Home Road off Highway 210 west of Smithfield. County Home Road is the primary access road to the site.

Area development is a mix of primarily residential and agricultural use. **Figure 3** indicates that there are relatively large tracts of undeveloped land surrounding the landfill. There are no public water supply intakes within the 1/4-mile radius of the site. County water is supplied along Hwy. 210, Black Creek Road (the section within 1/4-mile radius), S.R. 1010 (Cleveland Road) and along Swift Creek Road. Roads that are not serviced with County Water are S.R. 1341, and Dickinson Road (S. R. 1505). Most of the development is located along the main roads.

A review of county water taps located within a 2000 foot radius of the site indicates all residences within this area are supplied with county water. Although individuals may have potable wells in this area, according to County regulations it is illegal to use potable well water for drinking water purposes after a county water tap has been supplied. No potable wells are located between the landfill and the nearest ground water discharge feature, Middle Creek at the north end of the permitted facility boundary. The locations of potable wells are shown on **Figure 3**. There are no easements on-site, and there are no schools or historic sites within the 2000 foot radius. Zoning classifications within the 2000 foot radius are AR- Agricultural/Residential with the exception of the Landfill property itself which is zoned CLD - County Land Development. There are no commercial or industrial businesses or buildings within the 2000 foot radius. Private residences are indicated by the small squares on **Figure 3**.

2.2 Facility Development Plan - .0504 (1) (a) and (b)

The proposed Lined C&D facility will occupy the former borrow area to the east of the unlined Phase 3 landfill. Ground surfaces vary within the study area from EL. 150 feet to EL. 260 feet at the top of Phase 3. The site grading plan will take advantage of the topography to minimize earthwork requirements.

2.3 Applicable Location Restrictions - .0503 (1) (a) – (d), and .0504 (1) (f)

2.3.1 Flood Plain - .0503 (1) (a)

The main drainage feature on the site is Middle Creek that is located along the edge of the permitted property. An unnamed tributary to Middle Creek is located to the east of the proposed lined C&D landfill.

An inspection of FEMA FIRM mapping, reprinted in **Appendix A**, indicates that no areas of the site exist within the 100 year flood limits. This is the most recent FIRM mapping. Design grades are set such that no restriction to the flow of Middle Creek, or its unnamed tributary will occur and the risk of exposure of the waste due to flooding or scouring will be minimal. There will be minimal disturbance to the wooded area adjacent to the surface water bodies.

2.3.2 Endangered and Threatened Species - .0503 (1) (b) (i and ii)

Based upon correspondence from 1994 between McKim and Creed Engineers and the U.S. Fish and Wildlife Service as well as the North Carolina Wildlife

Resources Commission, it appears that several endangered or threatened species may be present in middle Creek in the vicinity of the landfill. These include the dwarf wedge mussel (alasmidonta heterodon). This previous correspondence indicates that if a buffer of 300 feet is kept between the waste disposal unit and Middle Creek, the habitat of these species, including the dwarf wedge mussel would be protected. The proposed lined C&D landfill maintains a 300 foot buffer from Middle Creek and its floodplain. Correspondence from 1994 is included in **Appendix B**. Additionally, it should be noted that the proposed lined C&D landfill will also act in a remedial capacity to reduce leachate production by Phase 3, thus improving water quality downgradient toward Middle Creek.

2.3.3 Archaeological and Historical Site - .0503 (1) (b) (iii)

A Cultural Resource Study was performed in 1994 for the site. That study indicated no significant historical or cultural artifacts within the site boundary. A copy of the study is included in **Appendix C**.

2.3.4 State Nature and Historic Preserve - .0503 (1) (b) (iv)

No state park/recreation areas are located at the Johnston County Landfill.

2.3.5 Airport Safety - .0503 (1) (c)

There will be no putrescible wastes placed in the planned lined C&D landfill. Birds are not expected to be attracted to this facility. There are no known public airports that service piston-powered aircraft within 5000 feet of the site. The nearest public airport is approximately 2 miles northeast of the landfill.

A small private crop-dusting airport is location approximately 1500 feet from the landfill facility boundary at its closest point. Due to the private nature of this airport and the non-putrescible content of this landfill, no compromise of airport safety is expected due to the proposed lined C&D landfill.

2.3.6 Cover Soils -.0503 (1) (d)

Cover soils for the proposed lined C&D landfill unit will come from Borrow Area E located to the east of the proposed lined C&D landfill. Soils from this borrow area are clayey sands. There are sufficient soils on-site to meet anticipated cover material needs.

2.4 Site Design Requirements - .0503 (2) (a) through (g)

2.4.1 Explosive Gases - .0503 (2) (a)

The site will be managed such that explosive gas concentrations will not exceed regulatory thresholds in on-site structures and at the property line. This will be accomplished through waste segregation. The inert waste stream is not anticipated to produce methane in sufficient quantities to cause an explosion concern. No explosive gas control devices are anticipated to be required.

2.4.2 Public Access -.0503 (2) (b)

The site will be accessible to the public only during daylight business hours. An operator will be on duty during operations. The site is secured by the facility fence and entrance gate.

2.4.3 Surface Water Protection - .0503 (2) (c)

The site will not discharge pollutants into the waters of the State, in accordance with NPDES requirements and applicable state and federal law. No dredged material or fill material will be placed into waters of the State, including designated wetlands. The site shall not cause non-point source pollution to the waters of the State that exceeds assigned water quality standards. These requirements will be met through best management practice for storm water run-off control and proper waste screening.

2.4.4 Ground Water Protection - .0503 (2) (d)

The site drawings demonstrate that the bottom elevation of the waste will be a minimum of four feet above the seasonal high water table as determined by the site study. The site will be managed to prevent the likelihood of ground water impact. Due to the installation of a liner system, impact to the groundwater from this landfill is unlikely. Furthermore, this lined C&D landfill will work as part of the remedial action for the Phase 3 unlined MSW landfill unit. Therefore, this landfill is unlikely to contribute to groundwater impact and is designed to reduce impact from the Phase 3 unlined MSW landfill unit.

2.4.5 Open Burning - .0503 (2) (e)

Open burning of waste will not be allowed. The Operations Plan for the facility will reflect this.

2.4.6 Horizontal Buffers - .0503 (2) (f)

A minimum 300-foot buffer will be observed along the property line. There are no private dwellings or water wells within 500 feet of the planned facility. A 50-foot buffer will be observed along unnamed tributaries adjacent to the site.

2.4.7 Sedimentation and Erosion Control - .0503 (2) (g)

A sedimentation and erosion control plan will be implemented and proper maintenance of control structures will be observed to meet this requirement.

3.0 GEOLOGY AND HYDROGEOLOGY - .0504 (1) (C)

3.1 Soil Boring Investigation - .0504 (1) (c) (i)

A test boring investigation of the planned Lined C&D site was performed in 1998. A total of 12 test borings were installed and named PZ-1, PZ-1A, PZ-2 through PZ-9, PZ-9d and PZ-10. Seven (7) additional wells were installed to evaluate the effects during a pump test conducted on-site. The pump test was conducted to evaluate the effect of the diabase dikes on groundwater flow in the site area. Some of the borings were advanced into bedrock, while others were completed above auger refusal. Test boring data are summarized on **Table 1**. **Figure 4** shows the locations of the test boring and ground water level observation points. Boring logs are included in **Appendix D**.

3.1.1 Soil Classification - .0504 (1) (c) (i) (A-C)

The soil test borings were sampled with standard penetration test techniques (ASTM D-1586). Soil samples were visually classified by an experienced soils technician. Laboratory testing was performed on representative samples to confirm the field classifications. The results of the laboratory testing are presented in **Table 2**. Soil boring logs are presented in **Appendix D**. Soil classifications consist of sands, silts, clays and some partially weathered rock. There are three main descriptions of unconsolidated soils at the site: Silty sands, sand and clay.

3.1.2 Geologic Considerations - .0504 (1) (c) (i) (D)

No unusual geologic features or conditions, including seismic hazards or unstable areas, have been identified on the site with the exception of two diabase dikes crossing the proposed lined C&D landfill site. The diabase dikes have been identified and are accounted for in the proposed groundwater monitoring program. Bedrock is present in the proposed Lined C&D footprint at depths of ranging from approximately 16 feet to approximately 33 feet below grade. Site soils and bedrock are consistent with what has been observed on the Subtitle D Landfill portion of the site.

3.1.3 Undisturbed Samples - .0504 (1) (c) (i) (E)

Undisturbed samples have been collected adjacent to PZ-5 and PZ-7 in the proposed lined C&D area. These samples were analyzed for grain size, permeability and consolidation and the results are discussed in **Section 3.4.1**.

3.1.4 Remolded Samples - .0504 (1) (c) (i) (F)

No remolded samples were collected as geologic features were evaluated from split spoon samples collected.

3.1.5 Site Stratigraphy - .0504 (1) (c) (i) (G)

Hydrogeologic profiles are presented in **Figure 5**. The bedrock in this area is a felsic metavolcanic rock that is highly weathered at the surface and more competent below.

3.1.6 Water Table Information - .0504 (1) (c) (i) (H)

Short term water level observations (taken at the time of boring and 24 hours after boring) are tabulated in **Table 3**. Seven day water levels were not acquired, however, water levels were monitored 6 days after completion of the first piezometers and monthly thereafter.

3.2 Test Boring Locations - .0504 (1) (c) (ii)

The test borings and relevant site features are shown on **Figure 4**. Vertical and horizontal control is tied to the State – Plane coordinate system.

To proceed with permitting of the proposed C&D area and evaluate ground water quality in this area, GNRA has installed a total of 13 shallow (Type II) and five (5) deep (Type III) piezometers and monitoring wells. The locations of these wells are shown on **Figure 5** and the boring logs are included in **Appendix D**.

The piezometers were constructed with 2-inch diameter PVC screen and solid PVC riser pipe. Each piezometer was screened across the water table with the annular space up to one foot above the screened interval filled with sand pack. Above the sand pack, a two-foot thick bentonite layer was placed and hydrated for a seal. A grout layer was placed in the annular space from the top of the bentonite to grade. Each well was completed with locking caps.
GNRA also installed five deep, Type III piezometers/monitoring wells. One of these wells PZ-9d, was installed nested with piezometer PZ-9 to evaluate vertical gradients and ground water quality in the deeper aquifer on-site. A second one MW-19d is nested with MW-19 near the floodplain to evaluate vertical gradients near Middle Creek. The remaining three deep wells were installed to conduct the aquifer pump test adjacent to the diabase dikes (PW-2, PW-3 and PW-4).

The deep wells were installed as Type III wells with 4-inch outer casing installed to the depth of the top of bedrock. This outer casing was grouted into place, and the grout was allowed to set for a minimum of 24 hours. A 2-inch diameter monitoring well was installed within the 4-inch outer casing and extending down into the bedrock aquifer. Bedrock drilling was accomplished through air hammer techniques in the deep wells except PZ-9d where a rock core was collected. Upon completion of coring, an air hammer drill rig was used to ream out the borehole to a wider diameter for well installation. The annular seal for the Type III wells was similar to the Type II wells in regard to the sand pack surrounding the screened interval and the bentonite and grout seal. The deep wells were completed with between five and 15 foot screened sections depending upon the boring and its purpose. In general, the wells utilized for pump testing had longer screened sections than those for ground water monitoring. Each well was completed with a locking well cap and steel protective casing. Upon completion, each well was developed by surging and over-pumping.

3.3 Potentiometric Surface Map - .0504 (1) (c) (iii)

The groundwater potentiometric surface, based on composite high groundwater elevations are shown on **Figure 6.** The long term water level measurements from the permanent monitoring wells surrounding the C&D landfill have been used to create a composite Long Term Seasonal High groundwater map. This composite map is conservative in that it depicts the highest water levels detected in each well surrounding the proposed lined C&D landfill as well as the highest water levels recorded in each piezometer. Additionally, a seasonal high groundwater potentiometric surface map from August 2005 is included as **Figure 7**. The potentiometric surface reflects a subdued expression of the surface topography, and indicates a groundwater flow pattern toward Middle Creek to the north. Groundwater consistently flows in this direction as shown by potentiometric maps generated on a semi-annual basis for groundwater monitoring at the site.

3.4 Geologic and Hydrogeologic Evaluation - .0504 (1) (c) (iv)

3.4.1 Local and Regional Geology

The site is underlain by bedrock which consists of metamorphic rock types. Within the southern half of Johnston County sediments have been deposited on the bedrock through a series of sea level changes in the geologic past. The site is underlain by sediments of the Middendorf Formation which were deposited largely in a deltaic system. According to Geology of the Carolinas (Horton/Zullo, 1991) the formation consists of unfossiliferous, interbedded, thin clay and sand. The stratigraphy tends to be very discontinuous, indicating that the sediment deposits are lenticular. Most of the sediments range from silty clay to a coarse clayey sand and gravel with thin lenses of dense clay. There are occasional concretions of iron oxide minerals which form very hard thin layers within the sand layers. The Middendorf Formation is underlain by highly weathered metamorphic rocks of the Carolina Slate Belt.

The metamorphic rocks of the Carolina Slate Belt are characterized by low grade metamorphism which grades from the amphibolite to the greenschist facies. The Geologic Map of North Carolina shows the proposed C&D area to be underlain by Cenozoic Phyllite and Schist. This unit includes sheared fine-grained metasediments and metavolcanic rock.

In July 2003 for this assessment, GNRA installed 11 piezometers (10 shallow and 1 deep) in the proposed C&D area (PZ-1a, PZ-2, PZ-3a, PZ-4 - PZ-9, PZ-9d, and PZ-10). Additionally, there are several ground water monitoring wells in this area including MW-13, MW-13d, MW-4b, MW-4d, PZ-3, and MW-5a). In June 2004 additional wells (three shallow and four bedrock) were installed at the site. Three wells (PW-2, PW-3 and PW-4) were installed into bedrock for the performance of an aquifer pumping test. Four additional wells were installed (PW-1 - renamed MW-19d, MW-19, MW-20 and MW-21) for ground water monitoring. Monitoring wells MW-19, MW-20 and MW-21 are all shallow wells completed to the top of bedrock. Well MW-19d is a well completed in the bedrock. It should be noted that PW-2, 3, and 4 as well as MW-19d were drilled into the bedrock using air hammer techniques and no rock core was collected.

The boring logs for these piezometers and wells are included in **Appendix D** while the construction details are included in **Table 1**. Geotechnical analytical data and bedrock data are included in **Table 2**. In general, the unconsolidated sediments consisted of mainly medium to coarse sands with some silts and clays.

Three undisturbed samples were collected from a depth of approximately 5 feet and 7 feet adjacent to piezometers PZ-5 and PZ-7. These samples were collected to characterize the clays observed at the site. The permeability of the clay ranges from 6.16 E-06 to 5.2 E-07 cm/sec. The grain size and permeability data is included in **Appendix E** and are summarized on **Table 2**. The results of the consolidation analysis are not completed. This data will be forwarded upon completion and review. Geotechnical analyses of these and other soil samples are included in **Appendix E**.

The bedrock that was encountered was drilled using rock coring techniques in PZ-9d. The RQD value calculated for PZ-9d was 74%. The bedrock encountered was a felsic metavolcanic. This is consistent with what has been logged at the site previously.

In June, 2004 a geophysical study was completed across the proposed C&D area to evaluate whether any diabase dikes exist in this area. Two diabase dikes were found in the area. The study and its results are included in **Appendix F**.

3.4.2 Ground Water Flow Characteristics

The uppermost aquifer in the footprint of the site is located within the unconsolidated sediments above the bedrock at the site. Groundwater across the site consistently flows toward the north towards Middle Creek. Middle Creek is the discharge point for the uppermost aquifer as evidenced by vertical gradients observed in nested pairs close to the creek. As noted above, a long term composite high potentiometric surface map is included as **Figure 6** as the Long Term Seasonal High Water Table Map, and a Seasonal High Water Table Map is included as **Figure 7**.

3.4.3 Ground Water Gradients and Velocities

A summary of measured hydraulic conductivities (based on slug tests in wells and published data for unsaturated soils) and apparent horizontal hydraulic gradients and velocities is presented in **Table 4** and the slug test data is included in **Appendix G**. Horizontal hydraulic gradients were estimated based on potentiometric contours. Ground water velocities at each piezometer were calculated using apparent horizontal hydraulic gradients, hydraulic conductivity values and empirical effective porosity values according to the equation:

$$V = KI/n:$$

Where:
- V = Ground Water Velocity
- K = Hydraulic Conductivity (from rising head slug tests)
- I = Hydraulic Gradient (from water table elevations)
- n = Porosity (based on referenced values)

Hydraulic conductivity values for the bedrock aquifer range from 0.016 ft/day to 0.854 ft/day. Horizontal ground water gradients range from 0.023 to 0.210. Ground water velocities range from 0.002 to 0.130 ft/day.

3.4.4 Aquifer Pump Testing and Results

An aquifer pump test was performed June 19th - 22nd 2004. Prior to initiating the pump test, a short duration test similar to a step test was conducted to determine the optimum pumping rate for the longer term test. The short term test indicated a pumping rate of 1.5 gallons per minute (gpm) could be sustained by the aquifer without damage to the pump. Well PW-3 was used for the aquifer pumping test well.

The aquifer pumping test was run for a total time of approximately 72 hours. During the test a total of 11 observation wells were monitored. Seven of these were monitored by datalogger (PW-2, PW-4, PZ-5, PZ-6, PZ-7, MW-19d, and MW-5a) and the remaining wells (PZ-9, PZ-9d, PZ-4, PZ-8, and PZ-3) were monitored by hand with an electronic water level indicator.

Drawdown in the observation wells ranged from 0.16 feet to 4.44 feet. The cone of depression during the pump test shows a N70°E orientation which is consistent with the diabase dike. The average hydraulic conductivity is 2.7 ft/day and the average transmissivity is 135 ft^2/day. The pump test yielded a cone of depression that effectively reached over 1,500 feet in the N70°E direction and only 180 feet in the N20°W direction. The complete pump test report is included in **Appendix H**.

3.4.5 Summary of Hydrogeologic Evaluation

The planned lined C&D landfill will partially overlie (piggy-back) the previously closed unlined Phase 3 MSW landfill unit. The lined C&D landfill unit is proposed as a part of the continuing remedial efforts for unlined landfills at the site. The reduction of rainwater infiltration into the unlined Phase 3 MSW landfill unit will reduce the potential production of leachate from the landfill to impact groundwater at the site.

No ground water receptors (water wells) are located between the planned lined C&D landfill and the nearest ground water discharge feature (Middle Creek). Although groundwater in the area of the Phase 1&2 and Phase 3 MSW units is impacted, monitorability for the lined C&D landfill should not be an issue through the use of intra-well statistical analysis. The Water Quality Monitoring Plan will provide effective monitoring of ground water beneath this site. The Water Quality Monitoring Plan is included in **Appendix I**.

Based on the investigation of the Lined C&D study area and previous studies conducted at the site, geologic and hydrogeologic conditions are consistent throughout this portion of the site. Based on this characterization, the study area appears to be well suited to development of a lined C&D landfill.

Table 1
Monitoring Well / Piezometer Construction
Johnston County Proposed C&D Landfill

Well Number	Total Depth (ft.)	TOC Elevation	Ground Elevation	Top of Screen (ft)	Top of Screen Elevation	Bottom of Screen (ft)	Bottom Elevation	Bedrock Depth (ft)	Bedrock Elevation
PZ-1	15	178.87	176.7	5	171.7	15	161.7	N/A	N/A
PZ-1A	21	178.93	176.4	5	171.4	20	156.4	N/A	N/A
PZ-2	20	175.27	172.9	3	169.9	18	154.9	N/A	N/A
PZ-3A	16	171.04	168	5	163	15	153	N/A	N/A
PZ-4	20	158.29	155.4	5	150.4	20	135.4	N/A	N/A
PZ-5	18	155.82	154.2	3	151.2	18	136.2	N/A	N/A
PZ-6	23	161.22	159.1	8	151.1	23	136.1	N/A	N/A
PZ-7	20	168.82	166.6	5	161.6	20	146.6	N/A	N/A
PZ-8	18.5	168.01	166.4	3.5	162.9	18.5	147.9	N/A	N/A
PZ-9	23	160.5	157.7	8	149.7	23	134.7	N/A	N/A
PZ-9d	45	160.71	157.6	40	117.6	45	112.6	32.5	128.21
PZ-10	14.5	177.07	173.6	4.5	169.1	14.5	159.1	N/A	N/A
MW-13	20	179.57	174	9	165	19	155	NA	NA
MW-13d	53	172.7	171.82	48	123.82	53	118.82	38	133.82
MW-19*	10	127.41	124.9	5	119.9	10	114.9	10	114.9
MW-19d*	30	127.63	125	25	100	30	95	11	114
MW-20*	35	162.12	159.6	20	139.6	35	124.6	NA	NA
MW_21*	28	175.27	172.8	13	159.8	28	144.8	NA	NA
PW-2	31.5	159.62	156.6	21.5	135.1	31.5	125.1	18.5	138.1
PW-3	45	165.4	162.5	35	127.5	45	117.5	25	137.5
PW-4	32	159.71	156.9	22	134.9	32	124.9	16.5	140.4

PZ-1 drilled for Phase 4A Permitting in 12/98 by GNRA.

* These wells were installed initially with different names:
MW-19 = PSW-1
MW-19d = PW-1
MW-20 = PSW-2
MW-21 = PSW-3

Table 2
Bedrock and Geotechnical data
Johnston County Proposed C&D Landfill

Well Number	Core Depth	Run Length (feet)	Recovery (percent)	RQD (percent)
PZ-9d	33.00	10.0	97.50%	74%

Well Number	Sample Depth	Sieve Analysis				Liquid Limit	Plastic Limit	Plasticity Index	Permeability cm/sec
		% Gravel	% Sand	% Silt	% Clay				
PZ-1A	10 - 11.5 ft	1.80	86.60	4.40	7.20	15	NP	NP	na
PZ-2	10 - 11.5 ft	0.90	80.60	10.60	7.90	9	NP	NP	na
PZ-3A	5 - 6.5 ft	0.00	96.00	1.30	2.70	10	NP	NP	na
PZ-4	20 - 21.5 ft	0.00	15.50	54.40	30.10	28	24	4	na
PZ-5	15 - 16.5 ft	0.20	45.80	34.60	19.40	27	24	3	na
PZ-5*	5 ft	0.00	32.84	60.70	7.00	46	31	15	6.16 E-06
PZ-5	7 ft.	0.80	13.36	84.85	1.00	38	28	10	na
PZ-6	20 - 21.5 ft	32.80	49.20	10.30	7.70	8	NP	NP	na
PZ-7	5 - 6.5 ft	3.40	81.70	9.20	5.70	12	NP	NP	5.2 E-07
PZ-7	5 ft.	0.00	76.89	18.11	5.00	26	16	10	na
PZ-8	5 - 6.5 ft	0.30	72.30	7.90	19.50	17	NP	NP	na
PZ-9	10 - 11.5 ft	1.40	31.00	38.90	28.70	34	29	5	na
PZ-10	10 - 11.5 ft	0.70	89.30	6.80	3.20	17	NP	NP	na

* Indicates undisturbed shelby tube sample taken within 5 feet of the piezometer mentioned at the depth described.

Table 3
Johnston County Proposed C&D Landfill
Groundwater Elevation Data

Well Location	Top of Casing Elevation	Ground Elevation	T.O.B. WTE	24 hour WTE	Aug-03 WTE	Aug-04 WTE	8/29/2005 WTE	9/26/2005 WTE	10/27/2005 WTE	11/25/2005 WTE	12/26/2005 WTE	1/24/2006 WTE	2/20/2006 WTE	3/10/2006 WTE	4/11/2006 WTE
PZ - 1	**178.87**	**176.7**	na	na	171.33	171.37	170.79	171.27	171.34	171.42	171.51	171.51	171.33	171.20	171.16
PZ - 1A	**178.93**	**176.4**	na	176.75	176.73	177.75	176.90	177.08	177.11	177.33	177.71	177.78	177.46	177.38	177.25
PZ - 2	**175.27**	**172.9**	162.90	170.49	171.59	172.23	169.76	169.79	170.44	170.90	172.36	172.66	171.81	171.67	171.27
PZ - 3A	**171.04**	**168**	163.00	165.28	165.48	165.46	164.05	164.88	164.83	165.18	165.69	165.78	164.79	164.73	164.81
PZ - 4	**158.29**	**155.4**	137.40	154.42	155.77	155.95	154.38	155.14	155.85	156.02	156.23	156.29	155.94	155.75	155.56
PZ - 5	**155.82**	**154.2**	149.20	152.42	153.64	154.38	153.94	154.07	154.62	155.01	155.22	155.27	154.69	154.50	154.36
PZ - 6	**161.22**	**159.1**	138.10	154.20	155.14	155.86	154.96	155.19	155.62	156.07	156.43	156.51	155.67	155.48	155.42
PZ - 7	**168.82**	**166.6**	161.60	163.11	163.76	163.74	162.59	162.62	162.71	162.94	163.64	163.70	162.95	162.84	162.81
PZ -8	**168.01**	**166.4**	161.40	163.84	164.85	164.60	163.30	164.28	164.26	164.60	165.35	165.52	164.43	164.33	164.29
PZ -9	**160.50**	**157.7**	142.70	145.86	146.96	146.40	144.75	144.78	145.48	146.04	147.01	147.22	146.42	146.30	145.29
PZ -9D	**160.71**	**157.6**	na	na	146.97	146.67	145.19	145.24	145.92	146.41	147.30	147.52	146.76	146.65	145.32
PZ -10	**177.07**	**173.6**	168.60	na	172.17	171.67	171.01	171.00	171.04	171.27	171.45	171.40	171.17	171.09	171.01
MW-13	**179.57**	**na**	na	na	161.17	na	na	na	na	na	na	164.72	164.36	164.27	163.92
MW-13d*	**172.70**	**na**	na	na	152.72	152.92	na	na	na	na	na	154.07	153.51	153.35	153.20
MW -19 (PW-1)	**127.41**	**124.9**	120.9	na	na	123.81	121.38	121.60	122.87	123.48	123.93	123.97	123.45	123.24	123.13
MW -19D (PSW-1)	**127.63**	**125**	na	na	na	124.14	124.03	123.33	123.11	123.08	123.89	124.39	124.52	124.53	124.46
MW - 20 (PSW-2)	**162.12**	**159.6**	148.6	na	na	153.62	151.27	151.72	152.67	153.26	154.03	153.95	152.67	152.24	152.17
MW - 21 (\PSW-3)	**175.27**	**172.8**	151.8	na	na	164.12	162.43	161.78	161.64	161.49	163.56	164.49	163.99	163.71	163.37

TOC = Top of Casing.
T.O.B = Time of boring.
WTE = Water Table Elevation
Highlighting indicates highest water level recorded.
Note 24 hour water levels for PZ-7, PZ-8 and PZ-9 were actually collected 6 days after the well was installed.
*Data from MW-13D was from December 2003 and October 2004. Monitoring Well MW-13 was dry during these sampling events.
Data from MW-13 for August '03 was actually collected in June 2003.

Table 4
Ground Water Velocities
Johnston County Proposed C&D Landfill

Well	K (ft/day)	I	n	Velocity ft/day
PZ-1	na	0.027	0.200	na
PZ-1A	0.203	0.032	0.200	0.032
PZ-2	0.049	0.210	0.200	0.051
PZ-3A	0.016	0.027	0.200	0.002
PZ-4	0.518	0.037	0.200	0.096
PZ-5	na	0.036	0.200	na
PZ-6	0.087	0.023	0.200	0.010
PZ-7	0.082	0.075	0.200	0.031
PZ-8	0.057	0.025	0.200	0.007
PZ-9	0.259	0.100	0.200	0.130
PZ-9d	0.707	na	0.100	na
PZ-10	0.854	0.030	0.200	0.128

Vertical Hydraulic Gradient
Nested Well Pairs
Johnston County Landfill Phases 1 through 4

Data from June and August 2003 sampling events

Nested Pair	Top of Screen	Bottom Of Screen	Midpoint Of Screen	Water Elev.	Vertical Gradient	Direction
MW-4b*	187.34	176.2	181.8	177.35	-0.06	up
MW-4d*	117.2	112.2	114.7	181.66		
MW-13	166	154	160.0	161.17	0.22	down
MW-13d	121.45	116.45	119.0	152.14		
PZ-9	152.5	137.5	145.0	146.96	0.00	none
PZ-9d	120.71	115.71	118.2	146.97		
MW-19	119.9	114.9	117.0	123.81	-0.02	up
MW-19d	100	95	97.500	124.14		

Vertical Gradient calculated using the following equation:

$$\frac{\text{(WTE Shallow - WTE Deep)}}{\text{(Shallow MOS - Deep MOS)}}$$

Where:

WTE= Water Table Elevation
MOS = Midpoint of Screen

* denotes water table elevation from 3/99.