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Cherry Island Landfill Expansion Project Wilmington, Delaware

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for

CHERRY ISLAND LANDFILL EXPANSION PROJECT

Wilmington, Delaware

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TABLE OF CONTENTS

1. INTRODUCTION 1
   - 1.1 Terms of Reference 1
   - 1.2 Overview of Vertical Expansion Project 1
   - 1.3 CIL Layout and History of Development 3
     - 1.3.1 CIL Layout 3
     - 1.3.2 History of CIL Development 4
   - 1.4 Organization of this Report 5
2. REGULATORY REQUIREMENTS 7
3. FACILITY LAYOUT AND DESIGN CONCEPT 9
   - 3.1 Introduction 9
   - 3.2 Design Criteria for the Landfill Expansion 9
   - 3.3 Expansion Design Overview 10
     - 3.3.1 Foundation Improvements 10
     - 3.3.2 Leachate Management System Improvements 11
       - 3.3.2.1 Overview of Leachate Management System 11
       - 3.3.2.2 Permanent Leachate Management System 12
       - 3.3.2.3 Temporary Leachate Management System 12
     - 3.3.3 LFG Management System Upgrades 13
     - 3.3.4 Closure System 14
     - 3.3.5 Monitoring Program Enhancements 14
   - 3.4 Plan of Implementation 15
4. FACILITY COMPONENTS 17
   - 4.1 Overview 17
   - 4.2 Liner System 17
     - 4.2.1 Introduction 17
     - 4.2.2 Foundation and Liner System Design Criteria 18
     - 4.2.3 Proposed Liner System Layout 19
     - 4.2.4 Proposed Liner System Components 19
     - 4.2.5 Liner System Performance 21
       - 4.2.5.1 Introduction 21
       - 4.2.5.2 Separation Distance between Liner and Groundwater 21
       - 4.2.5.3 Settlement 21
       - 4.2.5.4 Stability 23

TABLE OF CONTENTS
(continued)

4.2.5.5 Protection of the Liner System 27
4.3 Leachate Collection, Removal, and Transmission System 27
4.3.1 Regulatory Requirements 27
4.3.2 Temporary Leachate Transmission System 28
4.3.3 Leachate Collection System 29
4.3.3.1 Introduction 29
4.3.3.2 Leachate Collection System Description and Design Criteria 29
4.3.3.3 Leachate Collection System Layout 30
4.3.3.4 Leachate Collection System Components 31
4.3.3.5 Leachate Generation 32
4.3.3.6 Effects of Settlement 32
4.3.3.7 Leachate Collection Piping 34
4.3.4 Leachate Removal System 35
4.3.4.1 Introduction 35
4.3.4.2 Perimeter Manhole Sumps 35
4.3.4.3 Leachate Removal Pumps 36
4.3.4.4 Slopes Riser Pipes 36
4.3.4.5 Flow Meters and Valves 36
4.3.5 Leachate Transmission System 37
4.3.5.1 Overview 37
4.3.5.2 Leachate Transmission System Features 37
4.4 LFG Management System 39
4.4.1 Purpose and Organization 39
4.4.2 Design Concepts and Criteria 40
4.4.3 System Layout and Features 41
4.4.3.1 Existing LFG Management System 41
4.4.3.2 Proposed Expansion of LFG Management System 42
4.4.3.3 Horizontal Collectors 43
4.4.3.4 Vertical Wells 43
4.4.4 Staged Development of the LFG Management System 44
4.4.4.1 Introduction 44
4.4.4.2 Rational for Three Stage Development 45
4.4.4.3 Initial Construction Stage 46
4.4.4.4 Main Active Filling Stage 47
4.4.4.5 Final Closure and Post-Closure Stage 52

TABLE OF CONTENTS
(continued)

4.4.5 Gas Extraction and Management System Components 56
4.4.5.1 Introduction 56
4.4.5.2 Horizontal LFG Collection Trenches 56
4.4.5.3 Vertical LFG Extraction Wells 57
4.4.5.4 LFG Transmission Piping 59
4.4.5.5 LFG Flare Station 60
4.5 Final Cap System 61
4.5.1 Introduction 61
4.5.2 Settlement 61
4.5.2.1 Overall Compressibility 62
4.5.2.2 Local Heterogeneity 63
4.5.2.3 Method of Analysis 63
4.6 Access Road Design 64
4.7 Stormwater Management System 65
4.7.1 Introduction 65
4.7.2 Existing and Future Conditions 65
4.7.3 Regulatory Requirements 67
4.7.3.1 General 67
4.7.3.2 Erosion and Sediment Control Plan 68
4.7.3.3 Stormwater Management Plan 68
4.7.4 Stormwater Management System Design 69
4.7.4.1 Overview 69
4.7.4.2 Stormwater Management Feature Design Basis 71
4.7.4.3 Design Summary 73
5. CONSTRUCTION METHODS 76
6. FACILITY CONSTRUCTION SCHEDULE 77
7. FACILITY DISPOSAL CAPACITY AND LIFE PROJECTIONS 78
7.1 Introduction 78
7.2 Anticipated Waste Quantities 78
7.3 Facility Life Projections 78
8. CONSTRUCTION QUALITY ASSURANCE PLAN 79
9. REFERENCES 80

TABLE OF CONTENTS
(continued)

FIGURES

Figure VIb-1: General Site Plan
Figure VIb-2: Facility Layout
Figure VIb-3: Facility Final Grades
Figure VIb-4: Entrance Area Plan
Figure VIb-5: Foundation Improvement Approach – Schematic
Figure VIb-6: Incline Leachate Removal System
Figure VIb-7: Seismic Impact Zone Map
Figure VIb-8: Expansion Area Development Schedule

APPENDICES

Appendix VIb-A: Reduced Size Set of Permit Drawings
Appendix VIb-B: Disposal Capacity Volume Computations
Appendix VIb-C: Settlement Analysis
- Appendix VIb-C.1: Leachate Manhole Settlement Analysis
- Appendix VIb-C.2: Settlement of Existing LCS Pipes
- Appendix VIb-C.3: Settlement of Proposed Phase Va Liner

Appendix VIb-D: Slope Stability Calculations
- Appendix VIb-D.1: Evaluation of Partially Consolidated Undrained Parameters
- Appendix VIb-D.2: Landfill Stability Analysis - (Static) – Phases III to V
- Appendix VIb-D.3: Landfill Stability Analyses (Seismic) – Phases III to V
- Appendix VIb-D.4: Mechanically Stabilized Earth Berm Construction Stability Analysis
- Appendix VIb-D.5: Assessment of Dredge/Alluvium Drained Conditions
- Appendix VIb-D.6: Prefabricated Vertical Drain Evaluation

Appendix VIb-E: Miscellaneous
- Appendix VIb-E.1: Structural Stability of Existing Navigation Beacon Tower

Appendix VIb-F: Liner System Calculations
- Appendix VIb-F.1: Geomembrane Puncture Resistance-Liner
- Appendix VIb-F.2: Liner System Veneer Stability on Side Slopes
- Appendix VIb-F.3: Anchor Trench Calculations

TABLE OF CONTENTS
(continued)

Appendix VIb-G: Leachate Collection, Removal, and Transmission System Calculations
- Appendix VIb-G.1: Leachate Generation Analysis
- Appendix VIb-G.2: Geotextile Filter/ Protective Cover Soil Clogging Evaluation
- Appendix VIb-G.3: Flow Capacity of Leachate Collection Pipes
- Appendix VIb-G.4: Structural Integrity of Leachate Collection Pipes
- Appendix VIb-G.5: Pump Station Hydraulic Calculation – Incline P.S.

Appendix VIb-H: Landfill Gas Management System Calculations
- Appendix VIb-H.1: Sizing of Landfill Gas Extraction and Transmission System Components
- Appendix VIb-H.2: Structural Integrity of Landfill Gas Collection Pipes

Appendix VIb-I: Stormwater Management Calculations
- Appendix VIb-I.1: Selection of Post-Development Hydrologic Parameters
- Appendix VIb-I.2: Stormwater Routing Analysis: 25-yr, 24-hour Design Storm
- Appendix VIb-I.3: Stormwater Routing Analysis: 100-yr, 24-hour Design Storm
- Appendix VIb-I.4: Sideslope Terraces, Swales, and Perimeter Drainage Channels Design
- Appendix VIb-I.5: Downchute Geometric Design
- Appendix VIb-I.6: Downchute Lining Design
- Appendix VIb-I.7: Drop Inlet Design
- Appendix VIb-I.8: Stormwater Outlet Culvert Design
- Appendix VIb-I.9: Culvert Outlet Protection Design
- Appendix VIb-I.10: Stormwater Outlet Culvert Settlement Analysis
- Appendix VIb-I.11: Stormwater Outlet Culvert Structural and Pipe Bedding Design

Appendix VIb-J: Erosion and Sediment Control Plan

Appendix VIb-K: Cap System Calculations
- Appendix VIb-K.1: Analysis of Final Cover System Settlement

Appendix VIb-L: Technical Specifications

Appendix VIb-M: Construction Quality Assurance Plan

1. INTRODUCTION

1.1 Terms of Reference

This Engineering Report describes the design of the proposed vertical expansion at the Cherry Island Landfill (CIL), which is located at the Northern Solid Waste Management Center (NSWMC) in Wilmington, New Castle County, Delaware. The Delaware Solid Waste Authority (DSWA) owns and operates the CIL. This engineering report addresses the requirements of Section (§) 4.B.1.d (i.e., Engineering Report), §5.A (i.e., Siting), and §5.B (i.e., Design) of the Delaware Regulations Governing Solid Waste (DRGSW). The engineering design of the proposed CIL expansion is presented in this report along with the manner in which the design of various expansion features address the requirements of the DRGSW.

This engineering design and this report were prepared by GeoSyntec Consultants (GeoSyntec) of Columbia, Maryland, and Pennoni Associates of Philadelphia, Pennsylvania. This report was prepared by Dr. R. David Espinoza, P.E., Mr. Douglas T. Mandeville, Mr. William M. Steier, P.E., Ms. Carrie H. Pendleton, Dr. Carlos A. Lazarte, P.E., Dr. Jeremy W.F. Morris, Mr. Thomas B. Ramsey, P.E., and Ms. Shana M. Opdyke, all of GeoSyntec's Columbia, Maryland office, and Mr. James McCann, P.E., and Mr. Robert Campbell, P.E., of Pennoni Associates in Philadelphia, Pennsylvania. Components of the engineering design were reviewed by the following technical experts: Dr. J. Michael Duncan, P.E., Dr. James K. Mitchell, P.E., and Mr. Peter J. Nicholson, P.E. The report was prepared under the direction of Mr. Michael F. Houlihan, P.E., and it was reviewed by Mr. Houlihan and Mr. Eric S. Steinhauser, P.E., both of GeoSyntec.

1.2 Overview of Vertical Expansion Project

The CIL is located near the intersection of 12th Street and Interstate 495 (I-495) in Wilmington, Delaware. The location of the site is identified on Figure VIb-1. The CIL site was initially permitted for solid waste management in 1982. The facility contains several solid waste management features, including a landfill for disposal of solid waste. The CIL has been used for disposal of solid waste since 1985. Since that time, waste has been disposed in six disposal cells having a combined area of about 240 acres. The general layout of the landfill facility is illustrated on Figure VIb-2 and is described in detail in Section 1.3 of this Engineering Report. In 2000, DSWA performed an evaluation of the stability of the facility (Schnabel 2001) and concluded that enhancements were needed to allow continued waste disposal. The design that is

described in this engineering report was developed to provide the required stability enhancements and to increase the disposal capacity of the landfill.

The concept for enhancing stability and increasing disposal capacity is illustrated in detail in the drawings entitled, "*Construction Drawings for Landfill Expansion, Cherry Island Landfill, New Castle County, Delaware*" (i.e., Permit Drawings), prepared by GeoSyntec and dated 13 June 2004. The increased disposal capacity depicted in the Permit Drawings is based on a maximum finish grade elevation of 195 ft-msl as shown on Figure VIb-3.

As shown on Drawing 4 (i.e., Landfill Expansion Development Plan) in Appendix VIb-A, the plan for enhancing stability and increasing capacity includes the following components, each of which is addressed in Section 4 of this Engineering Report (i.e., Facility Components).

- Constructing a *stabilizing berm* around the perimeter of Phases III, IV, V, and Va of the disposal area.
- Installing *prefabricated vertical drains* (PVDs) beneath the stabilizing perimeter berm to accelerate the stabilizing effect of the berm.
- Relocating the current stormwater management ponds and constructing a new liner system over this area.
- Constructing a *new leachate transmission system* around the perimeter of the landfill to replace the existing system, which will be decommissioned as a result of construction of the stabilizing perimeter berm.
- Expanding and improving the *landfill gas management system* to accommodate the increased quantity of landfill gas (LFG) that will be generated by the expanded landfill.
- Upgrading the system for *management of stormwater runoff* from the landfill, which will control the anticipated stormwater flows of the expanded landfill.

The engineering design of these landfill expansion features is described in detail in Sections 3 and 4 (i.e., Facility Layout and Design Concept, and Facility Components) of this Engineering Report.

1.3 CIL Layout and History of Development

1.3.1 CIL Layout

As described in Section 1.2, the CIL facility is located at 12th Street near I-495 in Wilmington, Delaware. The facility is bounded to the north by the City of Wilmington Wastewater Treatment Plant, to the east by the Delaware River, to the south by the Christina River, and to the west by both the Getty Pipeline property and the Wilmington Harbor North (WHN) dredged material management area, which is operated by the United States Army Corps of Engineers (USACOE). Since the facility was developed, several features have been developed at the facility to support waste management operations. A brief description of each of the primary features of the facility is presented below.

- *Landfill Entrance.* The entrance to CIL includes two scale houses, a maintenance building, and administrative offices. Construction of the new landfill entrance is to be completed by summer or fall of 2003. The layout of the new landfill entrance is shown on Figure VIb-4.

- *Waste Disposal Area.* The CIL consists of six discrete landfill disposal areas (phases), which are referred to throughout the project documents as Phases I, IA, II, III, IV, and V. For each phase of development, except Phase IA, a new area was prepared for waste disposal and then the area was filled with waste; in contrast, Phase IA was developed as an overfill of the Phase I and Phase II areas. The order of development of these phases and key design features of each phase are identified below. Municipal solid waste is no longer disposed of in Phases I, IA, and II, but these areas do serve as a staging area for compost and white goods. In addition, asbestos disposal continues in Phase IA. The liner system for the landfill is a natural liner that meets the requirements of DRGSW §5.C.2.b (i.e., Natural Liner) except on the side slopes of the perimeter berm around Phases IV and V, which are lined with a geosynthetic clay liner (GCL).

- *Leachate Collection Systems.* Each phase is underlain by a leachate collection system (LCS). The LCS for each phase consists of a drainage layer constructed over the natural dredge liner and a series of lateral and main collection pipes. The lateral pipes subdivide the phases into discrete areas that are designed to route leachate to the main pipes. The main pipes route the collected leachate to one of 26 exterior collection manholes. The main pipes within the landfill were constructed in aggregated-filled trenches having a

slope between 0.93 and 3 percent. The depth of the trench is as much a 30 ft below ground surface. According to CIL facility personnel, approximately 170,000 gallons of leachate is generated each day.

- *Leachate Removal and Transmission System.* In the existing waste disposal cells, leachate drains by gravity to an exterior manhole, from which the leachate is directed to one of six pump stations. At each of these pump stations, submersible pumps force the leachate to the next manhole or pump station through a transmission line. The last and seventh pump station (see Northern Pump Station on Drawing 45) transfers liquid to the adjacent City of Wilmington Wastewater Treatment Plant.

- *Stormwater Management System.* Stormwater runoff from the eastern portion of CIL is currently discharged to the Delaware River through one of two outfalls, one of which is located near the northeast corner of Phase III and the other is located near the confluence of the Delaware and Christina Rivers. Stormwater runoff from the western portion of the site is directed toward the entrance area, where water is discharged to a surface drainage feature near the I-495 right-of-way and to either the Brandywine Creek or the Christina River.

- *Landfill Gas Management System.* LFG is collected through a series of LFG collection wells in Phases I, IA, II, III, IV, and V. In addition, LFG is collected at the six pump stations. LFG that is collected in the wells and at the pump station is routed through aboveground transmission pipes to the LFG blower and flare located near the entrance of the facility. The LFG management system at CIL is currently owned and operated by Cereza under contract to DSWA.

1.3.2 History of CIL Development

The development histories of the six phases of the landfill are summarized below.

- The first waste disposal cell, Phase I, was constructed in 1985 on a 9-acre area. Each of the phases was constructed over dredge spoil placed in the area before the area was used for solid waste disposal.

- The second waste disposal cell, Phase II was constructed east of Phase I on an 18.3-acre area. Waste placement began in this area in 1987.

- Phase IA was constructed between Phase I and II in 1988. Waste placement began in Phase IA in 1989.
- In 1988, Phase III was constructed on a 19.4-acre area immediate east of Phase II. Geogrid reinforcement was placed in the foundation of Phase III to enhance the overall stability of the area. Waste placement began in Phase III in 1992.
- Phase IV was constructed in 1993 adjacent to Phase III on a 22.5-acre area. The berm in Phase IV is located over a foundation where PVDs were installed. The PVDs were installed to enhance the stability of the berms and the landfill in general.
- Phase V was constructed in 1996 immediately south of Phase IV. Each phase is surrounded by an earthen berm. The berm in Phase V is located over a foundation where PVDs were installed. The PVDs were installed to enhance the stability of the berms and the landfill in general.

1.4 Organization of this Report

This Engineering Report has been organized in a manner that follows the order presented in DRGSW §5.A and B (regarding siting and design of sanitary landfills) and §4.B (regarding engineering reports for sanitary and industrial landfills). The requirements of these sections of DRGSW and the location where the requirement is addressed in this report are as follows:

- a description of the regulatory requirements (DRGSW §5.A, B, and C) and the manner in which the design addresses requirements is presented in Section 2;
- the layout of the facility and the design concept are described in Section 3;
- a description of the features of the proposed design (DRGSW §4.B.1.d.(1), including the manner in which the design complies with the specific design requirements of DRGSW §5.D through §5.K, is presented in Section 4;
- the construction methodology for the proposed design and a description of the proposed installation methods and procedures for the features of the design (DRGSW §4.B.1.d.(2) are presented in Section 5;
- a schedule of events for construction of the facility (DRGSW §4.B.1.d.(3) is presented in Section 6;

- the proposed design capacity of the landfill, in terms of total volume and volume of waste received per day (DRGSW §4.B.1.d.(4), is discussed in Section 7; and
- a construction quality assurance plan (DRGSW §4.B.1.d.(5) is presented in Section 8.

The engineering calculations and supporting documentation for the engineering design are presented in appendices to this Engineering Report.

2. REGULATORY REQUIREMENTS

In this section, the regulatory requirements for landfill design (i.e., DRGSW §5.B) are addressed. These regulations address the minimum design standards for landfills that will accept household waste.

DRGSW §5.B.1 requires that landfills be planned and designed by a professional engineer registered in the State of Delaware. Accordingly, CIL has been designed and planned by, and under the direct supervision of, a professional engineer licensed to practice engineering in the State of Delaware, as shown on the cover sheet of this report. Also, as required by DRGSW §5.B.1, the design is consistent with the purpose and intent of the DRGSW, based on both: (i) empirically derived data regarding landfill design and performance; and (ii) state-of-the practice engineering technology.

The minimum design standards of DRGSW §5.B.2 are identified below and the manner in which the CIL design meets the standards is presented.

- *Sanitary landfills must be designed to minimize releases and to prevent significant adverse impacts on human health and the environment at the point of compliance.* CIL has been designed to be protective of groundwater, surface water, land, and air resources at the point of compliance, as demonstrated in Section 4 of this Engineering Report. The design meets all of the performance requirements of DRGSW and 40 CFR Part 258 (i.e., the Federal Subtitle D regulations), both of which are intended to be protective of human health and the environment. Also, a comprehensive monitoring system has been operated at the facility for the past 18 years and will continue to be operated throughout the operating and post-closure care periods. The system was designed and is being operated to detect releases of landfill constituents to groundwater, surface water, and air.

  If a release is detected during future monitoring, then the contingency provisions of the DRGSW will be performed to evaluate the extent of the release and, if needed, approaches to mitigate the problem. In this manner, the landfill has been designed to minimize releases and to prevent significant adverse impacts on human health and the environment.

- *A liner and leachate collection system that meets the requirements of DRGSW §5.C and D must be constructed.* As described in Sections 4.2 and 4.3 of this engineering report, the liner and leachate collection system for the CIL expansion disposal area is designed to meet the specific requirements of DRGSW §5.C and 5.D.

- *A setback area, including a buffer zone with appropriate screening, must be established and maintained at the facility.* A facility is set back from adjacent properties to the degree possible, as shown on Drawing 3 (i.e., Existing Site Conditions) in Appendix VIb-A.
- *A gas control system that meets the requirements of DRGSW §5.E must be established and maintained.* A gas control system exists at the site and will be operated in compliance with applicable air quality regulations (i.e., Title V of the Clean Air Act and the NSPS and the Delaware Air Quality Standards), and the system will be expanded as shown on Drawings 71 through 77 of the Permit Drawings provided in Appendix VIb-A to collect the additional LFG that will be generated in the expansion areas. The design of the features of the LFG management system is described in Section 4.4 of this Engineering Report.
- *A surface-water management system that meets the requirements of DRGSW §5.F must be established and maintained.* As described in Section 4.7 of this engineering report, a stormwater management system will be established and operated during the active life and post-closure care period for the CIL facility.
- *A ground-water monitoring system that meets the requirements of DRGSW §5.G must be established and maintained.* As described in Part VII (i.e., Hydrogeologic Assessment Report) of this Permit Modification Application, a groundwater monitoring plan exists for the site, and the plan has been modified slightly as a result of the proposed expansion. The monitoring system will be operated throughout the active life and post-closure period of the landfill.
- *A capping system that meets the requirements of DRGSW §5.H.* The approved capping system described in Section 4 of the report entitled "*NSWMC – Cherry Island Landfill, Phase IV Disposal Area Hydrogeologic, Geotechnical and Landfill Capping Report*" (Weston, 1992) will be used for the final cover system.

3. FACILITY LAYOUT AND DESIGN CONCEPT

3.1 Introduction

In this section, the layout of the expanded CIL is described and the overall design approach is presented. The purpose of this section is to illustrate the proposed features of the expanded CIL and to provide a framework for the detailed descriptions of the facility components that are presented in Section 4 of this Engineering Report. The overall criteria that were used for the design of the landfill are presented in Section 3.2. An overview of the primary features of the expansion is presented in Section 3.3. A description of the plan for implementing the features of the expansion design is presented in Section 3.4.

3.2 Design Criteria for the Landfill Expansion

Eleven criteria were used to develop the design for the stability and capacity enhancements at the CIL. These criteria, and the location in this report where the criteria are addressed, are presented below.

1. Protect the environment (addressed throughout this Engineering Report and in the Environmental Assessment Report, Part VII of the Permit Modification Application).
2. Verify the stability of the entire landfill under current permit conditions (addressed in Section 4.2. of this Engineering Report).
3. Maximize the disposal capacity of the expansion, providing disposal capacity through at least 2023 (addressed in Section 7 of this Engineering Report).
4. Provide stability at an appropriate factor of safety and a high degree of reliability for the expanded CIL (addressed in Section 4.2 of this Engineering Report).
5. Arrange for continued operability of the LCS, in accordance with the requirements of DRGSW §5.D.2, under all conditions (addressed in Section 4.3 of this Engineering Report).
6. Provide uninterrupted waste management operations throughout the development and operation (in a manner that considers strength gain, construction, changes to the leachate management system (LMS), etc.) (addressed in Part VIII, Operations Manual, of this Permit Modification Application document).

7. Coordinate with USACOE to ensure that the design of the expanded CIL and the operation of the WHN dredge area are coordinated and waste management activities and dredge management activities are performed in a manner that does not adversely impact the environment (addressed in Section 4.2 of this Engineering Report).
8. Provide adequate capacity of the LFG management system for the future LFG generation rates and landfill geometry (addressed in Section 4.4 of this Engineering Report).
9. Revise the design of the stormwater management system to accommodate the anticipated flows from the expanded landfill (addressed in Section 4.7 of this Engineering Report).
10. Provide that the improvements are constructible and reliable using: (i) construction methods that are established to the degree practical; and (ii) test methods that verify performance of critical features of design [PVD installation details, spacing requirements, surcharge effects, rate of actual pressure dissipation, scale-up effects on productivity, wall facing, and settlement effects on leachate transmission system (LTS)] (addressed in Section 4 of this Engineering Report).

3.3 Expansion Design Overview

3.3.1 Foundation Improvements

To improve the general stability of the landfill, improvements will be made to the foundation around the perimeter of the facility. The improvements will include installation of PVDs and construction of a perimeter stabilization berm over the PVDs. The purposes of these two features are described below and are illustrated on Figure VIb-5.

- *Prefabricated Vertical Drains.* The purpose of the PVDs will be to accelerate consolidation of the dredge/alluvium at the perimeter of the landfill, thereby accelerating the increase in strength of the material.
- *Perimeter Stabilization Berm.* The purposes of the perimeter stabilization berm that will be constructed over the PVDs will be to: (i) increase the shear strength of the foundation soils; and (ii) counterbalance the lateral load on the foundation soils caused by the waste in the landfill. The manner in which the perimeter berm will increase the shear strength of the foundation soils is

described in Section 4.2.5.4. In general, the counterbalance berm resists lateral instability of the landfill by applying a load comparable to that being applied to the soils beneath the waste at the edge of the landfill. To maximize the load applied to the foundation soils, the berm will be constructed having a steep outer slope [e.g., 3 vertical to 1 horizontal (3V:1H)] that will be reinforced using mechanically-stabilized earth (MSE) techniques.

The approach to placement of PVDs is illustrated in Appendix VIb-A on Drawings 9 (i.e., Prefabricated Vertical Drain Installation Plan), 10, and 11 (i.e., Prefabricated Vertical Drain Details I and II). These drawings provide the PVD installation locations and PVD installation details. The perimeter stabilization berm (which referred to throughout the drawings and other Permit Modification Application documents as the perimeter berm or MSE Berm) is illustrated on several plans in Appendix VIb-A, including Drawing 13 (i.e., Perimeter Berm Plan), Drawings 32 through 36 (i.e., MSE Berm Cross Sections I through V), and Drawings 37 through 39 (i.e., MSE Berm Typical Details, I, II, and III). These drawings illustrate the locations where the perimeter berm will be constructed, the configuration of the berm, and the typical details of construction of the berm.

3.3.2 Leachate Management System Improvements

3.3.2.1 Overview of Leachate Management System

The existing LMS will be modified during and after the new perimeter berm has been constructed because construction of the perimeter berm will extend over existing LMS manholes. New manholes and pump stations will be constructed outside of the proposed berm and connected to the existing manholes. Therefore, a new LMS will be constructed as part of the landfill expansion . The design of the leachate management system is described in general in this section and in detail in Section 4.3 (i.e., Leachate Management System) of this Engineering Report. The LMS is designed to limit the head of leachate on the liner system to less than one foot in both the expansion areas and the existing waste disposal area. The LMS will consist of a series of manholes where leachate will be collected and then transferred to a transmission piping system, which will route the leachate to the on-site discharge point to the City of Wilmington Wastewater Treatment Plant (WWTP). Because the LMS will need to function continuously during the construction of the expansion, the new LMS will be constructed in stages, as described below. The proposed permanent LMS is described in Section 3.3.2.2, followed by a description of the temporary LMS, which will be operated during construction of the landfill expansion.

3.3.2.2 Permanent Leachate Management System

The permanent LMS will be operated following construction of the landfill expansion features and throughout the operating and post-closure period of the landfill. A conceptual cross-section of the leachate removal system configuration is shown on Figure VIb-6. For the permanent system, leachate will be collected at existing leachate collection manholes, from which the leachate will be pumped through a new removal pipe system (i.e., incline removal pipes shown on Figure VIb-6) to a new pump station located on top of the new perimeter berm (i.e., on the lower tier portion of the perimeter berm). At the new pump stations, the leachate will be transferred to a new leachate transmission forcemain, which will route the leachate to the WWTP. The configuration of the permanent LMS is shown in Appendix VIb-A on Drawing 45 (i.e., Leachate Management System Plan), and the details of the leachate removal approach are illustrated on Drawing 58 (i.e., Incline Pump Station Cross Sections). To route leachate from the new liner system in the expansion areas to the existing leachate collection system, a drain system will be constructed as shown on Drawing 48 (i.e., Expansion Berm Perimeter Toe Drain Plan and Profile).

3.3.2.3 Temporary Leachate Management System

The temporary LMS will be constructed in a manner that ensures continuous collection and removal of leachate throughout the construction of the landfill expansion system features. The temporary LMS will consist of a series of transmission pipes connected to the existing leachate manholes, which will all be located outside of the expansion construction area. The layout of the temporary LMS is shown on Drawing 56 (i.e., Temporary Bypass Piping Site Plan) in Appendix VIb-A and the general sequence of development of the LMS is illustrated on Drawing 46 (i.e., Leachate Management System Tie-In to Current System). As shown on these drawings, the temporary LMS will be constructed using the existing manholes and, except for the manholes, will be located on the landfill disposal area outside of the expansion construction areas. The temporary LMS is designed to use as many of the features of the current system as practical. For example, existing pumps will be used for the temporary LMS. The temporary LMS will be decommissioned after construction of the permanent LMS is completed, as illustrated on Drawing 46.

3.3.3 LFG Management System Upgrades

The LFG management system for the landfill will be upgraded and expanded so that the quantity of gas generated by the new landfill can be effectively managed. Another goal of the new system is to better collect LFG to prevent the potential for odor problems. DSWA believes that an enhanced LFG management system will provide additional protection of air resources and minimize the possibility of odor impacts to the community surrounding the site. The LFG management system will consist of several layers of horizontal gas collection pipes, a network of vertical gas collection wells, a system of gas transmission header pipes, and associated valves and controls. Because the LFG management system must function continuously throughout the period of construction of the landfill expansion features, the system will be installed in stages. The layouts of the different stages of the LFG management system are illustrated on Drawings 71, 72, and 73 (i.e., LFG Management System Plan Layouts I, II, and III). The staged construction approach is described below.

- During the *Construction Stage,* the existing gas management system will be modified as shown on Drawing 71. The construction stage includes the period of time when the permanent LFG management system features are being constructed. During this stage, LFG will be managed using the existing features plus temporary features (e.g., transmission pipes, valves, etc.). Management of LFG during this stage is described in Section 4.4.4.3.

- The *Main Active Filling Stage* of LFG management includes the period of time from the end of the LFG management system construction until about two to four years before the end of waste placement in the landfill. During this stage, LFG will be first managed using the system illustrated in Drawing 71, and then using the expansion of the system illustrated on Drawing 72. Management of LFG during this stage is described in Section 4.4.4.4.

- During the *Closure and Post-Closure Stage,* LFG will be managed using the completed LFG management system as illustrated on Drawing 73. This stage includes the period of time from the end of the main active filling stage until the end of the post-closure care period. At the beginning of this stage, several modifications will be made to the system (e.g., installation of vertical gas collection wells in the top layers of the landfill, etc.). Management of LFG during this final stage is described in Section 4.4.4.5.

3.3.4 Closure System

DSWA will construct a capping system over all waste disposal areas after waste in an area has been filled to the final permitted grades. The capping system final grades are illustrated on Drawing 78 (i.e., Landfill Final Development and Grading Plan), and the details of the final cover system are illustrated on Drawing 80 (i.e., Cover System Details). In general, the landfill will be closed after waste placement has been completed in an area; however, closure activities may be performed in stages involving closure of portions of the landfill that have been filled to final grades, but before the entire CIL is filled and closed. The capping system is illustrated on Drawing 79. The details of the capping and closure system are described in Section 4 of the report prepared by Weston (1992) and it is provided in Volume 14 of this permit modification application. If future landfill cells are permitted adjacent to CIL (e.g., in the Wilmington Harbor North Dredge Material Management Area) that result in future overfilling in areas of the proposed expansion, then the final landfill cover will not be constructed in these areas until after the overfill areas are completely filled; such activities, if any, would be described in a future application for permit modification.

3.3.5 Monitoring Program Enhancements

Both the geotechnical monitoring and environmental monitoring (i.e., groundwater) systems at the facility will be upgraded during implementation of the design described in this Engineering Report. The purpose of upgrading the geotechnical monitoring plan is to ensure that the performance of the foundation soils is monitored and that the findings of the monitoring activities are incorporated into the construction and operation plans for the expansion. These monitoring activities are needed because the phasing of both construction and filling of the landfill depend on gains in strength of the dredge and alluvium soils beneath the perimeter berm. In order to verify that the required strength gains are occurring, specific monitoring procedures will be needed. The geotechnical monitoring program is described in detail in the Operations and Maintenance Manual (Part V, Appendix G).

The purpose of upgrading the groundwater monitoring system is to monitor the quality of the aquifers beneath the landfill. The change to the groundwater-monitoring plan is presented in Part VIII (i.e., Hydrogeologic Assessment) of this Permit Modification Application and includes moving wells that are located within the proposed construction area to a location outside of the construction area.

3.4 Plan of Implementation

The foundation improvements and expansion design described in this Engineering Report will be constructed and implemented over a period of several years after the permit is received. In general, the plan for implementation involves a series of construction, monitoring, and operations events that are designed to provide the disposal capacity needed for ongoing disposal operations without compromising stability or facility operations (e.g., leachate management, disposal, LFG management, etc.). The plan for implementing the improvements and enhancements is illustrated on Drawings 5, 6, and 7 (i.e., Generalized Construction Sequence Plans) and Drawings 81 through 85 (i.e., Development Sequence Plans) in Appendix VIb-A of this Engineering Report. As shown on these drawings, development will occur in the following order:

1. Erosion and sediment controls will be established for the construction areas and general site preparation activities will be performed (e.g., clearing and grubbing, preparing ground surfaces for construction activities, preparing access to the site, etc.).

2. Environmental monitoring features within the construction area will be relocated and then, after the appropriate period of overlap in monitoring, the existing features will be decommissioned.

3. The temporary LMS and LFG management system will be installed and elements of the existing systems that are within the expansion construction area will be demolished.

4. Perimeter foundation improvements (i.e., installation of PVDs) will be performed, first at the existing sediment pond near Phase V, which will be used as a soil stockpile area during construction, and then around the perimeter of the landfill (i.e., outside of the current limits of waste).

5. Following installation of the PVDs, the perimeter berm will be constructed in increments of height that will be determined based on the response of the foundation (i.e., settlement and strength gain) to the previous increment of fill.

6. The permanent LFG and LMS will be constructed and operation will be transitioned from the temporary systems to the permanent systems.

7. Waste will be placed in completed portions of the landfill expansion areas. Based on the actual construction sequence, some portions of the expansion area may be completed and ready for waste placement before other portions;

the actual sequence of construction will be based on whether or not the DSWA needs to begin placing waste in the expansion areas before construction of the entire expansion area is completed (i.e., the plan will be focused on completing a portion of the expansion area if the capacity of the existing landfill is filled before construction of the entire expansion area is completed.

8. After the perimeter foundation improvements have been implemented, based on the proposed construction sequence, waste will be placed sequentially from existing elevations to Elevation 195 ft-msl (see Drawings 81 through 86). The final stage of waste placement (Drawing 86) includes waste placement in Phase Va as well as Phases III to V up to Elevation 195 ft-msl. The expected airspace for each of the filling stages as well as the estimated timetable are indicated in Drawings 81 through 86. The actual sequence of waste placement will depend upon the information collected by the geotechnical monitoring devices during the perimeter berm construction.

4. FACILITY COMPONENTS

4.1 Overview

In this section, a description of all of the features of the expanded CIL disposal area and related facilities is presented, as required by DRGSW §4.B.1.d.(1). For each feature of the proposed expansion, a description is presented of: (i) the criteria used to design the feature; (ii) the general layout of the feature; (iii) the components of the feature; and (iv) the performance of the feature, based on design calculations that are attached to the report. The section is organized as follows:

- the design of the landfill liner system, including the rationale for the layout of the liner area and the detailed design of the liner system, is presented in Section 4.2;
- the design of the leachate collection, removal, and transmission systems, including the efficiency of the proposed liner system in expansion areas, is presented in Section 4.3;
- the design of the LFG management system is presented in Section 4.4;
- the design of the final cap system is presented in Section 4.5;
- the design of the on-site access roads is presented in Section 4.6; and
- the design of the surface-water management system is presented in Section 4.7.

4.2 Liner System

4.2.1 Introduction

A liner system will be installed at CIL between the existing and proposed phase boundaries. The purpose of this section is to describe the proposed features of the liner system for CIL and to demonstrate that the design complies with the requirements of DRGSW §5.C (i.e., "Liner"). The specific requirements of §5.C and the location in this Permit Modification Application where the requirements are addressed are identified in the checklist portion of the permit modification application. The design issues discussed in this section are: (i) separation distance between the liner system and groundwater; (ii) settlement of the liner system; and (iii) stability. Aspects of the liner system that relate to leachate management are addressed in Section 4.3.

The remainder of this section is organized as follows: (i) a list of the design criteria used in designing the liner system is presented in Section 4.2.2; (ii) a description of the liner system layout and cross section is presented in Section 4.2.3; and (iii) demonstrations that the expected performance of the liner system is in accordance with the applicable sections of DRGSW are presented in Sections 4.2.4 and 4.2.5.

4.2.2 Foundation and Liner System Design Criteria

The following criteria were applied to the design of the proposed liner system, as required by DRGSW §5.C.1, 2, and 3.

- An impermeable liner will be provided to restrict the migration of leachate from the landfill and to prevent contamination of the underlying groundwater areas between the existing phase boundary and the proposed phase boundary, in accordance with DRGSW §5.C.1.a.
- The post-settlement elevation of the bottom of the liner will be at least 5 feet (1.5 m) above the seasonal-high water table, as described in Section 4.2.5.2.
- DNREC will be notified at least 15 days before liner construction begins, as described in the CQA Plan presented in Appendix VI-M, in accordance with DRGSW §5.C.3.a.(1).
- The subbase will be capable of supporting the loads imposed on it and will have a smooth surface as described in Section 4.2.5.3 and as required by DRGSW §5.C.3.a.(2). Also, the landfill is designed to be stable, as described in Section 4.2.5.4. The following landfill configurations are analyzed in this report for stability: (i) the liner system prior to waste placement; (ii) temporary landfill configurations during filling; and (iii) the final closed landfill configuration.
- The post-settlement grades of all proposed liner and leachate collection system layers will meet or exceed the required slopes, as shown in Section 4.2.5.3. The required minimum liner slopes are two percent on "controlling" slopes and 0.5 percent on "remaining" slopes [DRGSW, §5.C.3.a.(3)]. The "controlling" slopes are the cell-floor cross slopes (i.e., the slopes in the direction of leachate flow toward leachate collection pipes); the "remaining" slopes are the slopes of the leachate collection pipes.

- There will be minimal penetrations through the liner within the limits of waste placement (i.e., only one new penetration, which will be in the Phase Va area), in fulfillment of DRGSW §5.C.3.a.(4).
- Bridging, seaming, and equipment for constructing the geomembrane liner components will comply with the requirements of DRGSW §5.C.3.a.(5), (6), and (7), as shown in the CQA Plan in Appendix VIb-M.
- The primary geomembrane will be protected from the waste by at least 2 ft (0.6 m) of protective cover soil in accordance with DRGSW §5.C.3.a.(8), as described in Section 4.2.5.5.
- The construction requirements of DRGSW §5.C.3.C will be followed as illustrated in the CQA Plan in Appendix VIb-M.

4.2.3 Proposed Liner System Layout

The proposed liner system will be laid out in a configuration that meets the grading and containment requirements of the DRGSW. The layout of the liner system (i.e., the design grades) is shown on Drawing 47 (i.e., Phase Va Liner and Leachate Collection System Plan). The cell is graded to drain to low points within the cell where perforated leachate collection pipes will drain the leachate out of the cell to leachate manholes where it can be removed. The slope on the liner system ranges from three percent at the ridges to two percent in the trenches. The perforated leachate collection pipes are sloped at two percent while the solid-walled leachate collection pipe is sloped at 1.45 percent. These slopes are designed to provide the required minimum post-settlement slopes for the leachate collection systems.

4.2.4 Proposed Liner System Components

The landfill foundation and liner system will be comprised of the following components, listed in order from bottom to top.

- *Existing Soil.* The existing sands, silts, and clays at the site will be left undisturbed. Topsoil will be stripped prior to subgrade fill placement and stored on-site for future use.
- *Subgrade.* If required, common fill will be used to provide the liner foundation with the design grades prior to liner construction.

- *Liner System.* A cross-section of the liner system is presented on Drawing 43 and the components of the liner system, from top to bottom, are: identified below.
  - foundation soil layer;
  - geosynthetic clay liner;
  - 60-mil geomembrane liner (textured); and
  - 24-in. (0.6-m) thick leachate collection/protective cover zone.

Each of the liner system components is described below.

- *Geosynthetic Clay Liner.* The geosynthetic clay liner (GCL) will consist of granular bentonite material glued to a textured HDPE backing. The bentonite side of the GCL will be placed against the geomembrane so that the bentonite will be encased between two geomembranes. This will protect the GCL from hydration, which would reduce its shear strength.

- *Geomembrane Liner.* The geomembrane liner will be textured, 60-mil (1.5-mm) thick, and may be either an HDPE or a 45-mil polypropylene (PP) geomembrane. Both HDPE and PP geomembranes are considered to be acceptable for use as the liner material as long as the material properties comply with the requirements stated in the Technical Specifications. For the purpose of consistency in this report, HDPE geomembrane liner is used. The specifications for the geomembrane liner satisfy the requirements of DRGSW §5.C.2.c.(1).(c) (i.e., physical strength, chemical resistance, material quality, etc.). HDPE is considered to be chemically inert to municipal solid waste (MSW) leachate (Haxo et al., 1982; Schwope et al., 1985). PP has been demonstrated to be equally inert to MSW leachate (Shah and Frobel, 1993; Shah 1994).

- *Leachate Collection/Protective Cover Zone.* The leachate collection zone (LCZ) will be a 12-in. (0.3-m) thick layer of sand having a hydraulic conductivity of at least 1×10^{-2} cm/s. As demonstrated in Appendix VIb-G.1, this hydraulic conductivity is needed to maintain the head of leachate on the liner below 12 in. (0.3 m). The LCZ will be overlain by a layer of protective cover soil. To prevent clogging of the LCZ, the protective cover soil will be a 12-in. (0.3-m) thick layer of a material that satisfies the gradation for filters, as described in the technical specifications.

Alternatively, the leachate collection/protective cover zone may be replaced by a geocomposite overlain by a 24-in thick layer of protective cover zone. The

geocomposite drainage material shall consist of a 200-mil (5-mm) thick HDPE geonet with a nonwoven 8 oz/yd^2 (270 g/m^2) nonwoven geotextile heat-bonded to each side. Calculations presented in Appendix VIb-G.1 show that the leachate collection layer is expected to maintain the head of leachate on the liner below 12 in. (0.3 m). The geocomposite is only required on the flat slopes of the Phase Va. To prevent clogging of the geotextile component of the geocomposite, the protective cover soil will be a 24-in. (0.6-m) thick layer of a material that satisfies the gradation for filters outlined in Appendix VIb-G.2.

4.2.5 Liner System Performance

4.2.5.1 Introduction

In this section, an analysis of the performance of the existing and proposed liner system is presented. The following issues are addressed: (i) separation distance between the liner and groundwater (Section 4.2.5.2); (ii) settlement of the liner system (Section 4.2.5.3); and (iii) stability (Section 4.2.5.4).

4.2.5.2 Separation Distance between Liner and Groundwater

Based on regional hydrogeology, the groundwater elevation at the CIL site is approximately 5 ft-msl. As shown in the settlement calculations (Appendix VIb-C.2 and VIb-C.3), the maximum expected settlement of the liner system is approximately 23 ft. The initial liner elevation for Phases III, IV, and V is approximately 45 ft-msl. Therefore, the final settled elevation of the bottom of the liner system will be 22 ft-msl, or 17 ft above the groundwater elevation.

The elevation of the liner system in the Phase Va area at the time of construction will be approximately 32 ft-msl. Because the proposed Phase Va will be pre-loaded, the maximum expected post settlement after waste placement is 6.8 ft. Therefore, the final settled elevation of the bottom of the liner system will be 25.2 ft-msl, which is 20.2 ft above the groundwater elevation. Based on these considerations, the liner system at the CIL will be much greater than 5 ft above the seasonal high groundwater table elevation.

4.2.5.3 Settlement

The expected settlement of the liner beneath the expanded cell was calculated to demonstrate that: (i) the liner system design satisfies post-settlement slope criteria; and (ii) the predicted settlement will not cause excessive straining of geosynthetic components. A summary of the settlement analysis is presented in this section. The

settlement calculations performed for the existing and proposed liner systems are presented in Appendices VI.b-C.2 and VIb-C.3, respectively.

The results of the settlement calculations for the existing liner system are shown in Appendix VI-b-C.2 and are summarized below.

- The magnitude of calculated total settlement for Phases III to V ranges from 19.8 ft to 23.0 ft.
- Based on the post-settlement slopes of intervals between settlement computation locations, the post-settlement slopes for most of the leachate collection pipes (i.e., non-controlling slopes) ranges from 0.2 to 2.6 percent. At two locations, reverse grades were calculated. However, the analysis is very conservative because it does not consider: (i) the three-dimensional effect of the applied landfill load, thereby making the differential settlements significantly larger; and (ii) the calculations are based upon final conditions after all consolidation settlement have taken place. Because of the PVD installation, settlement around the perimeter berm will take place within the first two years after berm construction, whereas settlement within the landfill will continue to take place for approximately 35 to 100 years after waste placement activities have concluded. Hence, during the active life of the landfill, reverse gradient will not take place at these locations. If reverse gradients is suspected at any point in time during the active life of the landfill, an internal sump will be installed.

The results of the settlement calculations for the proposed liner system are shown in Appendix VIb-C.3 and are summarized below.

- The magnitude of calculated settlement ranges from 4.8 ft to 6.8 ft after cell construction. The actual settlement magnitude will depend of the amount of pre-loading in the Phase Va area.
- Based on the post-settlement slopes of intervals between settlement computation locations, the post-settlement slopes of leachate collection pipes (i.e., non-controlling slopes) ranges from 0.5 to 1.9 percent.
- Post-settlement controlling slopes range from 2.53 percent to 2.1 percent. The calculated liner strains are less than 0.025 percent, which is much less than the minimum yield strain of HDPE of 13 percent (which is much less than the allowable yield strain of PP geomembrane), indicating that liner strains are expected to be negligible.

In conclusion, the design of the proposed liner system exceeds the requirements of DRGSW, as outlined in Section 4.2.2.

4.2.5.4 Stability

Overview

The currently permitted landfill expansion is stable up to Elevation 172 ft-msl without additional foundation improvements. The proposed foundation improvements will allow expanding the landfill up to Elevation 195 ft-msl. The proposed CIL expansion is designed to be stable for the following landfill configurations: (i) the liner system prior to waste placement; (ii) temporary landfill configurations during filling up to Elevation 195 ft-msl; and (iii) the final closed landfill configuration. Additional analyses were performed to evaluate the stability of the mechanically stabilized earth (MSE) berm during construction. Because the CIL site is in a seismic impact zone (see DRGSW §5.A.4.i), a discussion of the seismic stability is also provided in this Section. The results of analyses performed to evaluate the landfill stability are subsequently described.

Design Criteria

According to Table 2-4 of the technical manual published by the USEPA entitled, "*Solid Waste Disposal Facility Criteria*" (USEPA, 1993), the minimum recommended factor of safety against slope stability failure for permanent conditions is 1.5. For the temporary conditions, the recommended minimum factors of safety for analysis are:

(i) 1.25 for cases when the consequence of slope failure does not pose an imminent danger to human life of a major environmental impact; and

(ii) 1.5 for cases when the consequence of slope failure may pose an imminent danger to human life or a major environmental impact. Similarly, the standard of practice (U.S. Army Corps of Engineers, 2003) for static slope stability analysis recommend the use of minimum factors of safety against slope stability failure for temporary (e.g., construction) and permanent conditions of 1.25 and 1.5, respectively.

Based on the above, the factors of safety selected for the slope stability analysis are as follows. After waste placement has ended and the proposed final grades have been reached, the proposed final configuration was designed with a minimum factor of safety of 1.5. This value is consistent with both the USEPA (1993) recommended values and the standard of practice for slope stability analysis. Similarly, for interim

waste configurations, before final grades are achieved (i.e., temporary conditions), the selected factor of safety is 1.45. This value is higher than the standard of practice for slope stability analysis for temporary conditions. For all other temporary conditions that are not related to waste placement (e.g., construction of perimeter berm, analysis of the 100-yr flood), a factor of safety of 1.3 is used. In addition to these deterministic requirements, a reliability analysis was performed to evaluate the likely range of factors of safety for the design, considering the range of possible input values for the analysis. As shown in the reliability analysis (Appendix VIb-D.2), a probability if failure equal to 0.000% was obtained.

For long-term conditions, after waste placement has ended, a minimum factor of safety of 1.5 is used. In general, waste placement is a temporary condition. However, based on the estimated rate of waste placement, it will take approximately 20.5 years to reach the proposed final landfill configuration. Therefore, using a factor of safety of 1.25 for this "temporary" timeframe is believed to be unconservative. Accordingly, a factor of safety during waste placement of 1.4 is used for design. For other temporary conditions (e.g., analyzing the 100-yr flood elevation), a factor of safety of 1.3 is used. In addition to these deterministic requirements, a reliability analysis was performed to evaluate the likely range of factors of safety for the design, considering the range of possible input values for the analysis.

For seismic design, the criterion to evaluate seismic stability relies on the assessment of the seismically induced permanent deformation. The current standard of practice is that a permanent displacement of 12 in. or less in the slopes of waste disposal facilities is acceptable when considering seismically induced deformations (Seed and Bonaparte, 1992).

Liner System

The stability of the liner system constructed on a 2H:1V sideslopes was evaluated using a two-part wedge analysis (Giroud and Beech, 1989). The liner system has been designed to have a factor of safety for temporary conditions (i.e., during construction) of 1.25 against veneer failure. Because of the slope height (approximately 30 ft at some locations), the 2-ft thick liner system (i.e., the protective cover and leachate collection zone) cannot be placed on top of the geomembrane at once. The maximum height that the liner system can be placed at once varies from 4.0 ft to 16.8 ft. A detailed description of the analysis is presented in Appendix VIb-F.2.

Temporary/Final Landfill Configuration

The stability of potentially critical interim landfill configurations was evaluated using a limit equilibrium method in the computer program SLIDE (Rocscience, 2002). Slope stability was evaluated at multiple intermediate stages of landfill development following the start of waste placement. Because the shear strength parameters of the dredge/alluvium under the existing waste are time and load dependent, the time-rate of change of the shear strength parameters for each of these interim conditions was evaluated. The computer program CONSOL was used to model the change in shear strength of the soils over time to predict the unconsolidated shear strength parameters at different times (see Appendix VIb-D.1). These shear strength parameters were then used in the stability calculations presented in Appendix VIb-D.1. For final conditions, the drained shear strength parameters for the dredge/alluvium were used to calculate the stability for long-term conditions; this is appropriate because, at that time, excess pore pressures that resulted from waste placement will have completely dissipated. The parameters used in the analyses were obtained from the Geotechnical Characterization Report presented in Part VI.

Eight critical cross sections were selected for evaluation of the stability of the interim/final landfill configuration. The sections were analyzed using SLIDE for both circular and non-circular failure surfaces. The landfill stability was calculated conventional limit equilibrium theory. For the eight cross-sections analyzed, the factor of safety for the interim (i.e., temporary) landfill configurations vary from 1.4 to 1.5 for circular failure surfaces and from 1.4 to 1.7 for non-circular failure surfaces. A detailed description of the analysis procedure can be found in Appendix VIb-D.2. For the final (long-term) landfill configuration, the calculated factor of safety varied from 1.5 to 2.3 for circular failure surfaces and from 1.8 to 2.6 for non-circular failure surfaces.

In order to verify the results obtained from the computer program SLIDE, an additional slope stability analysis was performed by GeoSyntec using a different slope stability program (SLOPE/W). This additional analysis was performed by a design team that was not involved in the project so as to provide an additional verification of the analysis procedure. For the cases analyzed, the factors of safety calculated with SLOPE/W were similar to those calculated with SLIDE; the analysis performed using the SLOPE/W program are also provided in Appendix VIb-D.2.

Next, an evaluation of the reliability of the slope stability analysis was performed using SLIDE for the most critical section (i.e., Section E-E). The method consists of performing deterministic slope stability analysis to identify the slip surface with the overall (Global Minimum) factor of safety of all the slip surfaces analyzed. Then,

critical parameters are assumed to be random variables. A probabilistic analysis is then carried out on the global minimum slip surface, using the samples generated for each random variable. The variables that were considered in the analysis (i.e., as random variables) were the unit weight and shear strength of waste and dredge/alluvium as well as the location of the liquid levels in the dredge/alluvium. The ranges of reasonable values for these parameters were obtained from the Geotechnical Characterization Report. For both circular and non-circular failure surfaces, the calculated probability of failure is 0.000 percent. Due to the significant digits used in the calculation of probability of failure, a value of 0.000 percent indeed implies that the probability of failure is less than 1×10^{-5}. This result indicates that the proposed design is highly likely to have a true factor of safety for any combination of input parameters of greater than 1.0, implying that the design is very safe against failure.

Finally, stability during construction of the proposed MSE berm was evaluated. For the most critical failure surface, the factor of safety for the perimeter MSE berm during construction is 1.3. The details of the calculations are presented in Appendix VIb-D.4.

As discussed in detail in Appendices VIb-D.2 and Appendix VIb-D.4, stability of the MSE berm and landfill depends on installation of Prefabricated Vertical Drains (PVD) in the dredge/alluvium layer under the MSE berm. The assumption of drained conditions of the dredge/alluvium with PVDs during waste placement/berm construction is an important consideration in the stability analysis. Drained conditions can be assumed to exist if the loading rates caused by soil or waste fill placement are slow enough to prevent build-up of excess pore pressures during waste placement. Installation of PVDs allows excess pore pressure to dissipate during loading. A detailed evaluation of the influence of the PVDs on the build-up of excess pore pressure in the dredge/alluvium is presented in Appendix VIb-D.5. The detailed design of the PVD components is presented in Appendix VIb-D.6. To verify that the conditions assumed in the analysis shown in Appendix VIb-D.5 actually occur, a Geotechnical Monitoring Plan has been prepared and will be implemented (see Appendix G to Part V, Operations Manual, of this Permit Modification Application).

Seismic Stability

Because the CIL site is in a seismic impact zone, (see DRGSW §5.A.4.i and Figure VIb-7), the components of the landfill need to be designed to withstand the expected seismic event. The calculated displacement at the base of the landfill due to a seismic event is calculated to be 2.8 in., which is lower than the recommended maximum

displacement of 12 in. during a seismic event. This amount of displacement is considered small and is not expected to cause any detrimental stress on the flexible components of the liner system (e.g., pipes, geomembrane liner). Similarly, the calculated displacements for the top of the landfill are negligible, and therefore, no special design is required. A detail description of the evaluation of seismic stability is provided in Appendix VIb-D.3.

Conclusions

The different analyses performed show that MSE berm construction and waste placement can be performed while maintaining an appropriate factor of safety throughout construction and waste placement. The calculated factors of safety are greater than the recommended minimum values provided under the Design Criteria paragraph of this section. Similarly, the reliability analysis performed for the most critical cross-sections indicates a high degree of reliability of the proposed design.

4.2.5.5 Protection of the Liner System

Based on the analysis presented in Appendix VIb-F.1, heavy construction equipment such as a Caterpillar D6H Series II LAG and D6H Series II operating with a minimum of one foot of cover soil will not compromise the geomembrane puncture resistance or cause a bearing capacity failure of the overlying soil. Other vehicles with equal or lower ground pressures may also operate safely. Similarly, the pressure exerted by the overlying waste will not cause excessive pressures on the liner system that could puncture the liner system.

4.3 Leachate Collection, Removal, and Transmission System

4.3.1 Regulatory Requirements

This section contains a description of the design of components of the leachate collection, removal, and transmission system. The leachate collection, removal, and transmission system is designed to comply with the requirements of DRGSW §5.D.2.a (i.e., Leachate Collection). The components of the system and the location in this section where the components are described are as follows:

- A temporary leachate transmission system, which will consist of the existing manholes and pumps and a new transmission piping system that is located over the waste, where it will not be damaged during construction, is described in Section 4.3.2;

- A leachate collection system drainage layer and piping, which will transmit leachate from the drainage soil layer to the leachate collection system sump, is addressed in Section 4.3.3;
- A leachate removal system, where leachate will be pumped and transferred from the collection sump (i.e., the existing leachate collection manholes) to the leachate transmission vaults, is addressed in Section 4.3.4; and
- A permanent leachate transmission system, which will transmit leachate from the leachate vaults to the City of Wilmington Wastewater Treatment Plant (WWTP), is described in Section 4.3.5.

4.3.2 Temporary Leachate Transmission System

The temporary leachate transmission system will be employed during the construction of the MSE wall and associated improvements (e.g., PVDs, liner, permanent leachate transmission, stormwater management) required for the CIL expansion. At the end of construction, the temporary leachate transmission system will be decommissioned as the permanent leachate transmission system commences.

During MSE wall construction, the existing double-wall leachate forcemain will be removed and replaced by the temporary leachate transmission system. The temporary transmission will consist of new double-wall forcemain piping will be placed on existing waste slopes in Phases III, IV, and V away from active construction areas. The existing leachate wet wells (e.g., MH-14 through 20, East, Southeast, South, Southwest, and Central) and their associated electrical controls, valves, and meters, will remain in service.

The temporary leachate transmission system will consist of 3-in. to 6-in. diameter HDPE pipe within a 10-in. HDPE containment pipe. Because leachate generation rates will not change significantly as a result of the expansion, (see Appendix VIb-G.1), this pipe is of the same diameter as the permanent transmission system designed for CIL. Leachate transmission pipe sizing calculations are found in Appendix VIb-G.3. The temporary leachate transmission forcemain will be located on the sideslopes of Phases III, IV, and IV, away from active construction areas (see Drawing 56). The forcemain will be placed within existing intermediate cover and have additional fill placed over it so that it is covered by at least three feet of dirt to prevent freezing.

For Manholes 14, 18, and 20, a submersible pump and control system must be installed since construction of the MSE wall will cause enough settlement of the Phase

III leachate wet wells to prevent gravity flow from MH-14 to MH-13. Settlement calculations provided in Appendix VIb-C.1 show that gravity leachate flow will continue from MH-17 to MH-16 and from MH-19 to MH-18. To avoid periodic monitoring of the flow directions along the manholes on the east side of the landfill, during operation of the temporary leachate transmission system, submersible pumps will be installed at MH-14, MH-16, MH-18, and MH-20, and the leachate will be pumped to MH-13.

4.3.3 Leachate Collection System

4.3.3.1 Introduction

The features of the leachate collection system are described in this section. As described in Section 3, the leachate collection system will consist of both existing features (i.e., in the currently-filled areas of Phases III, IV, and V) and new features (e.g., Phase Va). A key goal of the design of the CIL expansion is to ensure that the features of the existing landfill will continue to comply with the requirements of the DRGSW under the conditions of the expanded landfill. As described in this section, all new leachate collection system features are designed in accordance with the requirements of DRGSW §5.C and §5.D.

4.3.3.2 Leachate Collection System Description and Design Criteria

Description

The purpose of the leachate collection system is to route leachate from the landfill disposal area to the leachate collection sumps (i.e., the existing leachate manholes) at the perimeter of the landfill, where it can be removed from the landfill. The leachate collection system is designed to meet the requirements of DRGSW §5.D by conveying the leachate collected on the liner to a location where it can be removed from the landfill. The liner system will be graded (as described in Section 4.2) to convey leachate through a leachate drainage material toward leachate collection pipes, which will then convey the leachate to a leachate collection sump located in a manhole at the perimeter of the disposal area.

Design Criteria

Criteria that were used to design the leachate collection system were obtained from: (i) DRGSW; (ii) Federal regulations; and (iii) experience with similar projects.

The following criteria from DRGSW §5.C.2.c.(1).(e) and §5.D.2.a was used to design the leachate collection systems:

- the leachate collection system must be resistant to clogging (see Appendix VIb-G.2);
- the existing and proposed leachate collection piping must have adequate flow capacity and structural integrity (see Appendices VIb-G.3 and VIb-G.4);
- the systems must be designed to drain by gravity to a sump that will function, either by gravity or automatically, to remove leachate from the landfill (see Section 4.3.4.6);
- cleanouts will be constructed at key locations to allow cleaning of leachate collection pipes (see Section 4.3.3.7);
- the head of leachate on the liner must be maintained below 12 in. (0.30 m) in accordance with DRGSW §5.C.3.a.(3) (see Section 4.3.3.6); and
- the systems should be designed with minimal liner penetrations as required in DRGSW §5.C.3.a.(4) (see Drawing 46).

4.3.3.3 Leachate Collection System Layout

The layout of the existing leachate collection system is shown on Drawing 8 (i.e., Leachate Management System Plan – Existing Conditions) and the proposed leachate collection system is shown on Drawing 47 (i.e., Phase Va Liner and Leachate Collection System Plan). The design slopes of the existing leachate collection pipes ranges from 0.93 to 3.4 percent to provide positive drainage to the perimeter leachate manholes. The existing design of the Phases III through V disposal areas (Gannett Fleming, 1990a and b; Weston, 1992 and 1995) demonstrated that leachate would flow to the perimeter manholes even after the liner system has settled under the weight of the landfill waste. The design was developed, however, only for a maximum landfill elevation of 140 ft-msl; because the actual landfill elevation under the proposed expansion will be 195 ft-msl, the effect of this new landfill height on settlement and grades of the leachate collection system were evaluated, as described in Section 4.3.3.6 of this Engineering Report.

The design of the leachate collection system in the new disposal areas (i.e., the Phase Va area and the area adjacent to the perimeter of Phases III and IV) is shown on

Drawing 47. As shown on this drawing, the slopes of the leachate collection layer in these areas will be either 3.0 percent (i.e., on the base slopes of the Phase Va area), 50 percent (i.e., on the 2H:1V slopes of the inside slope of the landfill perimeter berm), or 5 percent (i.e., where the inside slope of the landfill perimeter berm terminates outside of the existing landfill disposal area. An evaluation of the post-settlement grades of these slopes is shown in Section 4.3.3.6. A system of leachate collection pipes will be installed at the toes of perimeter berm slopes, as shown on Drawings 48 and 49; the design of these pipes is described in Section 4.3.3.7.

Leachate from all collection pipes will be routed into perimeter manhole sumps, which are shown on Drawing No. 45, from which the leachate will then be pumped out of the landfill through sloped riser pipes. The leachate removal and transmission system is described in Section 4.3.5.

4.3.3.4 Leachate Collection System Components

Introduction

In this section, the design of each individual component of the leachate collection system in new lined areas is described. The components of the leachate collection system are: (i) a 24-in. (0.6-m) thick layer of protective cover/leachate collection zone; (ii) a perforated 8-in. (0.2-m) diameter HDPE pipe; (iii) pipe bedding gravel; and (iv) leachate collection sumps at perimeter manholes. Calculations addressing the performance of the leachate collection systems components (e.g., pipe size, crushing strength, post-settlement grades, etc.) are found in Appendix VIb-G.

Protective Cover/Leachate Collection Zone

The purposes of the protective cover soil are: (i) to protect the underlying geosynthetic liner system from damage during construction or operation of the landfill; and (ii) to provide a permeable medium for the flow of leachate into the manholes. The components of the protective cover/leachate collection layer zone are addressed in Section 4.2.4.

Leachate Collection Pipes

The purpose of the leachate collection pipes is to rapidly convey leachate to the leachate collection sumps. Existing leachate collection pipes in Phases III, IV, and V consists of 4-in., 6-in., and 8-in. SDR 15.5 HDPE. Leachate collection pipe for Phase Va will be 8-in. (0.2-m) diameter SDR-17 HDPE pipe, which is a thick-walled

pipe capable of withstanding the loading of the waste fill. Pipes in the leachate collection toe drain trench (i.e., at the bottom of perimeter berm sideslopes) will be 4-in., as shown on Drawing 49. The diameters of the pipes in the Phase Va area and the perimeter berm toe drain were selected to facilitate cleaning the pipes using pressure-jetting technology and provides far more flow capacity than is required. Cleanouts will be provided for all leachate collection pipes.

Pipe Bedding Gravel

The bedding gravel for the leachate collection pipes will be AASHTO Coarse Aggregate, Number 57 stone (also DELDOT No. 57 stone). The bedding gravel is designed to provide: (i) high permeability to rapidly convey leachate to the leachate collection pipes; (ii) open spaces to resist clogging; and (iii) structural support for the leachate collection pipes.

4.3.3.5 Leachate Generation

Estimates of leachate generation rates were calculated for CIL using: (i) the USEPA's Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 2 (USEPA, 1984a; 1984b; and other unpublished documents by Schroeder et al. for Version 2); and (ii) historical records of leachate generation from Phases III, IV, and V at CIL. Experience has shown that results from the HELP Model tends to be conservative by predicting leachate generation rates that are higher than those measured in the field. These calculations are presented in Appendix VIb-G.1.

As show in the calculations in Appendix VIb-G.1, over the life of CIL (about 37 years), the maximum volume of leachate produced in a year is expected to be on the order of 70 million gallons or 800 gpad, and the maximum volume of leachate produced in 30 days is expected to be on the order of 6 million gallons. These quantities were calculated for a scenario that is based on the following assumptions: (i) the new Phase Va area is operating and contains a one 10-ft (3-m) thick lift of waste overlain by a 6-in. (0.15-m) thick layer of daily cover; and (ii) the remainder of the landfill generates leachate at rates that are consistent with average generation rates of the past five years.

4.3.3.6 Effects of Settlement

Introduction

Because the proposed expansion at CIL raises final grades from elevation 140 ft-msl to elevation 195 ft-msl, the effects of additional settlement of unconsolidated

dredge and alluvium materials beneath CIL must be evaluated to ensure that leachate head remains within acceptable limits during the active and post-closure life of the facility. In this section, a description of the effects of this settlement on the existing leachate collection system in Phases III, IV, and IV at CIL will be described as well as proposed remedies should settlement prevent the proper collection of leachate from the base of CIL. Detailed calculations reviewing expected settlements in the existing leachate collection system of Phases III, IV, and V are found in Appendix VIb-C.2.

Post-Settlement Leachate Collection System Grades

The maximum expected head of leachate on the liner is a function of the maximum length of flow in the drainage material, the permeability of the leachate drainage material, the slope of the leachate drainage material, the rate of impingement of leachate on the liner, and the total settlement that will occur over the disposal period. Since settlement will impact the slope of the leachate collection system, post-settlement grades must be considered for the long-term performance of the leachate collection system at CIL. As shown in Appendix VIb-C.2, under worst-case conditions the leachate collection system will retain a minimum positive grade of 0.3 percent. Therefore, leachate will continue to flow towards leachate removal sumps and pumps throughout the life and post-closure period of CIL.

In addition, as described in the Geotechnical Monitoring Plan, the settlement of the liner system will be evaluated annually using an extensive network of settlement plates and geotechnical investigation borings. Based on the results of these evaluations, continued positive drainage of the leachate collection system to removal pipes can be monitored throughout the life of the landfill and post-closure period. In the unlikely event that adverse grades exist, they will be identified and, if necessary, vertical leachate removal sumps will be installed at those locations.

Post-Settlement Leachate Head

The maximum anticipated head of leachate on the liner system after settlement was obtained from the HELP analysis assuming final cover over 250 ft of waste. The effect of flows into the leachate collection system from consolidation of the dredge/alluvium layer was estimated and incorporated into the calculation of leachate flow rate and head on the liner. Based on this calculation, the post-settlement slopes in these areas are adequate to provide collection of leachate and to minimize the head of leachate on the liner. In the existing disposal areas, it was found that the head of leachate for the expanded CIL will be less than 12-in. throughout the operating period of the landfill and

that following final closure leachate heads remain below the 1-ft regulatory maximum. Detailed calculations are found in Appendix VI.b-G.1.

4.3.3.7 Leachate Collection Piping

Introduction

Leachate collection piping will be placed within the leachate collection system protective cover soil layer of expansion areas to transmit leachate from the soil drainage layer to the leachate collection sump. Also, existing leachate collection piping within the Phases III, IV, and V areas must continue to route leachate to the perimeter manholes under the conditions of the expanded CIL. The location of the leachate collection piping in existing Phases III, IV, and V and in the Phase Va area is shown on Drawing No. 8 (i.e., Leachate Management System Plan – Existing Conditions). As shown on the drawing, piping in the Phase Va expansion area will consist of 8 in. (20 cm) diameter pipes that are designed to drain leachate to sumps, as required in DRGSW §5.D.2.a.(5). In this section, the methodology and results of analyses that were performed to design the leachate collection piping system (and to meet the requirements of DRGSW §5.D.2.a) are presented in Appendix VIb-G.3. The leachate collection pipes require a minimum diameter of about 4 in. (10 cm) to meet the flow capacity requirements, however, based on pipe cleaning and clogging considerations (see Section 4.6.2.2), 8 in. (20 cm) diameter pipes are specified.

Pipe Flow Capacity

The pipe network for the leachate collection system is shown on Drawing No. 8. The network includes pipes from the existing Phases III, IV, and V disposal areas and the Phase Va expansion area (i.e., in the area of the existing sedimentation pond). Each of these pipes is required to have adequate flow capacity to provide free flow of leachate to the leachate collection sumps at the perimeter manholes. In this section, an evaluation is provided for: (i) the adequacy of the flow capacity of the existing pipes to convey the flow quantities from the expanded landfill; and (ii) flow capacity of the pipes in the Phase Va area.

The maximum leachate flow rate entering each pipe equals the maximum design leachate generation rate (obtained from historic data and HELP modeling) multiplied by the largest portion of the cell (i.e., approximately 10 acres for Phase Va) that contributes flow to the pipe. The leachate flow rate for the maximum leachate generation rate of 2,366 gpad (based on peak daily flow) is 16.4 gal/min (or gpm) (1.0×10^{-3} m^3/s), as shown in Appendix VIb-G.3.

The available flow capacity of the 6-in. (15-cm) and 8-in. (20-cm) diameter pipes was determined using Manning's equation. The calculated flow capacity of an 8-in. (0.20-m) nominal diameter HDPE SDR-17 pipe with a 1 percent slope is 556 gpm (1.6×10^{-2} m^3/s). Based on these considerations, the leachate collection pipes will provide free flow of leachate to the leachate collection sumps.

As described in Section 4.3.3.3, the leachate collection system has been designed to efficiently remove leachate from the landfill sidewalls and bottom of the waste; the design criteria that was used to quantify the efficiency of the liner system was a maximum of one foot (30 cm) of leachate above the primary liner. As shown in the calculations in Appendix VIb-G.1, the calculated maximum thickness of leachate head on the primary liner is less than one foot (assuming a leachate collection pipe spacing as shown on Drawings 8 and 47). Therefore, the design is expected to be efficient at removing leachate.

4.3.4 Leachate Removal System

4.3.4.1 Introduction

The leachate removal system consists of all components that are used to transmit leachate from the leachate collection sumps located at the perimeter manholes to the leachate transmission line (which is described in Section 4.3.5). The system is illustrated in detail on Drawings 46 through 58. The components of the leachate removal system are as follows:

- leachate perimeter manholes;
- leachate removal pumps and sloped removal pipes;
- leachate wetwells; and
- miscellaneous flow meters and valves.

Each of these components is described in the following sections.

4.3.4.2 Perimeter Manhole Sumps

The existing manholes at the perimeter of the landfill will be modified so that instead of removing leachate vertically out the top of the manhole, submersible pumps will access the manhole through a sloped riser pipe. The sizes of the sumps at the

manholes are based on the cycle times of the leachate removal pumps; the volume of each sump should be large enough so that the pump does not turn on and off too frequently. Each manhole has a diameter of 6 ft. Therefore, a depth of between 7 and 10 ft was selected for the manholes to provide an efficiently sized sump. The dimensions of the sumps are described on Drawing No. 54. The perimeter manhole sumps will be extended vertically as additional wastes are placed so that access is maintained to the perimeter sumps.

4.3.4.3 Leachate Removal Pumps

Leachate removal pumps will be provided to transmit leachate from the leachate perimeter manholes to lift station manholes along the leachate transmission line. The locations of the pumps in relation to the other leachate transmission system components are shown on Drawings Nos. 32 through 39. As shown on the drawings, leachate will be removed from the cells using submersible pumps. As previously noted, the pumps will be placed in sumps in the landfill cells through the sideslope riser pipes, which are described in the next paragraph. Leachate will be pumped from the sumps to lift station wetwells located on top of the first tier of the perimeter berm, from which it will be pumped into the leachate transmission system (see description in Section 4.3.5). The leachate removal pumps will be explosion proof and will be able to be operated either automatically or manually. Leachate removal pumps will typically be operated in the automatic mode. In this mode, pumps will be controlled by level sensors.

4.3.4.4 Slopes Riser Pipes

The pipes that will be used to access the leachate collection sumps at the perimeter manholes will be two 12-in. (0.3-m) nominal diameter HDPE SDR-17 solid-wall pipes contained within a 30-in. (0.8-m) steel jacking pipe. These pipes will provide access to the leachate collection sumps from the top of the first tier of the perimeter berm. The pipes will be installed into the existing perimeter manholes by advancing a guided-bore hole from the top of the first tier of the perimeter berm to the manhole, where a hole will be cut in the manhole to accommodate the sloped pipe; this concept is illustrated on Drawing 50.

4.3.4.5 Flow Meters and Valves

A below ground riser vault will be installed at the top of each sloped riser pipe for installation of flow meters and necessary valving. Flow meters will be used at the landfill to measure the quantity of leachate passing through the leachate transmission system. Flow will be measured at the leachate collection system discharge line at each

riser vault. The detail of the piping in the riser vault is shown on Drawings No. 52. Check values will be used to prevent backflow through components of the leachate removal system that are designed to transmit flow in only one direction. Check valves will be installed downstream of every flow meter at the CIL and downstream of the pumps in the leachate collection system sumps. Finally, gate valves will be used as an on/off valve to control flow through a pipe. A gate valve will be installed in order to facilitate the removal or replacement of a pump, flow meter, or other valve without requiring shut-down of the entire leachate transmission system.

4.3.5 Leachate Transmission System

4.3.5.1 Overview

The leachate transmission system will consist of all manholes, piping, flow meters, and valves that are used to transmit leachate from the leachate riser vaults to the off-site wastewater treatment plant.

4.3.5.2 Leachate Transmission System Features

The leachate transmission system consists of the features that will be used to route leachate from the removal pumps to the discharge point at the City of Wilmington WWTP. The features of the system include:

- leachate wetwells and wetwell pumps;
- leachate transmission vaults;
- leachate transmission gravity and forcemain pipes; and
- a truck-loading station.

Each of these features is described below.

Leachate Wetwells and Wetwell Pumps. A leachate wetwell will be constructed on the perimeter berm at locations where sideslope riser pipes exit the landfill. The purpose of the wetwell is to transfer the leachate into the leachate transmission line. Because of the very long distances that leachate must be pumped, it is not cost-effective to use the leachate removal pumps to transmit leachate to the WWTP discharge location. Therefore, leachate will be routed to this location using larger pumps located at the wetwells. At the wetwells, leachate will be transferred by suction pump into the leachate transmission system, which will be located at the leachate transmission vault adjacent to the wetwells (a discussion of leachate transmission vaults in provided in the next paragraph). An advantage of using suction pumps is that the pumps can be easily

maintained because they will be located on the tops of the wetwell vaults instead of in the confined-space environment of the inside of the wetwell. The sizes of the wetwell pumps is provided on Drawing 54.

Leachate Transmission Vaults. A leachate transmission system vault will be constructed on the first tier of the perimeter berm next to each wetwell. The purpose of the vault will be to protect the valves and fittings from weather and accidental damage. The locations of the leachate transmission vaults are shown on Drawings Nos. 31 through 39, and details of the houses are shown on Drawing Nos. 51 through 53. As shown on these drawings, the leachate transmission vaults are designed to contain spilled leachate (from a ruptured pipe or other source). A high-level sensor will exist inside each riser house; if activated, the sensor will shut down the submersible pumps in the adjacent leachate collection sumps and set off an alarm. The contents of the vaults (i.e., valves, fittings, pipes, pumps, etc.) are identified on Drawing No. 52.

Leachate Transmission Gravity and Forcemain Piping. Leachate will be transmitted to the City of Wilmington WWTP via a system of pipes located within the first tier of the perimeter berm. The layout of the piping is shown on Drawing 46. As shown in the drawings, the transmission line will be a forcemain around the entire perimeter berm, discharging into MH-13 adjacent to Phase III. Thereafter leachate will flow by a gravity transmission line to the existing Central lift station adjacent to the entrance facility for pumping to the Wilmington WWTP. The transmission line will be a double-walled pipe with a leak detection zone for detecting leaks in the pipe. The leachate carrying pipe will vary from a diameter of 3 in. to a diameter of 6 in., and the containment pipe will vary from a diameter of 6 in. to a diameter of 10-in. The pipes are designed to resist damage due to overburden stress, flexure, chemical attach, clogging, and freezing, and are designed to transmit the maximum quantity of leachate that is generated at any time throughout the life of the facility.

Truck-Unloading Station. Because the Wilmington WWTP is also used for treatment of leachate from other DSWA landfills, CIL requires leachate truck unloading stations. One such station is currently in service next to the Central Pump Station at the entrance facility of CIL. To better manage peak truck volumes, a second unloading station will be constructed adjacent to the Northeast Pump Station. The leachate unloading station will be located near the existing Northeast Pump station in the entrance facility. Design details of the leachate unloading station are provided in Drawing 57. The leachate unloading station is designed with quick disconnect standpiping for unloading leachate from tanker trucks and has secondary containment.

4.4 LFG Management System

4.4.1 Purpose and Organization

The purpose of this section is to:

- identify all applicable regulatory and operational requirements for the project;
- describe applicable design and operating criteria for the LFG (LFG) collection system and control facility;
- present the results of calculations performed to estimate the quantity of LFG that will be generated at the landfill and which will be managed by the LFG management system (system); and
- illustrate the manner in which the proposed system meets all of the regulatory and operational requirements for the system.

Several regulatory criteria apply to the collection and control of LFG. These are contained in the following regulations:

- the Delaware Regulations Governing Solid Waste (DRGSW);
- the Delaware Air Quality Standards (DAQS); and
- regulations promulgated or proposed under the Federal Clean Air Act (CAA), including the New Source Performance Standards (NSPS) for municipal solid waste (MSW) landfills (i.e., regulations contained in 40 CFR 60.30 Subpart C and Subpart WWW Sections 60.750 through 60.759.

In the context of this report section, the specific purpose of the system is to comply with the requirements of DRGSW §5.E by:

- preventing accumulation of LFG on-site or off-site;
- preventing and controlling damage to vegetation; and
- preventing odors from being detected at the facility property line.

In addition to these requirements, rules promulgated under DAQS and the CAA require that LFG be managed to prevent air quality impacts. Although the design is cognizant of these requirements, they are not directly addressed in this Engineering

Report or in this permit modification application document; instead, they will be addressed in a separate permit application that will be submitted before any modification or improvements to the existing LFG management system at the facility are made that are not addressed in the current air quality permit for the site.

The system is described in the four remaining Sections that complete this report section, as detailed below:

- in Section 4.4.2, the overall approach to the design is presented, including a summary of design criteria and goals;
- in Section 4.4.3, the layout and main features of the system are described;
- in Section 4.4.4, the staged development of the system is presented, along with a discussion of the rationale for the layout and staged development; and
- in Section 4.4.5, the individual components of the system are described and the approach for designing the components is presented.

4.4.2 Design Concepts and Criteria

The system was designed to efficiently manage LFG throughout the life of the landfill without disrupting landfill operations. The following specific operational criteria were applied to the overall design of the system.

- The system must be operable throughout the life of the landfill. However, precedence will be given to system function and flexibility during the operational phase (particularly with regard to its compatibility with waste filling operations) over function during the post-closure phase.
- The system design and operation must comply with the requirements of applicable regulations referenced in Section 4.4.1 (i.e., DRGSW, DAQS, and the Federal CAA). The prevention of off-site odors is of particular concern because wastewater treatment sludge is managed at the site and this material has the potential to produce odors.
- The system must be designed to prevent leachate, free liquid within the landfill (if present), and/or condensate in LFG transmission piping from clogging LFG transmission piping and/or impairing LFG management operations, especially LFG collection.

- The system must be tied into the leachate management system to collect LFG that accumulates in leachate risers.
- The system must be able to operate without being damaged by settlement of the landfill waste.

The majority of LFG collection structures at the facility will comprise horizontal collectors in extraction trenches (collectors) as described in the discussion on the system layout in the next section. The maximum total length of individual collectors is anticipated to be approximately 1,500 ft. The collector design is based on that described at Puente Hills Landfill in the greater Los Angeles metropolitan area in California (Tchobanoglous et al., 1993), in which 6-in diameter pipe sections were placed in trenches with total lengths up to 3,000 ft. Collector spacing at Puente Hills is 200 ft horizontally and 80 ft vertically.

4.4.3 System Layout and Features

4.4.3.1 Existing LFG Management System

The layout of the existing system is illustrated on Engineering Drawing 71. The main features of the existing system are:

- numerous vertical LFG extraction vents and wells, the most recent of which were installed in September 2003;
- LFG transmission piping, the most prominent features of which are an 8-in. diameter perimeter header around the entire site and a 12-in. diameter express line for LFG extracted from Phases III through V which routes around the southern edge of Phases I and II;
- various condensate drains and LFG flow control/isolation valves; and
- a LFG control facility (flare station), including a blower, condensate knockout, gas utilization plant, and back-up flare.

The LFG utilization plant is currently operated by an outside developer. The layout of the existing system, and the long-term needs of the developer, were considered throughout the design process and impacted the final layout and construction sequencing of the system expansion.

4.4.3.2 Proposed Expansion of LFG Management System

The layout of the proposed system is illustrated on Engineering Drawings 71 through 73. The system will be constructed in stages as the facility is filled to enable operation throughout the life of the landfill. In accordance with regulations, LFG extraction from existing waste in the facility will be ongoing at all times.

The planned sequence of waste filling at the facility is illustrated on Engineering Drawings 71 through 73. Cross sections through the completed landfill are shown on Engineering Drawing 74. Details of the system are shown on Engineering Drawings 74 through 77. The system will be constructed in three stages:

- the Initial Construction Stage;
- the Main Active Filling Stage; and
- the Final Closure and Post-Closure Stage.

The layout of the Initial Construction Stage is dictated by the layout of the existing system and the requirements for current and future waste placement and construction activities that will be necessary until after construction of the perimeter berm. The layout and filling sequence of all three stages were designed to allow system construction and landfilling operations to proceed simultaneously at different locations without interfering with each other. The requirement for installation of the system and landfill operations to proceed simultaneously with minimal disruption, coupled with the very large size and final depth of the landfill, are the main drivers behind the proposed use of horizontal collectors in all but the final lifts of waste in the facility. The system will primarily consist of the following elements:

- horizontal collectors consisting of perforated piping installed in aggregate back-filled trenches in the waste mass;
- vertical gas extraction wells (wells) consisting of performed piping installed in aggregate back-filled boreholes;
- solid transmission piping connecting the trenches and wells to the flare station; various condensate drains and LFG flow control/isolation valves; and
- the existing flare station.

Transmission piping, condensate drain and valve details and specifications are shown on Engineering Drawing 76. Upgrading the existing flare station (if this is

necessary) is not considered within the scope of this permit modification application and has not been addressed in the design except with regard to the total capacity required to handle the expected LFG flow. The planned sequence of system construction during each of the three stages is described in more detail in Section 4.4.4. Both horizontal collectors and vertical wells will be used for LFG extraction at the facility.

4.4.3.3 Horizontal Collectors

Horizontal collectors will be installed during the Main Active Filling Stage only in Phases III through V of the facility at up to three levels, depending on location (i.e., final elevation of the facility). These levels will be sequentially installed with vertical spacing 40 ft when the top elevation of the waste reaches the following nominal elevations:

- Level 1: elevation 70 -80 ft-msl (depending on existing elevations);
- Level 2: elevation 95 ft;-msl; and
- Level 3: elevation 135 ft-msl.

The 2-ft wide by 3-ft deep collector trenches will be horizontally spaced 200 ft on-center, with each level staggered 100 ft horizontally (i.e., Levels 1 and 3 are aligned vertically along the length of perimeter header around Phases III through V as shown in the schematic layout on Engineering Drawing 75). To minimize the total length of trenches, and thus the potential loss of vacuum at the end of long trenches, collectors are installed in four quadrants protruding radially into the center of the landfill in Phases III through V (see layout in Engineering Drawing 72). Trenches will end a minimum of 20 ft from the landfill sideslopes, and trench ends will be sealed with bentonite plugs and geomembrane boots, to minimize the potential for air to be drawn into the landfill. Details of the horizontal collectors are shown in Engineering Drawings 74 and 76. Collector components are further described in Section 4.4.5.

4.4.3.4 Vertical Wells

Vertical wells in 36-in. boreholes will be installed during the Final Closure and Post-Closure Stage at a density of not less than one per acre (i.e., with radius of influence of approximately 125 ft) as follows:

- Through the final waste lifts in Phases III through V. (i.e., between the elevation of Level 3 collectors and the top surface of the landfill at final

grade). Each well must extend vertically down to within 10 ft of the collector level.

- Throughout completed Phases I and II such that LFG can be extracted from the entire depth of waste in place. Existing wells in these phases will be extended where possible.

Vertical well details and specifications are shown in Engineering Drawing 76. Wells will only be installed in portions of the facility at which final grade has been reached and the final cover system applied. The components of the wells are further described in Section 4.4.5.

4.4.4 Staged Development of the LFG Management System

4.4.4.1 Introduction

In this section, gas management activities, design criteria, a description of the gas management systems, and the expected performance of the system (i.e., LFG extraction and construction and operation phasing of the system) are described in relation to the staged development of the LFG management system. During each of the three stages, some features of the LFG management system will be constructed and operated. A brief description of each of these phases is provided below, along with the location where the gas management activities for that stage are described.

- The *Initial Construction Stage (Initial Stage)* is essentially a transition stage between the existing LFG management system and the proposed new system. This stage includes the period of time when the landfill expansion features are being constructed, including permanent LFG management system features. During this phase, LFG will be managed using the existing system and additional temporary features as required (e.g., transmission pipes, valves, etc.). Management of LFG during the construction stage is described in Section 4.4.4.3.
- The *Main Active Filling Stage (Main Stage)* includes the period of time from the end of the LFG management system construction to a period two to five years before the end of waste placement in the landfill. The majority of waste placement at the facility will occur during this stage. Management of LFG during this stage is described in Section 4.4.4.4.
- The *Final Closure and Post-Closure Stage (Final Stage)* includes the period of time from the end of the main active filling stage until the end of the post-

closure care period. Management of LFG during this final stage is described in Section 4.4.4.5.

4.4.4.2 Rational for Three Stage Development

The rational behind development of the system in three stages, and the emphasis on using horizontal collectors for the majority of LFG extraction, is based on the need for:

- extraction of LFG from existing waste to be ongoing throughout the landfill expansion and LFG management system construction process;
- waste filling operations to be limited to specific areas until after construction of the perimeter berm has been completed;
- system construction, LFG extraction, and landfilling operations to proceed simultaneously at different locations without interfering with each other;
- the very large total area and final depth of the landfill; and
- LFG extraction to be compatible with a variety of cover system alternatives.

Use of the horizontal collector system allows LFG extraction to proceed during the majority of the operational life of the facility with minimal disruption to operational activities. Installation of horizontal collectors allows a 'bury it and forget it' approach to be taken for system construction and operation, eliminating the disruption typically associated with continually needing to extend vertical wells as additional waste lifts are placed. In addition, the need to continually move and reconnect exposed LFG transmission piping on the landfill surface, along with the disruptions to and limitations placed on site traffic routing associated with this, is eliminated. Switching to vertical wells for extraction of LFG from the final lifts of waste ensures that horizontal collectors are buried far below the final cover system. This allows flexibility in cover system design while still ensuring high performance of the LFG system. Installation of vertical wells and associated transmission piping is carried out after cessation of landfill operations and application of the final cover system in closed landfill areas.

LFG transmission piping and the capacity of the flare station are designed to handle the peak LFG flow that will be expected at the facility. This will occur in the first year after cessation of all waste placement activities and will hence occur during the Final Stage.

4.4.4.3 Initial Construction Stage

Introduction

This section is organized as follows:

- a description of the system layout is presented;
- a general description of the elements of the system and activities that will occur during the "Initial Stage of the LFG management system is presented; and
- a description of the design criteria and expected performance of the system is presented.

Layout

The layout of the Initial Stage is shown on Engineering Drawing 71.

General Description of System Elements and Activities

The elements and activities that will occur during the Initial Stage are outlined below. This stage is expected to represent LFG management for an interim period of approximately five years, although a significant degree of overlap between the Initial and Main Stages is expected at localized areas of the landfills. This is because additional waste placement after construction of the perimeter berm is expected to be localized: some areas may have a number of waste lifts in place before any additional waste has been placed in other areas.

- The existing system described in Section 4.4.3.1 will continue to be operated and maintained as per the current program. Depending on the time taken for additional waste placement across the entire area comprising Phases III through V, additional vertical wells in the existing waste in this area may be required to supplement LFG extraction using the existing system.

- Horizontal collectors will be installed in the perimeter waste filling areas of Phases III through V at nominal elevation 70 to 80 ft-msl (i.e., Level 1) at horizontal spacing of 200-ft on-center at the locations shown on Engineering Drawing 71. These collectors will be temporarily connected to the nearest existing lateral as shown in Detail 4A on Engineering Drawing 76. Limited LFG extraction can commence after the depth of waste placed above a collector exceeds 10 ft, supplemented by continued extraction via proximal

vertical wells (which will need to be extended vertically). After 40 ft of waste (or adequate temporary cover) is in place above a collector, full LFG extraction via the collector can commence, and the vertical wells decommissioned as shown in Detail 1 on Engineering Drawing 77. Decommissioned wells will serve as conduits to aid the vertical flow of LFG and moisture through landfilled layers of differing permeability. Use of conduits in this way will enhance the overall performance of the horizontal system. Careful control of the rate of LFG extraction from these collectors will be required to ensure that air is not drawn into the waste.

- If required, the existing system may be connected to existing leachate risers to collect LFG accumulating in the risers.

Design Criteria and System Performance

No design computations specific to the Initial Stage were performed because it essentially comprises continued operation of the existing system. The system is thus expected to continue operating as per the current program. Design criteria for the existing system and any temporary additions to the existing system are:

- LFG extraction from existing waste in all phases must be ongoing;
- the new Level 1 horizontal collectors installed in the perimeter area must be temporarily connected to the existing system after sufficient depth of waste has been placed above them;
- LFG extraction via the temporary connections to these Level 1 collectors must continue until they can be permanently tied into the new leader located on top of the perimeter berm; and
- existing leachate risers can be tied into the existing system if required.

4.4.4.4 Main Active Filling Stage

Introduction

This section is organized as follows:

- a description of the system layout is presented;

- a general description of the elements of the system and activities that will occur during the Main Stage of the LFG management system is subsequently presented; and
- last, descriptions of the design criteria and expected performance of the system during the Main Stage based on design computations (which are included in appendices to this report), are presented.

Layout

The layout of the Main Stage is shown on Engineering Drawing 72.

General Description of System Elements and Activities

The elements and activities that will occur during the Main Stage are outlined below. The primary means of LFG extraction during the Main Stage will be via horizontal collectors, a general description of which was given in Section 4.4.3.3. As previously noted, significant overlap in the transition between the Initial and Main Stages is expected due to the localized nature of landfill operations and waste placement that may be required at the facility following construction of the perimeter berm.

- After construction of the perimeter berm has been completed, a new, larger-diameter perimeter header will be installed on top of the berm and continued around both sides of Phases I and II to tie into the existing (or upgraded) flare station up flow of the condensate knockout. All required connections for transmission pipes from horizontal collectors will be installed at this time, along with necessary condensate drains and LFG flow control/isolation valves as shown in Engineering Drawings 72 and 73.

- The new perimeter header will be tied into the new leachate risers located on the support berm level as shown in Engineering Drawings 72 and 73 (layout and location of risers) and 74 and 75 (connection schematic and detail). The existing LFG transmission piping in Phases I and II will be reconnected to the new header such that LFG can be routed to either the north or south portion of the perimeter header.

- The temporary Level 1 horizontal collectors connections to the existing header will sequentially be disconnected and the collector extended as necessary and connected to the new header as shown on Engineering Drawing 75 (schematic), Detail 4A on Engineering Drawing 76, and Details 2 and 6 on Engineering Drawing 77.

- The sequence of construction described in the item above will be repeated around the entire perimeter area of Phases III through V until all areas have Level 1 collectors connected to the new header. At this time, the existing system will have been completely dismantled in these three phases. It should be noted that, due to the high degree of flexibility that will likely be required during waste placement and landfill operations, it is possible that some areas will have additional lifts of collectors installed (see next items) before other areas have Level 1 collectors installed. In this way, LFG management under the Initial Stage (i.e., existing system) or the Main Stage (i.e., new system) may coincide.

- Construction of Level 2 (i.e., Elevation 95 ft-msl) horizontal collectors will proceed sequentially after localized waste placement in the perimeter areas reaches this elevation. Again, after 10 ft of waste has been placed above the entire length of a Level 2 collector, limited LFG extraction via that collector can commence, with extraction at full design capacity occurring when 40 ft of waste is in place above the collector.

- In a similar sequence to that described above, construction of Level 3 (i.e., Elevation 135 ft-msl) horizontal collectors will proceed after localized waste placement reaches these elevations.

- Vertical gas conduits (18-in. diameter borings backfilled with aggregate) will be installed at nominal 200 ft intervals along the length of each collector in each level (except where existing decommissioned vertical wells can serve this purpose for Level 1) as shown in Sections A and B on Engineering Drawing 74 and Detail 7 on Engineering Drawing 77. Conduits should extend 50-ft below the elevation of the level they are associated with.

Design Criteria and System Performance

The criteria applied to the design of the system during the Main Stage of construction and operation, and the expected performance of the system based on design computations (which are included in the appendices to this report), are outlined in this section.

LFG Generation Rate

The LFG generation rate affects the design of all the components in the LFG extraction system. The LFG generation rate for the facility during the Main Active

Filling Stage was estimated based on the existing weight of waste placed prior to, and the anticipated weight of waste that will be placed during, this period. The maximum estimated LFG generation rate during this period is 8,450 standard cubic feet per minute (scfm). LFG generation calculations are presented in Appendix VIb-H.l. The horizontal LFG extraction and transmission system components have been sized based on the largest flow rate that they are expected to handle. For most of the transmission piping, this flow rate will occur after the Main Active Filling Stage (see Section 4.4.4.5 for details).

LFG Extraction and Transmission System Design

The LFG extraction components of the system are designed to function in accordance with applicable state and federal regulations (listed in Section 4.4.1). Calculations regarding: (i) LFG generation rate per lift of LFG collectors and LFG flow rate from each collector; (ii) radius of influence of collectors; (iii) head loss and flow velocity in LFG collectors and transmission piping; (iv) sizing calculations; and (v) expected condensate volumes are presented in Appendix VIb-H.l.

The LFG flow rate from each collector was assumed to be proportional to the volume of waste influenced by that collector (i.e., the length of any particular collector relative to the total length of collectors. Other assumptions used in design calculations are listed in the relevant sections and attachments of the appendices. The maximum flow in any one collector (i.e., worst case) was used to size LFG collectors and downslope pipes (i.e., transmission piping from collectors to headers). Downslope pipes from alternate levels are connected to the header every 100 ft along the length of the header as described in Section 4.4.3.3. All collector and transmission piping was sized to: (i) limit head loss to one in. of water (one in.-water per 100 ft of pipe) to reduce the required blower horsepower; and (ii) limit flow velocity to less than 2,500 ft/minimum to reduce the entrainment of condensate.

Radius of Influence and Spacing of Horizontal Collectors

The maximum radius of influence (ROI) of each collector was calculated in Appendix VIb-H.1 to be 113 ft. Based on this value and USEPA's guidance document "*Air Emissions from Municipal Solid Waste Landfills – Background Information for Proposed Standards and Guidelines*", which recommends that the horizontal spacing of horizontal collectors should be twice the ROI and the vertical spacing should be half the ROI, the horizontal and vertical collector spacing was conservatively assumed to be 200 ft and 40 ft on-center, respectively. Collector lifts are staggered by 100 ft as described in Section 4.4.3.3.

Sizing of Collectors and Transmission Piping

The maximum collector length is 1,500 ft at Collectors 7, 9, 11, and 13 in Level 1 of Quadrant 3. Based on this length, the maximum LFG flow to a collector is calculated as 100 scfm and the perforated collector pipes are all sized at 6-in. diameter.

The length of downslope pipes (i.e., the distance down the landfill sideslope from the end of a collector to its connection on the perimeter header) is approximately 240 ft (where highest level is Level 3) and 120 ft (where highest level is Level 2). The solid downslope transmission pipes are all sized at 6-in. diameter. The perimeter header was sized based on the maximum LFG flow expected during the Final Stage (see Section 4.4.4.5).

Construction and Operation Sequencing

The proper sequencing of construction, overfilling, and operation of the LFG collectors are important to the proper functioning of the system. At completion of construction of the collectors, they will be close to the landfill surface; if a vacuum is applied to the system with little cover over the collectors, air will likely infiltrate into the landfill causing a possible fire hazard. Therefore, vacuum extraction will not commence until a minimum 10 ft lift of waste has been filled over the collectors, and extraction at full design capacity will not occur until 40 ft of waste is in place above the collectors.

Condensate Management

In the eastern United States, LFG is typically saturated with water vapor and has a temperature between 80°F and 120°F in the landfill. When LFG is extracted, it cools, causing water vapor to condense. This condensate must be managed to prevent the flooding of LFG transmission lines and damage to the flare station equipment. The LFG transmission pipes on the surface of the landfill will be sloped to condensate drains, where the condensate will be routed back into the waste mass (see Detail 2 on Engineering Drawing 76). At locations along the header where connections to leachate risers or Level I collectors below the elevation of the header exist, these features will serve as condensate drains (see Details 5 and 2, respectively, on Engineering Drawing 77). Condensate in the header that is not drained into the waste will be removed at a knockout tank located just upstream of the flare station.

The expected volume of condensate, and hence the size of condensate knockout required, is calculated based on the largest LFG flow rate that it is expected to handle.

This flow rate will occur after the Main Active Filling Stage (see Section 4.4.4.5 for details of calculation).

Pipe Crushing Strength

The wall strength of perforated collector pipes in Level 1 (i.e., worst case) was calculated to ensure that the pipes were of sufficient size and strength to resist stresses applied by the overlying waste. All LFG transmission piping will be buried within the final cover system or above the berm. Compared to laying the pipe on the ground surface, this reduces thermal expansion and contraction and the resulting pipe movement and does not present an obstruction to site traffic or mowing. The wall strength of buried solid transmission pipes was calculated to ensure that it was sufficient to resist stresses applied by site traffic driving over them. The calculations are shown in Appendix VIb-H.2.

4.4.4.5 Final Closure and Post-Closure Stage

Introduction

This section is organized as follows:

- a description of the system layout is presented;
- a general description of the elements of the system and activities that will occur during the Final Stage of the LFG management system is presented; and
- descriptions of the design criteria and expected performance of the system during the Final Stage based on design computations (which are included in appendices to this report), are presented.

Layout

The layout of the Final Stage is shown on Engineering Drawing 73.

General Description of System Elements and Activities

This stage is expected to represent LFG management for the period between the end of the Main Stage and closure of the landfill, as well as during the post-closure period. As previously noted, significant overlap in the transition between the Main and Final Stages is expected due to the localized nature of landfill operations and waste

placement that may be required during staged closure of the facility. During the Final Stage, the following specific activities will take place.

- New vertical wells will be installed through the top lifts of waste in all phases (a general description of the vertical wells was given in-Section 4.4.3.4).
- Transmission piping connecting the wells to an internal header on the top surface of Phases III through V will be installed in the manner shown on Engineering Drawing 73. The internal header will connect to the perimeter header via downslope pipes at two locations as shown on the drawing.
- Existing wells in Phases I and II will need to be extended to ensure continued collection from lower waste levels. New transmission piping connecting new wells in Phases I and II to the header will be required as well as reconnection of the transmission piping to the extended existing wells.

Although these will already be in place, the peak total LFG flow and condensate volume expected in the system during the Final Stage were used to size the system installed during the Main Stage.

Design Criteria and System Performance

Additions to the system in the Final Stage comprise: (i) vertical LFG extraction wells; (ii) condensate drains; and (iii) a network of transmission piping and control valves. Although the required size/capacity of the blowers and condensate knockout can be specified as a result of the total LFG flow calculated here, detailed design of these flare station features is considered to be outside the scope of work. The following criteria were applied to the design:

- the depths of the extraction wells in Phases III through V must extend vertically to 5 ft below the highest horizontal collector in that area;
- at the time when waste in Phases III through V is placed above 175 ft-msl, vertical wells will be installed in this area and extended upwards as waste is placed. In areas where vertical wells are required to collect LFG, these wells will be installed when waste reaches final grades in these areas.
- the depths of the new extraction wells in Phases I and II must extend 10 ft below the base of new waste in that area;

- the extraction wells will be constructed in a manner that prevents damage to the wells as the landfill cover settles;
- the quantity of gas that is collected from each well will be estimated based on the volume of waste within the radius of influence of the well;
- gas transmission piping will be sized to limit head loss to 1 in. of water per 100 ft of pipe to reduce the required blower horsepower and to limit velocity to less than 2,500 ft/min to reduce the entrainment of condensate; and
- head loss and flow velocity were calculated for each pipe segment using the estimated flow rates from the collectors/wells and the Spitzglass formula, which is an empirical formula for calculating head loss for gases under low pressure based on flow temperature.

LFG Generation Rate

The LFG generation rate affects the design of all the components in the LFG extraction system. The LFG generation rate for the facility during the Final Active Filling Stage was estimated based on the existing weight of waste placed prior to, and the anticipated weight of waste that will be placed during, this period. The maximum estimated LFG generation rate during this period is 8,930 scfm. LFG generation calculations and assumptions are presented in Appendix VIb-H.l.

Vertical LFG Extraction and Transmission System Design

The LFG extraction components of the system are designed to function in accordance with applicable state and federal regulations (listed in Section 4.4.1). Calculations regarding: (i) LFG extraction well ROI; (ii) LFG flow rate from each well; (iii) sizing of LFG transmission piping; and (iv) condensate management are presented in Appendix VIb-H.1. The LFG flow rate from each well was assumed to be proportional to the volume of waste influenced by that well.

Vertical LFG Extraction Wells

The maximum ROI of the wells in the top lifts of waste in Phases I and II and Phases III through V were calculated to be 147 ft and 124 ft, respectively. A nominal value of 125 ft was used, which corresponds to an area of influence of one acre.

LFG Transmission Piping

The pipe diameter will vary as follows:

- the perimeter header will have an 18-in. diameter;
- the internal header have an 8-in. diameter; and
- the downslope pipes connecting the internal header to the perimeter header will have a 10-in. diameter.

As shown in the calculation in Appendix VIb-H.l, the perimeter header was sized such that LFG flow will occur counterclockwise (transmitting LFG from all horizontal collectors in Quadrants 1 and 2 in Phases III through V, half of the LFG from the vertical wells in Phases III through V, and half of the LFG from the vertical wells in Phases I and II) and clockwise (transmitting LFG from all horizontal collectors in Quadrants 3 and 4 in Phases III through V, half of the LFG from the vertical wells in Phases III through V, and half of the LFG from the vertical wells in Phases I and II). The perimeter header is not of sufficient size to transmit LFG from the entire site in one direction only while still meeting the criteria for head loss and flow velocity. Depending on the final construction details of the condensate knockout tank, a 50-ft long transition from the two 18-in. diameter header pipes to a single 26-in. diameter pipe may need to be incorporated in the system upstream of the knockout tank. Alternatively, the two halves of the header loop can be routed separately into one tank, or two separate tanks.

Condensate Management

Condensate management features are described under the Section on the Main Stage (see Section 4.4.4.4). The expected maximum volume of condensate was calculated to be 1,012,620 gal/yr (see Appendix VIb-H.1).

Pipe Crushing Strength

All LFG transmission piping will be buried within the final cover system or above the berm. The wall strength of buried solid transmission pipes was calculated to ensure that it was sufficient to resist stresses applied by site traffic driving over them. The calculations are shown in Appendix VIb-H.2.

4.4.5 Gas Extraction and Management System Components

4.4.5.1 Introduction

The entire system comprises the following four sub-systems: (i) horizontal collectors for LFG extraction; (ii) wells for LFG extraction; (iii) LFG transmission piping; and (iv) flare station (i.e., blowers, condensate knockout, LFG utilization plant, and back-up flare). Upgrading of the existing flare station is not considered within the scope of this design. Specific structures and components comprising or associated with each sub-system are described below.

4.4.5.2 Horizontal LFG Collection Trenches

Overview

The trench components are: (i) a geonet separator; (ii) aggregate and structural soil backfill materials; (iii) a perforated LFG extraction pipe; and (iv) a geomembrane boot and bentonite plug at trench end nearest the landfill sideslope. Vertical gas conduits are also associated with the trenches. Each of these components is described separately in the following paragraphs. LFG monitoring, sampling, and flow adjustment functions are performed at control points located on the specific LFG transmission pipe connected to each trench.

Geonet Separator

As shown in Detail 8 on Engineering Drawing 77, the trenches will be lined with a geonet to: (i) provide separation between the waste and the trench backfill material; and (ii) minimize impedance to the flow of LFG and any moisture present in the trench.

Backfill Materials

The 5-ft deep trench backfill will consist of: (i) a 3-ft deep layer of aggregate; and (ii) a 2-ft thick layer of structural fill overlying the aggregate. The aggregate surrounds the perforated pipe in the trenches and should be DELDOT No. 3 stone or engineer-approved alternatives such as crushed stone, alluvial gravel, or waste materials such as tire shreds or glass chips. A large size of aggregate is required to minimize the potential for clogging of the system. Structural fill should be used for the entire trench depth for the 20 ft horizontal distance between the trench end and landfill sideslope.

LFG Extraction Pipe

LFG will be extracted through 6-in diameter perforated HDPE SDR-17 pipes that will be placed in the center of the aggregate backfill in the trenches. Pipes will be placed in 20-ft sections, loosely connected with 4-ft long loose collars comprising 8-in. diameter HDPE SDR-17 pipe sections. Pipe sections are connected with loose collars rather than welded to allow for the large amount of differential settlement expected at the CIL.

Geomembrane Boot

The purpose of these boots is to prevent shortcutting of liquid into or out of the landfill along the trench line and to prevent leakage of LFG out of or air into the trench. The boots comprise a 20-ft square section of 40-mil HDPE geomembrane with a center elliptical hole cut for a trench's transmission pipe to protrude through. The boot is welded to the pipe around the hole and tucked into the landfill cover soil around its edges.

Bentonite Plug

A 2-ft thick plug of bentonite should be placed 20 ft from the intersection of each trench within the landfill sideslope. The plug serves essentially the same purpose as the boot.

Vertical Conduits

Vertical gas conduits (18-in. diameter borings backfilled with aggregate) will be installed at nominal 200-ft intervals along the length of each trench. Conduits aid the vertical flow of LFG and moisture through landfilled layers of differing permeability. Use of conduits in this way will enhance the overall performance of the horizontal system.

4.4.5.3 Vertical LFG Extraction Wells

Overview

Each well will be comprised of: (i) a well head assembly; (ii) a well casing; (iii) a pipe sleeve; (iv) aggregate backfill; and (v) bentonite grout. Each of these components is described below.

Well Head Assembly

The wellhead assembly will provide monitoring, sampling, and adjustment functions. The monitoring and sampling functions will be provided by a temperature gauge and three self-sealing quick connect fittings that will be used for: (i) gas sampling; (ii) static pressure measurement; and (iii) dynamic pressure measurement by means of an impact pitot tube installed in the well head. The flow rate and level of vacuum applied to the well will be adjustable by means of a gate valve on the wellhead.

The wellhead will be connected to the transmission piping by a flexible PVC hose to allow for differential settlement. A union (i.e., a threaded connection) included on the wellhead will allow for easy disconnection from the transmission piping, if needed.

Well Casing

The vertical well casing will consist of 4-in. diameter Schedule 80 PVC pipe that is perforated for approximately the lower three-quarters of its length. The top perforation will be located a minimum of 8 ft below the ground surface to minimize the potential for drawing air into the landfill. Schedule 80 pipe will be used to withstand the impact of gravel backfill being dropped into the deep borehole.

Pipe Sleeve

The landfill surface surrounding each extraction well is expected to settle more than the well. To allow for this, a PVC pipe sleeve will surround the top of the well casing. The annular space between the well casing and pipe sleeve will be filled with bentonite-amended soil to provide a slip surface as well as a hydraulic barrier.

Aggregate Backfill

The annular material around the perforated portion of the well casing will consist of crushed stone (DELDOT No. 3), or engineer-approved equivalent, which will provide a high-permeability medium that is resistant to fouling by the surrounding waste.

Bentonite Grout

The annular material will be overlain by a minimum 2-ft thick layer of bentonite.

4.4.5.4 LFG Transmission Piping

Overview

LFG will be conveyed from the extraction trenches and wells to the flare station through the LFG transmission piping network. In addition, the system will be tied into the leachate management system to collect LFG that accumulates in leachate risers. The LFG transmission piping network will consist of: (i) HDPE SDR-17 transmission pipes (pipes); (ii) control points (i.e., valves with associated monitoring and sampling features); and (iii) condensate drains. At locations where the system is tied into leachate risers, these risers will serve as condensate drains. Control points for LFG monitoring, sampling, and flow adjustment functions for each horizontal LFG extraction trench are located on trench-specific pipes as close to the junction with the trench outlet as is practicable.

Transmission Pipes

The LFG transmission piping will be HDPE SDR-17 pipe designed to be chemically resistant and to withstand the expected external loads. The transmission piping network will comprise the following pipes: (i) a main perimeter header; (ii) direct downslope connectors from horizontal extraction trenches to the main header; (iii) top internal header for vertical wells in Phases III, IV, and V; (iv) lateral connections from vertical wells to internal header (Phases III, IV, and V) or to main perimeter header (Phases I and II); (v) downslope connectors from top header to main header; and (vi) tie in connectors to leachate risers. Pipe diameters will vary from 6-in. to 16-in. according to the expected LFG flow rate in each segment of the network.

All pipes will be buried as shown in Detail 6 on Engineering Drawing 76 (laterals and headers) and detailed on Engineering Drawing 77 (downslope connectors). A pipe detection system comprising: (i) detectible marker tape; and (ii) plastic-coated 12-14 AWG copper wire will be installed above all buried pipes.

Control Points

As shown in Engineering Drawings 76 and 77, the transmission piping connectors to each horizontal trench will contain control points comprising: (i) PVC butterfly valves to throttle or cut off the vacuum applied to the extraction trenches as needed; and (ii) monitoring and sampling features. The latter comprise: (i) a vapor-filled thermometer; and (ii) quick connect samples ports for LFG sampling. Similar control points exist on the top and main headers at locations shown in Engineering Drawings 72

and 73. These are used to isolate or throttle the vacuum applied to groups of extraction trenches and/or vertical wells.

Condensate Drains

The LFG transmission piping network will also include condensate management features. Condensate that forms in the LFG extraction pipes in horizontal trenches will drain from the pipe perforations into the waste mass. Condensate that forms in the LFG transmission pipes connecting the trenches to the main header will either: (i) drain into Level 1 trenches; (ii) drain into leachate riser connections; (iii) drain into the waste mass at condensate drains located at low points on the perimeter and internal headers; or (iv) be removed by a condensate knock-out tank at the flare station.

4.4.5.5 LFG Flare Station

The LFG transmission pipes will terminate at the existing flare station. The location of the flare station is shown on Engineering Drawings 71 through 73. The design and specifications for upgrading the existing flare station are not considered within the scope of work for this engineering report. A detailed design of the flare station upgrade will be performed at a later time. The station should contain the following equipment:

- a condensate knockout tank;
- a blower that is capable of creating sufficient vacuum;
- a flame arrestor;
- electrical controls and wiring; a LFG utilization plant; and
- an enclosed back-up flare that is capable of 99 percent destruction of organic compounds.

Condensate from the knockout tank will be automatically pumped out and transferred to the leachate storage tanks. In addition, the knockout tank should be equipped with a high-level alarm that closes an electrically actuated valve at the tank LFG outlet and shuts off the LFG blower to prevent damage to the flare station equipment.

4.5 Final Cap System

4.5.1 Introduction

The final cap system is described in this section and it is based on the design proposed by Weston (1992). A description of the final cap system is presented in Section 4 of the report prepared by Weston (1992). Cross sections of the permitted capping system are provided in Drawing 80.

In general, because the landfill final slopes are the same as the one already permitted, the vertical expansion will not affect the hydraulic and stability performance of the cap system. This section includes discussions regarding: (i) the final cap system geometry; (ii) the components and cross-section of the final cap system; and (iii) the specific materials that have been recommended for the components of the final cap system. In this section, issues associated with the performance of the final cap system due to the vertical expansion are presented.

Because larger settlements will be obtained for the expanded landfill, a discussion regarding the impact of settlement on the final cap system is presented in subsection 4.5.2; the impact of settlement in the final cap system is considered in terms of total and differential settlement, and the impact of this settlement on tensile strains in the geomembrane component of Alternative 2 of the final cap system is addressed.

4.5.2 Settlement

In order to evaluate the performance of the CIL cap system, it is necessary to characterize settlement of the CIL waste with respect to the following two factors: (i) overall compressibility; and (ii) localized heterogeneity. Settlement of the final cap system will occur over time due to compression of the waste under its own weight and under the additional load imposed by the cap system. Settlement of the final cap system will also occur as a result of local heterogeneity of the underlying waste. The impact of settlement on the cap system is primarily associated with the potential for elongation and tensile strain in components in the cap system due to differential settlements.

The maximum acceptable tensile strain for the cap system is taken as that of the textured geomembrane, which is the cap system component having the smallest value of allowable tensile strain. The other components of the cap system, or components of earthen cap system alternatives are considered to be less susceptible to damage from tensile strain.

4.5.2.1 Overall Compressibility

The term "overall compressibility" refers to the area-wide settlement potential of waste when subjected to an increase in overburden stress. Settlement resulting from overall compressibility is assumed to be characterized by two components, a rapid primary settlement, and a longer-term, time-dependent secondary settlement. The mechanisms involved in the overall settlement of municipal solid waste are complex and include the following (Edil et al., 1990):

- mechanical compression due to self-weight and surface loads;
- raveling (i.e., movement of fines into voids between larger waste particles);
- chemical changes including corrosion, oxidation, and combustion; and
- biodegradation under aerobic and anaerobic conditions.

A waste layer placed in a landfill cell experiences an immediate mechanical settlement (sometimes referred to as "primary" settlement) under its own weight and the weight of layers above it. This settlement is due to the compression and rearrangement of the waste particles and usually occurs rapidly, within days to months after the waste layer has experienced a new load (Sowers, 1973; NAVFAC, 1983; and Burlingame, 1985). Mechanical settlement results from compression, breakage, and rearrangement of waste materials. Raveling of fine particles into voids between larger waste particles also usually occurs rapidly. For practical purposes, it is commonly assumed that raveling occurs in conjunction with mechanical settlement.

After mechanical settlement has occurred, waste will continue to settle due to creep, chemical reactions, and, more importantly in municipal solid waste, biodegradation. This time-dependent settlement is often referred to as "secondary" settlement. The rate of secondary settlement is usually assumed to be independent of load. The rate of secondary settlement is known to be dependent on waste composition, availability of moisture and oxygen, and temperature. Secondary settlement continues for many years after waste placement, but the rate of secondary settlement decreases with time as the waste becomes more decomposed and stable.

Primary compression of the waste is caused by densification due to added surcharge. Secondary compression of the waste will occur through the post-closure period of the landfill. The influence of the additional weight from the final cover system on settlement of the underlying waste is expected to result in relatively small settlements that are uniformly distributed over the aerial extent of the cap system. Time

dependent settlement due to self-weight and secondary settlement due to decomposition and creep will result in a decrease in overall waste height. As a result, the cover system is not expected to undergo any elongation as a result of total settlement and, therefore, no tensile strains from total settlement are expected.

4.5.2.2 Local Heterogeneity

Types of waste heterogeneity that should be considered in evaluating the performance of the CIL cap system are: (i) buried appliances, or other hollow metal objects, that have a potential to collapse due to either increased overburden stresses or loss of strength due to rust or corrosion; and (ii) localized differences in waste compressibility. With respect to the potential for the collapse of an appliance, such as a refrigerator buried in waste, the Operation and Maintenance Manual (Part V of this Permit Modification Application, Section 4.3.1.1) specifies that such appliances will not be placed in the landfill or will be crushed prior to placement in the landfill. Therefore, local depressions due to the collapse of a buried appliance will not occur.

With respect to localized differences in waste compressibility, localized differential settlement of waste can result from the compression of adjacent hard and soft waste materials, for example, construction debris adjacent to yard waste. The likelihood of adjacent placement of hard and soft waste volumes, is, however, reduced by daily landfill operations, including waste compaction, waste spreading, and placement of daily cover soil. If, however, localized differences in compressibility do occur in the waste, then an analysis of the impact on the CIL cap system should account for the fact that any angular distortions (i.e., defined as the differential settlement between two points divided by the distance between the points) that occur at depth in the waste mass will tend to be attenuated as the settlements propagate upward to the top of the existing waste.

4.5.2.3 Method of Analysis

The development of a depression of significant size due to a locally compressible zone adjacent to the cap materials is not likely based on modern waste management practices. To evaluate the tensile behavior of the geomembrane impermeable barrier should a depression occur within the waste, the size and depth of the compressible zone must be established. The size and shape of the local compressible zone for this analysis was estimated taking into account modern waste placement practices and the attenuation of any displacements occurring within the waste.

The shape of the compressible zone is assumed to be an infinite cylinder with a diameter of 8 ft. The infinite cylinder is considered to be representative of a zone created by several successive loads of waste with high compressibility or degradation potential placed in a line, or by a single waste load spread in one direction only. The 8-ft (2.4-m) diameter of the compressible zone is selected to represent either: (i) several 2 to 3-ft (0.6 to 0.9-m) thick dumped and spread waste loads of high compressibility placed sequentially; or (ii) one waste load that is dumped but not spread.

The analysis for tensile strain in the cap system is performed for top slopes and sideslopes of the cap system. A 50-percent reduction in the original volume of the compressible zone results in a maximum vertical displacement of the bottom of the cover of 6 ft. The calculated strain in the geomembrane is a function of this displacement and the zone of influence for the local compressible zone. The calculated maximum tensile strain in the geomembrane is 0.012 percent, which is less than the maximum acceptable tensile strains for VLDPE, PP, and HDPE geomembranes, as discussed in Section 4.8.5.1. Detailed calculations for settlement and tensile strain as a result of a local compressible zone are presented in Appendix VIb-K.1.

4.6 Access Road Design

Access roads will be constructed at three locations on the expanded landfill:

- at the top or lower tier of the perimeter berm;
- at the toe of the perimeter berm (i.e., the access road that will be used for access by the USACOE to the Delaware and Christina Rivers); and
- on the final cover.

Each of these access roads is designed to accommodate the load of off-road vehicles. Each road will be constructed having a geotextile at the bottom of the road and a one-foot thick layer of crushed stone, per the specifications of the Delaware Department of Transportation. The roads will be constructed to be passable in all conditions and to shed water quickly.

4.7 Stormwater Management System

4.7.1 Introduction

The proposed stormwater management system for the Cherry Island Landfill (CIL) Expansion Project is designed to control stormwater discharge from the landfill expansion area during construction, operation, and post-closure period. The remainder of this section is organized as follows.

- The existing site conditions as they relate to SWM and the impact of the landfill expansion on the SWM system are described in Section 4.7.2.
- A description of the regulatory framework and required documentation for the erosion and sediment control and stormwater management aspects of the project are presented in Section 4.7.3.
- The individual components of the erosion and sediment control system and stormwater management system are described in Section 4.7.4, including the regulatory based design requirements, final design configuration, and material requirements, as appropriate.

4.7.2 Existing and Future Conditions

The existing sediment and stormwater management features at the CIL include perimeter drainage channels, two erosion and sediment control ponds, and associated outfalls. The existing landfill footprint is divided into five phases identified as Phase I through Phase V on the General Site Plan (Drawing 3). The predominant existing drainage patterns at the site include the following:

- Runoff from the northeast portion of Phases I and II are conveyed via existing perimeter channels to the site entrance area. Along the eastern and western portions of the site entrance area, a series of shallow swales and culverts directs runoff towards 12th Street and then into a wetland area between Interstate 495 (I-495) and the northwestern edge of Phase I. In 2003, DSWA began construction to improve the site entrance facilities, traffic flow and stormwater drainage patterns, which is anticipated to be complete by summer 2003.
- Runoff from the northwest and southwest portions of Phase I are conveyed via existing perimeter drainage channels to the wetland area between I-495 and the northwestern edge of Phase I. In addition to site stormwater, the existing

perimeter drainage channel along the southwestern side of Phase I receives decant water from the US Army Corps of Engineers Wilmington Harbor North Dredge Area.

- Runoff from the southwest portion of Phase II is conveyed via perimeter drainage channels toward the south, discharging to an existing HDPE culvert and ultimately into an open area on the north bank of the Christina River.
- Runoff from Phase III is conveyed via perimeter channels towards the existing sediment pond located at the northeast corner of the site. Outflow from the sediment pond is controlled by a multi-stage outlet riser structure, which discharges into an existing channel along the northern edge of the site and ultimately into the Delaware River.
- Runoff from Phase V is conveyed via perimeter channels towards the existing sediment pond located at the southeast corner of the site. Outflow from the sediment pond is controlled by a concrete weir structure, which discharges into a stabilized outfall channel and into the Delaware River.
- Runoff from Phase IV is directed to the north and south via perimeter drainage channels and into one of the two existing sediment ponds.

The CIL Expansion Project will incorporate an approximately 60-ft high MSE berm around Phases III, IV, and V. Construction of the MSE berm will displace the existing perimeter drainage channels adjacent to Phases III, IV, and V, as well as the two sediment ponds. The size of the MSE berm necessitates that landfill expansion construction proceed in a defined sequential manner; thereby providing ample time to establish interim erosion controls and upgraded permanent stormwater management features.

Revised drainage patterns and the associated permanent stormwater management features designed for the post-closure landfill expansion area are summarized as follows:

- Runoff from Phases III, IV, and V will be directed via a series of sideslope terraces, gabion downchutes, and perimeter drainage channels located atop the MSE berm towards drop inlet structures constructed within the MSE berm.
- A total of six drop inlet structures will convey stormwater discharge to the base of the MSE berm, where runoff will be discharged via outlet culverts into

stabilized channels at five outfall locations; three adjacent to the Delaware River, and two adjacent to the Christina River.

Detailed phasing approach to erosion and sediment control during the expansion of the CIL and during waste placement operations is addressed in the Erosion and Sediment Control Plan (ESCP) provided in Appendix VIb-J.

4.7.3 Regulatory Requirements

4.7.3.1 General

Regulatory requirements pertaining to erosion and sediment control and stormwater management for the CIL expansion project are contained in multiple state, and local regulations. The following summarizes the governing regulations and the requirements contained in each regulation.

- ***Delaware Regulations Governing Water Pollution (DRGWP) §9.1.06,*** effective 15 September 1998. Specific requirements of this regulation include: preparation and submittal of a Notice of Intent (NOI) for stormwater discharges associated with construction activity, compliance with monitoring and Stormwater Plan preparation requirements as provided by the Delaware Regulations Governing Solid Waste (DRGSW).
- ***Delaware Regulations Governing Solid Waste §5.F.,*** pursuant to Title 7 of the Delaware Code, Chapter 60. Specific requirements of the regulation include: preventing erosion of the waste cover, implementation of stormwater run-on and runoff control features, channeling of stormwater and leachate to appropriate treatment facilities or sedimentation control devices, and stormwater discharge in compliance with applicable federal and state regulations; applicable regulations include Delaware Sediment and Stormwater Regulations (DSSR).
- ***Delaware Sediment and Stormwater Regulations (DSSR),*** pursuant to Tile 7 of the Delaware Code, Chapter 40. Specific requirements of this regulation include: preparation of a standard application form and an ESCP, prepared in accordance with the Delaware Erosion and Sediment Control Handbook (DESCH), dated 1998 and approved supplements, and Stormwater Management Plan.

- ***New Castle County Code Chapter 12, Article 5.*** Specific requirements of this regulation include: submission of Sediment and Stormwater Plan to the New Castle Department of Land Use in conformance with DSSR, and DESCH.

A summary of the requirements and information contained in the ESCP follows.

4.7.3.2 Erosion and Sediment Control Plan

Construction of the CIL Landfill Expansion Project, and subsequent operation of the landfill, will require implantation of the ESCP (see Appendix VIb-J). In general, the intent of the ESCP is to minimize soil erosion, ponding water, and promote on-site control of sediment laden runoff from construction activities and interim waste cover during the landfill operations. Specific structural and vegetative features of the ESCP included: silt fence, temporary sediment traps, permanent and temporary vegetation, temporary diversion berms and channels, rock check dams, perimeter dike/swales, inlet protection, and earth dikes. Specific requirements of the ESCP are enumerated in the DSSR §10.2, and summarized below:

- The ESCP shall provide details of temporary and permanent stabilization measures and inclusion of the following statement.

  "Following soil disturbance or re-disturbance, permanent or temporary stabilization shall be completed within 14 calendar days as to the surface of all perimeter sediment controls, topsoil, stockpiles, and all other disturbed or graded areas on the project site."

- A sequence of construction including references to the following activities: clearing and grubbing for perimeter controls, construction of perimeter controls, clearing and grubbing for site grading, site grading, and removal of sediment controls.
- A description of predominant soil types.

The ESCP fulfills the specific requirements of DSSR §10.2, as well as the general requirements of DRGSW §5.F.1.a and b. (e.g., preventing erosion of the waste cover and preventing collection of standing water on the landfill).

4.7.3.3 Stormwater Management Plan

As described in the DSSR §10.3, management of stormwater quantity and quality are each important components of site-wide stormwater management. The regulations

also recognize that certain exceptional circumstances do exist, and case-by-case variances from the regulations may be granted by the approving agency. Because stormwater from the CIL Expansion Project will be discharged to either the tidally influenced Delaware or Christina Rivers, a waiver from the stormwater water quantity control requirements should be granted in accordance with DSSR §3.2.B(2), which states:

> *"Provisions will be made or exist for a non-erosive conveyance system to tidewater by either a closed drainage system or by open channel flow that has adequate capacity to contain runoff events being considered as a requirement of these regulations."*

Design of open channels to convey discharge from the landfill cover system to the tidally influenced Delaware and Christina Rivers, are described in Section 4.7.4 and calculations are presented in Appendix VIb-I.9.

As defined by the DSSR, stormwater management for water quality control includes:

> *"...a system of vegetative, structural, and other measures that controls adverse effects on water quality that may be caused by land disturbing activities or activities upon the land."*

Due to the unique proximity of the CIL Expansion Project to the Delaware and Christina Rivers, inclusion of the preferred water quality enhancement option (i.e., permanent stormwater quality basins) beyond the landfill perimeter is not feasible. However, during construction and operation of the landfill, erosion and sediment controls will be maintained to provide water quality control. Further, in its final configuration, the landfill final cover system will incorporate a system of natural vegetation (i.e., permanent seeding), which will provide the water quality control in accordance with the DSSR.

4.7.4 Stormwater Management System Design

4.7.4.1 Overview

The CIL Expansion Project post-closure stormwater management system design incorporates a series of stormwater conveyance and discharge features that direct stormwater runoff from the final cover system to multiple outlets located along the

Delaware and Christina Rivers. Because there is physically no space available to construct permanent stormwater detention features outside of the MSE berm, permanent detention features are not included in the final design. The following is a list of the permanent stormwater management features prepared for the project.

- Perimeter Drainage Channels;
- Sideslope Terraces;
- Drainage Swales;
- Gabion-Lined Downchutes;
- Drop Inlet Structures;
- Stormwater Outlet Culverts;
- Outlet Culvert Protection; and
- Outlet Channels.

Supporting calculations for design of each feature are presented in Appendices VIb-I.1 through VIb-I.11, which include:

- Appendix VIb-I.1: Selection of Post-Development Hydrologic Parameters
- Appendix VIb-I.2: Stormwater Routing Analysis: 25-yr, 24-hour Design Storm
- Appendix VIb-I.3: Stormwater Routing Analysis: 100-yr, 24-hour Design Storm
- Appendix VIb-I.4: Sideslope Terraces, Swales, and Perimeter Drainage Channel Design
- Appendix VIb-I.5: Downchute Geometric Design
- Appendix VIb-I.6: Downchute Lining Design
- Appendix VIb-I.7: Drop Inlet Design
- Appendix VIb-I.8: Stormwater Outlet Culvert Design
- Appendix VIb-I.9: Culvert Outlet Protection and Outlet Channel protection Design
- Appendix VIb-I.10: Stormwater Outlet Culvert Settlement Analysis
- Appendix VIb-I.11: Stormwater Outlet Culvert Structural and Pipe Bedding Design

4.7.4.2 Stormwater Management Feature Design Basis

Detailed descriptions of the design basis for each structural stormwater management feature are presented in the following paragraphs. Vegetative practices and temporary erosion and sedimentation control features are described in the ESCP.

Stormwater management features associated with the CIL Expansion Project include conveyance features (i.e., sideslope terraces, gabion revert mattress-lined downchutes, perimeter drainage channels, and drainage swales) and discharge features (i.e., drop inlet structures, stormwater outlet culverts, culvert outlet protection, and outlet channels). In general, the site-wide stormwater management system is designed to convey stormwater discharges based on the following criteria:

- permanent stormwater management conveyance features discharge to drop inlet structures, which discharge runoff to protected outfalls and channels at the Delaware River or Christina River;
- as required by the DRGSW §5.F.2, permanent stormwater management features are sized to convey, at a minimum, the peak discharge resulting from the 24-hour, 25-year design storm; and
- stormwater management lining materials are designed to be stable during the 24-hour, 25-year design storm discharge.

In addition to the above regulatory requirements, site-specific design requirements for stormwater conveyance features and stormwater discharge features are discussed below.

Stormwater Conveyance Features

Stormwater conveyance features are designed to minimize erosion on the landfill cover surface and prevent ponding of water. Sideslope terraces, gabion revert mattress-lined downchutes, perimeter drainage channels, and drainage swales, each provide a means of intercepting and transmitting runoff in a controlled manner at non-erosive velocities. These features are designed based on consideration of required flow capacity, and resistance to erosion. In general these features are designed such that:

- flow capacities of sideslope terraces are sufficient to convey the 24-hour, 100-year design storm without overtopping, and sideslope terraces are spaced every 33 ft vertically;
- flow capacity of gabion revert mattress-lined downchutes, perimeter drainage channels, and drainage swales is sufficient to convey the 24-hour, 100-year design storm without overtopping; and
- erosion resistance of sideslope terraces, gabion revert mattress-lined downchutes, perimeter drainage channels, and drainage swales is sufficient to resist discharge velocities and tractive forces associated with the 24-hour, 25-year design storm.

Stormwater Discharge Features

Drop inlet and stormwater outlet culvert discharge features provide an effective means of transmitting stormwater from the crest to the base of the MSE berm. These features are designed based on considerations of energy dissipation, required flow capacity, hydraulic characteristics, foundation settlements, culvert joint stability (i.e., leakage potential), and overburden loads. In general, the drop inlets and stormwater outlet culverts are designed such that:

- flow capacity of the drop inlet structures is sufficient to convey discharge from the 24-hour, 100-year design storm without overtopping;
- kinetic energy of freefalling water within the drop inlet structure is dissipated by a permanent plunge pool at the base of the drop inlet structure;
- flow capacity of the stormwater outlet culverts is sufficient to convey discharge from the 24-hour, 100-year design storm at sub-critical flow conditions;
- grade reversal of the stormwater outlet culverts due to overburden loads imposed by the MSE berm will not occur; and
- stormwater outlet culvert design strength combined with culvert bedding are sufficient to withstand the overburden MSE berm load, induced traffic loads, and trench backfill induced loads.

Outlet culvert protection and outlet channels convey runoff to the tidally influenced Delaware and Christina Rivers. These features are designed based on consideration of erosion resistance. In general, the outlet culvert protection and outlet channels are designed such that erosion resistance of the outlet culvert protection is

sufficient to resist the 100-year, 24-hour design storm discharge, and is based on the DESCH Standard Specification for Rock Outlet Protection I.

4.7.4.3 Design Summary

Final design configuration and material specifications associated with the stormwater management features designed for the CIL Expansion Project are presented in the Specifications and Drawings. In this section a summary of the design calculation results are presented. This summary provides confirmation that the specific design requirements outlined for each feature in Section 4.7.4.2 are achieved by the design. Design calculation outputs are summarized below.

Stormwater Conveyance Features

Stormwater conveyance features are designed meet flow capacity and erosion resistance requirements. Flow capacity of each feature was verified by calculation of the maximum flow depth within each structure, and erosion resistance was verified by comparison of the calculated maximum velocity and tractive force on the lining material to the allowable velocity and tractive force on the specified construction materials. The following presents a summary of the maximum flow depth, flow velocities, and tractive forces.

- Sideslope terraces, drainage swales, perimeter drainage channels, and gabion revert mattress-lined downchutes are designed to be constructed at various slopes and cross-sections as shown on the Drawings. The maximum flow depths calculated within these permanent stormwater conveyance features during the 24-hour, 100-year discharge is as follows:

sideslope terraces	1.1 ft;
drainage swales	1.2 ft;
perimeter drainage channels	1.3 ft; and
downchutes	2.2 ft.

  Each of the above calculated flow depths is less than the minimum feature depth as presented on the Drawings.

- Sideslope terraces, drainage swales, and perimeter drainage channels will be vegetated and lined with erosion control mat as shown on the Drawings and described in the Specifications. The maximum 24-hour, 25-year design storm discharge velocity and tractive force within each of these features is as follows:

sideslope terraces	5.3 ft/sec, 0.9 lbs/ft^2;
drainage swales	5.0 ft/sec, 0.9 lbs/ft^2; and
perimeter drainage channel	3.1 ft/sec, 0.3 lbs/ft^2.

Each of the above calculated flow discharge velocity and tractive force values is less than the specified erosion control mat allowable velocity and tractive force described in the Specifications.

- Downchutes will be stepped and gabion revert mattress-lined as illustrated on Drawings 60 and 61 (i.e., Stormwater Management System- Downchute Plan and Profile and Stormwater Management System Details I). The maximum 24-hour, 25-year design storm discharge velocity and tractive force within the permanent downchutes is 9.3 ft/sec, 25 lbs/ft^2, which is less than the design allowable velocity and tractive force.

Stormwater Discharge Features

Stormwater discharge features are designed to meet flow capacity, erosion resistance, and structural resistance requirements.

Flow capacity of drop inlet structures and outlet channels was verified by calculation of the maximum flow depth within the features. The maximum flow depth calculated within these permanent stormwater discharge features during the 24-hour, 100-year discharge is 1.8 ft, which is less then the inlet design height as shown on the drawings.

Flow capacity and flow condition (i.e., sub-critical flow) of outlet culverts are influenced by culvert slope size, and material. Hydraulic calculations were performed for selection of the minimum design slopes and culvert sizes. Culverts will be manufactured from reinforced concrete. Settlement calculations were performed to estimate the differential settlement of the outlet culverts, which will affect the post-settlement slope and design discharge of the culverts. Differential settlement is accounted for in the design based on induced loading from the MSE berm, and the maximum differential settlement of the stormwater outlet culverts will occur between the drop inlet structure and the face of the MSE berm. The maximum differential settlement calculated is 4.5 ft; design construction elevations will incorporate an offset to compensate for this settlement and maintain positive grades away form the landfill.

Outlet protection design is based on procedure presented in the Delaware Erosion and Sediment Control Handbook (DNREC, 1998). Culvert outlet protection will consist of riprap as shown on the Drawings, and riprap sizes are is based on the Delaware Department of Transportation Standard Specification 712.04. The maximum 24-hour, 100-year design storm discharge for culvert outlet protection design is 274 ft^3/sec. Outlet channels will be lined with riprap and vegetated erosion control mat as shown on the Drawings.

Structural resistance of the outlet culverts was verified by comparison of the maximum driving load on the stormwater outlet culverts to the allowable load for the construction materials specified on the drawings. Specified stormwater outlet culvert construction materials are based on American Association of State Highway Officials (AASHTO) Specification M170 for reinforced concrete pipe (RCP). The maximum calculated load on the stormwater outlet culverts is 2,860 pounds per linear feet per foot of interior culvert diameter, which is less than the allowable load for AASHTO Class V RCP as specified on the Drawings.

5. CONSTRUCTION METHODS

Prior to constructing the features of CIL, a complete construction bid package will be prepared for prospective construction contractors. The bid package will contain general conditions of the contract, technical specifications, a Construction Quality Assurance (CQA) Plan, and construction drawings. In the technical specifications, installation methods and procedures will be presented (as required by DRGSW §4.B.1.a.(4).(b)) for all features of the project. A draft of the technical specifications is presented in Appendix VIb-L. The construction bid documents will be submitted to DNREC for its review and DNREC's comments to the bid documents will be incorporated before the document is issued for bids.

6. FACILITY CONSTRUCTION SCHEDULE

The CIL expansion and its related features will be constructed over a period of approximately two years. The detailed schedule for construction will be prepared by the successful construction bidder (to meet the requirements of DRGSW §4.B.1.a.(4).(c)) after award of the construction contract. The contractor's schedule will be submitted to DNREC for its review and comment after it is received by DSWA. A preliminary construction schedule is presented on Figure VIb-8 for planning purposes.

7. FACILITY DISPOSAL CAPACITY AND LIFE PROJECTIONS

7.1 Introduction

In accordance with the requirements of DRGSW §4.B.1.d.(4), this section presents the anticipated quantities of solid waste that will be accepted at the CIL (in both tons and cubic yards per day) and the results of calculations used to calculate the projected life expectancy of the facility.

7.2 Anticipated Waste Quantities

The average anticipated quantity of waste to be received on a yearly basis at CIL during the design life of CIL is about 1,000,000 cubic yards per year based on projected analysis of the capacity of the landfill consumed per year over the past several years (see the Waste Characterization Report in the appendices to Part VIa of this Permit Modification Application). This quantity of waste is based on the volume of the recent waste stream accepted at CIL and represents all of the eligible waste generated in the CIL service area and includes daily and intermediate cover materials. The CIL accepts waste six days a week. Therefore, the average quantity of waste accepted at the facility on a yearly basis during the design life of the landfill is approximately 1,000,000 cubic per year.

7.3 Facility Life Projections

The projected life expectancy of the CIL is a function of the assumptions and anticipated waste quantities presented in the previous section, and the total volume of CIL available for waste placement. Based on the grading configuration presented on Figure VIb-3, the estimated available volume at CIL is approximately 20,700,000 yd^3 (inclusive of waste, daily cover, and intermediate cover soils). The corresponding life expectancy of the CIL is approximately 20.5 years (i.e., through the year 2025). Detailed volume calculations are presented in Appendix VIb-B.

8. CONSTRUCTION QUALITY ASSURANCE PLAN

CIL and its related features will be constructed under close observation of a representative of DSWA. According to DRGSW §4.B.1.a.(4), the Permit Modification Application must contain a description of the manner in which quality assurance will be carried out during the construction and installation of all design features. Accordingly, a CQA Plan was prepared specifically for construction of this facility. The CQA Plan is presented as Appendix VIb-M to this Engineering Report. In the CQA Plan, the required qualifications of the CQA team are presented and the observations, tests, and documentation that the CQA team will perform are identified.

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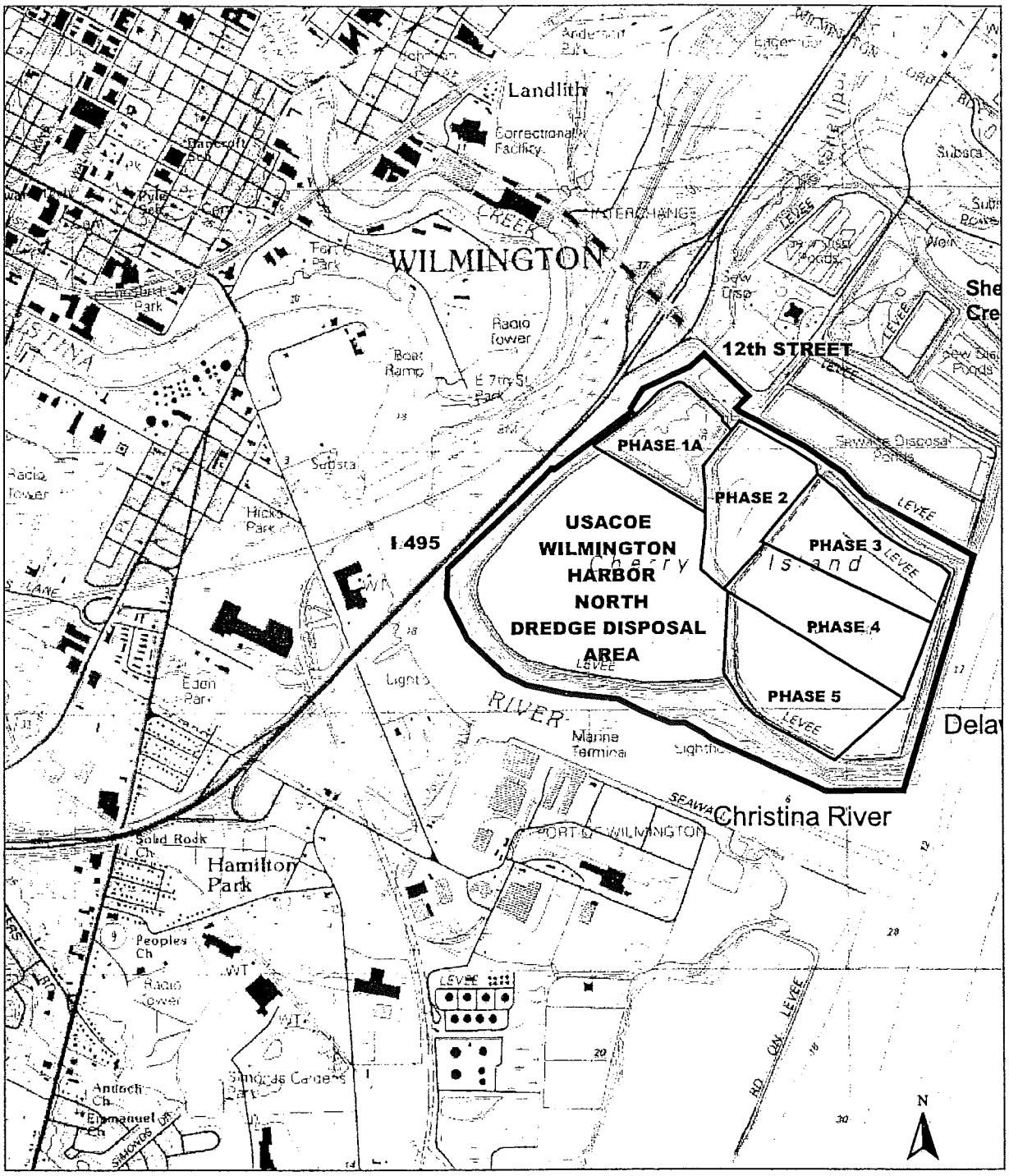


2000 0 2000 Feet

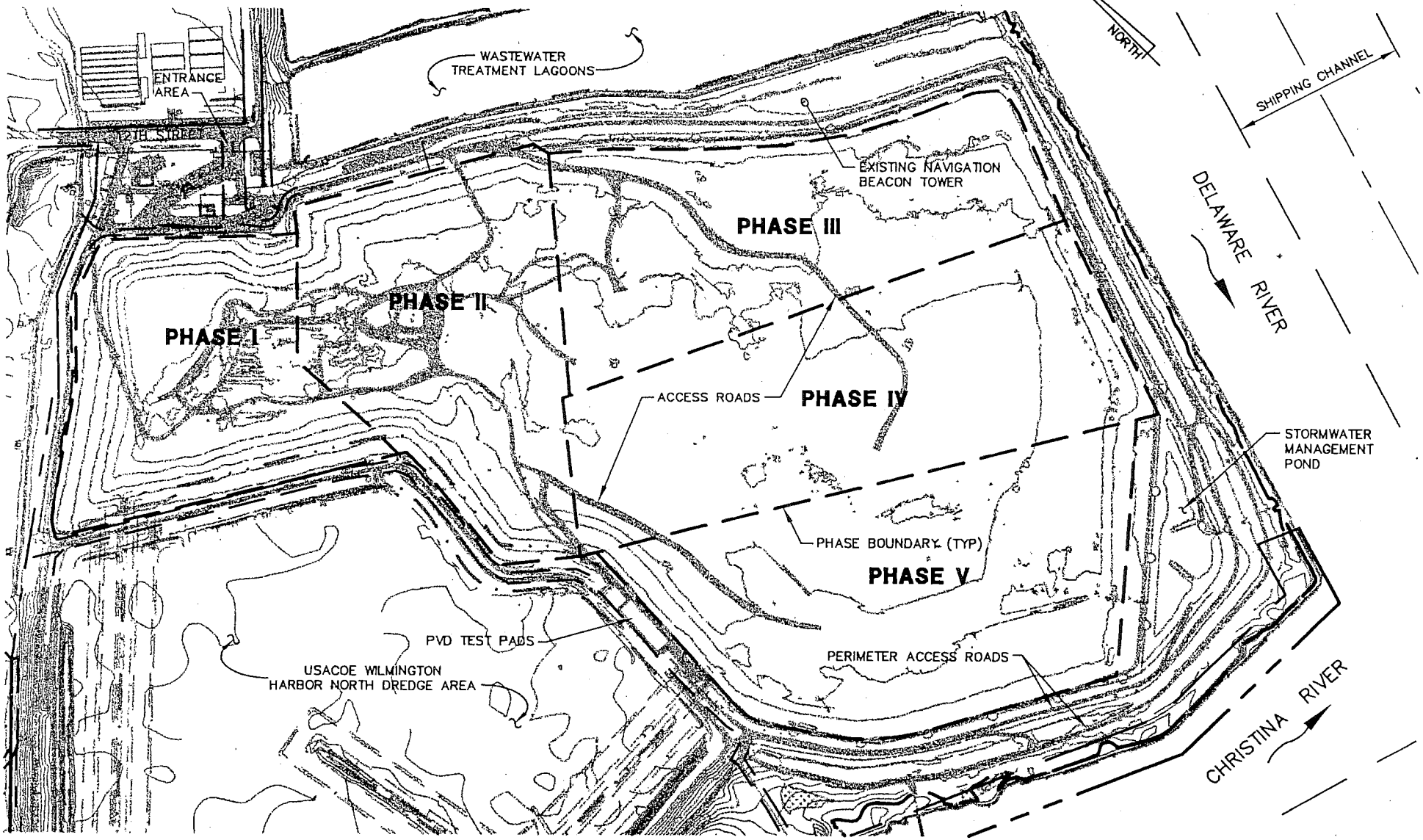
LEGEND

PHASE BOUNDARY
FACILITY BOUNDARY

SOURCE: USGS 7.5-Minute Topographic Map
Wilmington, DE-NJ Quadrangle
1993

GEOSYNTEC CONSULTANTS 10015 Old Columbia Road, Suite A-200 Columbia, Maryland 21046	GENERAL SITE PLAN AND LOCATION MAP CHERRY ISLAND LANDFILL WILMINGTON, DELAWARE	FIGURE VIb - 1 Cherry Island Landfill Project PROJECT- ME0250

FACILITY LAYOUT



650 325 0 650

SCALE; 1" = 650'

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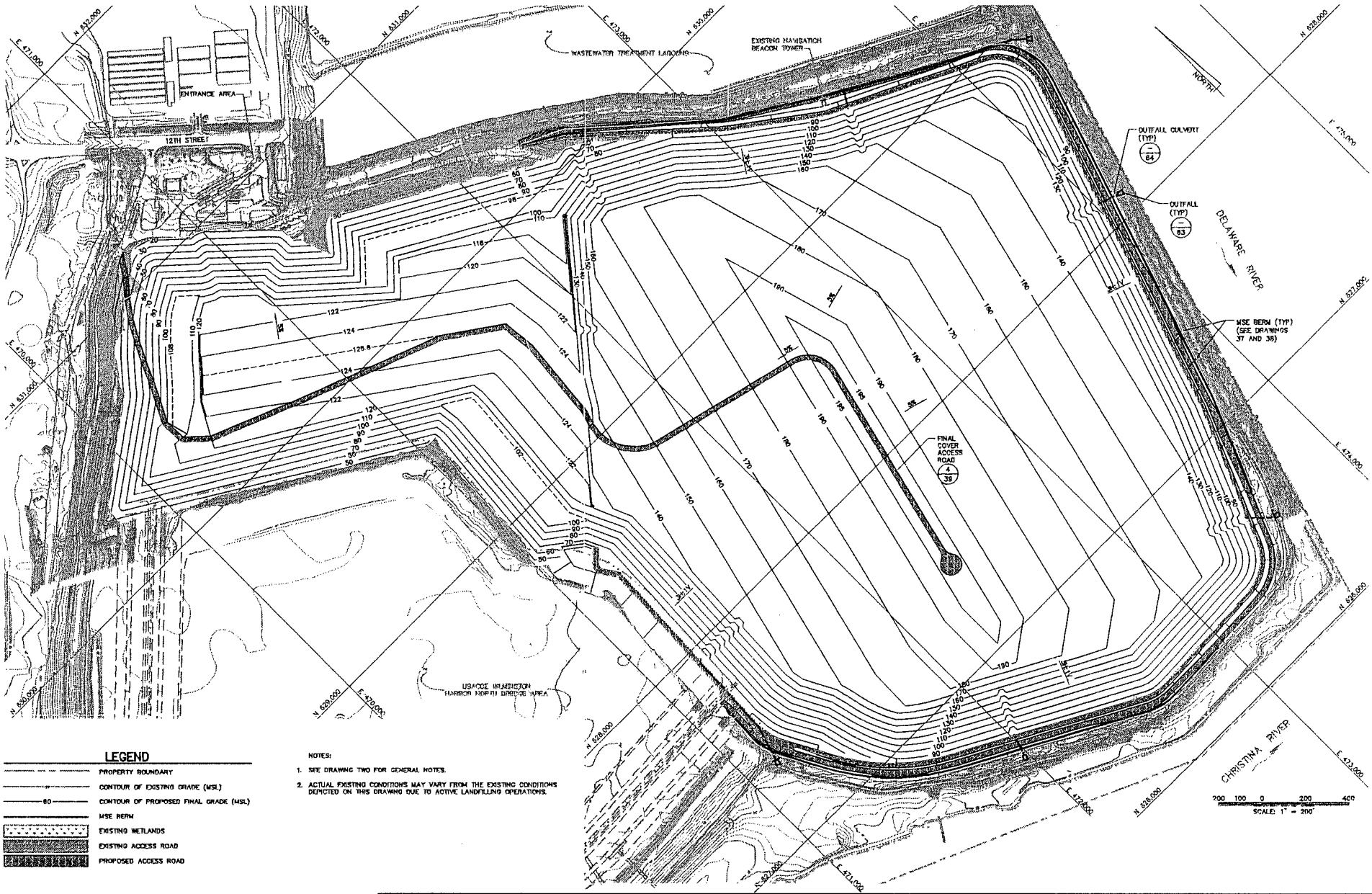
FIGURE NO.	VIb–2
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	0250F708



LEGEND

- PROPERTY BOUNDARY
- CONTOUR OF EXISTING GRADE (MSL)
- 60 CONTOUR OF PROPOSED FINAL GRADE (MSL)
- MSE BERM
- EXISTING WETLANDS
- EXISTING ACCESS ROAD
- PROPOSED ACCESS ROAD

NOTES:

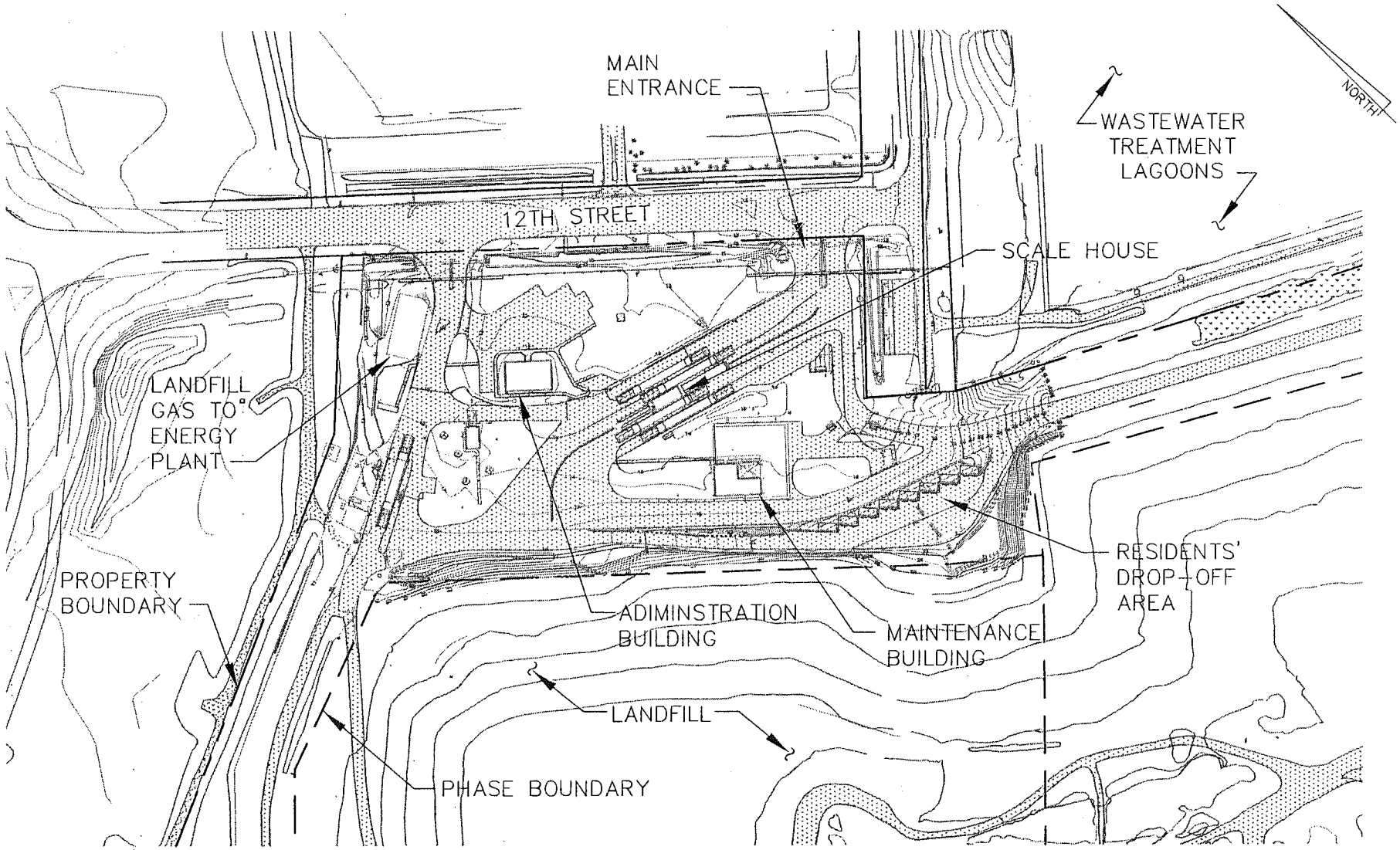
1. SEE DRAWING TWO FOR GENERAL NOTES.
2. ACTUAL EXISTING CONDITIONS MAY VARY FROM THE EXISTING CONDITIONS DEPICTED ON THIS DRAWING DUE TO ACTIVE LANDFILLING OPERATIONS.

REDUCED COPY - NOT TO SCALE

GEOSYNTEC CONSULTANTS
COLUMBIA, MARYLAND

FIGURE NO.	VIb-3
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	02501278

ENTRANCE AREA PLAN



200 100 0 200

SCALE: 1" = 200'

GEOSYNTEC CONSULTANTS

COLUMBIA, MARYLAND

FIGURE NO.	VIb-4
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	0250F1202

FOUNDATION IMPROVEMENT APPROACH – SCHEMATIC

SEE DRAWINGS 37 AND 38 FOR DETAILS

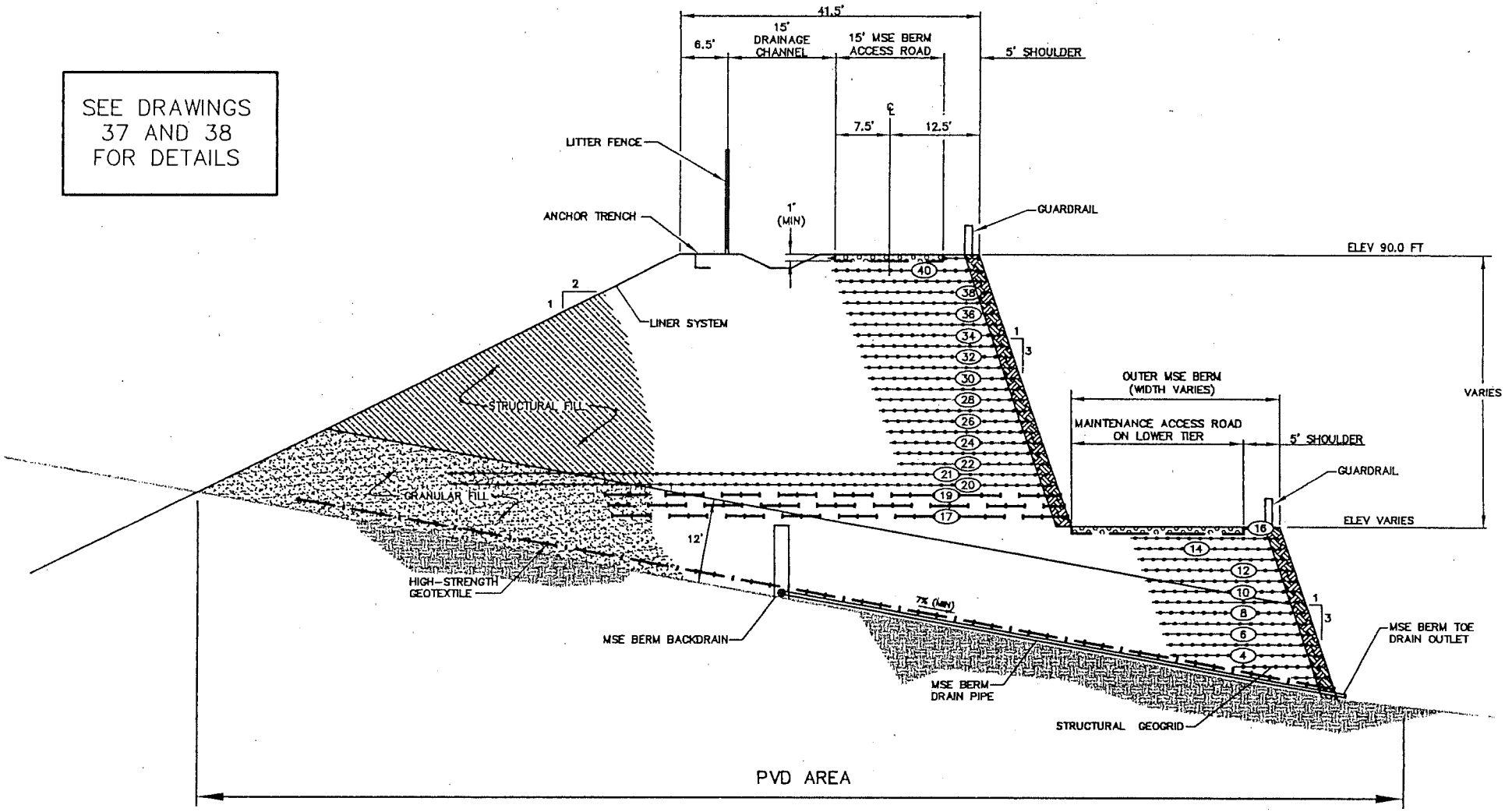


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FIGURE NO.	VIb–5
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	0250F701

INCLINE LEACHATE REMOVAL SYSTEM

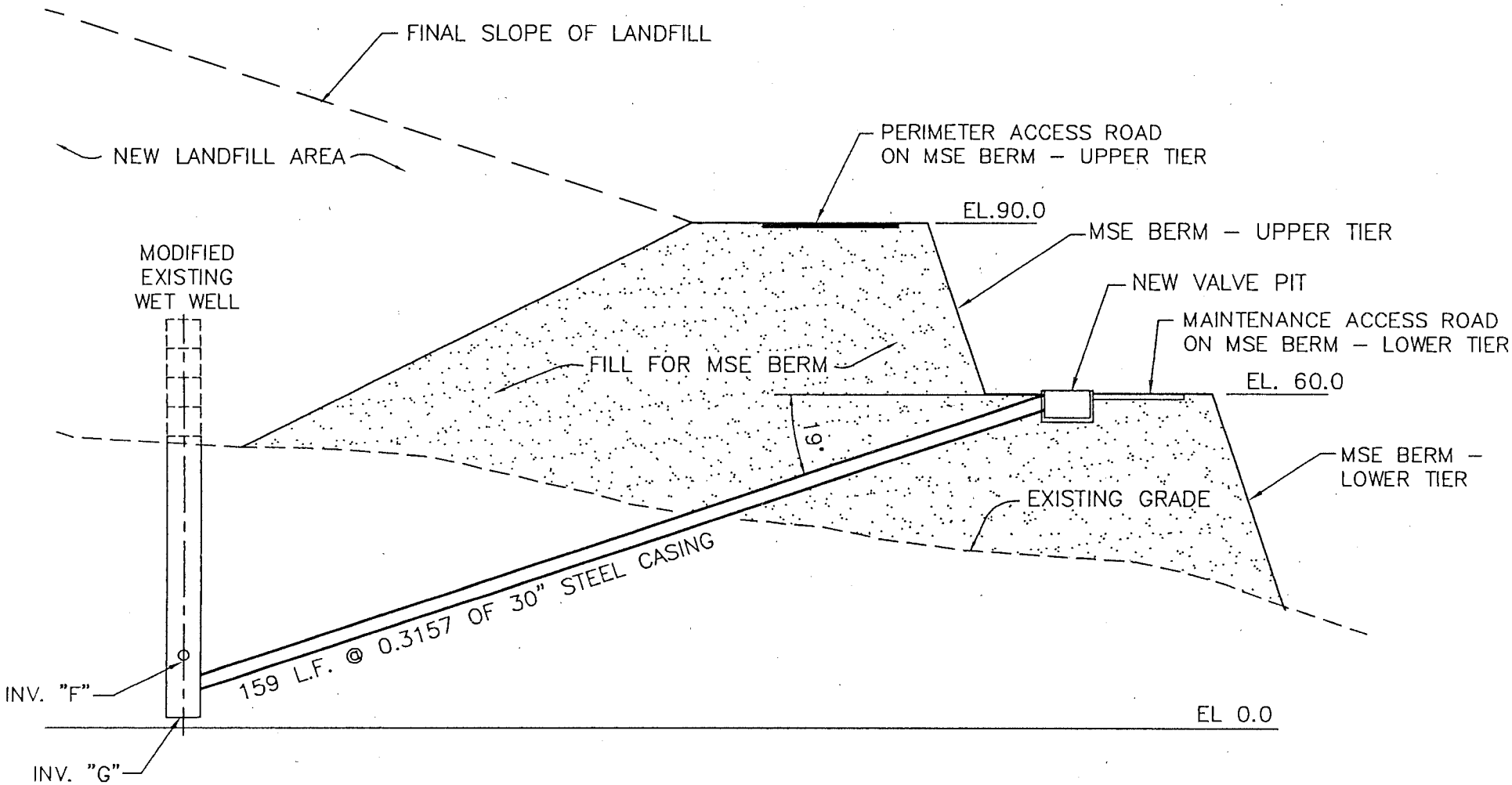

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FIGURE NO.	VIb–6
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	0250F701

SEISMIC IMPACT ZONE MAP

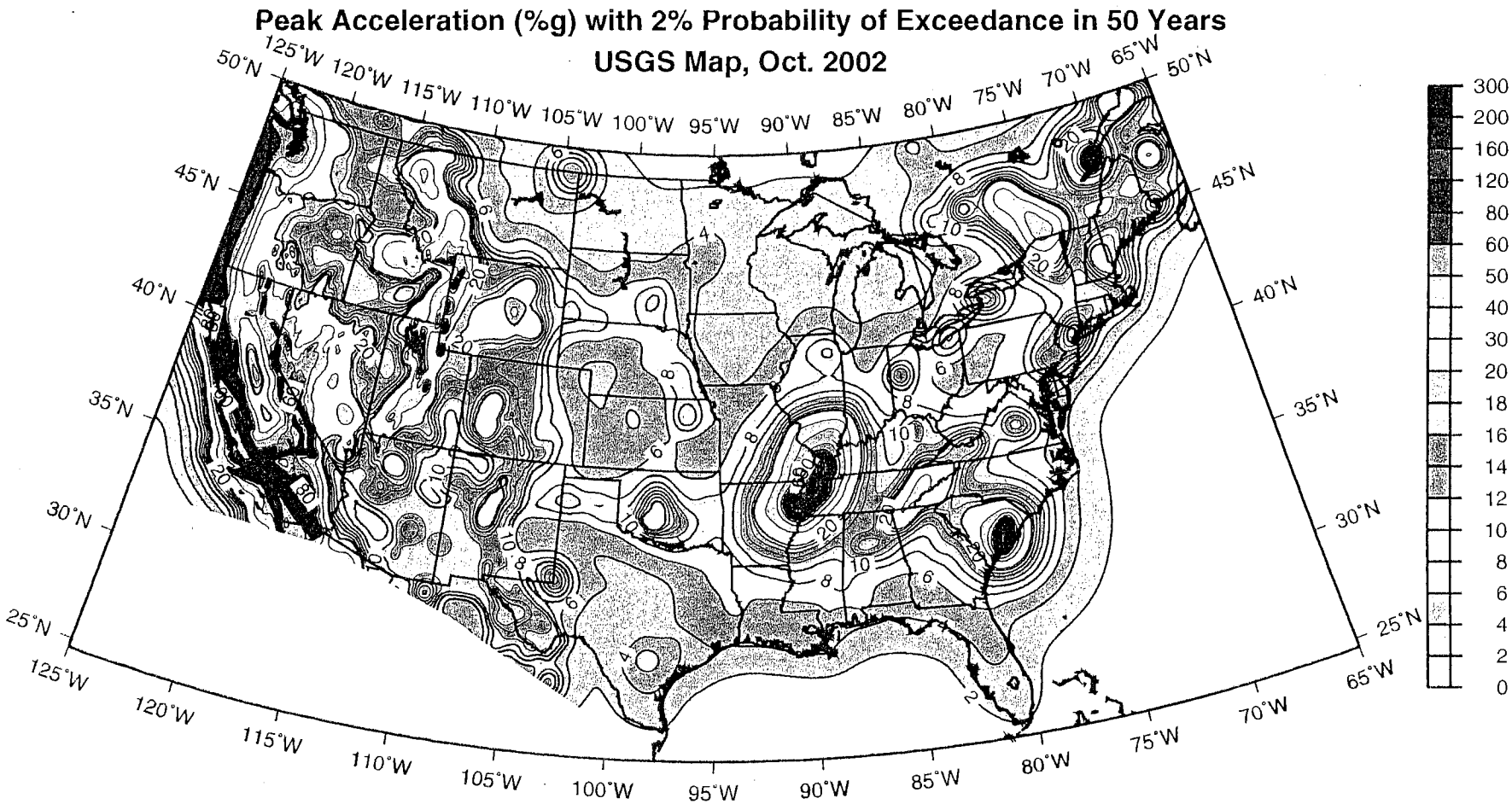


FIGURE 4: USGS NATIONAL SEISMIC MAP FOR THE UNITED STATES SHOWING PEAK GROUND ACCELERATION (%G) WITH 2% PROBABILITY OF EXCEEDENCE IN 50 YEARS.

REF:
HTTP://PUBS.USGS.GOV/OF/2002/OFR-02-420/USPGA2500V3-508.PDF

GEOSYNTEC CONSULTANTS
COLUMBIA, MARYLAND

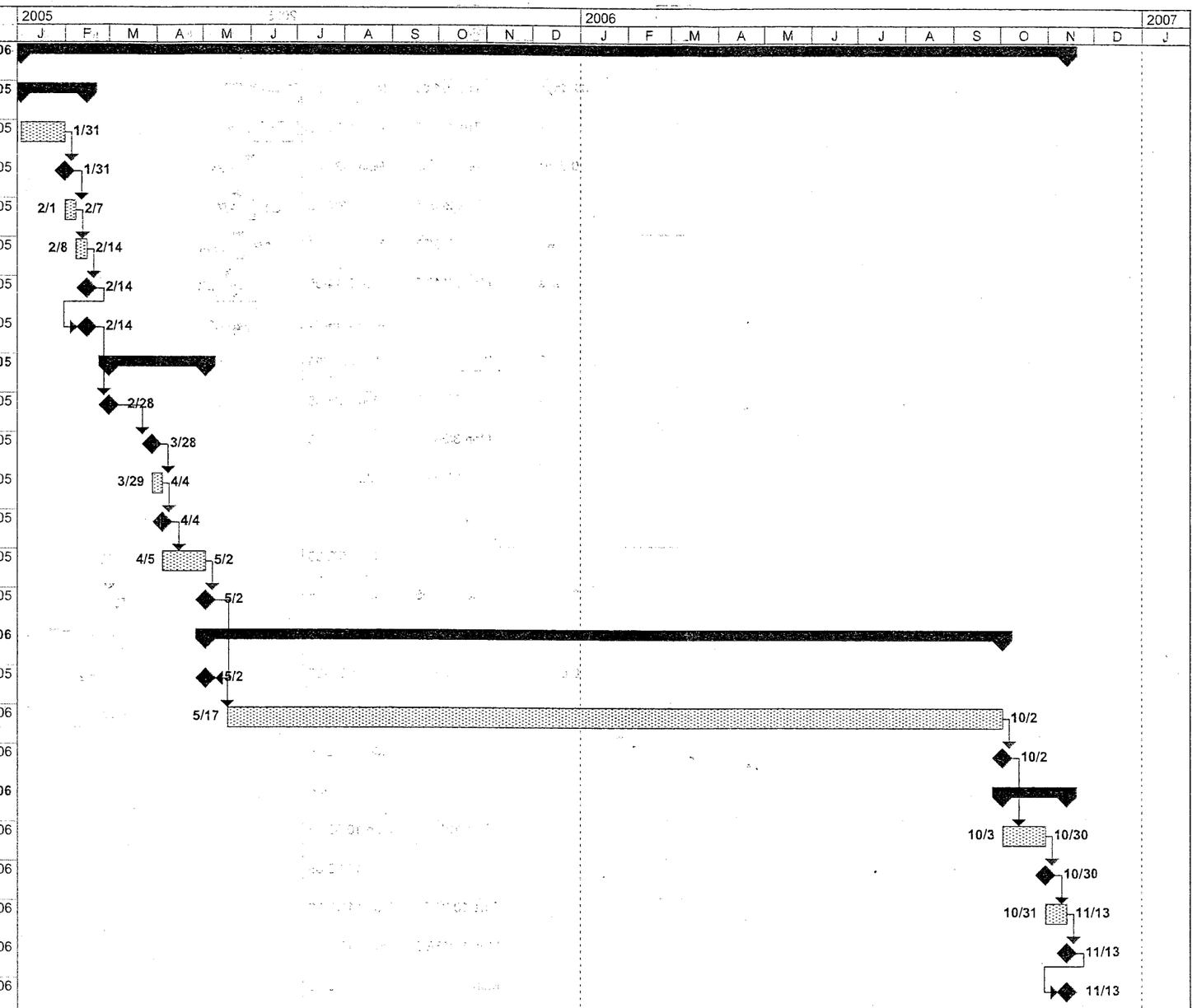
FIGURE NO.	VIb-7
PROJECT NO.	ME0250
DOCUMENT NO.	
FILE NO.	0250F1203

Preliminary Construction Project Schedule

Cherry Island Landfill Expansion Project

Contract S01455NC

ID	Task Name	Duration	Start	Finish
1	**PRELIMINARY CONSTRUCTION SCHEDULE**	**485 days**	**Tue 1/4/05**	**Mon 11/13/06**
2	**1. Prepare Bid Documents**	**30 days**	**Tue 1/4/05**	**Mon 2/14/05**
3	Prepare Bid Documents	4 wks	Tue 1/4/05	Mon 1/31/05
4	Submit Draft Bid Documents to DSWA	0 days	Mon 1/31/05	Mon 1/31/05
5	DSWA Review	1 wk	Tue 2/1/05	Mon 2/7/05
6	Incorporate DSWA Comments	1 wk	Tue 2/8/05	Mon 2/14/05
7	Submit Bid Docs to DSWA	0 days	Mon 2/14/05	Mon 2/14/05
8	DSWA Issue Bid Documents	0 days	Mon 2/14/05	Mon 2/14/05
9	**2. Evaluate Bids and Make Recommendations**	**45 days**	**Mon 2/28/05**	**Mon 5/2/05**
10	Prebid Meeting	0 days	Mon 2/28/05	Mon 2/28/05
11	Receive Bids from Contrctors: Bid Opening	0 days	Mon 3/28/05	Mon 3/28/05
12	Bid Analysis	1 wk	Tue 3/29/05	Mon 4/4/05
13	Provide Bid Analysis and Engineer's Recommendation	0 days	Mon 4/4/05	Mon 4/4/05
14	Contract Negotiation and Procurement	4 wks	Tue 4/5/05	Mon 5/2/05
15	Award Construction Contract	0 days	Mon 5/2/05	Mon 5/2/05
16	**3. Construction Activities**	**370 days**	**Mon 5/2/05**	**Mon 10/2/06**
17	Notice to Proceed to Contractor	0 days	Mon 5/2/05	Mon 5/2/05
18	Perform Construction	18 mons	Tue 5/17/05	Mon 10/2/06
19	Complete Construction	0 days	Mon 10/2/06	Mon 10/2/06
20	**4. Post-Construction Activities**	**30 days**	**Tue 10/3/06**	**Mon 11/13/06**
21	Prepare Draft CQA Report	4 wks	Tue 10/3/06	Mon 10/30/06
22	Submit Draft Report to DNREC	0 days	Mon 10/30/06	Mon 10/30/06
23	DNREC Review CQA Report	2 wks	Tue 10/31/06	Mon 11/13/06
24	Certification of Construction	0 days	Mon 11/13/06	Mon 11/13/06
25	**5. Begin Waste Placement in Expansion Area**	0 days	Mon 11/13/06	Mon 11/13/06



'ect: Project Schedule
.e: Thu 6/10/04

Task		Milestone		Rolled Up Critical Task		Split		Group By Summary	
Critical Task		Summary		Rolled Up Milestone		External Tasks			
Progress		Rolled Up Task		Rolled Up Progress		Project Summary			

FIGURE VIb-8