PARE PROJECT NO. 03053.20
GZA PROJECT NO. 32767.08

PROPOSED PHASE VI LANDFILL - PERMITTING APPLICATION

CENTRAL LANDFILL
JOHNSTON, RHODE ISLAND

VOLUME 1 OF 3

PREPARED FOR:

RI RESOURCE RECOVERY CORPORATION
65 SHUN PIKE
JOHNSTON, RHODE ISLAND 02919

PREPARED BY:

PARE CORPORATION
8 BLACKSTONE VALLEY PLACE
LINCOLN, RHODE ISLAND

GZA GEOENVIRONMENTAL, INC.
530 BROADWAY
PROVIDENCE, RHODE ISLAND

ORIGINAL SUBMISSION APRIL 2007

REVISED APRIL 2010

TABLE OF CONTENTS

APPENDICES

A. Design Drawings – See attached drawing package (rolled)
B. Report 78 and Landfill Service Calculations
C. Summary of Geohydrologic Report
D. Conservation Easement and Statement of Deed
E. RIDEM Freshwater Wetlands Program Insignificant Alteration Permit
F. CLF Endangered Species Review
G. Summary of Geotechnical Analysis
H. Chemical Resistance of Landfill Components
I. Drainage Analysis
J. Leachate Collection
K. Agreement Related to Leachate Disposal
L. Leachate Analytic Results
M. Gas Management Plan
N. Erosion and Sedimentation Plan
O. City of Cranston – Industrial Wastewater Discharge Permit
P. Surface Emission Monitoring Plan
Q. Fire Department Response Letter
R. Groundwater Leachate Monitoring Plan
S. Ambient Air Monitoring
T. Financial Assurance for Closure
U. Supporting Documentation for Design Equivalency
V. Air Pollution Control Permit Application
W. Host Community Agreement

LIST OF TABLES

SECTION 1

1.0 INTRODUCTION

1.1 PURPOSE

The Rhode Island Resource Recovery Corporation (RIRRC) serves the waste disposal needs of most of the municipal and commercial solid waste generators in the State of Rhode Island. It conducts the landfilling activities and the other operations related to solid waste and recycling on a 1200-acre parcel of property it owns located in the Town of Johnston, Rhode Island. Other facilities at the site include the Materials Recycling Facility, the Methane Gas Recovery Facility, Leachate Pretreatment Facility, Compost Facility, Recovermat Facility, Eco-Depot, and a Tipping/Transfer Facility.

RIRRC is hereby requesting licensing for the construction and operation of a 103-acre base cell area to be known as the Phase VI Landfill. It will be situated on RIRRC property, adjacent to the Phase I portion of the Central Landfill. The relationship between the proposed and existing landfills is shown graphically in the Preliminary Design Drawings, Appendix A.

Appendix B1 contains the Rhode Island Comprehensive Solid Waste Management Plan (State Guide Plan Element 171) including Landfill Siting adopted on April 12, 2007. Appendix B2 contains the projected Landfill Life Service Calculations. This plan describes the need for landfill capacity in the State, examines the capacity of RIRRC's existing landfill facilities, explains the methodology which was used to identify potential landfill sites, and makes recommendations to develop this specific additional landfill capacity.

The location of the Phase VI Landfill will allow RIRRC to continue utilizing the existing landfill operation's equipment, infrastructure, support buildings (existing and proposed), and experienced staff after other portions of the landfill have ceased active disposal operations.

1.2 BACKGROUND

Landfill operations on the site began in 1955 under the ownership of Sylvestri Brothers. The property containing the landfill was purchased by the Rhode Island Resource Recovery Corporation in December 1980. The Central Landfill (Phase I), now full, was licensed for approximately 121 acres. Phases II and III represent an additional 32 acres and has reached its licensed capacity. The currently licensed Phase IV cell represents an additional 44 acres and is currently in operation along with the Phase V cell, which includes an additional 32 acres of licensed area. The capacity in Phase IV is expected to be consumed in less than one year based on the current landfilling rates while Phase V is expected to reach capacity sometime in early 2010.

1.3 STATEMENT OF NEED

The projected service life of the presently licensed landfill areas is through September 2013. The licensing of the Phase VI Landfill will provide additional capacity for approximately 26,200,000 C.Y. (approximately 13,100,000 tons) of solid' waste for a service life of about 17.5 years, assuming RIRRC will continue to receive solid waste from all of its current municipal and commercial sources at the current rate of approximately 750,000 tons/year. The capacity projections are calculated in Appendix B2.

1.4 CONTENT OF THIS LICENSING DOCUMENT

The intent of this engineering report and the accompanying engineering drawings is to provide the design documentation for the approval and issuance of a facility license for the Phase VI Landfill. The design of the landfill, presented in this report and engineering drawings, incorporates a double composite liner system and dual leachate collection system for a footprint area of approximately 103 acres and a "piggy back" area of approximately 50 acres overlying the Phase I landfill. This document includes the following elements, which describe the design, operation, construction, and closure of this facility:

- Site Information
- Landfill Design Elements
- Leachate Management Plan
- Gas Management Plan
- Sedimentation and Erosion Control for Construction
- Quality Assurance/Quality Control Report
- Operating Plan
- Closure Plan

As part of the design of the Phase VI Landfill, a hydrogeologic investigation was completed by GZA GeoEnvironmental, Inc., of Providence, RI. The results of the investigation are presented by GZA in the report entitled, *"Central Landfill Proposed Phase VI Landfill Geohydrologic Study Report, Johnston, Rhode Island," dated December 2006* (previously submitted to and approved by RIDEM). A summary of this report is presented in Appendix C of this licensing document.

This engineering design report and the accompanying engineering drawings includes the required information for granting the license to operate from the Division of Waste Management of the Rhode Island Department of Environmental Management. The design report and engineering drawings are intended to serve as guidelines for future site operations. They are not, however, intended to serve as construction documents.

1.5 BASIS OF SUBMITTAL

This document has been prepared to fulfill the requirements set forth in the "State of Rhode Island, Department of Environmental Management, Office of Waste Management, Solid Waste Regulation No. 2 – Solid Waste Landfills -January 1997" (RIDEM-OWM-SW02-97). The following Table 1.1 lists verbatim the table of contents of that regulation and then notes where the applicable response is to be found within the licensing document.

1.6 REGULATION INTERPRETATION

In accordance with RIGL 23-18.9-9.1, a 600 feet vegetated buffer zone is required from the edge of waste placement to adjacent properties not owned by the applicant. A 600 feet vegetated buffer zone has been delineated and shall be maintained along the northern and eastern boundaries of the proposed Phase VI Landfill footprint and in areas bounded by developed residential properties. A 600' buffer zone along the southern boundary of the proposed Phase VI Landfill footprint shall be established, however, the adjacent properties owned by Rhode Island Resource Recovery Corporation and being predominately industrial should not require a vegetated buffer area. The southern buffer zone currently contains drainage control ponds, paved access roadways to the facility, Scale House Facilities, the Materials Recycling Facility (MRF), and the Leachate Pretreatment Facility, all previously permitted with Phases IV and V. In addition, in accordance with RIGL 23-19-34, Rhode Island Resource Recovery maintains a 1000 feet buffer zone from the proposed licensed limit of the Phase VI Landfill footprint and any residential zoned property.

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Sections Final\Section 1 rev1-wma.doc

TABLE 1.1
REGULATION CROSS REFERENCE LIST

REGULATION				CHAPTER SECTION
PART I – ADMINISTRATIVE AND ORGANIZATIONAL MATTERS; DEFINITIONS				
1.00	FINDINGS AND POLICY			No Response Required
2.00	ORGANIZATION AND METHOD OF OPERATION			No Response Required
3.00	DEFINITIONS			No Response Required
PART II- LICENSING				
4.00	PROHIBITIONS			
	4.01	General		No Response Required
	4.02	Water		No Response Required
	4.03	Air		No Response Required
	4.04	Low Level Radioactive Waste		No Response Required
5.00	GENERAL REQUIREMENTS AND PROCEDURES			
	5.01	Plans and Specifications		Engineering Plans and Reports
	5.02	Time of Application		No Response Required
	5.03	Documentation of Ownership		Certification on file with DEM
	5.04	Certification Report		Engineering Plans and Report
	5.05	Zoning		Radius Plan, Dwg. C-2
	5.06	General Plan Requirements		Engineering Plans and Reports
	5.07	Need		Sec. 1.0.3
	5.08	Equipment Addition		No Response Required
	5.09	Closure Procedures		
		a.	General	Sec. 9.0
		b.	1) Financial Responsibility	Sec. 9.6
			2) Bond Requirements	Not Applicable at this time
		c.	Notification of Closure	Not Applicable at this time
6.00	ISSUANCE, RENEWAL AND CONDITIONS OF LICENSES			No Response Required
7.00	SANITARY LANDFILLS			
	7.01	General Information		No Response Required
	7.02	Engineering Plans		
		a. Locus Map		Cover Sheet
		b. Radius Plan		Dwg. C-2
			1) Zoning	Sec. 2, Dwg. C-2

REGULATION	CHAPTER SECTION
2) Site Plan Buildings and Dwellings	Dwg. C-2
3) Water Supplies	Appendix D
4) Surface Water Course and Wetlands	App. E., Dwg. C-2
5) Water Supply Aquifers	Not Applicable
6) Roads	Dwg. C-2
7) Boring Locations	Appendix G
8) Legal Boundary of Site	Dwg. C-2
9) North Arrow	All
10) Extent of 100-year Flood Plan (Site not within Flood Plain)	Not Applicable
11) Other Features	Dwg. C-2
12) Legend	Dwg. C-2
c. Site Plan	Appendix A Dwg C-2 to C-4
1) Initial Ground Contours	Dwg. C-3
2) Final Proposed Contours	Dwg. C-14
3) Boring Locations	Appendix G
4) Liner System location	Dwg. C-4
5) Leachate Collection System Location	Dwg. 5 to 9
6) Gas Controls (if any)	Dwg. C-19 to C-24
7) Buildings (if any)	None
8) Water Supply Wells	None
9) Surface Water Courses	Dwg. C-3
10) Roads	Dwg. C-3
11) Cross Sections Lines	Dwg. C-16 to C-18
12) Areas to Store Salvaged/Recycled Material	None
13) Areas for Special Wastes	None
14) Groundwater Monitoring Wells	Appendix C
15) Legal Boundaries	Dwg. C-2
16) Power Lines, Pipelines, Right-of-Ways, etc.	Dwg. C-2
17) Proposed Fences	None
18) Weighing Facilities	Dwg. C-2
19) North Arrow	All
20) Location of Borrow Areas	None
21) Boundaries of Areas to be Filled	Dwg. C-3
22) Benchmarks	Section 3.3
23) Lateral and vertical limits of filled areas	Dwg. C-10 to C-13
24) Wind Rose	Dwg. C-2
25) Surface run-off control features	Dwg. C-4
26) Leachate storage, treatment and disposal systems	Dwg. C-8
27) Roadway sections/profiles	None
28) Legend	All Dwgs.
d. Cross Sections	
1) Proposed Lifts	Dwg. C-10 to C-13
2) Virgin ground	Dwg. C-16 to C-18

	3) Maximum Groundwater Table	Dwg. C-16 to C-18
	4) Bedrock Location	Dwg. C-16 to C-18
	5) Side Slopes	Dwg. C-16 to C-18
	6) Details of Surface Drains and Ditches	Dwg. C-28
	7) Final Fill Elevations and Grades	Dwg. C-16 to C-18
	8) Limits of Excavations	Dwg. C-4
	9) Final Cover Elevations	Dwg. C-14
	10) Details of Access Road Construction	Dwg. ???
	11) Details of Liner System	Dwg. C-26 to C-28
	12) Details of Leachate Collection System	Dwg. C-26 to C-28
	13) Details of Gas Venting Facilities (if any)	Dwg. C-25
	14) Details of groundwater Monitoring Wells	Appendix C
7.03	Operating Plan	Sec 8.00
	1) Type of Landfill Method	Sec.8.7.6
	2) Proposed Sequence of Filling Operations	Sec. 8.8.1, Dwg. C-10 to C-13
	3) Fire Control and Prevention	Sec. 8.15.1
	4) Operating Hours	Sec. 8.2
	5) All Types of Refuse Accepted, with Corresponding Approximate Percentages of Total refuse	Sec. 8.7
	6) Personnel and Duties	Sec. 8.4
	7) Project Use of Completed Site	Sec. 8.1
	8) Dust Control Program	Sec. 8.15
	9) Vector Control Program	Sec. 8.15
	10) Litter Control Program	Sec. 8.15
	11) Odor Control Program	Sec. 8.15
	12) Procedures to Promote Vegetative Growth	Sec. 8.15
	13) Equipment to be on Site	Sec. 8.15
	14) Substitute Equipment Arrangement	Sec. 8.15
	15) Communications Equipment	Sec. 8.16
	16) Population and Service Area	Sec. 8.1
	17) Winter Operations	Sec. 8.15
	18) Provisions for Limited Access	Sec. 8.3
	19) Weighing Facilities	Sec. 8.8
	20) Estimated life of Landfill	Appendix B
	21) Salvaging Operations	Sec. 8.7.1
	22) Handling Procedures for Special Wastes	Sec. 8.7.2
	23) Leachate Collection Removal and Disposal Operations	Sec. 8.11, Dwg. C-5 to C-9
	24) Leachate Treatment Operations	Sec. 8.12
	25) Groundwater Monitoring	Sec. 8.11
	26) Air and Gas Monitoring	Sec. 8.13
	27) Surface Drainage Control Methods	Sec. 8.12
	28) Smaller Vehicle Convenience Access for Waste Disposal	Sec. 8.7

REGULATION			CHAPTER SECTION
7.04 Sedimentation and Erosion Control Plan			Sec. 6.0
a.	Areas of disturbed, erodible, non-vegetated, non-stable soils		Sec. 6.0
b.	Areas of potential erosion from planned activity		Sec. 6.1
c.	Locations of temporary sediment and erosion controls		Sec. 6.1
d.	Types of temporary sediment and erosion controls		Sec. 6.3
e.	Installation of temporary sediment and erosion controls		Sec. 6.3
f.	Maintenance of temporary sediment and erosion controls		Sec. 6.3
g.	Sediment removal		Sec. 6.1
h.	Existing vegetation to be retained		Sec. 6.3
i.	Proposed vegetation		Sec. 6.3
j.	Seeding and planting schedule for landfill development stages		Sec. 6.3
k.	Seed mixture and fertilization		Sec. 6.3
l.	Planting plan and schedule		Not Applicable
m.	Existing vegetation cutting and clearing schedule		Not Applicable
7.05 Engineering Report			Sec. 3.0
a.	Proposed design capacity		See 3.2 Appendix B
b.	Analysis of existing topography		See 3.2 Appendix C
	surface water and subsurface geology		Appendix C
c.	Materials and construction methods		
	1)	Groundwater monitoring wells	Appendix C
	2)	Gas venting system	Sec. 3.7, Dwg. C-19 to C-24
	3)	Liner and leachate collection and removal system	Sec. 3.5
	4)	Leachate storage treatment and disposal system	Sec. 3.5
	5)	Cover system	Sec. 3.6
d.	Quantity of leachate to be generated		Sec. 4.5
	1)	Annual water budget	Sec. 4.6
	2)	Liner and leachate collection system efficiencies	Sec. 4.4
	3)	Static head of leachate on liners	Sec. 4.3
e.	Design of leachate storage facility		Sec. 4.7
f.	Contingency plan for construction phase		Sec. 8.15
g.	Daily and intermediate cover material		Sec. 8.7
h.	Procedure during placemen of first lift of refuse		Sec. 8.7
7.06 Quality Assurance/Quality Control Report			Sec. 7.0
7.07 Contingency Plan			Sec. 8.15
7.08 Hydrogeological Report			Appendix C
7.09 Closure Plan			
a.	1) Fence, Gates		See Sec. 9.2
	2) Groundwater and Surface Water Monitoring Devices and Stations		Appendix C
	3) Final Grades		Dwg. C-14

REGULATION			CHAPTER SECTION
		4) Legal Boundaries	Dwg. C-2
		5) Final Cover System	Sec. 9.1 Dwg. C-15
	b.	1) Date of Proposed Closure	Sec. 9.1
		2) Methods of Restricting Access and Preventing Additional Waste Disposal	Sec. 9.7
		3) Methods of Protecting Groundwater and Surface Water and Controlling Air Emissions	Sec.9.7
		4) Date of Final Cover System Installation	Sec. 9.1
		5) Method of Maintaining Drainage Control Structures	Sec. 9.7
		6) Method of Maintaining Post-Closure Soil Cover Integrity	Sec. 9.7
		7) Method of Maintaining Leachate Collection and Disposal System	Sec. 9.7
	c.	Post-Closure Monitoring and Maintenance Operations Manual	Sec. 9.7
	d.	Estimate of Closure Costs	Sec. 9.6
	7.10 Site Engineering		In Progress
	7.11 Conservation Easement		Appendix E
	7.12 Landfill Gas Recovery Facilities		Sec. 5.0, Dwg. C-19 to C-24
8.00	INCINERATORS		Not Applicable
9.00	TRANSFER STATIONS		Not Applicable
10.00	WASTE TIRE STORAGE AND RECYCLING		Not Applicable
11.00	PETROLEUM-CONTAMINATED SOIL PROCESSING FACILITIES		Not Applicable
12.00	COMPOST FACILITIES		Not Applicable

PART III – OPERATING REGULATIONS

13.00	GENERAL OPERATING STANDARDS		
	13.01	Applicability	No Response Required
	13.02	Access	
		a. Time	Sec 8.2
		b. Physical Restraints	Sec. 8.3
	13.03	Salvage	Sec 8.7
	13.04	Processing of Bulky Waste	Sec. 8.7

REGULATION		CHAPTER SECTION
13.05	Vector Control	Sec. 8.15
13.06	Signs	Sec. 8.3
13.07	Communication	Sec. 8.15
13.08	Inspections	As required
13.09	Endangered Species	Appendix F
13.10	Dust Control	Sec. 8.15
13.11	Control of Litter	Sec. 8.15
13.12	Safety Provisions	
	a. General	Sec. 8.16
	b. Bird Hazard	Sec. 8.16
13.13	Operating and Engineering Plans	As required
13.14	Closure Procedure	Sec. 9.0

14.00 SANITARY LANDFILL CONSTRUCTION STANDARDS

14.01	General	No Response Required
14.02	Horizontal and Vertical Control	Sec. 3.3
14.03	Liner System	Sec. 3.4
14.04	Leachate Collection and Removal System	Sec. 3.5
14.05	Landfill Subgrade	Appendix G
14.06	Soil Component of the Liner System	Appendix J
14.07	Geomembrane Liners	Appendix J
14.08	Soil Drainage Layers	Sec. 4.4, Appendix J
14.09	Leachate Collection Pipes	Sec. 4.7
14.10	Geosynthetic Drainage Layers	Appendix J
14.11	Filter Layer Criteria	Appendix J
14.12	Final Cover System	Sec. 3.6, 9.0
14.13	Construction Certification Report	No Response Required at this Time
14.14	Equivalent Design	Appendix V Sec. 3.4

15.00 SANITARY LANDFILL OPERATING STANDARDS

15.01	General	No Response Required
15.02	Working Face	Sec.8.7, 8.8
15.03	Lift Height	Sec. 8.9
15.04	Cover Material	
	a. Initial Cover	Sec. 8.9
	b. Intermediate Cover	Sec. 8.9
	c. Final Cover	Sec. 8.9
	d. Cover Material Supply	Sec. 8.9
	e. Maintenance of Cover Material	Sec. 8.9
15.05	Water Pollution	
	a. General	Appendix G
	b. Surface Water	Appendix G
	c. Groundwater	Sec. 2.5
	d. Groundwater Reservoirs and Recharge Areas	Sec .2.5

REGULATION		CHAPTER SECTION
15.06	Waste Handling	
	a. Unloading of Waste	Sec. 8.8
	b. Spreading and Compacting of Waste	Sec. 8.7
	c. Litter	Sec. 8.15
	d. Special Waste	Sec.8.7
15.07	Equipment Requirements	Sec. 8.6
15.08	Gas Control	Sec. 8.13
15.09	Fire Protection	Sec. 8.15
15.10	Surface Drainage	Sec. 8.12
15.11	Monitoring Wells	Appendix C
15.12	Distance to Property Lines	Dwg. C-2
15.13	Limited Access	Sec. 8.3
15.14	Floodplain	Not Applicable
15.15	Deed Restrictions	Appendix D
15.16	Height Monitoring	Sec. 8.9
15.17	Excavation	Will Comply
15.18	Resource Recovery and Soil Waste Incinerator Ash Residue Monofills	Not Applicable
16.00	INCINERATOR AND RESOURCE RECOVERY FACILITY OPERATION STANDARDS	Not Applicable
17.00	INCINERATOR AND RESOURCE RECOVERY FACILITY OPERATION STANDARDS	Not Applicable
18.00	TRANSFER STATIONS AND COLLECTION	Not Applicable
19.00	WASTE TIRE STORAGE AND RECYCLING FACILITY OPERATING STANDARDS	Not Applicable
20.00	COMPOST FACILITIES OPERATING STANDARDS	Not Applicable
21.00	PETROLEUM-CONTAMINATED SOIL PROCESSING FACILITY OPERATING STANDARDS	Not Applicable
22.00	PETROLEUM CONTAMINATED SOIL PROCESSING FACILITY DESIGN STANDARDS	Not Applicable

PART IV – APPLICABLE OF REGULATIONS

23.00	EXISTING SOLID WASTE MANAGEMENT FACILITIES	No Response Required
23.01	General Applicability	No Response Required
23.02	Currently Licensed Facilities	No Response Required
23.03	Other Existing Facilities	No Response Required
23.04	Existing Rules	No Response Required

REGULATION	CHAPTER SECTION
24.00 NEW SOLID WASTE MANAGEMENT FACILITIES	No Response Required
PART V - VARIANCES	
25.00 PROCEDURES FOR APPROVAL OR DENIAL OF VARIANCES	No Response Required
25.01 Applications for Variance	Section 1.6, Section 3.2.1
25.02 Review by Licensing Agency	No Response Required
PART VI – APPEAL AND HEARING PROCEDURE	
26.00 OPPORTUNITY FOR HEARING	No Response Required
26.01 Denials	No Response Required
26.02 Violations	No Response Required
26.03 Time of Filing	No Response Required
26.04 Hearings, Administrative Procedure	No Response Required
PART VII – EFFECTIVE DATES	
27.00 EFFECTIVE DATES	No Response Required
PART VIII – FEES	
28.00 FEES	No Response Required
28.01 General Information	No Response Required
28.02 Multiple Operations at One Facility	No Response Required

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Sections Final\table1-1.doc

SECTION 2

2.0 SITE INFORMATION

2.1 GENERAL DESCRIPTION OF THE SITE

The proposed Phase VI Landfill is located in the Town of Johnston, Rhode Island north of Shun Pike, on an approximately 1200-acre parcel of property owned by the Rhode Island Resource Recovery Corporation. The property is also the location of Rhode Island Resource Recovery Corporation's (RIRRC) landfill activity, the Materials Recycling Facility, the two methane gas recovery facilities and other RIRRC projects related to solid waste and recycling. Presently, the existing licensed limits of waste placement on the site encompass an area of approximately 198 acres, comprised of the Central Landfill (Phase I), Phases II and III, Phase IV and Phase V landfills. RIDEM has unlimited access to the site as specified in the Conservation Easement (Appendix D). Deed restrictions are also included in Appendix D.

The Phase VI Landfill site will be located to the east of the existing disposal areas. The site is situated southwest of the Almy Reservoir, and north of the Upper Simmons Reservoir. Surface water from the majority of the site drains to the Upper Simmons Reservoir via the Cedar Swamp Brook. As part of the Phase VI Landfill expansion, diversion benches, swales and stormwater detention ponds will be constructed to manage the stormwater runoff from the Phase VI expansion. The stormwater will be conveyed through new drainage structures and controls to the Upper Simmons Reservoir. Regional topography and surface features are shown on the location map on the cover sheet of the engineering drawings.

Several wetlands are located on the RIRRC property. Classification of the wetlands has been performed, and the flagged locations were mapped for submittal to RIDEM Water Resources Division as part of the Cedar Swamp Brook Relocation Projects (Phases I & II) in February 1994 and July 2001, respectively. Most of the wetlands are found in the western portion of the property and serve as the headwaters of the Cedar Swamp Brook. A small wetland is located east of the proposed Phase VI footprint. This wetland was previously identified as part of the "Lakeside Industrial Park" wetlands submission RIDEM Permit No. 03-0552. A new preliminary wetlands determination application (Appendix E) is submitted in conjunction with this solid waste license application to RIDEM Division of Fresh Water Wetlands for the purpose of obtaining an "Insignificant Alteration" Permit. The activities associated with the Phase VI Landfill will not occur within regulated wetland perimeter boundaries.

The site topography is characterized by moderate to sharp relief, typical of the region, and reflecting glacial influence. Currently, support facilities and ancillary operations are located on a portion of the Phase VI site. These facilities house the tipping facility, administration building, equipment garage, power plant, Eco Depot, compost facility and the Recovermat facility.

Topography of the landfill site (date of topography, April 2006), RIRRC property, and surrounding areas, is depicted on the overall Site Plan of the Drawings (Appendix A). The highest elevation of the RIRRC property is the top of the Central Landfill, which is permitted to reach approximately 575 feet. The lowest point on the site is at an elevation of approximately 292 feet where Cedar Swamp Brook leaves the site and enters the Upper Simmons Reservoir.

Based upon the "State of Rhode Island '208' Area-Wide Water Quality Management Plan" for Water-Related Sensitive Areas, no portion of the RIRRC landfill site property is located within an area designated as "Groundwater Reservoir" or "Groundwater Recharge Area." Also, the site is not within the 100-year floodplain. (See Flood Insurance Rate Map included in Appendix F.)

Based upon an inventory of flora and fauna on the site of the proposed Phase VI Landfill, there are no threatened or endangered species on this site. An Endangered Species Review is included as Appendix F.

2.2 LAND USE AND ZONING

All Landfill property is zoned industrial by public law RIGL Chapter 23-19 as amended in July 2001.

The zoning classifications, as shown on the Town zoning maps, are noted on the Radius Plan (Appendix A, sheet C-2.1). As noted above, several parcels have changed zoning classifications since the zoning maps were originally published by the town. In addition, drawing C-2 details RIRRC's other Owned Property and Neighboring Parcels. Many of these additional parcels were acquired as a result of the residential property buyout in 1990 and subsequent years.

The Phase VI Landfill site is located in a rural area of the Town of Johnston that is characterized primarily by undeveloped lands, mixed light and heavy industrial and some agricultural land. The Radius Plan (Sheet C-2.1 of Appendix A), depicts buildings and other structures in the vicinity of the site.

2.3 TRANSPORTATION ROUTES

A network of Interstate, State, and Municipal Highways provide direct vehicular access to the proposed Phase VI Landfill site. Landfill truck traffic travels via Interstate 295 to a dedicated interchange (Exit 5) for the RI Recovery Corporation and Industrial Park. Except for local refuse collection trucks, all truck traffic to the landfill primarily travels this route to the site. RIRRC has no direct control over truck routing of the third party users of the facility.

2.4 WASTE QUANTITIES AND CHARACTERISTICS

RIRRC's landfill facilities currently accept municipal solid waste, commercial solid waste, industrial solid waste, industrial and municipal wastewater treatment plant sludge, other non-hazardous materials, and construction & demolition debris. Construction & demolition debris received at the landfill is sorted and is converted to RecoverMat™ for use as alternate daily cover. This policy is not anticipated to change for operations at the Phase VI Landfill, however, the RecoverMat™ facility will be relocated. During the period of July 1, 2005 to June 30, 2006, RIRRC accepted wastes for disposal at an average rate of approximately 3,800 tons per day for 303 days in the year for a total of 1,175,900 tons. Based on projections in the "Rhode Island Comprehensive Solid Waste Management Plan", under current conditions, landfilled waste is expected to increase on an average of 0.57% per year.

2.5 GEOHYDROLOGIC CONDITIONS

A geo-hydrologic report was prepared by GZA and submitted in December 2006 to RIDEM. A summary of the report is given in Appendix C. Drawings C-4.1 and 4.1A provided in Appendix A show the explorations and the determined groundwater contours used for baseliner design.

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Sections Final\Section 2 rev-wma.doc

SECTION 3

3.1 GENERAL

The design of the Phase VI Landfill has been prepared to meet or exceed the requirements set forth in the State of Rhode Island Solid Waste Regulations No. 2, Solid Waste Landfills, RIDEM-OWM-SW02-97. This section describes the overall configuration and design of the Phase VI landfill. The methods of design for certain facility components are described in detail in Section 5 (Landfill Gas Management Plan) and Section 9.0 (Closure Plan) of this report.

The proposed Phase VI Landfill will be located directly east of the existing Phase I and Phase V Landfills and will piggy back over the eastern sideslope of the capped Phase I Landfill and the eastern end of the Phase V Landfill. As such, the total Phase VI Landfill footprint will occupy approximately 153 acres, of which approximately 103 acres are base liner and approximately 50 acres are side slope ("piggyback") liner.

The landfill design was based upon the following considerations:

- Site hydrology / geology / hydrogeology;
- Anticipated leachate generation rates and leachate collection system hydraulics;
- Geotechnical considerations, including static and seismic stability;
- Configuration of the existing landfill units, site infrastructure, and surrounding grades;
- Construction sequencing to manage stormwater and leachate, and allow time for the relocation of existing infrastructure;
- Feasibility of relocating or eliminating existing site infrastructure located within the proposed Phase VI footprint, including the tipping facility, administration building, gas recovery plant, hot spot remedial system, Eco-Depot, stormwater detention / sedimentation ponds, and other on-site facilities;
- Waste placement / operations sequence to maximize capacity and life of each sub-area;
- Leachate management, including control of leachate generation, collection, and disposal;
- Surface water drainage, water quality, and temporary and permanent erosion controls;
- Cover material management; and
- Environmental monitoring programs;

3.2 CONFIGURATION AND CAPACITY

3.2.1 Site Configuration

The proposed limits of the Phase VI Landfill were established by maintaining minimum set back distances, for waste placement, from wetlands and property boundaries (distance of 600 feet from property boundaries / industrial properties and 1,000 feet from residential properties). The proposed southern boundary of the Phase VI

Landfill footprint is located approximately 420 feet from Shun Pike (refer to Drawing C-2.2 in Appendix A). However, it should be noted that the RIRRC owns the properties across Shun Pike bordering Upper Simmons Reservoir and therefore maintains more than 600 feet.

The proposed Phase VI footprint also formerly encroached within 600 feet of the property line to the north in the location of an existing Town of Johnston water booster pump station. The RIRRC has since purchased this property with the intent of relocating the town's pump station. The property line now extends to Central Avenue, and the 600-foot property line setback requirement is now being met at this location.

As indicated above, the Phase VI Landfill will "piggyback" over the eastern sideslope of the capped Phase I Landfill area and the eastern end of the Phase V Landfill. As such, the total Phase VI Landfill footprint will encompass approximately 153 acres. Approximately 103 acres of new base liner will be constructed. The Phase VI Landfill will be developed as five sub-areas (cells), 1 through 5. Area 1 will be developed first followed by Area 3, Area 2, Area 4, and finally Area 5. The footprint of the new base liner in each cell is as follows:

Area 1:	27.3 acres
Area 2	15.4 acres
Area 3:	20.3 acres
Area 4:	16.5 acres
Area 5:	23.6 acres

The Preliminary Drawings included as Appendix A depict the configuration and design of the proposed Phase VI Landfill.

The phased construction and operations sequence depicted on the filling plans in Appendix A is proposed to accomplish the following:

- Maximize developed landfill capacity while providing for operational effectiveness;
- Maintain existing infrastructure for as long as possible throughout the construction and operational life of the Phase VI Landfill;
- Limit the volume of leachate to be generated at any given time during the filling process;
- Effectively and efficiently manage stormwater run-on and run-off; and
- Effectively manage capital expenditures during the construction period.

Construction of Area 1 will follow the construction of a new perimeter access road and perimeter swale along the northern side of Phase VI. Area 3 will be constructed next, followed by Areas 2, 4, and 5. During the construction of Area 3, Pond 3 will be decommissioned and the necessary stormwater ponds to handle any uncontrolled flow will be constructed adjacent to the existing Administrative Office Building. Also during the construction of Areas 3 - 5, some of the facility ancillary structures, such as the OU-1 "hot spot" groundwater treatment system, Eco-Depot, gas recovery plant, tipping facility building, administration building, and other support facilities will be relocated and/or decommissioned as necessary to accommodate construction activities.

The perimeter roadway and swale that will be constructed as part of the construction of Area 1, will allow for access into and around the Phase VI Landfill and will divert surface water away from the Phase VI Landfill. Stormwater runoff from the active landfill cells and from subgrade preparation will be controlled by a network of temporary drainage swales and existing/proposed ponds. In an effort to further improve the efficiency of the landfill operation and limit leachate production, Areas 1 and 3 will be constructed in stages, as depicted on Sheet C-6.1 and C-6.2. Please refer to Section 8 of this permit application for additional information.

3.2.2 Capacity

Table 3.1 below presents the approximate available capacity of the Phase VI Landfill. The volume calculations were performed utilizing the Civil Design Module of AutoCAD Land Development Desktop computer software by Autodesk, Inc. The calculated waste volume includes the total airspace between the base grades (as shown on Sheet C-4.6) and the final cap subgrade elevations (as shown on Sheet C-9.1). The waste volume estimate assumes an overall in place density of the refuse and a cover material utilization rate and does not account for settlement of the waste mass.

Table 3.1
Phase VI Landfill Capacity

	Area 1	Area 2	Area 3	Area 4	Area 5	TOTAL
Total Volume (cy)	4,800,000	2,500,000	8,900,000	5,800,000	4,200,000	26,200,000
Final Cap (cy)	210,000	65,000	185,000	70,000	95,000	625,000
Daily Cover (cy)	826,200	438,300	1,568,700	1,031,400	738,900	4,603,500
Solid Waste (cy)	3,763,800	1,996,700	7,146,300	4,698,600	3,366,100	20,971,500
Solid Waste (tons)*	2,352,375	1,247,938	4,466,438	2,936,625	2,103,813	13,107,189

* - Estimated capacity based on conversion assumptions presented in Appendix B2

"Total Volume" represents the volume of solid waste including daily cover and final cap. An in-place waste density equal to 1,250 pounds per cubic yard was utilized in the calculation and is based on average compaction testing performed during filling operations of the Phase V Landfill. "Daily Cover" was assumed to equal approximately 18 percent of the total volume, based on compaction studies. For the purposes of this capacity analysis, "Final Cap" includes material associated with the 24-inch-thick final cover section. Detailed landfill capacity calculations are presented in Appendix B2.

3.3 SITE PREPARATION

Prior to installation of the baseliner system for the Phase VI Landfill, the footprint shall be prepared to the proposed subgrade contours shown on Drawing C-4.1, submitted in Appendix A of this application. Some site preparation will be required. The site requires excavation within the majority of the landfill footprint areas and fill for the perimeter road, with excess soil stockpiled for cover material, and, as such, the overburden will be stripped essentially to bedrock and close to the groundwater table in some areas. Based on the Geohydrological Investigation conducted for the Phase VI Landfill (refer to Appendix C) most of the site preparation involves a considerable "cut to remove overburden and underlying bedrock, particularly in the northern portions of Phase VI, to provide a minimum 5' vertical separation between the bottom of the baseliner system and seasonal high groundwater." Some portions of the Phase VI Landfill, particularly the southwestern corner, will require limited filling in areas to obtain the required 5' vertical groundwater table separation. The estimated seasonal high groundwater contours and the proposed baseliner subgrade contours are depicted on Drawing 4.1A and in cross sections shown on the Drawings in Appendix A. Existing Pond 3, located within the Phase VI footprint, will be abandoned and filled in as part of the site preparation. Site preparation will also include removal of trees and vegetation, and the removal and relocation of the existing electric generating facility, tipping facility, Recovermat facility, administration building, EcoDepot, the residential/commercial recycling area, and other ancillary facilities, as necessary.

3.4 BASE GRADES AND LINER SYSTEM

3.4.1 General

The extent of the Phase VI Landfill base liner system is defined by an anchor trench located along a perimeter berm. The primary purpose of the perimeter berm is to provide containment for both waste and leachate, and to prevent stormwater runoff from entering the landfill from upgradient drainage areas. The minimum height of the perimeter berm above the landfill floor is four feet. The perimeter berm ranges in height from a minimum of 4 feet along much of the south side and up to about 34 feet along the northwest side of the Phase VI landfill. The perimeter berm is designed with an interior slope of three horizontal to one vertical (3H:1V). The exterior slope of 3H: 1V was selected for ease of maintenance and to conform to final and existing grades. The configuration of the perimeter berm is depicted on Sheet C-4.1. Base grades are also depicted on Sheet C-4.1. The floor of each sub-area (cell) is graded to drain in a generally southerly direction. The slopes of the cell floors vary from a minimum of 2 percent to about 6 percent to promote positive drainage of the primary and secondary leachate collection systems.

The base liner for the Phase VI Landfill will consist of a double composite liner system, which will be anchored within the perimeter berm around the north, east, and south sides of the landfill footprint and tied to the piggyback "sideslope" liner system on the west. From the top down, the liner system will consist of the following four systems, which are described in detail in Sections 3.4.2 through 3.4.5:

- Protection layer and primary leachate collection system;
- Primary barrier layer;
- Secondary leachate collection system; and
- Secondary barrier layer.

The protection layer and primary leachate collection system of the base liner system, as discussed in Section 3.4.2, is a modification of the system utilized for the Phase V landfill. For the Phase VI landfill, the protection layer and primary leachate collection system will consist of 24 inches of protection sand having a minimum hydraulic conductivity of 1 X 10^{-4} centimeters per second (cm/sec), underlain by a double-sided composite drainage net (CDN) that will serve as the primary leachate collection media. The hydraulic analyses discussed in Section 3.5.2 demonstrate that the proposed primary leachate collection system's performance significantly reduces the anticipated head on the primary barrier layer and, as such, exceeds the RIDEM prescribed design.

Refer to Section 3.4.7 for a discussion of base grade and liner system design criteria. Section 3.5.2 provides the basis for the design of the primary leachate collection system. Technical specifications for the materials and their installation will be included in the future project construction document submittal.

3.4.2 Protection Layer and Primary Leachate Collection System (Drainage Layer)

The top layer of the landfill liner system is the protection layer and primary leachate collection system (drainage layer). The protection layer will consist of a 24-inch-thick layer of fine to medium sand having a minimum hydraulic conductivity of 1×10^{-4} cm/sec. The sand protection layer will serve as a cushion between the waste and underlying geosynthetics. The sand protection layer will be underlain by a double-sided CDN, which will serve as the primary leachate collection media. The use of a sand protection layer and a primary CDN, in lieu of a sand drainage layer, is a modification of the system utilized for the Phase V landfill. This system will enhance the constructability and performance of the primary leachate collection system. To further limit head on the underlying primary barrier layer, a network of 8-inch diameter HDPE pipe laterals and headers will convey the leachate to sumps and subsequently out of the cell. Further discussion of the design of the leachate collection system is provided in Section 3.5.1.

3.4.3 Primary Barrier Layer

Immediately below the primary drainage layer is the primary barrier layer. This layer is a composite consisting of a flexible membrane liner (FML) overlying a geosynthetic clay liner (GCL). The GCL is a manufactured product consisting of a layer of granular bentonite confined by geotextile fabric (woven and/or non-woven) on both sides and shear reinforced. The reported hydraulic conductivity of GCLs is 1×10^{-9} cm/sec. The GCL is proposed as an alternative to a 12-inch-thick compacted clay liner to simplify construction. This design is consistent with the approved Phase V Landfill primary barrier layer design. The use of GCLs has a proven record and is preferred to compacted clay liners due to their consistent and uniform hydraulic conductivity properties and their ability to "self heal" defects.

The FML installed as part of the new base liner consists of textured (both sides) 80-mil HDPE. The FML installed as part of the piggyback liner over the existing Phase I Landfill, will consist of textured (both sides) 80-mil LLDPE, consistent with the Phase V piggyback liner system. HDPE and LLDPE were chosen because they are highly resistant to chemical and biological attack from landfill leachate (See Appendix U). These materials are also highly resistant to physical damage caused by tensile stresses / strains induced during filling. The liner is installed in a panel configuration, with each adjacent panel track welded to the next to cover the area.

The GCL will be placed directly under the primary FML with the non-woven side down to prevent migration of bentonite particles into the underlying CDN of the secondary leachate collection system.

3.4.4 Secondary Leachate Collection System (Drainage Layer)

The secondary leachate collection system (drainage layer) will consist of a double-sided CDN, consistent with the approved Phase V Landfill secondary leachate collection system (drainage layer) design. This layer acts as a leak detection system and collects any potential leakage through the primary barrier layer. The CDN will drain to a series of 4-inch diameter perforated HDPE leachate pipe laterals and headers.

3.4.5 Secondary Barrier Layer

The role of the secondary barrier layer is to provide a second level of protection in the event the primary liner system failure. The installation of a secondary leachate collection system above this barrier provides a leak detection system and serves as a redundant leachate collection system. The minimum slope on this liner is 2 percent to positively drain any leachate within the secondary drainage layer. The composite secondary barrier layer system described below is consistent with the Phase V Landfill liner system.

The secondary barrier layer is a composite consisting of a (from top down) FML, GCL, and a compacted clay barrier layer. The 12-inch-thick clay barrier will be placed immediately over prepared subgrade and is intended to have a maximum in-place hydraulic conductivity of $1x10^{-7}$ cm/sec. The GCL will be installed over the clay barrier layer and has a reported hydraulic conductivity of $1x10^{-9}$ cm/sec. A textured (both sides), 60-mil HDPE FML will be placed directly over the GCL material.

3.4.6 Piggyback Liner System

The piggyback area of the Phase VI Landfill over the Phase I Landfill will utilize components of the existing Phase I cover system as the secondary leachate collection system and barrier layer. From the existing ground surface down, the Phase I cover system consists of a 6-inch vegetated soil layer, 18 to 24 inches of sand, a double-sided CDN, and a 40-mil textured LLDPE FML. The FML, CDN, and up to 18 inches of the existing sand protection layer will remain in place and serve as the piggyback liner's secondary barrier layer and overlying leachate collection system. A new primary FML, consisting of textured (both sides) 80-mil LLDPE, will be installed directly over the existing sand protection layer that remains. This will require the removal of the existing 6-inch layer of vegetated soil, as well as the riprap installed on diversion benches and downchutes. A new double-sided CDN will be deployed over the primary FML. A 24-

inch-thick layer of sand having a minimum hydraulic conductivity of $1x10^{-4}$ cm/sec will be placed over the CDN and serve as a cushion between the waste and underlying geosynthetics.

3.4.7 Design Criteria

General - Design considerations include geotechnical issues such as liner and cover system stability, the bearing capacity and elastic settlement of the foundation soils relative to support of the waste mass, and settlement of the piggyback liner system due to consolidation of the existing (Phase I) waste mass; and hydraulic issues such as the drainage capacity of the leachate collection system and efficiency of the lining system, and strength and flow capacity of the leachate laterals and header pipes. Geotechnical analyses completed by GZA to support base grade and liner system design are discussed in this section. Supporting geotechnical calculations are included in Appendix G. Hydraulic analyses completed by GZA to support the design of the Phase VI Landfill leachate collection system are discussed in Section 3.5.2. Analyses prepared by PARE in support of the Phase VI cap design are discussed in Section 9.

Base Liner stability - GZA analyzed static stability to assess the factor of safety against sliding between components of the lining system under short- and long-term conditions. The short-term scenarios evaluated the veneer stability of the new base area liner sideslopes and the piggyback liner over the existing Phase I landfill prior to waste placement. The short-term analyses were completed using infinite slope procedures, which conservatively neglect the buttressing provided by the 24-inch-thick sand protection layer of the Phase VI liner system. The long-term scenarios evaluated the stability of the piggyback and base liner systems under the full waste loads anticipated for the Phase VI Landfill. These static stability analyses were completed using STABL-based slope stability software (Slope, Version 6.19 by GEO-SLOPE International, Ltd.). Seismic stability of the long-term scenarios was also evaluated using methods presented in the USEPA manual entitled "RCRA Subtitle D (258) Seismic Design Guidance for Municipal Solid Waste Landfill Facilities," dated April 1995.

GZA's static analyses evaluated the minimum required interface shear strength (stated as friction angle) necessary to achieve a short-term factor of safety of at least 1.3 and a long-term factor of safety of at least 1.5. The seismic analyses evaluated the minimum required interface shear strength necessary to limit seismic-induced deformations to accepted reasonable magnitudes.

For the lining system, base geometry, and final grading conditions proposed for the Phase VI landfill, the results of the stability analyses indicate the following:

ANALYSIS CONDITIONS	MIN. ALLOWABLE FACTOR OF SAFETY	MIN. REQUIRED INTERFACE FRICTION ANGLE	COMMENTS
Short-term 3H: 1V sideslope veneer stability of liner system	1.3	24 deg.	Minimum predicted factor of safety of 1.35; infinite slope analysis
Long-term under full waste loads	1.5	10 deg.	Minimum predicted factor of safety of 1.59
Long-term with seismic loading	Not applicable – see comment	20 deg.	Predicted deformation less than 0.3 inches

The Phase VI contractor will be required to demonstrate through direct shear testing completed at the frequencies stated in the project specifications that each interface within the base liner and piggyback liner systems, and the internal shear resistance of the GCL meets or exceeds the criteria set forth below. Testing will be completed in accordance with ASTM D5321 (for interfaces not containing a GCL) or ASTM D6243 (for interfaces containing a GCL) using project-specific test parameters (e.g., seating loads, hydration criteria, overburden pressures, strain rates) that will be set forth in the specifications. The test results will include both the peak and large displacement (residual) interface strengths of each interface, as well as the internal strength of the GCL. The interface friction between the liner system components and the internal shear resistance of the assembled GCL product will be determined by the designer based on the laboratory test results provided by the contractor from a pre-approved independent testing laboratory and using the strength relationship: $\tau = \sigma_n \mathrm{TAN}\phi + a$, where τ is the shear resistance (strength), σ_n is the applied normal load, ϕ is the friction angle, and a is the adhesion.

In keeping with work by Koerner, Giroud, and, specifically, Stark and Choi, the specifications for the Phase VI base liner and piggyback liner construction will require the following with respect to peak versus residual interface shear strengths. For the base area of the base liner (having flatter slopes of about 2 to 6 percent), the proposed materials will be required to achieve a peak interface shear strength that is greater than or equal to the calculated shear strength (τ) when $\phi = 24$ deg. and a = 0 psf. For the steeper base liner sideslopes and the piggyback liner, the interface having the minimum peak strength will be required to achieve a large displacement interface shear strength that is greater than or equal to the calculated shear strength (τ) when $\phi = 24$ deg. and a = 0 psf. This approach accounts for the relative slippage that is expected on the flatter versus steeper slopes under typical landfill operating conditions, and recognizes that the residual strength of an interface is realized only after mobilizing the peak strength.

As indicated above, evaluation of the test results will be completed by the designer and will consider both the peak and large-displacement results. Specifically, in addition to the above acceptance criteria, if the large-displacement strength of the interface having the minimum peak strength is questionably low an additional static stability analysis will be completed as follows, The large-displacement strength will be utilized for not only the steeper sideslopes/ piggyback areas, but also the flatter base liner areas to rerun the critical liner system static stability section to confirm that a factor of safety greater than unity is achieved.

Based upon GZA's experience, the minimum required interface shear strength criteria set forth above is readily achievable with the geosynthetic materials currently available on the market.

Static and seismic base liner stability methods of analysis, the basis for selecting critical sections, references, and calculations are provided in Appendix G.1.1 through G.1.3.

Subgrade Bearing Capacity and Settlement – The Phase VI landfill is underlain by a relatively thin layer of very dense, naturally occurring glacial till or will be underlain by a compacted engineered fill over bedrock. As such, the foundation soils will provide adequate bearing capacity for the anticipated waste loads. GZA evaluated the settlement of the foundation soils. The analyses indicate up to about 0.5 inches of elastic settlement of the foundation soils is anticipated to result from the Phase VI loads. This anticipated settlement will not adversely affect the integrity of the liner system nor the ability of the system to remove leachate. The analyses are included in Appendix G.2.

Settlement and Strain of Piggyback Liner System - The piggyback liner system is expected to settle due to the consolidation of the Phase I waste under the loads imposed by the overlying Phase VI waste. As a worst case scenario, an area of the Phase I piggy back area where septage sludge had previously been disposed of, was selected as the critical section because of the additional settlement expected in the septage waste versus mixed solid waste or soil. GZA evaluated settlement-induced strains in the piggyback liner system. The analyses indicate up to 2 percent tensile strain and up to 5 percent compressive strain could occur in the Phase I cover system / Phase VI liner system as a result of settlement of the Phase I waste. These predicted strains are well below the yield strain of HDPE (12 to 13 percent). The analyses are included in Appendix G.

Strains in the piggyback liner were evaluated using a Finite Element Model (FEM), as shown in Appendix G. The FEM was run using a two foot by two foot grid (i.e. , the area was divided into two foot by two foot squares and a liner strain calculated for each). To smooth out the dataset, i.e. present data at a more realistic and a more uniform scale, the FEM results were averaged over 5 grid spaces, roughly every 10 feet. This was done to demonstrate that the order of magnitude of anticipated strains is realistic; this analysis is presented in Appendix G.

Recognizing the inherent difficulties in accurately modeling the septage sludge, existing and future waste, and resulting deformations, RIRRC intends to utilize LLDPE for the new geomembrane installed as part of the piggyback liner and to install geogrid below the new LLDPE geomembrane over an estimated 400 foot by 100 foot area where septage sludge was previously landfilled.

3.5 LEACHATE COLLECTION

The proposed Phase VI leachate collection system has been hydraulically designed to convey leachate, maintaining a leachate head above the liner system of equal to or less than the thickness of the proposed geosynthetic composite, under the full load of the landfill (0.23 inches). Please note, the RIRRC does not intend to re-circulate leachate as part of standard land filling operations. The following modeling and design methods were utilized to design the leachate collection system:

- The HELP Model was used for the sole purpose of predicting steady-state impingement rates / leachate generation rates. The input into the HELP Model was intentionally varied to capture a reasonable range for each of the primary design variables (waste thickness, base slope, and drainage length) and evaluate the impact on the predicted impingement rate, thereby, serving as a parametric study.

- Giroud's Modified Equation and the peak impingement rates predicted by the HELP Model was utilized to determine the maximum allowable spacing between leachate collection laterals that would limit head build-up to less than or equal to the thickness of the compressed composite drainage net. Each lateral was evaluated individually to adjust the lateral spacing based on flow length and gradient. For example, a base slope of 2% the maximum lateral spacing is 450 feet for steeper base slopes the lateral spacing can be greater than 450 feet.

3.5.1 Configuration

As indicated in the previous section, the primary leachate collection system of the new base area will consist of a composite drainage net (CDN) and a series of 8-inch diameter either SDR 11 or SDR 9 HDPE perforated lateral collection drains and header pipes. The lateral collection drains are spaced a maximum of 450-feet apart across the base area of each cell (sub-area). The piping system is designed with a minimum slope of 1 percent and will be depressed below the CDN layer to promote positive drainage. Crushed stone will surround the perforated pipes to provide a natural filter. Two layers of non-woven geotextile fabric will be placed below the stone to protect the underlying CDN and FML from puncture. The stone also serves to support the pipe against the weight of the overlying waste. Analyses supporting the design of the pipes and stone filter are discussed in Section 3.5.2.

Each of the primary leachate collection system header pipes will transport leachate to a new gravity leachate sewer leading to the leachate pretreatment facility. Combined flow rates from the primary leachate collection systems for Areas 1 through 5 will be valve controlled and continuously metered. Section 4 provides a more detailed description of the leachate transmission system.

The secondary leachate collection system of each cell consists of a CDN and a 4-inch diameter SDR 11 or SDR 9 HDPE perforated header pipe, which will collect the flow from the CDN and ultimately discharge it to the new gravity sewer. Similar to the primary piping systems, the secondary header will have a minimum slope of 1 percent and be depressed below the CDN layer to promote positive drainage. Crushed stone will surround the perforated pipe to provide a natural filter. Two layers of non-woven geotextile fabric will be placed below the stone to protect the underlying CDN and FML from puncture. Secondary leachate for each cell will be conveyed separately through individual headers to the southern perimeter of Phase VI. Secondary flow rates from each cell will be valve controlled and individually metered prior to discharging to the proposed gravity leachate sewer line.

Primary leachate generated from the piggyback will be collected using a CDN installed over the proposed 80-mil LLDPE primary liner with 8-inch diameter SDR 11 HDPE perforated drain headers located at each existing diversion bench. The existing diversion benches are spaced no greater than 40 vertical feet apart and, as such, the spacing of the laterals will effectively limit the head on the primary liner. The 8-inch laterals will convey leachate, via gravity to a downchute location. An 8-inch diameter collection header will be installed at each downchute location and will discharge to a collection header at the toe of the piggyback in the new lined base area.

Likewise, secondary leachate from the piggyback will be drained via gravity within the existing sand drainage layer and/or an existing CDN to a 4-inch diameter perforated SDR 11 HDPE pipe that will be installed on every bench. The 4-inch laterals will convey leachate to a downchute location. A 4-inch diameter collection header will be installed at each downchute location and discharge to a secondary collection header located at the toe of the piggyback within the new lined base area.

With the exception of Area 3, the primary and secondary leachate collection headers will penetrate the base liner system at the low point of each cell. Penetration details are provided on Drawing C-8.5, Appendix A. Because of constraints imposed by existing grades and seasonal high groundwater, the base configuration of Area 3 requires the low point to be located away from (not proximate to) the perimeter berm. To avoid placing a liner penetration at a distance into the cell, two leachate sumps will be constructed, one each in Area 3A and 3B, and leachate removed via pumps located within side slope riser pipes. The sump will be constructed within the secondary and primary drainage layers and will consist of a stone bed collection area, perforated HDPE collection pipes equipped with submersible extraction pumps, and solid HDPE side slope riser pipes, which will exit the cell at the southern perimeter berm. The sumps will be constructed and implemented with controls to monitor and record secondary leachate and will independently operate through water level indicators built into the pumps. Manual operation by-pass controls will also be implemented into the system.

The submersible pumps will transmit the primary and secondary leachate to the proposed gravity sewer that ultimately discharges to the on-site leachate pretreatment facility. The sumps, side slope risers, and leachate vault configurations are depicted on Drawing C-8.5, Appendix A.

Prior to construction of Area 3, a temporary leachate sewer line for Areas 1 and 2 will be required in the vicinity of the existing tipping facility access road, which is located within the proposed Area 3 footprint. This temporary sewer will convey leachate from Areas 1 and 2. The existing "hot spot" remedial sewer, which is constructed of double- walled 6-inch diameter SDR 11 HDPE pipe, will be used for this purpose. Permanent leachate transmission lines for primary and secondary leachate from Areas 1 and 2 will be installed parallel with the Area 3 interior berm as part of Area 3 construction.

3.5.2 Leachate Collection System Hydraulic Analyses

Hydraulic analyses completed by GZA to support the design of the Phase VI Landfill leachate collection system are discussed in this section. Hydraulic analyses included the following:

- Evaluating the design transmissivity and hydraulic conductivity of the proposed primary and secondary CDN, including assessing reduction factors and overall factor of safety;
- Assessing the equivalency, in terms of transmissivity, of the proposed CDN versus the RIDEM prescribed primary and secondary sand drainage layers;
- Completing multiple hydrologic / water balance analyses to determine design impingement (liquid supply) rates and average leachate generation rates for sizing the multiple components of the leachate collection system;
- Utilizing the modified Giroud's equation to demonstrate that the anticipated head on the FML is less than the long-term in-situ thickness of the geonet core of the proposed CDN;
- Checking that the design transmissivity of the CDN used in the analyses meets or exceeds the criteria set forth by the GRI GC-8 design guidelines;
- Checking the fabric component of the proposed CDN with respect to permittivity;
- Considering the fabric component of the proposed CDN and overlying sand protection layer with respect to filter criteria;
- Evaluating the capacities of the primary and secondary leachate collection system laterals and headers; and
- Evaluation the strength / deflection of the primary and secondary leachate collection system laterals and headers.

Supporting calculations are included in Appendix J.

Design Transmissivity and Equivalency – GZA assessed the long-term in-situ hydraulic transmissivity of the proposed CDN utilizing methods presented by Koerner and Giroud and a secondary check analysis using methods established by the Geosynthetics Research Institute (GRI GC-8). The Koerner and Giroud method utilizes two steps as follows:

1. Reduction factors associated with a host of performance criteria are applied to a laboratory-based (measured) transmissivity to establish a reasonable value for long-term-in-situ transmissivity;

2. An experience-based overall factor of safety is then applied to the long-term-in-situ transmissivity to result in an allowable transmissivity to be used for design. An overall factor of safety of 2.5 was utilized for the liner system, while an overall factor of safety of 2.0 was utilized for the cap sections.

The Geosynthetics Research Institute (GRI GC-8) Method only considers reduction factors for creep, chemical clogging, and biological clogging. It is GZA's opinion that the GRI GC-8 method is not as rigorous an analysis as the Giroud- or Koerner-based analysis, but serves as a good check that an adequate overall factor of safety has been applied to the laboratory-based transmissivity to establish an allowable transmissivity to be used for design purposes.

Koerner and Girouds reduction factors were applied to a measured transmissivity determined in a laboratory under loading and boundary (material layers) conditions representative of the Phase VI landfill base liner system, and with a 100-hour seating time (rather than the standard 15-minute seating time), which applies immediate compression and immediate intrusion, as well as a significant amount of delayed intrusion. Koerner and Giroud recommend using a reduction factor for delayed intrusion between 1.0 and 1.2 for landfill leachate collection systems. Because the laboratory testing conditions were representative of the long-term-in-situ conditions with respect to delayed intrusion a factor of safety of 1.1 for delayed intrusion was utilized.

The design transmissivity considered the slope of the base area (minimum 2 to about 6 percent) and the piggyback area (20 to 33 percent), as well as the anticipated waste loads that will be imposed on the landfill liner system (up to 30,000 psf). Reduction factors were applied to account for such lifecycle influences as biological and chemical clogging. Additionally, a factor of safety was applied. Design transmissivity calculations were checked using criteria set forth by the GRI GC-8 design guidance.

For the flatter base slopes (2 to 6 percent), a design transmissivity of 3.4 cm^2/sec was utilized for design. For the steeper piggyback and sideslopes (20 to 33 percent), a design transmissivity of 0.88 cm^2/sec was utilized for design. Analyses are included in Appendix J.1.1. Based upon GZA's experience, the design transmissivity is achievable with the geosynthetic materials available on the market. The Phase VI construction documents will specify minimum transmissivity requirements and will require specific laboratory testing to verify the CDN product utilized to construct the landfill meets or exceeds the specification. Calculations demonstrating that the design transmissivity values meet the criteria established by GRI Standard GC-8 are included in Appendix J.1.2.

Also included as Appendix J.1.3, is an analysis that demonstrates the design transmissivity (for both base areas and piggyback areas) of the proposed CDN exceeds the equivalent transmissivity of a 24-inch thick layer of sand having a hydraulic conductivity of 1×10^{-2} cm/sec, as stipulated in the RIDEM solid waste regulations for primary leachate collection layers. Likewise, the design transmissivity (for base areas) of the proposed CDN exceeds the equivalent transmissivity of a 12-inch thick layer of sand having a hydraulic conductivity of 1×10^{-1} cm/sec, as stipulated in the RIDEM solid waste regulations for secondary leachate collection layers.

Impingement and Leachate Generation Rates - GZA designed the leachate collection system to provide for the efficient collection of leachate and to maintain the maximum anticipated head on the liner to less than the thickness of the geonet core of the CDN. As discussed below, GZA evaluated conditions throughout the active lifecycle of the Phase VI Landfill.

The impingement / leachate generation rates were evaluated using the U.S. EPA Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07.[1] This water balance computer model accepts climatologic, soil, and design input parameters to model the movement of water over and through a landfill. The model is capable of accounting for the effects of surface storage, runoff, evapotranspiration, infiltration, percolation, soil moisture storage, and lateral drainage. The HELP Model includes a synthetic weather generator to produce climatological data needed in the water balance equations. For the evaluation of the Phase VI Landfill, GZA utilized climatological (precipitation, temperature, solar radiation and evapotranspiration) parameters for Providence, Rhode Island that are contained in the HELP Model database. Supporting calculations are included in Appendix J.2.

For the purpose of designing the Phase VI leachate collection system, GZA modeled the landfill base and piggyback areas as four-layer systems, in descending order, as follows: a layer of waste of varying thickness, a vertical percolation layer consisting of 24 inches of sand having a hydraulic conductivity of approximately 1×10^{-4} cm/sec, a lateral drainage layer consisting of the proposed CDN, and a barrier layer consisting of an 80-mil HDPE FML. The design of the secondary leachate collection media (CDN) is similar to the primary leachate collection media, and was considered to be essentially as efficient in collecting leachate. Although the landfill cells will be filled rapidly, the HELP Model runs conservatively assumed the landfills would be open for 10 years, so that saturated, steady-state conditions were assessed. Selected models were also run for 50-year simulations to confirm that steady-state conditions had been achieved. As presented in Appendix J.2, GZA ran several scenarios, to model potentially critical combinations of drainage length, waste thickness, and base slope.

For the Phase VI design, based upon the HELP Model analyses, we utilized a peak daily impingement (liquid supply) rate of about 0.21 inches per day (5,700 gallons per acre per day (gad)) for intermediate waste heights and 0.19 inches per day for full waste heights; and an average annual leachate generation rate of 1,510 gad (regardless of waste height).

Head Analyses - Using the peak daily flow output from the HELP Model, predicted head build-up was used to set the spacing of the leachate collection laterals to maintain a head equal to or less than the compressed CDN thickness (0.23 inches). Giroud's Modified Equation was used to determine the drainage distance where head build-up equaled the thickness of the compressed geonet core of the composite drainage net. It should be noted, the head predicted by Giroud's Modified Equation is a maximum

1 HELP Model Version 3.07 dated November 1, 1997. Developed by the Environmental Laboratory, U.S. Army Engineers Waterways Experiment Station, Vicksburg, Mississippi, for USEPA Risk Reduction Engineering Laboratory, Cincinnati, Ohio.

and should not be considered constant between two points and the overlying sand starts to saturate when the leachate head exceeds the thickness of the geonet core.

For a base slope of 2 percent, the maximum distance between outlets (leachate collection laterals) is 450 feet. Head build-up is a function of gradient and distance, as well as impingement rate and design hydraulic conductivity. Therefore, since the base slope of each cell (sub-area) vary, the spacing of the laterals can also vary. GZA evaluated head build-up on a cell- and leachate collection lateral-specific basis. For each lateral, we utilized the minimum tributary slope and associated typical maximum tributary flow distance. The lateral-specific Giroud's Modified Equation calculations that demonstrate that head build-up does not exceed the thickness of the compressed geonet core of the composite drainage net for each lateral are presented in Appendix J.3. The leachate lateral layouts are presented on Figures 4.2 and 4.4.

Leachate Collection System Component Compatibility – GZA evaluated the compatibility of the leachate collection system components. Specifically, we considered the following:

- Permittivity of the fabric component of the proposed CDN (Appendix J.4); and
- Filter criteria between the fabric component of the proposed CDN and the overlying sand protection layer. Gradation specifications included in the future Phase VI construction documents for the 24-inch-thick sand protection layer will be such that the filter criteria required pursuant to the RIDEM Regulations will be achieved.

The analyses are provided in Appendix J and will form the basis for the material specifications.

Collection Pipe Size and Strength - The primary leachate collection laterals and headers were sized using the peak daily leachate generation rate from the HELP Model runs and the hydraulic component of AutoDesk's Land Development Software. The program uses Manning's Equation to determine pipe size, based on pipe type (Manning's "n" value), pipe slope, and anticipated flows. Pipe deflection calculations were performed utilizing procedures suggested by the manufacturer of the HDPE pipe (Driscopipe). The "Standard Dimension Ratio (SDR) Method" was used to calculate crushing and buckling stresses. The Standard Dimension Ratio (SDR) is the ratio of outside diameter to wall thickness; the lower the SDR, the thicker the pipe wall. The analyses considered the maximum anticipated waste loads over the Phase VI base area. Based on the analyses, 8-inch diameter SDR 11 and SDR 9 HDPE pipe is specified for the primary leachate collection laterals and headers. Supporting calculations are provided in Appendix J.5, which includes a summary of the anticipated stresses and the resulting factors of safety.

3.6 LEACHATE TRANSMISSION AND DISPOSAL

The proposed leachate collection laterals, horizontal pump casing and header systems within the landfill base and piggyback areas will be constructed of single-wall SDR 11 or SDR 9 HDPE. Immediately prior to the collection pipes exiting the landfill liner system, the single-wall HDPE collection pipes will be transitioned to double-walled SDR 11 HDPE pipes. These double-walled pipes will be booted to both the primary and secondary FMLs to create a watertight seal. The double-walled pipes will transmit the leachate to individual valve vaults located within the perimeter berm at the south end of the proposed cells. Each vault for both primary and secondary leachate collection systems will contain separate gate valves, flow meters, monitoring ports, and sampling ports for each cell. Through the use of the gate valves in the proposed vaults, each sub-area of the Phase VI Landfill may be monitored and controlled individually.

The proposed horizontal pumps, which will service Area 3, Cells A and B, has been designed and sized based on EPG Companies recommendations for horizontal wheeled sump drainers. The primary leachate collection pump capacity is based the peak daily leachate generation rate with an adjustment factor equivalent to the ratio of 100 year design storm with the 50 year design storm with no service factor. The secondary leachate collection pump is based the maximum ALR of 200 gal/acre/day. The selected primary pump is and EPG SureFlow model 12-1, 1 horsepower and the secondary pump is an EPG SureFlow model 8-1, 0.5 horsepower. EPG pumps were utilized for the pump station hydraulic analysis, pumps with similar hydraulic capacities, manufactured by others maybe also be utilize with engineering review and approval. The pump stations will convey primary and secondary leachate independently to a valve and metering vault. Hydraulic calculations and pump specifications are provided in Appendix J. Pump installation details are shown on figure C-8.4.

The piping within the valve vaults will be a combination of SDR 11 HDPE and Schedule 80 polyvinyl chloride (PVC). The proposed gate valves will be either PVC or cast iron. Flanged connections within the vaults provide an allowance for routine maintenance and adjustment of the flow meters as necessary. The piping networks within the valve vaults provide the following benefits:

- Ability to inspect the containment piping between the landfill and the vault to detect leakage of the carrier pipe.
- Direct access to both the primary and secondary pipes for cleaning.
- Independent sampling of primary and secondary leachate lines for both flow and quality.
- Ability to control flow in both primary and secondary lines via gate valves.
- Ability to measure flow for each sub-area individually.

As succeeding areas are constructed, the leachate will flow through manhole structures in series, by gravity down the south side of the landfill perimeter road through a new Leachate Transmission System. All underground piping will be double-walled SDR 11 HDPE piping. The carrier pipe will continue through the manholes with two 45 degree tee fittings to allow for cleaning of the sewer in both the up and down stream directions.

The double containment pipe will terminate at the entrance invert of each manhole and resume at the outlet invert. The seal for the containment pipe on each entrance invert will be tapped and fitted with a small valve to allow inspection for leakage of the double walled carrier pipe. The Phase VI landfill leachate flow will combine with the Central Landfill leachate flow at the existing pretreatment facility. The existing pretreatment facility is expected to be upgraded for compliance with the City of Cranston Industrial Pretreatment Program. Influent limitations for the City are presently under review with RIDEM. Upon approval by RIDEM and adoption into the local sewer ordinance by the

City of Cranston City Council, modifications to RIRRC's pretreatment permit (#1808) will be made and upgrades to the facility for the treatment for arsenic and ammonia will be undertaken.

The existing sanitary sewer pumping station serves the wastewater transport and disposal needs of the site and discharges via a force main in Green Hill Road to the municipal sewers located along Plainfield Pike. In addition to sanitary wastewater, the sanitary pump station receives the effluent generated from the onsite leachate pretreatment facility. As part of the Phase VI Landfill permit and construction process, the pump station, force main and outfall will require review and potential upgrades in hydraulic capacity to service the additional leachate generated by the Phase VI Landfill. The review and construction of the pump station and force main upgrades will be performed in a two phase process. Phase I will include a partial upgrade to the existing 8" force main with Phase II being upgrades to the existing pump station and gravity mains on Plainfield Pike.

3.7 FINAL CAPPING SYSTEM

Construction of the final capping system for the Phase VI Landfill is anticipated to be performed upon completion of filling the Phase VI Landfill, however, intermediate and/or permanent caps may be constructed over completed areas of the cell at an earlier time. The cap will encompass approximately 153 acres and will connect to the existing landfill caps throughout OU-1 and Phase V that abut the Phase VI Landfill filling limits. A complete description of the capping system design is included in Section 9.2. The final cap is depicted on Drawing C-9.1 in Appendix A.

3.8 GAS COLLECTION AND CONTROL SYSTEM

All municipal solid waste landfills produce gases (largely methane and carbon dioxide with trace amount of other organic compounds). Landfill gas (LFG) management is a vital component of the development of the Phase VI Landfill during both its operational life and post-closure period. Landfill gas is a byproduct of the natural decomposition process that occurs within municipal solid waste disposal sites. Landfill gas must be controlled due to its potentially harmful characteristics including the transmission of odors and fugitive emissions, as well as its explosive potential, if left uncontrolled.

The goals of the Phase VI LFG control systems design are to: 1) protect public health and safety, as well as avoid nuisance conditions by providing for the efficient and continuous collection and recovery of landfill gas to mitigate the potential for odors, migration and surface emissions; 2) comply with federal and state regulations related to landfill gas management and emissions control; 3) recover and treat/combust landfill gas in a cost effective and environmentally sound manner; 4) manage landfill gas condensate generated within the system; and 5) develop a closure plan for long-term protection and operation of the landfill gas collection system under post-closure conditions. The gas management plan also includes an operation and maintenance plan and a contingency plan to address emergencies associated with construction and operation of the landfill gas facilities.

Landfill gas management has been an on-going activity at the Central Landfill since the late 1980's when the first active gas collection and flaring system was installed within the Phase I Landfill. As the landfill grew and gas generation increased, the gas collection systems and recovery facilities were likewise expanded to the present day configuration. Currently, the active landfill gas collection system is comprised of approximately 245 vertical extraction wells over Phases I-IV, 2 horizontal collector trenches distributed over Phases I – III, 153 horizontal trenches distributed over the Phase IV Landfill,, and 77 interim horizontal trenches over the active Phase V Landfill. The gas collection system consists of a network of gas headers ranging in diameter from 6-inches to 24-inches and linking the wells and trenches to the combustion equipment.

A similar combination of horizontal and vertical gas control systems is proposed for the Phase VI Landfill. The practical method of collecting landfill gas from a landfill that is actively placing waste is through the use of horizontal gas collection trenches. As such, during the operational phase of the Phase VI life cycle, a system of horizontal collectors, similar to those currently being installed in the Phase V Landfill, will be employed. The horizontal gas collection trenches are constructed of 8-inch diameter perforated HDPE, which transitions to an approximately 50-foot section of 8-inch diameter solid HDPE prior to exiting the landfill sideslopes. As the Phase VI Landfill is brought to final grade and undisturbed surface areas become available, the horizontal trenches will be supplemented with and eventually replaced by a network of vertical extraction wells. The vertical wells will be constructed from sections of perforated and solid 8-inch diameter HDPE pipe. Vertical extraction wells, though costly to maintain during the period of active landfilling, provide for more efficient gas collection and fewer long-term maintenance issues upon landfill closure.

The primary destruction of landfill gas recovered from the Phase VI landfill will be through a beneficial use project, such as the current system that generates electricity via turbines or steam generators. Condensate collected from recovery operations will be conveyed to the existing leachate pre-treatment facility for treatment and subsequent discharge to the Cranston public sewer system. For a complete description of the gas collection and control systems, refer to Sections 5, 9.3, and Appendix M. Landfill gas collection details are shown in Appendix A

3.9 DRAINAGE

Proper drainage control is significant for the purposes of reducing leachate generation, minimizing surface soil erosion, and controlling peak rates of runoff. The proposed Phase VI Landfill configuration has been designed to enhance overland drainage and direct runoff through drainage swales away from the fill areas. Storm water runoff from all landfill areas will be directed to existing or proposed sedimentation/detention ponds to attenuate peak flows, volumes, and deposit sediment. Discharge from the sedimentation/detention ponds is routed through culverts under Shun Pike, and ultimately to the Upper Simmons Reservoir.

The principal drainage considerations are summarized as follows:

a) The minimum overland slope at any point in the final closure plan is approximately five percent. The maximum average grade of the side slopes is 33 percent (three horizontal to one vertical). These slopes discourage surface ponding and infiltration.

b) Diversion benches are located on the steeper slopes to intercept overland flow before it achieves erosive velocities. The diversion benches are designed with a slope of no less than two percent and are designed to pass the 100-year storm. The swales will be lined with vegetation or riprap stone for soil stabilization and to accommodate access by maintenance vehicles. Additional details are provided in Appendix N of this application.

c) Downchutes have been designed to convey collected runoff from the diversion benches on the upper portions of the site to the base of the landfill. The downchutes terminate in stilling basins in a perimeter drainage channel along the toe of the landfill and enter a detention pond. The downchutes have also been designed to pass the 100-year storm. One existing downchute in OU-1 Area 1, a proposed future downchute on the Phase V Landfill, and two proposed downchutes on the Phase VI Landfill will be used to convey stormwater collected from the Phase VI Landfill. It is anticipated that they will be constructed of concrete blocks, gabions, or riprap to discourage erosion. Additional details are provided in Appendix N of this application.

d) Perimeter drainage swales have been designed along the toe of the landfill to collect surface runoff from the lower slope of the landfill and runoff that discharges from the downchutes. The drainage swales are designed at a minimum slope of 0.5 percent, a typical width of 10 feet (minimum width is 6 feet), and a minimum depth of two (2) feet. Temporary swales, designed similarly to the permanent swales described above, will be used during Phase VI filling operations. Additional details are provided in Appendix N of this application.

e) Erosion protection has been provided wherever the channel velocity for the design storm exceeds the maximum non-erosive velocity for a vegetated earthen channel (approximately four feet per second).

f) A combination of four existing and proposed sedimentation/detention ponds will be used to control stormwater flows from the Phase VI Landfill. Stormwater from a small portion in the north of Phase VI will flow to existing Pond 4. Pond 4 flows through Quarry Stream to Cedar Swamp Brook and discharges into Upper Simmons Reservoir. Pond 4 will be expanded to 44.9 acre-feet to accommodate this additional stormwater flow.

   Stormwater from the southwestern portion of Phase VI will flow to existing Pond 2 through the proposed future downchute in Phase V. Pond 2 will not require expansion or modification to accommodate this stormwater as the overall watershed area will not increase. Pond 2 discharges into Upper Simmons Reservoir through culverts beneath Shun Pike.

   Stormwater from the central and eastern remaining portions of Phase VI will flow to two proposed sedimentation/detention ponds, Ponds 13 and 14, that will be located east and south of Phase VI, respectively. Pond 13 will be 52.6 acre-feet and Pond 14 will be 23.8 acre-feet. Pond 13 will discharge directly into Upper Simmons Reservoir through an existing culvert beneath Shun Pike. Pond 14 will discharge to the existing culvert under Shun Pike at the Pond 2 discharge. A temporary pond will be constructed in the vicinity of Pond 14 along the east side of the existing administration building to control the runoff after the decommissioning of Pond 3. After the administration building is removed, permanent Pond 14 will be constructed as shown on the permit drawings.

   The design of Ponds 13 and 14, and the capacity increase of Pond 4, will allow extended detention of the stormwater volume of the site and will account for the 19 acre-ft volume that was deficient in Phase V. Therefore, the overall volume following Phase VI will be less then that from the Phase IV existing conditions.

g) Temporary erosion control measures (silt fences, hay bales, temporary stilling basins, temporary swales, etc.) will be included in each construction project and as part of the regular landfill operations. Properly placed temporary erosion control will reduce the potential of sediment from un-vegetated areas moving beyond the storm water drainage system. Temporary erosion control measures will be maintained until sufficient vegetation is in place and erosion of these areas is not anticipated.

During each construction project, the Contractors will be responsible for installing and maintaining all erosion control measures, temporary and permanent, as shown on the Construction Drawings. Typically, the temporary control measures shown will be the minimum to be installed by the Contractor. Additional measures may be installed at the request of the Engineer.

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Sections Final\Section 3 rev- wma.doc

SECTION 5

5.1 LANDFILL GAS MANAGEMENT - OPERATIONAL PHASE

Landfill gas (LFG) is a natural byproduct of the solid waste decomposition process. The decomposition process goes through two stages, aerobic and anaerobic. During the aerobic stage, where the oxygen present in the waste mass is consumed, the LFG is typically comprised of carbon dioxide, nitrogen and oxygen. During the anaerobic stage, which is an oxygen depleted stage, the LFG is comprised of approximately 46-54% methane, 46-54% carbon dioxide and 0-4% other trace organic gases. It is the anaerobic stage end products that the facility needs to control. The anaerobic LFG generation can be expected to occur at measurable levels within 4-months to a year after the initial placement of waste in the Phase VI Landfill. Note that an Air Pollution Control Permit Application for the Phase VI Landfill has been submitted to RIDEM. A copy of the complete Air Pollution Control Permit Application, including additional submittal related to the application (Best Available Control Technology Evaluation and Air Quality Impact Assessment) is attached as Appendix V.

In order to control potential nuisance odors, limit surface emissions and mitigate lateral gas migration, landfill gas management procedures will be implemented during the operational phase of the new landfill. A complete description of the proposed landfill gas collection and destruction systems for the Phase VI Landfill is presented in Appendix M "Landfill Gas Management Plan". Design drawings depicting the system layout and construction details are provided on Drawings C-7.1 through C-7.8. The report and associated design drawings present the approaches to be implemented for landfill gas management during both the <u>operational</u> and <u>closure/post-closure</u> periods of the Phase VI Landfill lifecycle. As these two processes are necessarily related we have prepared one comprehensive document (Appendix M) to facilitate review and implementation of the program.

This document has been modified to reflect review comments provided by the Rhode Island Department of Environmental Management (RIDEM) on May 12, May 28, June 24, 2008 and July 15, 2009. It also reflects input provided by RIDEM at a technical review meeting held on September 18, 2008. The full text of GZA's responses to RIDEM's comments is provided in four letters dated May 22 and July 2, 2008 and February 12 and October 27 2009, which provide more detail on our design rational and operational considerations than was appropriate to present in the permit documents. This permit submission has been also been modified to reflect changes in the proposed control and destruction devices that have resulted from ongoing work on these designs and changes in the landfill's waste acceptance rate.

5.2 OVERVIEW OF OPERATIONAL LANDFILL GAS COLLECTION

The major challenge of landfill gas management during the operational phase of landfilling is overcoming the physical disturbance and obstacles presented by on-going filling activities. Installation and operation of landfill gas collection systems within active landfill cells must take into consideration access by trash hauling vehicles and loading impacts of heavy construction and compaction equipment. On-site operational experience has demonstrated the effectiveness and durability of horizontal collection trenches for recovery of LFG during active filling. The horizontal collection trenches will be constructed using a minimum 2.5-foot wide by approximately 4-foot deep trench in which 8-inch perforated high-density polyethylene (HDPE), butt-fused pipe sections are placed and backfilled with crushed stone or other suitable clean and durable aggregate. RIRRC currently plans to install the collection trenches at approximately 100-foot intervals across the top of every other lift of waste resulting in a vertical separation of 24 to 30 feet. Trenches will be installed beginning with the second refuse lift and in an off-set pattern (i.e., they will not directly overly each other but be off-set by approximately 50 feet). The end of each trench collector will be equipped with an 8-inch solid pipe connecting to an HDPE header leading to a centralized gas recovery/treatment and power generation or flaring system.

Note, that the final gas collection trench configuration and spacing may be modified based on the results of upcoming performance testing (e.g., radius of influence – ROI) of the systems currently being used in the Phase V Landfill.

The amount of vacuum and gas recovery from each trench will be regulated by a control valve. In order to prevent air intrusion and possible underground combustion from occurring, the initial vacuum levels will be kept to a minimum until sufficient fill materials are placed over the trenches installed in underlying waste lifts and the gas generation rates increase. A conceptual layout of the interim gas collection system and associated details are presented on Drawings C-7.1 through Drawing C-7.8.

As the Phase VI Landfill is constructed, it will piggy-back an impermeable liner and an existing vertical well landfill gas collection system along the eastern slope of the Phase I Landfill, ultimately burying as many as 60 Phase I wells. These wells will be decommissioned as installation of the Phase VI baseliner progresses up the Phase I Landfill slope. Due to the advanced age of most of the wastes within this portion of the Phase I Landfill, gas generation has already declined significantly. Based on the Phase I Landfill gas model, the Phase I piggyback area will produce a peak gas flow of approximately 925 scfm in 2010. By the time these wells are buried by the Phase VI Landfill, many can be expected to be low or non-producing, particularly those along the lower benches of the Phase I eastern slope.

However, to prevent the build-up of LFG below the Phase I cap, and limit the potential for subsurface migration of gases below the Phase VI cell, a system of shallow horizontal trenches will be installed beneath the Phase I cap as some wells are decommissioned. The location and extent of this horizontal collection system will be based on performance monitoring of the existing wells in areas to be decommissioned. Similar to the methods used in the Phase V overlap area, good producing wells will also be incorporated into the horizontal gas collection network. Based on LFG flow measurements recorded in January 2008, 38 wells from Phase I have been tentatively identified (shown on Drawing C-7.7) for connection into the below cap trench gas collection system. Wells were selected based on their current production levels and their proximity to the horizontal trenches. Methods and materials employed for this below cap collection system will be similar to those described above for the operational LFG collection trenches. Typical design details are shown on Drawings C-7.5 and C-7.6.

5.3 OVERVIEW OF OPERATIONAL LANDFILL GAS DESTRUCTION

A landfill gas generation model has been developed for the Phase VI Landfill based on the assumption that it will receive approximately 12,000,000 tons of solid waste beginning in the year 2010 and ending in 2020. Waste characterization information for the model was derived from the January 2006 ***Rhode Island Statewide Comprehensive Solid Waste Management Plan*** breakdown of waste from Table 171-5-3 of the study. The results of this modeling effort and its incorporation into the existing sitewide gas generation curves are provided in Appendix M. In summary, LFG production from the Phase VI Landfill is expected to peak in 2027 at a Base Case rate of 7,431 standard cubic feet per minute (scfm), with Accelerated Case generation this peak would reach 8,715 scfm also in 2027. At this time LFG generation from Phases I through V will be declining significantly with Base Case generation rates estimated to be on the order of 361 scfm for Phase I, 569 scfm for Phases II/III, 688 scfm for Phase IV and 563 scfm for Phase V. This results in a sitewide Base Case generation rate of approximately 9,612 scfm in 2027, with an estimated sitewide Base Case peak of 14,417 in the year 2009. A Regulation 9 pre-construction air permit for the proposed Phase VI Landfill has been developed and was submitted to RIDEM for review in June 2007.

As shown on the graphs in Appendix M, the peak projected recoverable rate of gas production occurred in 2008 at approximately 16,100 scfm for the Accelerated Case condition. Adding the 20 percent factor of safety yields a peak destruction capacity requirement for the entire site of approximately 19,320 scfm.

RIRRC is the current owner of the Central Landfill including the proposed Phase VI expansion area. Ridgewood Power Management of Ridgewood, New Jersey is the owner of the gas rights for the existing cells and will have rights to the gas from the proposed Phase VI expansion. Ridgewood Gas Services (RGS) operates and maintains the landfill gas collection and distribution systems (Operator). RGS is contractually obligated to RIRRC to collect and control landfill gas from the Central Landfill waste cells.

Under the terms of a pending agreement, Ridgewood Power Management will construct, own and operate a new approximately 42 megawatt (mW) electrical generating power plant (Stage 3) to replace the existing Ridgewood Power Management facility. Under this new agreement, a Ridgewood company similar to RGS will be the gas system operator. Ridgewood Power Management (or affiliate) will be the permitted operator of the destruction devices. Landfill gas (LFG) distribution will be preferentially directed to electrical generation (Stages 2 and 3). LFG flares will be backup and compliance devices. A new gas mover and treatment station will also be constructed to the south of the Phase V Landfill on the 73/75 Shun Pike property. The existing Ridgewood Power Management plant (and the two free standing Deutz engine/generators) will be decommissioned to make room for the Phase VI expansion. The new 42 mW Stage 3 power plant is currently proposed to be located to the south of the Phase VI cell as shown on Drawing C-7.1.

Current LFG destruction capacity consists of: 1) the main Ridgewood Power Management power plant with a capacity of approximately 5,100 scfm; 2) two free standing Deutz Generators at the main Ridgewood Power Management facility with a combined capacity of 820 scfm; 3) 2,032 scfm for the Stage 2 power plant; 4) an Ultra-low Emission (ULE) enclosed flare with a capacity of 6,000 scfm; 5) two existing 2,000 scfm remote utility flares (RF-2 and RF-3); 6) two older Perennial flares with a combined capacity of 2,600 scfm; and 7) RF-1 with a capacity of 450 scfm which together provide a LFG destruction capacity of 21,000 scfm, more than satisfying the 120 percent (19,320 scfm) landfill gas recovery requirements. However, when Phase VI is constructed the main Ridgewood Power Management plant, the two Deutz generators, and Perennial flares will be decommissioned by December 2010,

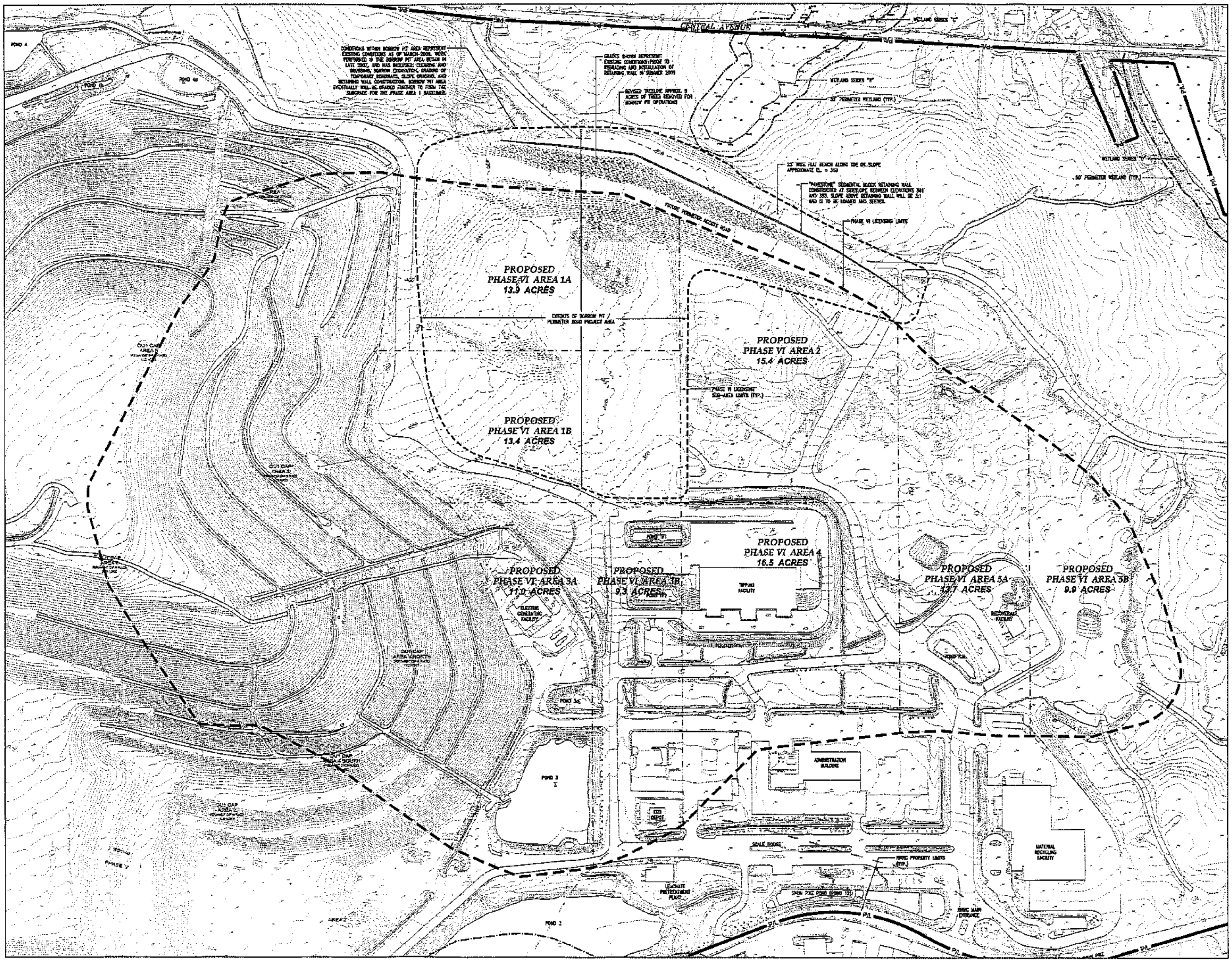
We anticipate that the new electrical generating facilities (Stage 3) will not be fully functional until July 2011. This results in a theoretical (because actual gas recovery is currently running between 12,000 and 13,000 scfm not the 19,320 scfm estimated by the recoverable fraction of the Accelerated Case model plus 20%) gas destruction shortfall of approximately 6,838 scfm (5,100 for the main plant, 820 for the Deutz's and 2,600 for the Perennial flares) for up to 7 months (December 2010 to July 2011). However, two new 3,000 scfm ground flares will be installed onsite by December 2010. They will be located at the new gas treatment and compression facility, which will be operational by December 2010 This will provide destruction capacity of approximately 18,500 which is more that the projected peak sitewide generation rate under the Accelerated Case model. To summarize:

- December 2010, the Stage 1 power plant, Deutz engines, and Perennial Flares will be decommissioned
- December 2010, the Hydrogen Sulfide Treatment portion of the gas conditioning plant will be operational and two new 3,000 scfm ground flares with a combined capacity of 6,000 scfm will be operational (co-located with the treatment facility)
- July 2011, the Stage 3 power plant is operational

In the long-term, a portion of this new capacity will serve as back-up to the new Stage 3 electrical generating facility and burn pretreated gas. The long-term sitewide LFG destruction capacity is equal to 30,682 scfm, which is well in excess of the highest gas generation predictions. This capacity will consist of: 12,200 scfm at the new Stage 3 facility, 2,032 scfm at the Stage 2 power plant, 6,000 scfm for the new ground flares at the new gas treatment and compression facility, 6,000 scfm for the ULE flare, and a combined 4,450 for the 3 remote flares. Assuming Phase VI begins receiving waste in January 2013, gas collection from this cell will be required by May 2013 (140 days from the installation of the first gas collection trenches in accordance with the current practice at the Site.

The flares will serve as backup to the electrical generating facilities. The goal of the collection and destruction system design is to distribute the landfill gas to maximize beneficial use. In the event that excess landfill gas is recovered, or generation is curtailed, gas can be redirected to a number of gas destruction flares through a series of interconnected headers as described in more detail in Appendix M and shown on drawing 7.8.

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Sections Final\Section 5 revised.doc



	RHODE ISLAND RESOURCE RECOVERY CORPORATION
	PHASE VI LANDFILL LICENSING PERMIT APPLICATION EXISTING CONDITIONS PLAN
PROJ. MGR.:	AJR
DESIGNED:	EMD
DRAWN:	RFD
CHECKED:	AJR
DATE:	APRIL 2007
SCALE:	1"=120'

PARE CORPORATION

GZA GeoEnvironmental, Inc. Engineers and Scientists 140 Broadway Providence, Rhode Island 02903

ARMANDO J. RICCI No. 7128 REGISTERED PROFESSIONAL ENGINEER CIVIL

REV	DESCRIPTION	BY	DATE
2	RIDEM OFFICE OF WASTE MANAGEMENT REVISED SUBMISSION	EMB	APR 2010
1	REVISED PER RIDEM REVIEW COMMENTS		NOV 2008

PROJECT NO. 03003.20

FIGURE NO. C-2.3

SHEET 4 OF 42

APPENDIX M

GAS MANAGEMENT PLAN

APPENDIX M - REVISED October 29, 2009

1.00 PHASE VI LANDFILL OPERATIONAL AND CLOSURE POST-CLOSURE LANDFILL GAS MANAGEMENT PLAN

1.10 LANDFILL GAS MANAGEMENT PLAN

This appendix describes both the operational and closure/post-closure landfill gas (LFG) management plans designed to collect and control landfill gas from the Phase VI Landfill cell. The plan was developed on behalf of the Rhode Island Resource Recovery Corporation (RIRRC). The LFG collection and control systems have been designed to achieve comprehensive control of landfill gas.

This document has been modified to reflect review comments provided by the Rhode Island Department of Environmental Management (RIDEM) on May 12, 28, June 24, 2008 and July 15, 2009. It also reflects input provided by RIDEM at a technical review meeting held on September 18, 2008. The full text of GZA's responses to RIDEM's comments is provided in four letters dated May 22 and July 2, 2008 and February 12 and October 27 2009, which provide more detail on our design rational and operational considerations than was appropriate to present in the permit documents. This permit submission has been also been modified to reflect changes in the proposed control and destruction devices that have resulted from ongoing work on these designs and changes in the landfill's waste acceptance rate.

1.20 INTRODUCTION

The following subsections provide an overview of the major plan components, applicable regulations, a summary of relevant related documents, a review of the existing LFG management systems and the LFG management plan objectives.

1.20.1 Operational Responsibilities

RIRRC is the current owner of the Central Landfill including the proposed Phase VI expansion area. Ridgewood Power Management of Ridgewood, New Jersey is the owner of the gas rights for the existing cells and will have rights to the gas from the proposed Phase VI expansion. Ridgewood Gas Services (RGS) operates and maintains the landfill gas collection and distribution systems (Operator). Currently, RGS is contractually obligated to RIRRC to collect and control landfill gas from the Central Landfill waste cells.

Under the terms of a pending agreement, Ridgewood Power Management will construct, own and operate a new approximately 42 megawatt (mW) electrical generating power plant (Stage 3) to replace the existing Ridgewood Power Management facility (Main Plant and two Deutz engines, designated Stage 1). The main Ridgewood Power Management plant, located to the east of the existing Phase I Landfill, (and the two free standing Deutz engine/generators) will be decommissioned to make room for the Phase VI expansion. The new 42 mW Stage 3 power plant is currently proposed to be located to the south of the Phase VI cell as shown on Drawing C-7.1.

Under the new agreement, a Ridgewood company similar to RGS will be the gas system operator. Ridgewood Power Management (or affiliate) will be the permitted operator of the destruction devices. Primary landfill gas (LFG) distribution will be preferentially directed to electrical generation. LFG flares will be backup and compliance devices.

1.20.2 Project Overview

LFG management is a vital component of the development of the Phase VI Landfill during both its operational life and post-closure periods. LFG is a byproduct of the natural decomposition process that occurs within municipal solid waste disposal sites. LFG must be controlled due to its deleterious characteristics including transmitting odors and causing fugitive air emissions as well as the explosive potential, if left uncontrolled.

This report presents a description of the plan for managing LFG generated by the Phase VI Landfill from its initial stages of development, through the periods of active filling, final closure and post-closure. The report is organized as follows:

- Section 1.20 - Introduction, includes this overview, presents a review of the applicable regulations, a summary of relevant existing documents, describes the existing LFG management systems on-site, and outlines the objectives for the LFG management plan.
- Section 1.30 - Integration of LFG Management with Landfill Operations, discusses the construction and operation of LFG facilities in conjunction with landfilling activities including filling and covering, managing leachate/condensate, and installing a final cap.
- Section 1.40 - LFG Management Facilities Design, describes the conceptual design issues surrounding the LFG system including gas generation modeling, gas collection, condensate management, gas recovery and utilization/destruction, and protection of the facilities.
- Section 1.50 - LFG Management Operations, discusses the various aspects of operating a LFG system simultaneously with landfilling activities as well as after closure including collection, recovery, and destruction of LFG, site personnel health and safety, emergency response, record keeping and reporting, and site security.
- Section 1.60 - Contingency Plan, identifies problems that may arise during landfill operations, related to LFG, that require implementation of contingency measures such as odors / emissions, gas migration, noise, personal injury, and fires / explosions.
- Section 1.70 - Closure Plan, presents the steps to be taken to integrate the landfill closure and capping with the gas system and protect the gas system from damage during closure, and discusses post-closure gas control issues.

1.20.3 Applicable Regulations

Regulations applicable to LFG management fall under two major categories: (1) safety related and (2) health related. The safety related regulations pertain to hazards of gas migration, uncontrolled combustion, and explosions. Regulations concerning health related issues include odors and emissions.

Regulations pertinent to LFG management on the federal level include:

- United States Environmental Protection Agency (EPA) New Source Performance Standards (40 CFR 60 Subpart WWW)
- EPA Resource Conservation and Recovery Act (RCRA) Subtitle D (40 CFR Parts 257 and 258)

Similarly, regulations pertinent to LFG management on the state level include:

- RIDEM Air Pollution Control Regulation No. 7 (Air Contaminants)
- RIDEM Air Pollution Control Regulation No. 9 (Permits)
- RIDEM Air Pollution Control Regulation No. 17 (Odors)
- RIDEM Air Pollution Control Regulation No. 22 (Air Toxics)
- RIDEM Solid Waste Regulation No. 2 (Landfills)

New Source Performance Standards (NSPS)40 CFR 60, Subpart WWW

The New Source Performance Standards for Municipal Solid Waste (MSW) landfills were promulgated by the EPA in March 1996. The NSPS applies to MSW landfills that accepted wastes after May 30, 1991 with a maximum design capacity equal to or greater than 2.5 million megagrams (Mg) or 2.5 million cubic meters and potential annual NMOC emissions of 50 Mg or above. Landfills exceeding these thresholds are required to construct a gas collection and control system to capture the LFG and direct it to a destruction system or beneficial utilization facilities. In addition, the rule requires specific monitoring of the facility and the gas collection and control system to demonstrate compliance with the rule.

National Emissions Standards for Hazardous Air Pollutants (NESHAPS) 40 CFR 63, Subpart AAAA.

The NESHAP for landfills became effective in January 2004. It applies to landfills subject to the gas collection and control system requirements of the NSPS. The NESHAP does not impose any additional requirements with respect to the collection system design, but it does require implementation of a startup, shutdown, and malfunction (SSM) plan, as well as imposing additional reporting requirements.

Resource Conservation and Recovery Act (RCRA) Subtitle D

RCRA legislation was originally passed in 1974 and has undergone several updates including regulatory standards for LFG collection and control issued in October 1991. Subsections of Parts 257 and 258 of RCRA Subtitle D set safety and control standards for landfill gases, including:

- A maximum allowable limit for explosive gases of 25 percent of the lower explosive limit (LEL) for methane within structures on-site or in the vicinity of the landfill. Structures used for the purpose of LFG recovery or control are exempt from this standard.
- A maximum allowable limit of 100 percent LEL (approximately 5 percent methane by volume) as measured at the property boundary.
- Implementation of a routine methane monitoring program to ensure compliance with the above standards.

In addition to the LFG safety standards, RCRA also places controls on the management of LFG derived condensate. In accordance with the regulations, condensate must be collected, treated and properly disposed at an approved facility. The RCRA Subtitle D regulations do permit the return of condensate to the landfill if certain standards are met including having an approved Subtitle D composite liner and operation of a leachate collection system.

RIDEM Air Pollution Control Regulation No. 7 (Air Contaminants)

Air Pollution Control Regulation No. 7 (APC No. 7) regulates the emission of air contaminants which, by way of their concentration or duration, may be harmful to human, plant or animal life, or cause damage to property or which unreasonably interferes with the enjoyment of life and property. Compliance with this regulation is satisfied by compliance with applicable primary and secondary national ambient air quality standards as well as compliance with certain sections of RIDEM regulations APC No. 9 and APC No. 22.

RIDEM Air Pollution Control Regulation No. 9 (Permits)

Air Pollution Control Regulation No. 9 (APC No. 9) pertains to permitting emissions of major and minor stationary sources of any air pollutant including certain volatile organic compounds found in LFG. RIRRC has submitted a minor source permit application for the proposed Phase VI Landfill to RIDEM under APC Regulation No. 9.

The landfill gas system operator (Ridgewood Power Management or affiliate) is responsible for permitting any new flares and electrical generation facilities. An APC Regulation 9 permit associated with the Phase VI Landfill expansion and the associated landfill gas was submitted by Ridgewood Power Management to

RIDEM on December 24, 2007. The application is currently under review and a permit has not yet been issued.

RIDEM Air Pollution Control Regulation No. 17 (Odors)

Air Pollution Control Regulation No. 17 (APC No. 17) prohibits the release into the atmosphere of any air contaminant, or combination of air contaminants, which create an objectionable odor beyond the property line. Since the uncontrolled release of landfill gases has the potential to lead to odorous conditions, adequate collection and destruction of LFG is required to ensure compliance with this regulation.

RIDEM Air Pollution Control Regulation No. 22 (Air Toxics)

Air toxics are defined as any substance emitted to the atmosphere as dust, fumes, gas, mist, smoke, vapor, or soot that has been shown to induce mutagenic, carcinogenic, fetotoxic, or other acute or chronic toxic effects listed in Table 1 of Air Pollution Control Regulation No. 22 (APC No. 22). Testing of the LFG from Phases I, II and III in May 2000 indicated that the site was subject to review under APC No. 22. An air toxics impact assessment for the existing portions of the Central Landfill was submitted to RIDEM Office or Air Resources in July 2007. The air toxics impact assessment for the Central Landfill including Phase VI will be submitted in the near future.

RIDEM Solid Waste Regulation No. 2 (Landfills)

Regulations for the control of LFG at the State level (SWR No. 2 Section 2.3.08) are similar to those under RCRA Subtitle D with one major exception. Under the State rule, the concentration of explosive gases (methane) cannot exceed 25 percent of the LEL at the facility property boundary. In comparison, the RCRA Subtitle D LFG Safety Standards (Part 257.3-8) allows a maximum concentration at the property boundary of 100 percent LEL. Since the state standards are more stringent, they take precedence.

The construction and operation of LFG recovery facilities are regulated by RIDEM under Solid Waste Regulation No. 2 (Section 2.1.12). The regulations require an application be submitted to the Department for approval to construct and operate a LFG recovery facility. The following information must be included in the submittal for the LFG recovery facility:

- Site plans showing existing and proposed site conditions with the location of the gas collection system and recovery facility as well as property boundaries and other relevant features;
- Construction and engineering plans, including specifications, related to all equipment and facilities of the LFG collection and recovery;

- An operating plan describing the operation of the LFG facilities and how the gas is to be used;
- A contingency plan that discusses the responses to unexpected events during construction and operation; and
- A closure plan that includes methods of operating and protecting the gas system for continued control of LFG.

This LFG Management Plan directly addresses many of the above noted regulatory requirements. Final design plans and specifications for the LFG collection and recovery system will be developed in conjunction with the detailed engineering construction documents in accordance with Solid Waste Regulation No. 2. A final capping and closure plan, including LFG control facilities has been developed and is provided with the design drawings.

1.20.4 Summary of Applicable or Relevant Existing Information

The following documents relate to or were prepared to meet the requirements of state and federal regulations applicable to landfill gas management, daily gas collection and monitoring operations, and reporting required at Central Landfill.

1. **GZA - Air Pollution Control Regulation No. 9 Permit Application for the Phase VI Landfill** – Application submitted July 2007. Draft permit provided by RIDEM on March 29, 2008. RIRRC submitted comments to RIDEM on ____ and they are currently under review.

2. **GZA - Air Pollution Control Regulation No. 9 Permit Application for the Phase II/III Landfill** – Application submitted January 2004. Draft permit provided by RIDEM on March 20, 2008. RIRRC submitted comments to RIDEM on ___, and they are currently under review.

3. **USEPA - Clean Air Act Consent Decree** (CD) [July 25, 2003]. Governs operation of Phases II, III, and IV and the ULE Flare until permits are issued. Includes permit application, monitoring, reporting, and recordkeeping requirements as well as minimum design standards.

4. **GZA - SOP No. 001 – Landfill Gas Quality Measurements** [rev2: 1/31/2006] -
This standard operating procedure discusses the various instruments, locations, time requirements and reporting criteria for the measurement of landfill gas quality for use at the Site.
    - *Sup 1.00 – Alternative Monitoring Equipment: SEM 500 Surface Emission Monitor* [Jan. 2006]
    - *Sup 2.00 – Alternative Monitoring Equipment: Jerome 631-x Hydrogen Sulfide Analyzer* [Jan. 2006]

5. **GZA - SOP No. 002 – Landfill Gas Flow and Pressure Measurements** [rev1: 1/31/2006]- This standard operating procedure discusses the various instruments, locations, time requirements and reporting criteria for the measurement of landfill gas flow and pressure for use at the site.

6. **Dufresne-Henry – Revised Gas Collection and Control System Design Plan** [March 31, 2000] – Prepared in response to EPA request in the October 21, 1999 Administrative Order and Reporting Requirements. The report provides and overview of the LFG system design and a summary of relevant operating parameters.

7. **GZA - Title V Air Permit Application** – Permit not yet issued. Original application prepared by GZA and submitted June 2000. Revised November 2000, Supplemental materials submitted June 2005.

8. **GZA - Air Toxics Operating Permit Application** - prepared by GZA and submitted April 2007, revised May 2008; permit not yet issued.

9. **RIDEM - Air Pollution Control Regulation No. 9 Permit for the Phase V Landfill** - Approval #1810, September 16, 2004. Contains emission limits, design standards, operating requirements and monitoring, recordkeeping and reporting requirements for Phase V. As the emissions limits contained within this permit document are assessed on a site wide basis they have relevance to the Phase VI expansion.

10. **RIDEM - Air Pollution Control Regulation No. 9 Permit for Destruction device RF-1** - Approval #1035, April 18, 1990.

11. **GZA - Air Pollution Control Regulation No. 9 Permit Application for Destruction devices RF-2 and RF-3** – Application contains operating, monitoring and reporting requirements. Permits have not been issued for RF-2 and RF-3. Both applications were prepared by GZA and submitted in March 2000.

12. **GZA - Air Pollution Control Regulation No. 9 Permit for Destruction device: Ultra Low Emission 6,000 SCFM ground flare (ULE)** – Application prepared by GZA and submitted September 2003. Operates under July 25, 2003 Consent Decree until permit is issued. Draft permit provided by RIDEM on March 20, 2008. RIRRC submitted comments to RIDEM on ___ and they are currently under review.

13. **RIDEM - Air Pollution Control Regulation No. 9 Permit for the Main Flares located at the Ridgewood Power Plant** - Approval #s 1037 and 1038, April 18, 1990. Contains operating, monitoring and reporting requirements.

14. **GZA - NO_X RACT Compliance Plan** [Dec 19, 2000] – This document provides a summary of the applicable requirements under Rhode Island Air Pollution Control Regulation Number 27. Plan specifies boiler maintenance and recordkeeping requirements, recordkeeping requirements for Flares RF-1, RF-2, and RF-3, and recordkeeping and engine timing adjustment requirements for emergency generators.

1.20.5 Existing and Proposed LFG Management System

LFG management has been an on-going activity at the Central Landfill since the late 1980s when the first active gas collection and flaring system was installed within the Phase I Landfill. As the landfill grew and gas generation increased, the gas collection systems and recovery facilities were likewise expanded to the present day configuration. Currently, the active LFG collection system is comprised of approximately 205 vertical extraction wells and 19 horizontal collector trenches distributed over Phases I – III, 84 horizontal trenches distributed over Phase IV Landfill – Areas 1 through 4 and 110 horizontal trenches distributed over the active Phase V Landfill. The gas collection system consists of a network of gas headers ranging in diameter from 6-inches to 24-inches and linking the wells and trenches to the recovery equipment.

LFG collected from Phases I-V is routed to the recovery and on-site LFG-to-electricity power plant as well as five on-site flare units. The existing gas collection and recovery systems are capable of capturing and destroying upwards of 21,000 scfm. The Ridgewood Power Management main power plant utilizes an average of 5,100 scfm to produce 12 megawatts (MW) of electricity, the two free-standing Deutz engine/generator sets are capable of combusting a combined 820 scfm producing approximately 2.5 MW of electricity, and the Stage II power plant utilizes an additional 2,032 scfm to produce 6 MW of electricity for sale to the utility company. The power plant is supplemented by the main flaring system with a capacity of 2,600 scfm. Three remote flare systems include a 2,000 scfm unit located at the northwest corner of Phase II (Remote Flare #3), a 2,000 scfm unit located at the southwest corner of Phase III (Remote Flare #2) a 450 scfm unit that is connected to the western header of the Phase IV Landfill (Remote Flare #1) and 6,000 scfm ultra-low emission (ULE) flare located south east of Phase IV.

The primary destruction of landfill gas recovered during the operational stage of the Phase VI Landfill will be through a beneficial use project utilizing the LFG for the generation of electricity via new turbines to be installed south of Shun Pike on property owned by RIRRC.

The goal of the collection and control system design is to distribute the landfill gas to the various control devices for beneficial reuse or destruction. In the event that excess landfill gas is recovered, or generation is curtailed, gas can be redirected to a number of gas destruction flares through a series of interconnected headers as described in more detail below.

A landfill gas generation model has been developed for the Phase VI Landfill based on the assumption that it will receive approximately 12,380,000 tons of solid waste beginning in January 2013 and ending in 2027. Waste characterization information for the model was derived from the January 2006 ***Rhode Island Statewide Comprehensive Solid Waste Management Plan*** breakdown of waste from Table 171-5-3 of the study. The results of this modeling effort are shown on the gas generation curves on Figures 1 and 2, below. As shown, LFG production from the Phase VI Landfill is expected to peak in 2027 at a Base Case rate of 7,431 standard cubic feet per minute (scfm), with Accelerated Case generation this peak would reach 8,715 scfm also in 2027. At this time LFG generation from Phases I through V will be declining significantly with Base Case generation rates estimated to be on the order of 361 scfm for Phase I, 569 scfm for Phases II/III, 688 scfm for Phase IV and 563 scfm for Phase V. This results in a sitewide Base Case generation rate of approximately 9,612 scfm in 2027, with an estimated sitewide Base Case peak of 14,417 in the year 2009. A Regulation 9 pre-construction air permit for the proposed Phase VI Landfill has been developed and was submitted to RIDEM on June 11, 2007.

As shown on Figure 3, the site-wide peak projected recoverable rate of gas production occurred in the year 2008 at approximately 16,100 scfm for the Accelerated Case condition. Adding the 20 percent factor of safety to the recoverable portion of the Accelerated Case yields a required peak destruction capacity for the entire site of approximately 19,320 scfm.

As described in Section 1.20.1 above, Ridgewood Power Management, in cooperation with RIRRC, is currently developing a replacement plan for the 11 generators that are within the Phase VI Landfill footprint. Drawing C-7.1 shows the tentative location of a new gas mover and treatment plant located to the south of the Phase V Landfill on the 73/75 Shun Pike property. A new power generating facility, consisting of eight LFG turbines and one steam recovery turbine with a gas destruction capacity of approximately 12,000 scfm, is proposed to be installed to the southeast of the Phase VI Landfill south of Shun Pike. This new power plant is designated Stage 3.

The existing flares serve as the primary backup to the electrical generating facilities. Concurrent with the development of the Phase VI cell, the existing main electrical generating plant, the two Perennial flares, and the two Deutz generators will be decommissioned by December 2010. We anticipate that the new electrical generating facilities (Stage 3) will not be fully functional until July 2011. This results in a theoretical (because actual gas recovery is currently running between 12,000 and 13,000 scfm not the 19,320 scfm estimated by the recoverable fraction of the Accelerated Case model plus 20%) gas destruction shortfall of approximately 6,840 scfm (19,320 scfm less the destruction of the remaining devices after the Stage 1 power plant, Deutz engines, and Perennial flares are decommissioned, which equals 12,480 scfm)) for up to 10 months (September 2010 to July 2011).

However, two new 3,000 scfm ground flares will be installed onsite by December 2010. They will be located at the new gas treatment and compression facility, which will be operational by December 2010 This will provide destruction capacity of approximately 18,500 which is more than the projected peak sitewide generation rate under the Accelerated Case model.

In the long-term a portion of this new capacity will serve as back-up to the new Stage 3 electrical generating facility. The total long-term sitewide LFG destruction capacity is 30,682 scfm which is well in excess of the highest gas generation predictions. This capacity will consist of: 12,200 scfm at the new Stage 3 facility, 2,032 scfm at the Stage 2 power plant, 6,000 scfm for the two new ground flares at the gas treatment and compression facility (3,000 scfm apiece), 6,000 scfm for the ULE flare, and a combined 4,450 for the 3 remote flares .

Assuming Phase VI begins receiving waste in January 2013, gas collection from this cell will be required by May 2013 (140 days from the installation of the first gas collection trenches in accordance with the current practice).

1.20.6 LFG Management Plan Objectives

The following objectives have been identified for the Phase VI Landfill LFG Management Plan:

- Projecting the long term generation rate of LFG using the established LFG modeling program for the Central Landfill as adjusted for the proposed Phase VI Landfill conditions;
- Efficient and continuous collection and recovery of LFG to mitigate the potential for odors, subsurface migration and surface emissions to protect public health and safety as well as avoid nuisance conditions;
- Compliance with federal and state regulations related to LFG management and emissions control;
- Design and construction of cost-effective systems for collection, recovery and destruction of LFG in an environmentally sound manner;
- Managing LFG condensate generated within the system to preclude pipeline blockages and treatment of collected condensate to industrial pretreatment standards for disposal at the Cranston Publicly Owned Treatment Works (POTW);
- Operation and maintenance of the LFG collection system in a manner compatible with landfill construction and closure activities, that minimizes personnel health and safety risks, and prevents fires and explosions;
- Implementation of a contingency plan to address emergencies associated with construction and operation of the LFG facilities; and
- Development of a closure plan for protection and operation of the LFG collection system under landfill post-closure conditions.

1.30 INTEGRATION OF LFG MANAGEMENT WITH LANDFILLING

1.30.1 Landfill Construction

Measurable quantities of LFG production are expected from the Phase VI Landfill within four to 12 months of filling being initiated, that is by May 2013 assuming waste placement begins in January 2013. Collection and destruction of this gas will be needed to limit unwanted migration and/or surface emissions. Management of LFG in conjunction with landfill construction requires careful planning and implementation to ensure success. Installation and operation of LFG collection systems within active landfill cells must take into consideration access by trash hauling vehicles and the movement and loading of heavy landfilling equipment.

In general, the LFG collection system must be entirely buried within the active landfilling zone and must be installed with sufficient depth and with materials of suitable strength to resist loading impacts. The gas collection system must also be designed to accommodate settlement of waste and header piping. Condensate drainage is a key element of the LFG collection system design in order to limit potential header blockages from its accumulation. Care must also be exercised in operating the LFG collection system within active landfilling areas to prevent underground landfill fires from taking place as a result of air intrusion into the gas system due to excessive applied vacuums.

1.30.2 Leachate Management

Leachate can interfere with the efficient recovery of LFG if not adequately collected. Recovery of LFG through perforated horizontal collector trenches or vertical extraction wells is inhibited by the presence of leachate in excessive amounts at the trench or well. The movement of LFG is constrained by liquids in the pore spaces of the waste materials and well media. Consistent collection of leachate in combination with proper management of surface drainage can limit the buildup of leachate within the gas collection zone.

The horizontal collection trenches within the Phase VI Landfill have been designed for a consistent burial depth of 4 feet assuming that the landfill waste lifts are constructed with an outboard pitch of 1% minimum to shed water. Additional condensate/leachate leaching sumps have also been added to the Phase VI design (as compared to that employed in Phases IV and V) to promote condensate and leachate drainage from the trenches.

1.30.3 Landfill Capping

The construction of the final landfill cap will need to accommodate the permanent gas collection systems including horizontal trenches, vertical wells, condensate traps, header piping, and miscellaneous fittings. Existing vertical wells at or near the pre-capping grade elevation will need to be raised to allow the cap to be constructed around the well casing. Generally speaking, wells within 1- to 40-feet of the capping grade can be successfully raised, at greater depths, replacement wells typically need to be installed.

In order to minimize interruption of gas collection during construction of the cap, the interim/operational header piping will remain in operation as a replacement header system is installed above the final cap for post-capping operation. The timeframe from burial of existing headers and laterals to installation of the new equipment above the cap should be kept as short as practicable. A permanent perimeter header has been utilized in the design that will serve both the interim/operational gas collection needs as well as the closure/post-closure period. This header will reside in virgin soils or compacted gravel fill between the liner anchor trench and the perimeter road and will help to reduce downtime due to system switchover.

1.40 LFG MANAGEMENT FACILITIES DESIGN AND CONSTRUCTION

The recovery and beneficial utilization (or destruction) of LFG will be necessary during the operational phase of the landfill as well as during closure and post-closure periods. Implementation of LFG management facilities will limit the potential for the generation of objectionable odors, control surface emissions, reduce lateral gas migration and provide a significant renewable energy resource. The design, construction and operation of the LFG recovery and reuse/destruction systems are critical to ensuring the preceding objectives are met. This section describes the components that will comprise the LFG management facilities for the Phase VI Landfill and provides specific design criteria and construction elements that are associated with facilities implementation. A report that describes the specific assumptions and calculations that formed the basis of our design as presented on the attached figures is provided at the end of this appendix in Attachment A.

1.40.1 Gas Collection

a. Interim/Operational Gas Collection System

LFG generation is expected to commence within 4 to 12 months from the placement of the waste in the Phase VI Landfill cell. Since the Phase VI Landfill has a projected useful life of about 10 years, gas collection will be necessary prior to closure. Under the terms of a Consent Decree between RIRRC and the United States Environmental Protection Agency, that is still in force at the site, gas collection for each cell is required within 140 days of the installation of the first collection trenches. The design and installation of a gas collection system must take into account the restrictions and impacts placed upon recovering LFG from an operating landfill cell with continual activities of waste filling, compacting, grading and covering.

The most practical method of collecting LFG from an active landfill site is through the use of horizontal gas collection trenches. The horizontal gas collection trenches are constructed of perforated 8-inch ID high density polyethylene (HDPE) pipe sections butt-fused together. The trenches will vary between SDR sizes depending on the depth of trash above each tier, as described in the attached design report.

The horizontal collection trenches will be constructed using a minimum 2.5-foot wide by approximately 4-foot deep trench in which 8-inch perforated HDPE, butt-fused pipe sections are placed and backfilled with 1-inch to 2-inch crushed stone or other suitable clean and durable aggregate, see Drawing C-7.4, detail #101. We currently plan to install the collection trenches at approximately 100-foot intervals across the top of every other lift of waste resulting in a vertical separation of not more than 30 feet. Trenches will be installed beginning with the second lift and in an off-set pattern (i.e., they will not directly overly each other but be off-set by approximately 50 feet). The end of each trench collector will be equipped with an 8-inch solid pipe connecting to an HDPE header leading to a centralized gas recovery system.

The final gas collection trench configuration and spacing may be modified based on the results of performance testing (e.g., radius of influence – ROI) of the system currently installed in the Phase IV and V Landfills. Results of this performance testing, if conducted, will be provided to RIDEM and the spacing will not be altered with RIDEM approval. Final spacing will be based on achieving a slight overlap in the radius of influence of adjacent trenches through the application of reasonable operational vacuum by the blower systems.

Due to the configuration of the Phase VI Landfill piggybacking over the Phase I cell, the trenches would be installed in alignment with the shorter distance in an north-south orientation for Areas 1-5. This orientation will allow the installation of the trenches to proceed in sequence with the anticipated filling pattern starting at the Phase I Landfill interface.

As noted above, trenches are designed to be sloped a minimum of 1 percent to the outboard side of the individual landfill cells to facilitate drainage of leachate and condensate toward the leaching sump at the outside slope end of each trench. The leaching pit is constructed near the end of the slotted pipe sections approximately 20-feet before the trench joins the 8-inch solid HDPE lateral pipe that connects the trench to the gas header system. Leachate sumps have also been placed at the approximate midpoint of trenches greater than 500 feet in length, to further aid in the draining of leachate and condensate. The leaching sumps have dimensions of 8-feet long by 8-feet wide by 10-feet deep and are to be backfilled with crushed stone (3-inch to 4-inch), or other suitable clean and durable aggregate material. Leaching sumps are covered by a layer of filter fabric and a minimum 2-foot thick layer of compacted clay to prevent air intrusion. Drilled sumps may also be utilized. We recommend that drilled sumps be 24-inch diameter and a minimum of 20 feet deep to penetrate the landfill cover material between successive layers of trash and into the underlying waste lift. A 4-foot long bentonite plug backfilled around the 8-inch solid HDPE pipe follows the leaching sump as shown on Detail # 113 on Drawing 7.6, and serves to preclude condensate/leachate from breaking out of the horizontal trench stone backfill to the outside landfill slope. An additional 4-foot long clay plug will be placed around the solid pipe at its intersection with the vertical gas collection trench-heads. The purpose of these clay plugs is also to minimize the potential for surface emissions from around the pipe and to prevent ambient air infiltration into the landfill which can result in landfill fires. Details of the proposed LFG collection trenches are shown on Drawings C-7.1 and C-7.3.

An HDPE end cap is installed on the buried end of the horizontal trench to prevent the entry of waste materials. The end of the 8-inch solid HDPE lateral at the downslope side of the trench is fitted with a blind-flange connection to permit inspection and cleaning of the trench should blockages occur after being placed in service. A butterfly valve is installed in the 4-inch trench lateral just upstream of the T-connection to a larger HDPE gas header. The gas header is constructed along the outside slope of the cell lift buried to a depth of 1- to 2-feet below grade. The gas header is run upslope from the permanent perimeter header in a pattern to maximize the pipe slope to promote condensate drainage. Some header pipes will also snake up and down the outside slope of the lift and will be laid at a minimum cross-landfill slope of 4 percent. Condensate traps will be located at key low points to drain condensate from the laterals before they enter the main header. Depending upon the location of the on-landfill gas headers, the condensate traps are constructed to either drain back to the landfill if sufficient waste depth (i.e., greater than 25 feet) exits or connect to the leachate collection system if insufficient waste depth exists for proper drainage and to minimize the potential for leachate outbreaks.

Since the Phase VI Landfill will piggyback over the existing Phase I and V Landfills, the gas collection system will also need to extend into this overlap area. Within this overlap area, the vertical wells will be installed to a maximum depth that places the bottom of the well no closer than 10-feet to the elevation of the landfill liner or underlying cap in closed piggyback areas. The existing Phase I vertical wells within the overlap area will be decommissioned and buried. Due to the advanced age of most of the wastes within this portion of the Phase I Landfill, gas generation has already declined significantly. At the time these wells are buried by the Phase VI Landfill, they are expected to be relatively low or non-producing wells, particularly those along the lower benches of the Phase I eastern slope.

However, to prevent the build-up of LFG below the Phase I cap (LFG pressures in confined landfill areas have been observed at up to 5 pounds per square inch (psi), which is more than enough to raise the full landfill cap cross-section off of the waste) and limit the potential for subsurface migration of gases below the Phase VI cell, a system of shallow horizontal trenches will be installed beneath the Phase I cap as wells are decommissioned. This system is shown on Drawing C-7.7 with details provided on Drawing C-7.5a. The location and extent of this horizontal collection system was based on performance monitoring of the existing wells in areas to be decommissioned. Similar to the methods used in the Phase V overlap area, good producing wells have been incorporated into the horizontal collection network. Methods and materials employed for this below cap collection system will be similar to those described above for the operational LFG collection trenches.

b. Final Gas Collection System

As the Phase VI Landfill is brought to final grade and surface areas become available, the series of horizontal trenches may be supplemented with and eventually replaced by a network of vertical extraction wells. The decision to supplement or replace the horizontal gas collection system with vertical wells will be based on performance testing and an operational assessment of the Phase IV and Phase V systems. Vertical wells offer a number of advantages over horizontal trenches: 1) better vertical zone of influence; 2) not subject to the significant loading and settlement that trenches may experience as the waste fill compacts with age; and 3) controlling the amount of gas recovery from a specific location is generally easier to manage with vertical wells in comparison to horizontal trenches. The major disadvantage of vertical wells is that they extend through the landfill surface making them impractical to use within portions of the landfill still accepting waste or those that will be covered by additional piggyback cells.

Vertical wells, if needed, will be installed as each area reaches its pre-capping final grade. The wells will be installed at an average spacing of 200-feet on center based on radius of influence testing conducted within the Phase I Landfill, or as needed to supplement the collection trenches. Testing[1] found the radius of influence of vertical wells in the Central Landfill ranged from a minimum of 108-feet to as much as 150-feet with

[1] "Radius of Influence Tests, Stage I – Interpretive Report, Central Landfill, Johnston, RI, February 2001", Prepared by GZA Geoenvironmental, Inc.

vacuum at the wellhead between 5 and 15 inches of water column (w.c.). The well spacing of 200-feet provides an overlap of the zones of influence to maximize the recovery of LFG and limit the possibility of surface emissions. The most efficient coverage of vertical wells over the landfill area is achieved by laying out the wells in a triangular pattern to the maximum degree possible. A conceptual layout of the vertical extraction wells at the final grade of the Phase VI Landfill is shown on Drawing C-7.2.

The vertical gas extraction wells will be constructed by drilling a 3-foot diameter borehole into the waste to a depth setting the bottom of well 10-feet above the base liner or 100-foot total depth, whichever is less. Even though portions of the Phase VI Landfill will reach depths of over 200-feet, the maximum practical limit of the bucket auger type drilling equipment is about 120-feet. In addition, on-site experience has shown that drilling wells greater than 100-feet is extremely difficult, increases the chance of well cave-in, and rarely provides any additional benefit since gas at those depths will rise upward (driven by pressure gradients) to wells above and outward to wells on lower portions of the landfill slope when a vacuum is applied.

The vertical wells will be constructed of 8-inch SDR 11 HDPE piping which will be perforated below a depth of 20-feet and solid for its upper portion. The perforated portion of the well will be backfilled with 1- to 1-1/2-inch crushed stone to enhance the movement of gas into the well. Acceptable perforation patterns for the screened portion of the wells are shown on Drawing C-7.6 detail #109. Linear low-density polyethylene (LLDPE) sheeting (60 mil) or filter fabric will be placed at the top of the stone fill followed by a 4-foot thick bentonite plug to limit air intrusion. The solid pipe portion of the vertical well will be backfilled with a low hydraulic conductivity soil (e.g., clay or clayey till) and topped with another 4-foot bentonite plug. A wellhead to connect the vertical well to the gas header will be installed atop the 8-inch HDPE well casing.

The vertical gas wellhead will include a butterfly valve to regulate the level of vacuum exerted on the well and isolate the well when maintenance and repairs are necessary. Sample ports are installed on the wellhead upstream and downstream of the valve to allow vacuum readings and monitoring of gas quality. A thermometer is mounted on the side of the wellhead for determining the gas temperature. The connection of the wellhead to the header is made via a flexible hose to the HDPE lateral off the gas header.

The on-landfill vertical well gas header system is comprised of a network of interconnecting HDPE piping that will range in size from 6-inches to as much as 28-inches. The gas headers are generally constructed along the alignment of the landfill slope with a minimum downward slope of 4 percent to promote condensate drainage. Due to the flatter slope of the upper portion of the wellfield, the gas headers will be installed in a cross-slope pattern to maximize condensate drainage.

Condensate traps will be installed at all low points of the gas headers to remove condensate that builds-up in the lines to avoid header blockages. Knock-out crosses will be installed at the design low points of the gas header system. The knock-out cross is constructed of an HDPE cross fitting matching the size of the gas header and installed in a vertical orientation. The lower portion of the cross drops three feet below the header invert and is fitted with a cap at the bottom to serve as a condensate sump. A 4-inch drain outlet is installed in the sump section allowing accumulated condensate to overflow into the interconnected condensate trap. The upper portion of the knock-out cross extends to the landfill surface and is fitted with a removable cover for inspection and maintenance purposes.

A 4-inch drain outlet is installed on the side of the knock-out cross that connects to the condensate trap. The condensate trap is made up of a 4-inch HDPE "U"-shaped piping configuration to isolate the atmospheric air from the vacuum within the gas header system. The two sides of the 4-inch HDPE "U" extend to the surface and are capped with blind flanges for use as clean-outs. The bottom of the "U" is set 8.34 feet (i.e., 100 inches) below the 4-inch inlet from the knock-out cross to provide protection from the systems vacuum un-priming the trap. The 4-inch outlet from the "U" is set 16 feet above the bottom of the trap. The outlet of the "U" trap is directed to the leachate collection system or back into the landfill, depending upon its location relative to the leachate collection system and the depth of waste. Where sufficient depth of waste exists to allow percolation of the condensate back into the landfill (i.e., 25 feet of depth or more), a large stone leaching sump or drilled stone column is constructed beneath the condensate trap casing, otherwise, the "U" trap outlet is tied into the leachate collection system.

A condensate trap will also generally be installed at the connection between the main on-landfill collection headers and the off-landfill perimeter header to limit the amount of condensate entering the perimeter header. A condensate trap and pump station will also be placed at key points along the run of perimeter header. The purpose of these pump stations is to remove condensate and/or leachate that enters or forms in the cooler perimeter header before it becomes an impediment to LFG flow. The pump stations will discharge to the leachate collection system and will be similar to that used in the Phase IV perimeter header.

Butterfly valves will be installed at the end of each header line serving 6 or more wells. These valves are used to provide gross adjustments to the vacuum exerted on the tributary wells. Fine tuning of the individual well vacuum is performed with the butterfly valve at the wellhead. Flow and gas quality monitoring stations will be installed at key junctions of the gas header system to check gas flows and quality from major segments of the wellfield and too provide for measurement of the phase specific total landfill gas collection volume and quality. The flow monitoring stations use a calibrated annubar flow measurement device inserted into the header that senses the drop in pressure across the device. This pressure drop is then converted into a velocity reading that is used to calculate the gas flow rate based on the pipe size. Gas quality parameters consisting of % methane, % carbon dioxide and % oxygen are measured using a real-time field portable meter such as the LandTec GEM 2000, or equivalent, calibrated in accordance with the manufactures recommendations; methane is used as a measure of gas quality and oxygen is used as an indicator of air intrusion.

The on-landfill gas header system will be constructed to lie above the final cap geosynthetic liner within the vegetative support layer. The purpose of this is to allow access to the header piping for maintenance and repair purposes without disturbing the cap membrane. The gas header - perimeter header system ultimately leads to the gas control devices.

Drawing C-7.2 of the Phase VI Landfill permitting plans shows a conceptual layout plan of the final Phase VI gas collection system. The actual final gas collection system configuration will be determined once the Phase VI Landfill approaches its final grade. Details associated with the Phase VI Landfill final gas collection system are presented on Drawings C-7.2.

1.40.2 Condensate Management

A byproduct of the collection and recovery of LFG is the production of condensate that must be properly handled to prevent system operational problems. Condensate is produced as a result of the warm saturated LFG extracted from vertical wells and horizontal trenches entering into the header system where cooler near surface temperatures allow vaporized moisture to condense. Condensate is also produced from mist entrained in the gas which drops out as the velocity of the gas that keeps the mist in suspension is reduced such as when the gas enters into a knockout tank. Condensate will collect at low points of the collection system and could create partial or total blockages if not removed.

Condensate management will occur at two levels in the Phase VI LFG system. The primary level is associated with condensate management within the gas collection headers buried in the landfill and around its perimeter. The secondary condensate management level occurs at the recovery facilities (e.g., gas treatment system). The main distinction between the primary and secondary level condensate management is the method of collection and disposal. Condensate produced within the wellfield gas headers and perimeter header will generally be collected at the header low points and routed to condensate traps that discharge the condensate to the landfill, either directly into the waste of the lined cells or into one of the numerous collection pipes associated with the primary leachate collection system. At the lower elevations of the Phase VI Landfill where insufficient depth (<25') of waste exists to assimilate the condensate without resulting in leachate or condensate outbreaks, the condensate piping is connected to the leachate collection system piping; whereas condensate collected at higher elevations may be drained into the waste via dug (or drilled) sumps or drilled drip legs. In contrast, condensate removed from the gas stream at the LFG recovery facilities will be collected and either routed to the on-site treatment facility via a gravity sewer connection, pre-treated, and discharged to the public sewer system, or collected in dedicated tanks for temporary storage then transported to an appropriate off-site disposal facility.

1.40.3 LFG Generation Modeling

Modeling of LFG generation from the Phase VI Landfill is based on the model that has been developed and refined for the Central Landfill. The LFG model is based on a first-order decay relationship between the amounts of organic waste available at any given time and the rate of gas generation. Input data to the model consists of: the estimated annual tonnage of waste placement; the composition of the waste in terms of decomposability categories; the weight based gas yield of each waste component category; and the decay rate coefficient and lag time.

Annual waste tonnage for the Phase VI Landfill is projected to be approximately 810,000 tons per year over its estimated 15-year life. This projection is based on information provided by RIRRC, which they expect to remain relatively steady into the future with increased recycling offsetting population and economic growth. The Phase VI Landfill will have a total capacity of approximately 12.0 million tons. Waste characterization information for the model was derived from the January 2006 ***Rhode Island Statewide Comprehensive Solid Waste Management Plan*** breakdown of waste from Table 171-5-3 of the study.

a. First Order Decay

The first order decay equation used as the gas generation model algorithm has the form:

$$G = Lo \times W \times [1 - e^{(-kt+l)}]$$

where,

G = gas generation rate at time t, cf/yr.
Lo = potential ultimate gas generation capacity of the waste component, cf/dry ton
W = annual waste placement, tons
k = gas generation rate constant, 1/yr
t = time since placement of the waste, years
l = lag time for start of gas generation, years

The first order decay equation calculates the annual quantity of gas generation for each waste component category (rapidly, moderately and slowly decomposable) assuming the peak occurs after waste placement subsequent to the lag period. The rate of gas production then diminishes exponentially as the organic portion of the waste is decreased by microbiological consumption. The total gas generation for each yearly period is determined by summing the values obtained from the first order decay equation for each waste component category. The annual gas generation values for each year of waste placement are then added together to derive the cumulative gas generation rate for any point in time.

b. Input Factors and Assumptions

The waste placement rate used for the Central Landfill Phase VI LFG Model input is the 810,000 tons per year noted above. Table 1 presents a summary of the data assumed for each waste component category used as input for the Base Case of the LFG Model. The input data includes the percent dry weight analysis of the waste, methane yield factor in cubic feet per dry ton for each waste category, half-life in years for each waste category and lag time in years for each waste category.

TABLE 1
WASTE COMPOSITION ASSUMPTIONS[1]
(Base Case Conditions)

Waste Component	Waste Analysis (% Dry Wt.)	Landfill Gas Yield Factor (CF/Dry Ton)	Half-Life (Years)	Lag Time (Years)
Readily Decomposable	9.1	4,610	0.5	0.1
Moderately Decomposable	32.9	14,453	3.8	0.8
Slowly Decomposable	5.9	1,500	12.5	3.6

Based on the waste composition assumptions shown in Table 1, ultimate average potential gas yield, Lo, is approximately 5,263 cubic feet of LFG per ton of waste (3.41 cf/lb.) and the weighted average decay rate constant, k, is approximately 0.164/yr.

c. Base Case Generation Model

The projected waste placement values together with the composition data in Table 1 were input to the Central Landfill LFG Generation Model to predict the total gas generation for the Phase VI Landfill site. The model projects total gas generation for a period of 30 years beyond the completion of filling in the Phase VI waste cells. The output from the model is displayed in Figure 1 that shows curves of the estimated gas generation rate in standard cubic feet per minute (scfm) for the years 2000 - 2042.

LFG production from the Phase VI Landfill is expected to peak in 2027 at a Base Case rate of 7,431 standard cubic feet per minute (scfm). The base case reflects the predicted gas generation rate as an average annual value for each year indicated. However this average annual value can vary significantly over the course of a year depending upon seasonal conditions or other unusual weather conditions that affect gas generation. The sensitivity of the model to such seasonal or unusual conditions is determined by varying certain parameters of the base case assumptions and re-running the model.

[1] Derived from data on waste composition and LFG generation produced by Robert K. Ham, Professor, University of Wisconsin, Dept. of Civil and Environmental Engineering, Presented at the "Sanitary Landfill Leachate and Gas Management Seminar", Madison Wisconsin, April 1993.

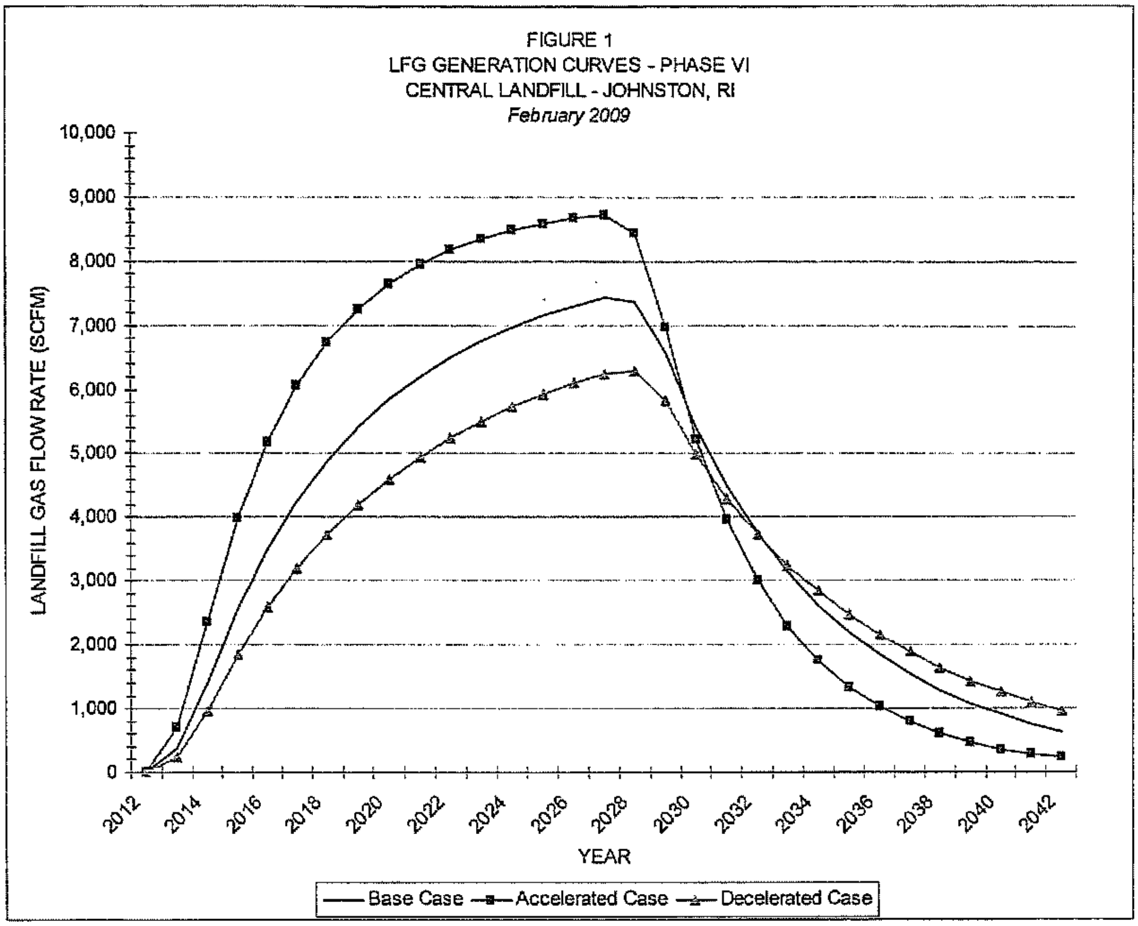


FIGURE 1
LFG GENERATION CURVES - PHASE VI
CENTRAL LANDFILL - JOHNSTON, RI
February 2009
LANDFILL GAS FLOW RATE (SCFM)
10,000
9,000
8,000
7,000
6,000
5,000
4,000
3,000
2,000
1,000
0
2012
2014
2016
2018
2020
2022
2024
2026
2028
2030
2032
2034
2036
2038
2040
2042
YEAR
Base Case
Accelerated Case
Decelerated Case

FIGURE 2
RECOVERABLE LFG CURVES - PHASE VI
CENTRAL LANDFILL - JOHNSTON, RI
February 2009

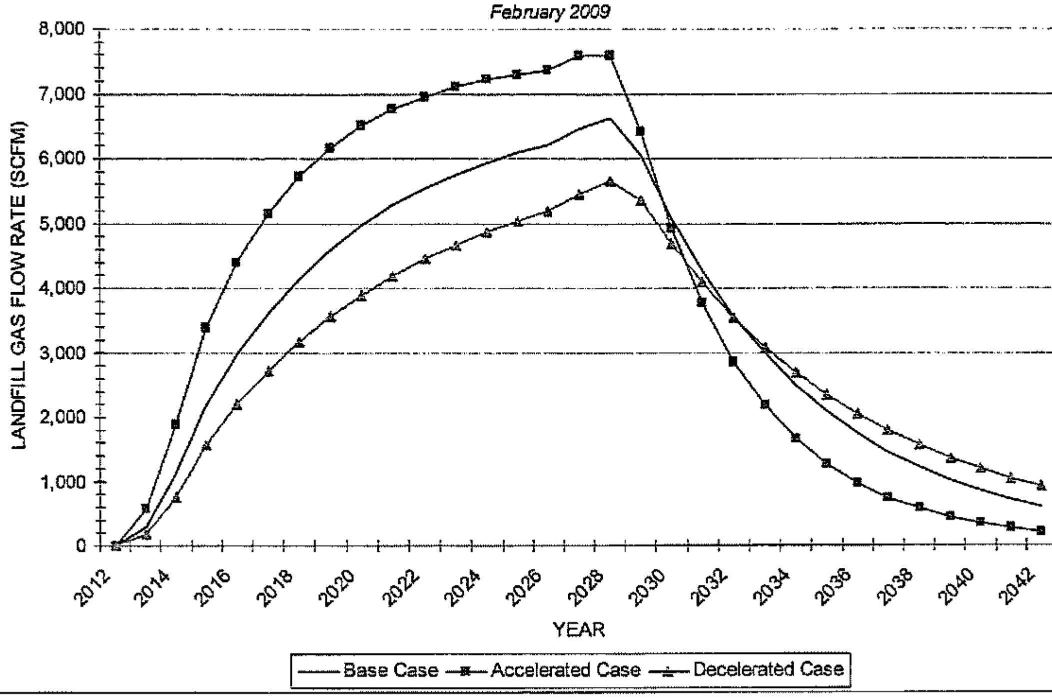
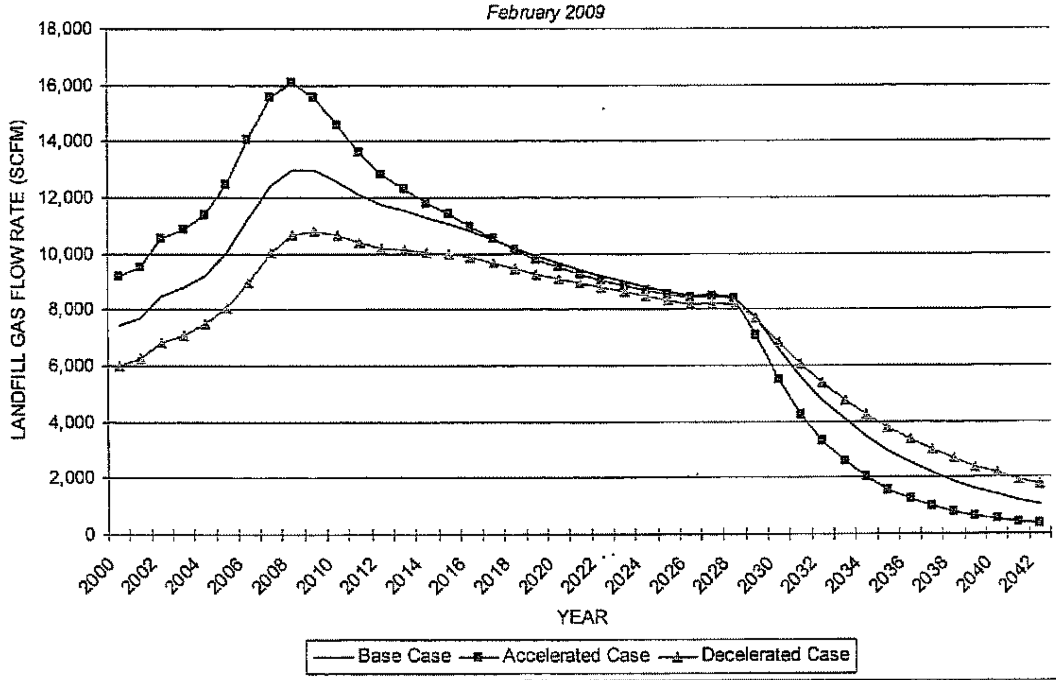


FIGURE 3
RECOVERABLE LFG CURVES - SITE WIDE
CENTRAL LANDFILL - JOHNSTON, RI
February 2009



d. Accelerated / Decelerated Decay Models

In order to gain an understanding of the possible high and low range of gas generation rates due to fluctuating conditions that might occur, the model input assumptions are varied to yield accelerated and decelerated decay rates. Under the accelerated case the waste component yield factors are increased while the corresponding half-life and lag time values are decreased. The affect of these adjustments is more rapid and earlier decomposition of the wastes producing higher gas generation rates in comparison to the base case conditions. Alternately, the decelerated case adjustments produce the opposite affect. Table 2 presents the input parameters assumed for the accelerated and decelerated gas generation cases.

TABLE 2
LFG MODEL INPUT PARAMETERS
ACCELERATED AND DECELERATED CASES[2]

Waste Component	Landfill Gas Yield Factor (CF/Dry Ton)		Half-Life (Years)		Lag Time (Years)	
	Accel.	Decel.	Accel.	Decel.	Accel.	Decel.
Readily Decomposable	5,000	4,400	0.5	0.8	0.1	0.1
Moderately Decomposable	16,000	13,000	2.5	5.0	0.6	0.9
Slowly Decomposable	1,500	1,450	10.0	15.0	2.5	4.6

The input parameters for the accelerated and decelerated decay rate cases were run in the LFG model. The results of the model output are plotted on Figure 1 showing the high range gas generation curve of the accelerated case and the low range gas generation curve of the decelerated case in comparison to the base case which should represent the long term average gas generation curve.

As shown, LFG production from the Phase VI Landfill is expected to peak in 2027 at a Base Case rate of 7,431 standard cubic feet per minute (scfm). A review of the gas generation curves in Figure 1 indicates peak generation rates of approximately 8,715 scfm and 6,285 scfm for the accelerated and decelerated cases, respectively. As shown in the figure, the accelerated decay rate produces a higher gas peak than is seen to decline more rapidly than the other cases after filling ceases. That is, the LFG generation capacity of the

[2] Adjustments to Base Case Conditions of Table 1 for Accelerated and Decelerated Conditions made to reflect increase and decrease, respectively, in gas generation rate associated with predominantly wet and predominantly dry weather conditions, respectively. The amount of adjustment for each case was based on calibrating the model for each case to actual gas recovery records from the Central Landfill during extended wet and dry weather periods.

waste is expended earlier in the landfill cycle. Conversely, the decelerated rate produces a lower gas peak and declines more gradually than the other cases.

e. Recovery Rate

Recovery of LFG from the Central Landfill is accomplished by the installation and operation of a gas collection system. As described in Section 1.40.1 above, the gas collection system will initially be comprised of a series of horizontal collection trenches during the active operational period of the site. That system will be supplemented or replaced with a network of vertical extraction wells as the site reaches final grade.

Estimated LFG recovery rates, as a percentage of the projected gas generation, generally vary between 80 percent and 95+ percent. This recovery rate range is typical of the values used by the industry. The lower end of the range corresponds to an uncapped landfill surface. A fully capped landfill surface (i.e., flexible membrane, clay) is expected to yield a recovery rate of 95 percent or more. These recovery rates assume complete coverage of the landfill with an active gas collection system. The uncapped landfill recovery rate is assumed to be less than the capped rate due to the lower permissible vacuum levels needed to prevent unacceptable air intrusion. The presence of an impermeable surface provided by a landfill cap allows operation of the gas collection system at higher vacuum levels with minimal threat of air intrusion.

The recovery rate is assumed to increase from 80 percent to 95 percent as the site transitions from uncapped to fully capped. As shown on Table 3, the assumed overall average recovery rate in Phase VI starts out at 80 percent and increases steadily to 95 percent by 2031, assuming a membrane cap is built up as the Phase VI cell reaches its capacity. A site-wide gas generation and recoverable gas table is provided as Table 4.

The assumed gas recovery rates are applied to the LFG generation model annual output values to determine the estimated yearly recoverable gas. Figure 2 shows a graphical representation of the gas generation and recovery curves for the Phase VI Landfill for the base, accelerated and decelerated case LFG Model conditions, respectively. As noted on Figure 2, the estimated peak recoverable gas under base case conditions for Phase VI is approximately 6,625 scfm. In comparison the estimated peak recoverable gas under the accelerated and decelerated case conditions is approximately 7,588 scfm and 5,656 scfm, respectively.

In December 1999, the RIRRC reached an understanding with the EPA and local Citizens Action Committee to design all future gas recovery and destruction systems to have a capacity equal to or greater than, the peak recoverable flow rate associated with the Accelerated Case LFG Model projection plus a 20 percent factor of safety. Accordingly, the gas management systems should be capable of recovering and destructing 9,106 scfm (120% x 7,588 scfm) from the Phase VI Landfill in 2027.

TABLE 3: LFG GENERATION AND RECOVERY PROJECTIONS
CENTRAL LANDFILL - JOHNSTON, RI
PHASE VI
February 2009

	LFG GENERATION (SCFM)			RECOVERY	LFG RECOVERABLE (SCFM)		
YEAR	BASE CASE	ACCELERATED	DECELERATED	FACTOR	BASE CASE	ACCELERATED	DECELERATED
2012	0	0	0	80%	0	0	0
2013	375	708	222	80%	300	567	178
2014	1,410	2,347	951	80%	1,128	1,878	761
2015	2,569	3,979	1,847	85%	2,184	3,382	1,570
2016	3,493	5,174	2,583	85%	2,969	4,398	2,196
2017	4,250	6,069	3,194	85%	3,613	5,159	2,715
2018	4,875	6,743	3,729	85%	4,144	5,732	3,170
2019	5,403	7,257	4,188	85%	4,592	6,168	3,559
2020	5,840	7,653	4,583	85%	4,964	6,505	3,896
2021	6,208	7,951	4,931	85%	5,277	6,759	4,191
2022	6,514	8,174	5,236	85%	5,537	6,948	4,451
2023	6,771	8,347	5,500	85%	5,755	7,095	4,675
2024	6,979	8,479	5,729	85%	5,932	7,207	4,870
2025	7,160	8,583	5,931	85%	6,086	7,296	5,041
2026	7,306	8,660	6,104	85%	6,210	7,361	5,189
2027	7,431	8,715	6,257	87%	6,465	7,582	5,444
2028	7,361	8,431	6,285	90%	6,625	7,588	5,656
2029	6,576	6,979	5,833	92%	6,050	6,421	5,367
2030	5,410	5,229	4,979	94%	5,085	4,915	4,680
2031	4,500	3,958	4,299	95%	4,275	3,760	4,084
2032	3,757	3,007	3,736	95%	3,569	2,857	3,549
2033	3,139	2,292	3,250	95%	2,982	2,177	3,088
2034	2,618	1,750	2,833	95%	2,487	1,663	2,692
2035	2,194	1,340	2,472	95%	2,085	1,273	2,349
2036	1,833	1,028	2,153	95%	1,742	976	2,045
2037	1,535	785	1,882	95%	1,458	745	1,788
2038	1,285	604	1,639	95%	1,220	574	1,557
2039	1,076	465	1,431	95%	1,023	442	1,359
2040	903	361	1,250	95%	858	343	1,188
2041	757	285	1,090	95%	719	270	1,036
2042	639	222	958	95%	607	211	910

TABLE 4: LFG GENERATION AND RECOVERY PROJECTIONS
CENTRAL LANDFILL - JOHNSTON, RI
SITE WIDE
February 2009

	LFG GENERATION (SCFM)			LFG RECOVERABLE (SCFM)		
YEAR	BASE CASE	ACCELERATED	DECELERATED	BASE CASE	ACCELERATED	DECELERATED
2000	9,028	11,236	7,201	7,471	9,225	5,989
2001	9,375	11,646	7,535	7,728	9,523	6,240
2002	9,750	12,111	7,847	8,498	10,544	6,839
2003	10,160	12,569	8,181	8,811	10,872	7,110
2004	10,514	13,035	8,500	9,226	11,381	7,477
2005	11,299	14,104	9,049	10,059	12,473	8,088
2006	12,583	15,931	10,014	11,216	14,089	8,962
2007	13,729	17,326	11,090	12,391	15,560	10,030
2008	14,347	17,806	11,750	13,005	16,066	10,667
2009	14,417	17,375	11,965	12,992	15,578	10,801
2010	14,021	16,306	11,826	12,590	14,564	10,640
2011	13,549	15,285	11,583	12,129	13,606	10,393
2012	13,174	14,486	11,417	11,757	12,848	10,215
2013	12,813	13,785	11,250	11,516	12,309	10,138
2014	12,472	13,167	11,069	11,288	11,804	10,053
2015	12,153	12,639	10,903	11,091	11,438	9,978
2016	11,847	12,174	10,750	10,817	10,988	9,854
2017	11,569	11,764	10,583	10,522	10,549	9,676
2018	11,292	11,403	10,417	10,199	10,141	9,468
2019	11,049	11,090	10,264	9,919	9,795	9,281
2020	10,813	10,826	10,104	9,654	9,507	9,093
2021	10,597	10,590	9,958	9,416	9,254	8,923
2022	10,410	10,382	9,826	9,210	9,035	8,769
2023	10,215	10,201	9,688	9,002	8,848	8,614
2024	10,042	10,049	9,549	8,818	8,690	8,462
2025	9,889	9,917	9,424	8,657	8,556	8,325
2026	9,736	9,792	9,306	8,499	8,430	8,198
2027	9,611	9,681	9,194	8,518	8,494	8,204
2028	9,306	9,264	8,972	8,456	8,374	8,182
2029	8,319	7,701	8,306	7,691	7,102	7,689
2030	6,979	5,847	7,257	6,562	5,499	6,820
2031	5,903	4,493	6,396	5,595	4,265	6,053
2032	5,021	3,472	5,667	4,758	3,295	5,362
2033	4,292	2,701	5,028	4,066	2,564	4,757
2034	3,646	2,111	4,479	3,454	2,003	4,236
2035	3,139	1,653	3,986	2,973	1,568	3,769
2036	2,688	1,313	3,556	2,545	1,245	3,361
2037	2,306	1,035	3,181	2,183	981	3,006
2038	1,979	826	2,833	1,873	783	2,677
2039	1,708	660	2,542	1,617	625	2,401
2040	1,479	535	2,285	1,399	507	2,158
2041	1,278	444	2,049	1,209	421	1,934
2042	1,118	361	1,840	1,057	342	1,738

1.40.4 Recovery / Processing Equipment

As described in Section 1.20.5 above, at the time the Phase VI Landfill is scheduled to be put in operation in January 2013, the RIRRC is expected to have in place a total gas recovery and destruction capacity of 30,682 scfm. This total capacity will be comprised of: 1) a 6,000 scfm enclosed ultra-low emissions (ULE) flare located at the southern juncture of Phases IV and V; 2) the two 2,000 scfm portable utility flares located at the northwest and southwest corners of Phases II/III (RF-2 and RF-3); 3) the 450 scfm remote utility flare (RF-1) connected to the leachate collection system along the western perimeter of Phases II/III;4) 12,200 scfm at the new Stage 3 facility; 5) 6,000 scfm for the new ground flares at the new gas treatment and compression facility; and 6) the 2,032 scfm Stage II Power Plant. The 5,100 scfm main LFG-to-energy power plant, the two free standing Deutz generators at the main Ridgewood Power Management facility with a combined capacity of 820 scfm, and the two older Perennial flares with a combined capacity of 2,600 scfm will have been taken off-line by December 2010 to make way for the construction of the Phase VI baseliner.

The Central Landfill LFG generation model was run to determine the peak rate of LFG generation for the entire site, inclusive of Phase VI, under the Accelerated Gas Generation Case scenario. The model projects that peak accelerated site wide rate of LFG generation has occured in the year 2008 at approximately 17,938 scfm with a peak accelerated recoverable rate of 16,100 having also occurred in 2008. Including the previously noted 20% factor of safety allowance, the peak LFG recovery and destruction requirement for the entire site is 19,320 scfm in the year 2009. The destruction capacity requirement is currently satisfied through a combination of the Ridgewood Power Management Plant capacity of 5,100 scfm, the two existing 2,000 scfm remote flares, the existing 450 scfm remote flare, the two Deutz generators at the existing Ridgewood facility (i.e., 820 scfm combined) the ULE enclosed flare with a capacity of 6,000 scfm, the Stage 2 Power Plant with a capacity of 2,032 scfm and the 2,600 scfm main backup flares (i.e., the Perennials) which have a combined capacity of 18,402 scfm.

As described in Section 1.20.5 above, Ridgewood Power Management is constructing a new electrical power station (designated Stage 3) with a LFG destruction capacity of approximately 12,200 scfm, to be online in July 2011. Two new 3,000 scfm ground flares will be installed concurrently with the new gas compression and treatment facility, all of which are expected to be on-line by December 2010. Note, that the new flares will address the shortfall in destruction capacity from the decommissioning of the main plant, Deutz engines, and Perennial flares in December 2010, prior to the Stage 3 plant being placed online. Once the new Stage 3 facilities are constructed the site will be serviced by 30,682 scfm of capacity which is well in excess of the highest gas generation predictions. This capacity will consist of: 12,200 scfm at the new Stage 3 facility, 2032 scfm at the Stage 2 power plant, 6,000 scfm for the two new ground flares at the gas treatment and compression facility, 6,000 scfm for the ULE flare, and a combined 4,450 for the 3 remote flares.

1.40.5 Permanent Gas Beneficial Use and Destruction Systems

The Phase VI Landfill is expected to have a peak rate of LFG recovery of about 9,106 scfm (accelerated case recovery conditions plus 20 percent). Primary destruction of landfill gas recovered during the operational stage of the Phase VI Landfill will be through a beneficial use project capturing LFG from Phases I through VI for the generation of electricity via combined cycle turbines.

The goal of the collection and destruction system design is to distribute the landfill gas to maximize electrical generation. In the event that excess landfill gas is recovered, or generation is curtailed, gas can be redirected to a number of gas destruction flares through a series of interconnected headers.

Two new enclosed flares will be constructed and serve as backup to the power generating project serving as the primary gas destruction device for the Phase VI Landfill. The enclosed flares, to be collocated with the gas treatment and compression facility, will have a design capacity of 3,000 scfm each. The systems will use an enclosed flare stacks designed to meet the Best Available Control Technology (BACT) standards for gas destruction.

Enclosed flares are designed to contain the entire combustion process within the stack with no flame visible from outside the unit. The enclosed flare units consist of burners located at the base of the stack encompassed by a tall refractory lined chamber open at the top to exhaust the combustion products. Adjustable louvered openings near the bottom of the flare stack allow air flow to the burners as an oxygen source for combustion and for controlling stack temperatures. The enclosed flare design offers better control over combustion temperature and residence time to achieve higher destruction efficiencies than the open style flare. In addition, the enclosed flare, unlike the open style, contains combustion sampling ports to allow testing of the stack gases for demonstrating compliance with state and federal emissions standards.

Common ancillary equipment and appurtenances to the flare stacks include:

- Pilot gas and ignition systems
- Flame arrestors
- Temperature probes and flame sensors
- Flare control stations
- Control valves
- Concrete support pad
- Electrical and mechanical systems

1.40.6 Gas System Expandability and Filling Compatibility

As with the preceding landfill phases, the gas collection system for the Phase VI Landfill has been designed to allow expansion as areas of the landfill are filled and brought to final grade. The main headers are sized to permit the maximum anticipated recoverable gas flow from Phase VI with head losses kept within the acceptable range of the recovery facilities (i.e., blower systems). The gas headers were sized to maintain, where possible, maximum velocities of less than 2,000 feet per minute in order to limit headlosses and allow for proper condensate drainage. At the termination of gas main headers and branch lines where future expansion is anticipated, a blind flange will be installed. When the gas system is expanded, the blind flange will be removed and the new header will be bolted to the existing header using a flanged fitting.

Ancillary gas facilities, such as condensate traps and flow monitoring stations, are also sized to handle the maximum projected future flow rate through that section of the system.

Since this will be an active landfill site with filling activities at times occurring in close proximity to the gas collection system, the facilities are designed and will be constructed to be compatible with landfilling and minimize any impacts of filling activities on the gas collection system. Where there is the potential for heavy equipment to cross a gas header (i.e., compactor, dozer, or large dump truck), the piping will be buried two feet or more below the surface and surrounded by a well compacted envelope of gravel for resistance to crushing. Where heavy and frequent traffic is anticipated to cross over a gas header, such as haul roads, the pipe will be placed in a larger diameter pipe sleeve, typically constructed of ductile iron (DIP) or corrugated metal pipe (CMP). In extreme cases, where the pipe depth is limited to under 2-feet, a concrete cap can be constructed over the pipe to distribute the load.

1.40.7 Corrosion, Heat and Settlement Resistance

The gas collection, recovery and control systems will use materials of construction that are resistant to the effects of corrosion and heat. The gas collection system design incorporates measures that provide protection against landfill settlement forces. All components of the gas collection system that come into contact with LFG will be made of plastic based materials that are not subject to corrosion. Components of the gas and condensate handling equipment (i.e., blowers, compressors, pumps, valves, knockout tanks) will be constructed of plastic based materials, stainless-steel, aluminum, or carbon-steel internally protected with corrosion resistant coatings.

The gas collection system piping and fittings will be rated for the maximum expected temperatures in the landfill environment (i.e., 150 degrees F.). Above grade gas piping at the flare system will be designed to accommodate the expansion and contraction effects of exposure to atmospheric temperature changes. Where practical, the above grade piping will be protected from the environment with insulation and aluminum or plastic jacketing. As needed, the above grade main header piping connecting to the gas moving and treatment equipment is braced against unacceptable movements. All parts of the gas control system that are exposed continuously to high heat conditions (i.e., flare stack) will be constructed of materials that are not subject to the deleterious effects of high heat.

Settlement of the landfill is inevitable and the gas collection system has been designed to remain intact with settlement impacts. The gas collection headers will be constructed of high density polyethylene (HDPE) pipe, sized as appropriate for the loading conditions. This pipe material is able to withstand significant loading and settlement without crushing or rupturing. The gas headers will be installed at a slope of at least 4 percent to provide condensate drainage even with some settlement. When header sections settle sufficiently to cause a condensate blockage, they will be located, excavated and regraded to restore their original slope and drainage. The gas system operator uses a number of methods for evaluating and locating blockages, primarily consisting of sequential gas pressure and flow readings along the suspect pipe segments to identify vacuum surges and/or significant pressure variations indicative of watered in conditions. Visual interior pipe inspections are generally considered a last resort for very difficult situations.

1.50 LFG MANAGEMENT OPERATIONS

Operations of the LFG management systems are conducted, under contract to RIRRC, by RGS and will span from the initial start-up of the interim/operational gas recovery trenches within the active landfilling phase; through post-closure operation of the vertical extraction wells and beneficial gas use. LFG management operations include: routine activities of inspecting and balancing the collection system; operation and maintenance of the gas recovery and destruction equipment; performing repairs and improvements to the wellfield components impacted by settlement or damaged by landfilling equipment; collecting, treating, and disposing of accumulated condensate; assuring personnel health and safety through proper safety training and implementation of safety procedures; compiling and maintaining operation and maintenance records, reporting of required information to various regulatory agencies, and controlling LFG systems' security.

1.50.1 Gas Collection System

Operation of the collection system, including maintenance, is required to maintain effective and efficient collection of LFG. Gas collection trenches and wells will be routinely monitored, generally monthly, for various operating parameters such as gas content (methane, a measure of gas quality, and oxygen, an indicator of air intrusion), vacuum levels (well and line sides), and gas temperature. Wells and trenches will also be assessed on a regular basis (e.g., annually or semi-annually) for the presence of water and well bore collapse. Adjustments to the well or trench control valve position are made in response to gas quality data. A well or trench exhibiting low methane (<30% CH_4) and/or high oxygen content (>5% O_2), would be throttled back, or closed to reduce the vacuum level, flow rate, and temperature. Conversely, a well or trench exhibiting high methane (>55%) and little or no oxygen may have its control valve opened an additional amount or, if fully open, possibly an increase of the total system vacuum.

A high gas temperature (>131 Deg. F.) can be an indicator of a possible underground fire. When such a condition is encountered, the well or trench may be throttled back and steps to investigate and/or mitigate the conditions immediately implemented. The well or trench may be monitored for the presence of carbon monoxide which is a byproduct of and an indicator of, combustion. Such steps include placement of low permeability soils over the area suspected of allowing oxygen into the landfill. The well or trench is generally kept at low or no flow until temperatures decline and there is assurance that the fire, if present, has been extinguished.

At the same time the routine trench or well monitoring is performed, a physical inspection is conducted. The technician looks for signs of deficiencies including settlement of the well or header piping, loose flex hose connection, fully extended flex hose (due to landfill settlement), cracked piping, missing or broken wellhead components, leaking well seal, and blocked or malfunctioning condensate trap. Such defects are noted on the technicians log sheet and repair work is scheduled.

Surging vacuum conditions observed during the gas collection system monitoring would be a strong indicator of a condensate blockage at some location within the header system. The general location of the blockage would be identified by the technician based on the degree of surging seen at individual wells or trenches. The closer the technician is to the blockage, the greater the intensity of the surging observed. Since condensate blockages are usually due to header settlements, once the technician has found the general location of the blockage, they will look for signs along the header alignment where the ground has settled. The settled header piping is then excavated, regraded and backfilled to remove the condensate blockage by restoring proper condensate drainage.

A sudden or dramatic rise in the oxygen content of the gas at the gas recovery facilities would alert the technician to a breach somewhere in the gas collection system. This may be caused by a flex hose coming loose or pulling off the header connection, rupturing of one of the gas headers by landfill or construction equipment, or inadvertent opening of a valve or blind flange allowing air to be drawn into the system. Upon learning of the high oxygen condition at the recovery facilities, the technician would notify personnel in charge of the gas control/destruction facilities to minimize disruption or damage of those facilities, track down the source of the air intrusion by working upstream from the gas recovery site sampling the gas at strategic junction points to identify which direction the oxygen is coming from. Once the air leak is discovered, the problem can generally be corrected immediately, unless the defect is serious, in which case the affected portion of the wellfield is turned off until repairs can be completed.

1.50.2 Condensate Collection, Treatment and Disposal

A byproduct of collecting LFG is the generation of condensate in the gas header systems and recovery facilities. Where feasible, condensate generated within the gas headers will be directed to condensate traps located at low points of the gas headers and other strategic locations throughout the collection system for return to the landfill. In some locations, there would be insufficient waste depth (i.e., where waste is less than 25 feet thick) to allow re-absorption of the condensate back into the lined landfill. In such instances, the condensate will be directed to the leachate collection system at the base of the landfill.

Condensate that leaves the confines of the landfill within the collection headers or that is produced within the gas recovery equipment may not be returned to the landfill and will be collected for treatment and disposal. Based on a peak LFG recovery rate of 10,300 scfm from the Phase VI Landfill, the estimated maximum daily volume of condensate that will be produced at the recovery and flaring facilities is approximately 31,000 gallons per day. This value is derived from experience with the primary condensate volume produced at the existing Ridgewood Power Management gas recovery plant for a similar amount of recovered gas. This estimated amount of condensate corresponds to the volume that would be produced from recovery for flaring (beneficial use equipment generally requires drier gas necessitating chilling and compression which can generate significant volumes of secondary condensate).

The condensate generated away from the landfill will be directed to a condensate sewer system for transport to the leachate pretreatment system before being discharged to the Cranston public sewer system. Alternatively, this condensate will be collected in dedicated tanks for temporary storage then transported to an appropriate off-site disposal facility.

1.50.3 Gas Recovery / Processing Equipment

The gas recovery/mover equipment and gas treatment systems are being designed by others as part of the ongoing partnering agreement between RIRRC and Ridgewood Power Management. The following general description provides an overview of the primary system components.

a. Condensate Knockout Tank

Typically, the first stage of the gas recovery / processing system is removal of excess moisture in the gas by means of a condensate knockout tank. The operation of the knockout tank is essentially automated. The excess moisture, in the form of a mist, drops out of the gas stream in the knockout tank as a result of the reduced gas velocity, changing flow direction and accumulation on the tank mist pad. The condensate rises at the bottom of the knockout tank until it reaches a pre-set depth that triggers the operation of the condensate pump and opening of a solenoid valve on the knockout tank drain outlet to discharge the condensate to an adjacent condensate sewer manhole. Once the tank is pumped down the pump shuts off and, the solenoid valve closes and the cycle is repeated as the tank refills with condensate. Operational activities associated with the knockout tank include regular inspection of the tank site glass to ensure proper drainage inspection of the differential pressure gauge to ensure proper operation of the system and annual cleaning of the mesh pad to remove built-up grit and debris.

b. Gas Extraction Blowers

The gas recovery system will include a system of gas extraction blowers operating on an alternating basis. The blowers will be started in conjunction with the flare operation in order to avoid the discharge of raw gas. Adjustable frequency drives that vary the speed of the blowers will be used to control the rate of LFG flow and applied vacuum. The flare control system will include a process for automatically eliminating power to the blower motor and shutting down the blower in the event of the loss of flame in the flare. In the event of a blower shutdown, a fail closed valve on the inlet manifold is activated to prevent any discharge of raw gas.

Maintenance of the blowers includes routine lubrication of the blower bearings, inspection for excess vibration and noise, annual replacement of the bearings (as needed), and adjustment of the blower belts.

c. Condensate Pumping System

In the event that the gas treatment systems are tied into the on-site leachate pretreatment plant, condensate generated within the knockout tank will be pumped to a condensate sewer manhole in the vicinity of the gas recovery facilities. The knockout tank will be equipped with level sensors to operate the pumping system that discharges condensate from the tank to the sewer manhole. The level sensor will be set to start the pump at a pre-set level and shut the pump after the tank water level is lowered to another pre-set level. If the condensate level reaches a pre-set high level condition, an alarm will be triggered and a technician will be dispatched to the flare station to diagnose and correct the problem.

Pumping system maintenance involves routine inspection of the pump for proper operation and looking for signs of leaks or blockages. The condensate discharge piping is also inspected regularly to determine if there are any leaks, and the integrity of the pipe heat tracing and insulation is verified during sub-freezing conditions. Over an extended period of time, the condensate manhole may accumulate grit and debris as well as floatables that need to be removed by a thorough cleaning.

d. Flow Metering Equipment

The rate of gas flow and cumulative gas volume recorded by the flow metering equipment will be routinely read by the technician in connection with the system operation. Maintenance of the flow metering equipment is limited to regular inspection for proper operation and any unusual readings, monthly accuracy checks using an annubar and annual recalibration by a certified technician.

e. Motor Control Center

The motor control center contains all the controls and indicators for the operation of the gas recovery blowers, condensate pumps, knockout tank and sump levels, and miscellaneous devices. Operation of the motor control center is automated once power is supplied to the unit and the equipment controls are placed in the "AUTO" mode.

f. Other Components

RIRRC, in conjunction with Ridgewood Power Management, is currently evaluating the applicability and feasibility of several LFG treatment systems for siloxane and hydrogen sulfide removal. The selection and design of these systems is ongoing and permitting associated with them is being conducted by the gas system operator.

1.50.4 Gas Destruction System

On-site flare units will serve as backup to the primary electrical generating gas destruction equipment. The generating facilities are currently owned and operated by Ridgewood Power Management. Ridgewood Power Management has their own facility permits and operation and maintenance plans that have been filed with RIDEM's Office of Air Resources. Backup flaring systems are currently owned by RIRRC and operated by Ridgewood Gas Services (RGS) under contract to RIRRC, CGLP and Ridgewood Power Management.

1.50.5 Safety Features and Procedures

The first and foremost priority of the LFG management system operations is the safety and health of the site personnel and the general public. By its very nature, working around an active gas collection system and flaring facilities presents certain dangers that the operating personnel must be aware of and trained to manage. Not only does uncontrolled LFG present risks of combustion or explosion, in confined spaces or areas of limited ventilation LFG can accumulate and raise the risk of impacting breathing and even cause asphyxiation. The presence of toxic gases such as hydrogen sulfide can also make LFG toxic by inhalation. Operation of mechanical and electrical equipment associated with the flaring system, including gas blowers, condensate pumps, and power supplies, present risks of injury or shock.

The health and safety of the technical staff and site personnel assigned to the LFG management system operations will be enhanced by providing the personnel with appropriate safety clothing and equipment, and requiring all personnel to receive the proper OSHA safety training in mechanical and electrical machinery operations, hazardous waste operations and confined space entry, including the use of self-contained breathing apparatus.

The gas mover/treatment and flaring system power supplies and wiring will be installed to meet or exceed the requirements of the local and state building codes. Fire extinguishers will be located at strategic locations around the facility per applicable local and state fire codes.

The flare systems will include an emergency shutdown "panic button" to immediately disengage power to all equipment and shut off the supply of gas to the flare stack. The flare system will also include pre-set out of range operating levels such as flare temperature extremes or loss of flame that will signal a complete shutdown of the flaring equipment. Any unscheduled shutdown of the flare system will be accompanied by the activation of an alarm condition transmitted via telemetry to maintenance staff for immediate attention.

Flare and gas mover/treatment sites will be equipped with suitable lighting to provide operations staff with sufficient illumination to safely perform their routine tasks and emergency repairs during all hours of the day or night.

1.50.6 Emergency Shutdown Procedures

The Phase VI LFG management system will incorporate safety features and written operating procedures for shutting down the gas recovery and flaring equipment in the event of an emergency. The blower and flare control panel will be equipped with, on its front in an easy to reach location, an emergency "panic button" that when pushed will immediately eliminate power fed to all recovery and flaring equipment shutting down the entire system. The manual emergency shutdown procedure will stop the gas blowers, close the main header inlet valve, eliminate flare combustion, and shut all other associated equipment such as condensate pumps.

The gas recovery and flaring equipment will also follow an emergency shutdown procedure in the event of a critical alarm condition including loss of flame in the flare, operation of the flare outside its normal temperature range, high water level in the condensate knockout tank, or excessive vibration or temperature at the blower. In the event that any of the preceding conditions occur, the blower and flare control panel will send a signal to shut down the system and activate an alarm to alert the system operator.

1.50.7 Record Keeping and Reporting

The Phase VI LFG Management System operator will be responsible for maintaining appropriate records of the operation and maintenance of the gas collection, recovery and flaring systems as well as records of problems that develop. LFG system technicians will be responsible for performing routine monitoring and logging of the collection system operation. The following paragraphs provide a general overview of the routine monitoring programs. Data at each wellhead that will be collected at least monthly includes:

- LFG quality (methane, oxygen and/or nitrogen content)
- Level of vacuum applied
- Gas temperature
- Wellhead control valve position and adjustments
- Physical conditions observed and notes on repairs needed

The gas recovery and flaring system will be inspected daily (Monday through Friday) by the technicians as well as any time an alarm condition is sounded. Information regarding the recovery and flaring system operation that will be regularly monitored and recorded includes:

- Total gas flow rate at the discharge from the blowers to the power plants and flare units
- Vacuum level applied on the wellfield
- Gas quality (i.e., methane, carbon dioxide and oxygen)
- Flare operating temperature, if operating
- Knockout tank headloss
- General physical conditions of the equipment and observations of unusual noises or vibrations indicating maintenance or repairs are necessary

In addition to the routine monitoring information and data collected by the gas system technicians, maintenance and repair records will also be kept. Maintenance and repair activities to be recorded would include lowering wellheads protruding as a result of landfill settlement, regrading header line sags, repairs to cracked or open headers and wellheads allowing air intrusion, filling over headers uncovered by washouts, lubrication and replacement of blower bearings, cleaning of the condensate storage tank, replacement of the flare pilot gas supply, and other similar routine maintenance items.

All LFG management system records collected by the site technicians will be compiled onto appropriate electronic spreadsheet files for reference by the operator and preserving and reporting to local, state or federal authorities as required. Written field logs and diaries will also be stored on-site in a secured file cabinet. An as-built drawing of the entire gas collection and control system is maintained by the gas system operator and updated monthly.

1.50.8 Site Security

The landfill site and facilities are monitored twenty-four hours a day, seven days a week by RIRRC staff at the site entrance, as well as by patrols that circulate around the site. The gas mover, treatment and flaring facilities will be located within areas enclosed by a high chain link fence with high intensity security lighting. Signs will be posted around the flare station site indicating no trespassing and describing the area as a high hazard location to discourage intrusion and vandalism.

1.60 CONTINGENCY PLAN

The purpose of a contingency plan is to identify the specific steps and procedures to be followed in response to unplanned events or incidents that disrupt normal conditions of the gas management system construction or operation. Issues covered by the contingency plan include:

- Odors and emissions
- Gas migration
- Objectionable noise
- Personal injury
- Fires and explosions
- Emergency operations

1.60.1 Odors and Emissions

LFG contains a number of elements that produce odors such as hydrogen sulfide, mercaptans, certain volatile organic and aromatic compounds, and other odor producing agents. The uncontrolled release of LFG to the atmosphere that contains these odorous elements, depending upon the direction and intensity of the wind, can lead to objectionable odors occurring off-site in neighborhoods surrounding the landfill site.

The RGS staff currently conducts regular odor and hydrogen sulfide surveys on-site around the perimeter of the landfill as well as off-site within neighborhoods adjacent to the landfill. This same approach will continue with the expansion into the Phase VI Landfill for the purpose of detecting LFG related odors and implementing corrective actions before the odors become an off-site problem.

The first step that is to be taken upon detection of LFG related odors is verifying that the gas recovery and destruction equipment is operating properly and that no alarm conditions has occurred. The flare stations will be inspected and the operator will check that the blowers are functioning. The operator will also confirm that there are no leaks in the blower discharge piping that could release LFG under pressure. If problems are discovered with any component of the gas recovery and destruction system, immediate steps will be implemented to correct the deficiencies.

Once the electrical generating facilities and/or flare stations operation is verified, the operator will conduct a drive-through of the entire site searching for evidence of uncontrolled release of LFG. If a suspect area is identified, the LFG technician will use a gas detector to scan the surface area for excessive emissions of methane or hydrogen sulfide that would indicate the uncontrolled release of LFG. If the technician discovers an area that has excessive emissions, the gas collection wells or trenches in the same vicinity will be inspected to determine if they are operating properly. The well's vacuum level and gas quality will be checked and the wells will be inspected for any signs of blockage or reduced gas extraction. Defects at the well or trench determined by the inspection will be immediately repaired in order to restore its full operational capabilities. In some instances, it may only require the opening of the well or trench control valve to increase the level of vacuum and rate of gas recovery from the problem area. Additional vacuum may also need to be exerted to the entire area by turning up the blower systems or further opening up a header valve that controls vacuum to a zone of the wellfield.

If the LFG technician identifies defects in the landfill cover, such as crevices, washouts, or insufficient cover depth, during the surface inspection looking for the source of odors, additional cover materials would be brought to the problem area, graded and compacted to adequately cover the surface. The placement of additional cover material over surface defects would be performed in conjunction with the adjustments or repairs to the wellfield, as necessary.

1.60.2 Gas Migration

Monitoring wells will be installed between the base of the landfill and the property boundary to allow testing for the presence of migrating LFG. RIDEM's allowable regulatory threshold for the concentration of methane gas at the property boundary is 25 percent of the Lower Explosive Level (LEL) which is equivalent to 1.25 percent methane. Monitoring of the perimeter gas monitoring wells will be conducted on a quarterly basis as well as any time there is suspicion of possible gas migration.

If elevated levels of gas were to be detected in any of the monitoring wells or possibly underground utility vaults or structures in proximity to the landfill site, corrective actions would be implemented to mitigate the gas migration. The remedial responses to gas migration problems are very similar to those described for addressing odor and emission problems. The gas recovery and flaring systems will be inspected to assure they are on-line and properly operating. The gas collection facilities in proximity and contiguous to the migration problem area will be checked to determine if the wells or trenches are deficient and in need of adjustments or repairs. The level of vacuum exerted on the wells or trenches in proximity to the migration area will be increased as a means of reducing the lateral movement of gas beyond the landfill boundary. The monitoring wells will be tested on a daily basis for the presence of LFG until levels drop below the regulatory threshold.

1.60.3 Noise

Noise could be a problem both during construction of the LFG facilities as well as their operation. Construction noise should not be a significant problem if operations are limited to normal landfill business hours since the same or similar equipment that is used for landfill operations would be used for constructing the gas collection system and the gas recovery and flaring systems. Gas collection trenches and header pipes are built with the use of excavators, loaders, dump trucks and dozers. Construction of vertical gas extraction wells is accomplished with a bucket auger type drill rig that uses rotary motion to core through the landfill as opposed to the much noisier impact motion of a pile driver. The allowable hours of operation for the gas system construction equipment would be limited to the landfill operational hours of 6:00 am to 4:00 pm weekdays and 6:00 am to noon on Saturdays.

Possible sources of noise related to operation of the LFG system include the gas blowers, gas compressors, chillers and other treatment components, and the flare stack. The blowers will likely be the centrifugal type that could generate unacceptable noise levels at certain operating ranges if not properly designed and installed. Maximum acceptable sound levels will be specified for the blowers that comply with local noise ordinances. If necessary, the blower manufacturer will be required to equip the blowers with sound-proofing enclosures and intake silencers that can be tested and verified for compliance. These same precautions will be taken in the design and installation of compressors and gas treatment system components.

It is possible under certain conditions to have the flow of gas and combustion air through a flare stack create noise levels that can travel significant distances. This noise is associated with the development of harmonic frequencies in the flare stack at specific rates of gas flow. The flare manufacturer will be required to demonstrate that the flare will not generate these harmonic frequencies and unacceptable noise levels over the full range of the operation in terms of gas flow and quality.

1.60.4 Personal Injury

Working around a landfill and LFG facilities presents inherent risks of personal injury that must be mitigated through use of personal protection measures by on-site workers. In the event that personal injury is sustained by a worker, immediate and appropriate actions must be taken to stabilize the individual and secure the necessary medical attention. A Health and Safety Plan providing detailed information on personal injury prevention and responses will be developed for the LFG Management personnel. A designated Health and Safety Officer will be responsible for the coordination and implementation of the Health and Safety Plan.

Personal injury hazards associated with working on a LFG facility include the following:

- Falling into open excavations, bore holes, or manholes
- Tripping over uneven terrain or equipment
- Cuts, scrapes and bruises
- Explosive environments
- Restricted breathing or possible asphyxiation from oxygen deficient atmospheres
- Toxic gases such as hydrogen sulfide
- Infections and diseases
- Burns from coming in contact with hot surfaces or flames
- Hearing impairment from exposure to dangerous noise levels related to equipment operation

The first defense for personal safety is remaining mentally alert, recognizing where hazards exist and following appropriate safety procedures. Personal safety measures that will be contained in the Health and Safety Plan include:

- Use of safety harnesses and safety lines, as appropriate, when working in the vicinity of trenches, vaults and openings in the ground
- Covering excavations and other openings at the end of the work day
- Wearing protective clothing, chemically protective coveralls, boots, gloves, and safety glasses as appropriate for the work requirements
- Having a first aid kit, eye wash station, fire extinguisher, and safety blanket readily available for emergency use
- Testing of the atmosphere in confined spaces for sufficient oxygen, explosive gases, and hydrogen sulfide before entry

- Use of positive ventilation equipment to provide continuous fresh air to confined spaces with workers present
- Wearing of Self Contained Breathing Apparatus or other respiratory protection as appropriate for the level of hazard
- Use of hearing protection when work requires exposure to loud or repetitive type noises

In the event of serious injury requiring emergency medical attention, contact will be made with appropriate emergency response services and the designated Health and Safety Officer will be notified. Emergency phone numbers will be posted in one or more conspicuous locations on-site and include:

- Fire Department
- Ambulance Service
- Poison Control Center
- Police Department
- Hospital
- RIDEM Division of Air and Hazardous Materials (if any release of hazardous materials)

1.60.5 Fires/Explosions

The presence of LFG means there is the potential for fires or explosions to occur under certain conditions. Methane is explosive in air at concentrations between 5 percent and 15 percent (referred to as the lower and upper explosive limits, respectively). Accordingly, precautions must be taken while working on the landfill and around equipment and facilities handling LFG. In the event of a LFG fire and/or explosion, site personnel must be trained on proper responses to personal injuries and mitigation of any hazards to people and property.

Landfill fires can be ignited by activities associated with the construction of LFG collection systems. A LFG fire could be ignited by an excavator digging a trench for installation of a gas header. These types of fires are not always readily apparent since methane burns with an almost invisible flame. However, the intense heat and noise given off by a LFG fire usually provides the evidence of such a fire. If such an incident were to occur, the best response would be immediately covering the hole or open excavation to cut off the supply or oxygen. RIRRC also utilizes a water truck with a water cannon that can be used to assist in the control of combustion. This is typically done by dumping a large load of soil that is stockpiled nearby into the hole or trench covering the burning materials. This step is usually sufficient to extinguish the fire. However, an emergency call should still be placed to the fire department so they can be dispatched to the site and take any further steps to make sure conditions are returned to normal.

Fires can also be started by spontaneous combustion underground as the result of overdrawing on a vertical gas extraction well or horizontal trench that induces air into the hot decomposing waste. These types of fires are more difficult to detect and extinguish than the construction related fires. Underground fires as a result of air intrusion can go undetected for several days or longer since there is no opening in the landfill surface with personnel nearby to sense the heat of the fire. Instead, such a fire is usually discovered by the observation of some amount of smoldering of burning waste or steam given off by the heat of combustion and presence of moisture in the wastes. There may also be settling of the landfill surface above the area of the fire due to underground voids created by burning wastes. Elevated temperatures and the presence of carbon monoxide in gas extraction wells or trenches are also an indicator of a potential subsurface fire. Once such a fire is discovered, the fire department should be immediately contacted along with the landfill supervisor and site personnel. That portion of the gas collection system affiliated with the underground fire area should be shut down to discourage air intrusion until the fire is under control. Upon the direction of fire officials, the affected area may also need to be excavated to get to the source of the fire in order to extinguish it.

Explosions generally occur by an ignition source coming in contact with LFG diluted by air near or above the landfill surface. In comparison, the methane concentration within the landfill will typically be above the upper explosive limit of 15 percent. An open flame from a cigarette or spark by a tool in the vicinity of a hole or open excavation venting LFG can lead to an explosion. Explosions can also occur off-site as a result of migrating LFG entering a building or other confined space where an ignition source is present. In the event of a LFG explosion, fire and rescue services should be immediately contacted to bring the situation under control and provide emergency medical attention to anyone injured by the explosion. In order to minimize the potential for on-site LFG explosions, no smoking rules on the landfill, around open excavations, or around gas handling and control equipment must be enforced, and only non-sparking rated tools should be used when working in the vicinity of any location where LFG may be emitted. Off-site explosions can be mitigated by routine inspection and testing of surface emissions and the perimeter gas monitoring wells to assure that fugitive gas migration is not occurring.

1.60.6 Emergency LFG System Operations

The normal operation of the LFG recovery and destruction systems will require a continuous source of electrical power to run the gas blowers and flaring equipment. Normal operations could be interrupted in the event of a power outage affecting the landfill area. In most cases power is restored within a few hours before there is a significant accumulation of gas within the landfill that could lead to offsite migration or odor problems. In those instances where normal power is not restored within a reasonable amount of time, emergency steps will need to be implemented to maintain proper LFG control.

The Phase VI LFG recovery and flaring system will be designed to permit the use of an emergency mobile generator unit to supply power to the facilities until normal utility power is restored. The emergency mobile generator unit will have sufficient capacity to operate a minimum of two of the blower units as well as the flare system components and ancillary devices required to run the recovery and flaring system. The electrical system will be capable of being switched from utility service to the emergency generator. The emergency generator unit will either be owned by RIRRC and stored on-site or readily available from a local supplier that can be mobilized within 2-hours of notification.

In the event that the Phase VI LFG recovery, beneficial use, and flaring system goes offline for an extended period of time due to a major equipment failure, one or more of the RIRRC's existing remote flaring units could be relocated to the Phase VI flare station or temporarily hooked up to the Phase VI main gas header, or gas can be re-routed to the remote flares via the perimeter header system to provide temporary gas control.

1.60.7 Operation and Maintenance Transition

Ridgewood Gas Services (RGS) and Ridgewood Power Management operate and maintain (O&M) the gas collection and electrical generation systems, respectively. They will continue to do so as long as electrical generation is economic, after which point this gas facilities contingency plan will be implemented. The contingency plan consists of RIRRC taking over control of the systems and burning recovered gas in the on-site flares. At this time gas generation will be down significantly from where it is today and the existing and proposed on-site flaring capacity and collection infrastructure will be sufficient to maintain adequate gas and odor control. RIRRC personnel, or a designated subcontractor, will continue to adjust, inspect and repair gas collection systems as needed, and provide semi-annual preventative maintenance (P&M) and as needed repair of the flaring equipment.

1.70 CLOSURE PLAN

1.70.1 Closure Date

At the current projected rate of waste disposal, the Phase VI Landfill is expected to be at its capacity some time in the year 2030. Closure would begin soon thereafter including completion of the final gas collection system in conjunction with the placement of a final landfill cap.

1.70.2 Access Restrictions

Access to the landfill in general and to the gas management systems specifically, will be restricted by site security. This particular site has the capacity and is expected to serve as the primary waste disposal facility for the State for many years into the future. Site security measures will be in place during normal operating hours as well as off-hours to keep close watch on the gas management systems to prevent property vandalism and injury to unauthorized personnel.

1.70.3 Controlling Air Emissions

The LFG management systems will need to operate for many years after the Phase VI Landfill has ceased receiving wastes in order to control air emissions as well as prevent gas migration. Air emissions will be further mitigated after the landfill has closed by the installation of an impermeable membrane over the area in combination with the active operation of the LFG collection system. Post-closure monitoring of the landfill will provide the means of verifying that surface emissions do not exceed the regulatory limit of 500 ppmV of methane.

1.70.4 Post Closure Operation

As noted above, the LFG management systems will continue to operate for many years subsequent to closure of the landfill. Active operation of the LFG management system may be expected to last upwards of 30 years after the site has closed in order to sufficiently control LFG emissions, odors and gas migration. RIRRC's staff or an assigned vendor will be responsible for the operation and maintenance of the LFG management systems for the duration of their active use.

At some point in the future, the rate of waste decomposition and associated gas production will diminish to the point where active recovery and flaring will no longer be required. At that time, the gas collection system will be deactivated and the gas recovery and flaring system will be dismantled and removed from the site or, if still usable, it may be relocated to a future landfill phase. It is anticipated that the gas collection system will be abandoned in place to avoid disturbing the landfill cap. The wellheads may be removed from the well casings and allowed to passively vent to limit any buildup of residual gas, as long as air emissions limits are not exceeded.

1.70.5 Capital Closure Costs

The capital costs of the closure of the Phase VI Landfill associated with the gas management systems are limited to the installation of the final gas collection system. In order to control emissions and odors during the active use of the Phase VI Landfill, most of the gas collection system will be installed and on-line. Some final wells may need to be installed after the site has reached its closure date to replace buried or damaged wells and to provide complete wellfield zone of influence coverage of the entire Phase VI area. A final gas collection header system would also be installed once the synthetic membrane cap is placed over the surface. The total estimated capital cost for the final LFG collection system installation associated with the closure of the Phase VI Landfill is $3.7 million in 2007 dollars broken down as shown on Table 9-1. This estimate does not include any operation and maintenance costs.

1.70.6 Future Facility Use

There are no short-term or long-term use plans for the Phase VI Landfill area following closure other than as an area of the overall landfill site.

ATTACHMENT A

GZA GeoEnvironmental, Inc. (GZA) prepared this Basis of Design Report for the Phase VI Landfill gas collection system at the Central Landfill in Johnston, Rhode Island on behalf of our client the Rhode Island Resource Recovery Corporation (RIRRC). The package consists of this overview of the design rational, associated assumptions and supporting calculations. Drawing and figures referenced in this document refer to the June 2009 plan consisting of ten 24" x 36" sheets. The design was prepared in accordance with the set conditions of Engagement of our July 1, 2007 Environmental Services Contract.

This design is for permit application purposes and is not intended to be used for final system construction. Construction drawings will need to be developed to implement full system construction once RIDEM has approved the concepts provided here.

BASIS OF DESIGN/OBJECTIVES

The new gas collection system in the Phase VI Landfill must address a number of issues. First, the system must provide for the efficient collection of landfill gas (LFG) from the Phase VI cell both during operations and final closure. Second, the complex header system must serve as an integral part of a site-wide system that permits LFG to be moved around the entire Central Landfill facility to various destruction devices, including the proposed Gas Cleanup and Compression Station. Lastly, the LFG System must be compatible with the final landfill closure system consisting of a new permanent synthetic cap to be installed on the Phase VI cell at closure. The final closure LFG system needs to be completed primarily above the cap where maintenance on the system can be performed as needed in the future. As directed, this design takes into account gas generation from Phase VI only; the system, including the perimeter header and gas line to the Gas Cleanup and Compression Station, was not sized to handle gas flows from any other landfill cell. Note that the line from the Gas Cleanup and Compression Station to the Landfill Gas to Energy (LFGTE) CO-GEN Plant is shown as a 16" steel compressed gas line. GZA did not design this transmission line.

LANDFILL GAS COLLECTION SYSTEM OVERVIEW

This gas collection system design supersedes the previous design prepared by GZA, as presented in the Phase VI Landfill Permit Application dated April 2007 and supersedes the Stantec Phase VI Gas System Conceptual Layout presented in their "Landfill Gas and Leachate Collection System Engineering Study, Central Landfill LFGTE Redevelopment Draft Report". This design builds upon the designs presented in those two reports. In general, the final post-closure LFG collection system piping layout is taken from the Stantec report, with slight modification.

As was employed for landfill Phases IV and V, the new Phase VI LFG collection system consists of an interim "operational phase" system and a final "post closure phase" system. The interim system will be made up of perforated horizontal HDPE collection pipes in stone filled trenches installed in lifts of waste during active landfill operations. A typical landfill gas collection trench is shown on the attached Proposed Phase VI Landfill June 2009 Revision 2 plan sheets. The horizontal gas collection trenches are constructed of perforated 8-inch ID HDPE pipe sections butt-fused together. The pipe used will vary between SDR-9, SDR-11, and SDR-17 depending upon the loading/depth of burial as discussed later in this report.

The end of each trench collector will be equipped with an 8-inch solid pipe connecting to an HDPE header leading to a centralized gas recovery and control system. The trenches will utilize a staggered perforation pattern, described in the table below.

Trench Segment, in Thirds*	Perforation Row Spacing
First	6.6"
Second	3.3"
Third	3"

*Note, First, Second and Third refer to the trench segment position moving from the outside landfill slope in.

This pattern was developed in order to achieve a more uniform distribution of vacuum in the long collection trench. We recommend a pilot test be performed in Phase V or the earlier stages of Phase VI to evaluate the effectiveness of this approach. An example perforation pattern is displayed in the attached plan set.

The post-closure system will be made of approximately 171 LFG collection wells and an above cap piping system. The LFG extraction wells consist of an 8-inch outside diameter (OD) SDR-11 high-density polyethylene (HDPE) perforated pipe placed vertically in the center of a 36-inch diameter borehole drilled through the refuse to depths ranging between 40 feet and 100 feet deep. The first 20 feet below grade of each well is solid 8-inch OD HDPE riser pipe, with a stickup of approximately 4 feet above grade. The remainder of the well is made up of perforated well screen. The borehole is filled with 1 ½-inch to 3-inch washeded stone or clean, durable aggregate free of fines wells will be sealed with a bentonite plug as shown on the attached drawings to prevent air intrusion. A typical well installation detail is shown on the attached plan set.

The wells are to be installed in a roughly triangular pattern approximately 200 feet on center as shown on the attached plan set. Spacing was selected based on a radius of influence (ROI) of 100 feet estimated by testing conducted at the site by GZA in October 2000 and documented in a report entitled ***Radius of Influence Test-Stage I Interpretive Report, Central Landfill, dated November 2000***. Note, two horizontal collection trenches have been included in the final post closure design, in order to collect gas from a large area of the Phase I piggyback, where it is impractical to install wells due to the shallow depth (less than 40 feet) of waste in this area.

The final post-closure phase system will ultimately consist of roughly 171 new extraction wells and 20 condensate traps/drip legs. These will be installed through our prior to placement of, the 40 mil LLDPE membrane cap. Following construction of the cap a series of header pipes, valves and meters will be installed above the and connected to the methane collection wells, as well as, existing extraction membrane that are still functioning sufficiently.

The primary on landfill gas conveyance headers will consist of 8-inch, 10-inch, 12-inch, 18-inch, and 24-inch SDR 17 HDPE pipe sized based on velocity limitations, estimated headloss, maintenance considerations and future expansion potential. Gas collection laterals, those pipes that lead from the primary headers to the wells, will generally consist of 6-inch SDR 17 HDPE piping to accommodate anticipated settlement.

In order to efficiently route Phase VI gas to the various destruction devices, a perimeter header is proposed around the Phase VI cell. The perimeter header will be made up of 24-inch, 28-inch, and 36-inch SDR 17 HDPE piping. The perimeter header will service both the interim and post-closure systems. It will be necessary to construct it in phases as Phase VI cells are constructed. The proposed location of the Gas Cleanup Station is the former "Anderson Property" located at 73/75 Shun Pike. GZA understands that the gas system operator does not possess the necessary equipment to fuse 48 inch OD pipe and due to this, the largest pipe used in this design is 36 inch OD. The calculated pipe size for the end run of the perimeter header (after all Phase VI gas is collected) to the Gas Cleanup and Compression Station is 48 inches; However, due to equipment considerations, the 48-inch OD pipe has been replaced with two 36-inch pipes. Note, in headloss calculations, a 48-inch OD pipe was used to simulate two 36-inch OD pipes, in order to simplify regulations.

Once this system is completed, either in its entirety, or sequentially, the valves that were closed during construction can be opened, the system will then be bled of oxygen, and a vacuum can be applied throughout the new piping. At this time any of the temporary system, that has been in operation below the cap during construction, can be valved off, cut and capped, or left on line depending on gas quality and flows, as appropriate, creating a fully functional and maintainable system above the cap.

HEADER SYSTEM DESIGN APPROACH

The first step in the landfill closure header piping system design was to evaluate the Phase VI Permit Application Design and the Stantec Conceptual design. The well layout has been modified from the original permit application design and the modified from the Stantec Conceptual Design. A number of wells were removed because they did not meet our minimum well depth criteria of 40 feet. That is, wells were not placed in areas where the screen length would be less than 20 feet. We assumed to limit air infiltration during operation in an "uncapped" condition that wells must be constructed with at least 20 feet of solid pipe from ground surface; a 40 foot deep well will have 20 feet of solid pipe and 20 feet of screen. The goal was to design an efficient piping network which would deliver the collected gas to the proposed Gas Cleanup and Compression Station. This design takes into account collection of the gas at the Gas Cleanup and Compression Station and does not take into account headloss or other conditions within/through the Station.

Flows generated in Phase VI were assumed to be equal to 1.5 times (factor of safety of 1.5) the maximum recoverable LFG from the Accelerated Case of the Phase VI gas generation model from April 2007 (i.e., 10,289 standard cubic feet per minute, SCFM), resulting in a maximum total flow rate of 15,561 SCFM. The Phase VI gas generation model from April 2007, when the original Phase VI license application was submitted, assumed a ten year life span for Phase VI, with 1,200,000 tons of waste accepted yearly. Since the original license application was submitted, waste acceptance and life span projections have been modified; at this time the life span of Phase VI is projected at 15 years, with the proposed cell receiving approximately 810,000 tons of waste per year. The Phase VI landfill gas generation model has been changed to reflect this information; the updated model results are presented in Section 5 and Appendix M of the license application. For conservatism, the LFG collection system design was not modified to reflect changes in the model, which yield a lower peak LFG generation rate.

The minimum design slope for the final on-landfill closure system was set at 4%, in order to maintain adequate drainage of condensate in an environment which will suffer from differential settlement. Steeper pipe slopes were used where appropriate but since the final cap grading at the top of the landfill is between 3% and 5% this became a limiting factor in some areas.

Headloss

The headloss criteria for pipe sizing was set at applying a minimum vacuum of 20-inch of water column (w.c.) at all well head(s) under normal operating conditions. In order to assess available vacuum capacity throughout the system a series of headloss calculations were run. Four flow paths were chosen for evaluation, as shown in the attached plan set. The central collection point for the Phase VI gas was assumed to be the proposed Gas Clean Up and Compression Station. It was assumed that 90 inches w.c of vacuum is applied to the system at the inlet of the Gas Cleanup and Compression Station (using blowers of compressors with a 100" wc vacuum capacity with 10" of headloss through the primary knockout at the gas compression station and all headloss pathways evaluated end at the Gas Cleanup and Compression Station. Headloss calculations are provided in spreadsheets, attached. Sample headloss calculations are also attached.

Headloss, using the Spitzglass equation, was calculated in two ways: assuming equal flow (15,500 scfm/171 wells, approximately 91 scfm) at each well head and by calculating flow at each well based on each well's length of screen. As described earlier, the maximum length of screen in a typical well is 80 ft, for a 100 foot deep well. Well depth was taken as the distance from proposed final landfill grade to 10 ft above the base liner (factor of safety against baseliner damage), with a maximum depth of 100 feet. The total length of well screen in Phase VI estimated to be is 11,472 feet, corresponding to 1.35 scfm per foot of well screen. The majority of wells have a well screen length of 80 feet, corresponding to a flow of 108 scfm. Headloss, using the equal flow approach, was also calculated using the Mueller Equation. The Mueller equation gave lower headloss results than the Spitzglass Equation and to be conservative the Spitzglass equation was used in final design. Pipes were sized using the method, equal flow or flow by well screen, which gave the larger size for each collection pipe in the system.

Pathways A and B represent flow paths under normal operating conditions and assume a split in flows in the main interior header, at the header high point (valves at header high point closed). Wells to the north of the high point flow north through the main interior header(s) to the northern portion of the perimeter header and wells to the south of the high point flow south through the interior header to the southern portion of the perimeter header. Pathways A and B also assume a flow split in other headers which cross the Phase VI high point: wells to the north of the high point flow north through these headers to the perimeter header and wells to the south of the high point flow south through these headers to the perimeter header. Pathways C and D assume worst case conditions and represent emergency scenarios. Pathway C assumes all wells connected to the main interior header must flow north (i.e., southern connection of main interior header and perimeter header severed or closed for maintenance and valves at high points open), and pathway D assumes all wells connected to the main interior header must flow south (i.e., the northern connection between the main interior headers and the perimeter header is severed or closed for maintenance, and valves at the high points open).

Headlosses for pathways A and B meet the 20-in w.c. vacuum criteria at the farthest point from the Gas Cleanup and Compression Station, indicating satisfactory operation of the system during normal operating conditions. In addition to headloss criteria, collection pipes were sized to have a maximum gas velocity of 2,000 feet per minute (fpm), to limit condensate interactions with gas flow. For pathways A and B this criteria is not violated. Pathways A and B (typical operating conditions) were used to size each collection pipe and the pipe sizing generated in pathways A and B was applied to pathways C and D. Pathway C violates the headloss criteria described above, while pathway D does not. Both pathways C and D violate the velocity criteria. However, these pathways represent a worst case/short-term scenario and we recognize that upsizing the system to address these infrequent occurrences is not cost warranted.

The slope of the perimeter header was maintained at a minimum of 1% and generally followed the slope of the perimeter road as this header is to be constructed in compacted sand and gravel, settlement is not expected to be an issue. Therefore, we believe this slope is adequate to support long-term condensate drainage.

We believe this approach resulted in a conservative estimate of actual headlosses to be generated in the system, due to the large safety factor applied to the flow generated at each wellhead. Actual flow rates should be lower than assumed, resulting in a slightly over-sized system which should provide good operational stability and flexibility. Vacuums available at the farthest point from the gas movers for pathways A and B far exceeded the 20-in w.c. minimum criteria, indicating that the system vacuum capacity exceeds the minimum necessary for routine system operation.

HEADER SYSTEM DETAILS

Also addressed were other significant design considerations such as the survivability of the system in the landfill environment, provision for system monitoring and maintenance, future expansion and cost. We selected 12, 18 and 24-inch SDR 17 high density polyethylene (HDPE) pipe as the primary headers. This is somewhat oversized based on the anticipated maximum flows from the Phase VI Landfills, but it allows RIRRC the capacity and flexibility to route the gas as needed to a variety of destruction/reuse equipment. This type of piping has been used successfully at the site for a number of years and has demonstrated survivability.

The primary headers will be installed across the top of the landfill and tie in the perimeter header. The perimeter header will then be connected to the site-wide network. The perimeter header, which ranges in size from 24-inch to twin 36-inch pipes, will allow gas from Phase VI to be efficiently routed to all onsite destruction devices.

Pipe cleanouts/access points will be installed at approximately 600 to 800 foot intervals for periodic maintenance of the collection system. Condensate and leachate from the gas collection trenches will drain by gravity into new stone sumps. The number of and depth of sumps has been increased over previous phase designs based on operational experience. Condensate traps have been located at key down gradient points and at the lowest lying areas of the new system to minimize the amount of condensate reaching the new perimeter header and any of the destruction/control devices.

The main headers are fed by a series of 6 and 10-inch SDR 17 HDPE laterals that branch off of the 12, 18, 24, 28, and 36-inch headers and run to the individual wellheads. Control valves will be used on the main branches leading to the main header pipes to direct the flow in the desired direction toward whichever of the devices RIRRC chooses. Valves were placed on all laterals with 6 or more wells feeding to them to add operational flexibility to the system for field tuning and maintenance. These valves are also situated to allow the entire new post-closure system to be isolated, opened to the atmosphere, cleaned and re-pressurized without the introduction of ambient air that would be harmful to any of the gas destruction/power generation devices.

MISCELLANEOUS DESIGN ISSUES

Pipe Strength

Interim pipe systems were sized using the dead load from the Phase VI Landfill cell above the trench lift in question. The first interim trench system will be placed in the second lift of trash, approximately 20 feet above the base elevation of the cell, resulting in a worst case loading of 204 feet of waste and daily cover above the bottom most trenches. The attached calculations show that wall buckling is the strength criteria which controls and is different at different heights above the base liner; therefore interim collection trenches will consist of SDR-9, SDR-11 or SDR-17 pipe. We evaluated bridging of the stone envelope around the pipe as a method to defray some of the applied load. However, bridging is only effective when the aggregate is constrained on the sides and bottom and in the landfill environment the stone envelope is free to deform and doesn't provide additional load capacity for the pipe. Note, the recommended maximum ring deflection is 7.5% and at worst case this is exceeded slightly, ranging between 9.6% for SDR-17 and 8.2% for SDR-9. Ring deflection is the percent deviation of the pipe from a circle and values slightly above 7.5% will not have an adverse affect on system operations of this type. Failure due to ring deflection generally does not occur until a ring deflection of between 25%-30% is attained. The ring deflections at worst case for the interim system were deemed acceptable and ring deflection did not control pipe sizing.

The final closure system was evaluated using a 2-foot pipe cover dead load and an A-40D grader live load. This also represents the loading condition for the interim system during and immediately after construction. Based on this loading, SDR-17 pipe was selected for all components of the final closure system.

Phase I Piggyback Area

As shown on the attached plan set, a system of shallow horizontal trenches will be installed under the Phase I cap in the Phase I piggyback area, in order to prevent buildup of gas under the cap. This approach was successfully employed in Phase V. Based on the Phase I Landfill gas model, the Phase I piggyback area will produce a peak gas flow of approximately 925 scfm in 2010. This estimate is based on the percentage of Phase I well screen within the piggyback area. The under cap trenches will be constructed similar to those used in the Phase V-Phase I overlap area and a typical detail is shown on the attached plan set. We also recommend that 38 wells from Phase I be tied into this trench system. Wells were selected based on production and proximity to the horizontal trenches. These wells are shown on the attached plan set and summarized in the table below.

Wells to be Connected
To Phase I Piggyback Trenches
Well Number

31	125	134	A-5
78	126	135	A-6
79	127	140	B-4
106	128	140R	B-5
107	129	145	B-11
108	130	146	
111	130R	147	
112	131	149	
116	132	150	
117	133	151	

The majority of the under cap trenches, and high producing wells to be tied into the under cap trench system are located on the Phase II overlap area, where the thickest layers of waste are located and where waste filling was most recent (i.e., relatively the youngest best gas producing waste in Phase I). Little gas is produced along the Phase I toe because of the relatively shallow depth of waste and the greater age of the waste. Gas production is also low around the Phase I Hot Spot, due to the large amount of gravel fill in this area. Because gas production is low in these areas, proposed gas collection infrastructure is sparse but adequate compared to higher producing areas of the Phase I piggyback.

J:\CLF\32767.08.eas\Phase VI Permit Application April 2010\Permit Application Appendices\Appendix M\Appendix M Attachment A revised October 2009.doc

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767.06
SHEET NO. 1 OF 6
CALCULATED BY RAC DATE 1/21/08
CHECKED BY EAS DATE 3/13/08
SCALE Not to scale

Pipe strength Calculations, Central Landfill Phase VI
Landfill Gas System Design

References: ① Driscopipe, Polyethylene Piping Systems Manual
www.driscopipe.com
② PPI Handbook of Polyethylene Pipe, chapter 6
http://plasticpipe.org/mi/water/publications.php

Interim Collection Trenches

Loading → Top elevation = 570'
Base elevation = 346'
First trench in 2nd lift of waste, ≈ 20' from Base
$\gamma_{waste+cover}$ = 85 lb/ft³ (conservative for waste)

$P_S = \gamma H = 85\ lb/ft^3 \cdot (570' - (346' + 20'))$

$= 17{,}340\ lb/ft^2 \cdot \frac{1\ ft^2}{144\ in^2} = 120.4\ psi$ ✓

PT = 120.4 psi

Wall Crushing

$S_A = P_T \cdot \frac{SDR-1}{2}$, where S_A = Compressive stress, psi
SDR = 17

$= 120.4 \cdot \frac{17-1}{2} = 963.2\ psi$ ✓

Safety Factor (SF) $= \frac{1{,}500\ psi\ (\text{yield strength of HDPE})}{S_A}$

$= \frac{1{,}500\ psi}{963.2\ psi} = 1.6$ (OK) ✓

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767-06
SHEET NO. 2 OF 6
CALCULATED BY RAC DATE 1/21/08
CHECKED BY EAS DATE 7/13/08
SCALE Not to Scale

Wall Buckling

Critical collaspe Differential pressure, $P_c = \frac{2.32 \cdot E_p}{SDR^3}$

where E_p = Modulus of Elasticity = 28,200 psi (Manufactures Recommended Value)

For SDR-17

$$P_c = \frac{2.32 \cdot 28{,}200}{17^3} = 13.32 \text{ psi}$$ ✓

Critical buckling pressure at pipe crown,

$P_{cb} = .8\sqrt{E' \cdot P_c}$, where E' is the soil Modulus
From attached chart, $E' = 1{,}500$ psi

$$= .8\sqrt{1{,}500 \cdot 13.32} = 113.1 \text{ psi} < 120.4 \text{ psi}$$ ✓

For SDR-11

$$P_c = \frac{2.32 \cdot 28{,}200}{11^3} = 49.2 \text{ psi}$$

$$P_{cb} = .8\sqrt{1{,}500 \cdot 49.2} = 217.3 \text{ psi}$$

$$SF = \frac{217.3 \text{ psi}}{120.4 \text{ psi}} = 1.8 \text{ (Not OK, SF} \geq 2)$$ ✓

For SDR-9

$$P_c = \frac{2.32 \cdot 28{,}200}{9^3} = 89.7 \text{ psi}$$ ✓

$$P_{cb} = .8\sqrt{1{,}500 \cdot 89.7} = 293.5$$

$$FS = 293.4/120.4 = 2.44 \text{ (OK)}$$ ✓

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

Transition to SDR-11

$FS = \frac{P_t}{P_{cb}}$, $2 = \frac{P_t}{217.3 \text{ psi}}$

$P_t = 108.7 \text{ psi} \cdot 144 \text{ in}^2/\text{ft}^2 = 15,653 \text{ lb/ft}^2$

$15,653 \text{ lb/ft}^2 = 85 \text{ pcf} \cdot H$

$H = 184'$ above pipe $\rightarrow 204' - 184' = 20' + 20'$

$= 40'$ above base elevation

transition to SDR-17

$2 = \frac{P_t}{113.1 \text{ psi}}$, $P_t = 56.55 \text{ psi} \cdot 144 \text{ in}^2/\text{ft}^2 = 8,143.2 \text{ lb/ft}^2$

$8,143.2 = 85 \text{ pcf} \cdot H$

$H = 96' \rightarrow 204' - 96' = 108' + 20' = 128'$ above Base elevation

Ring Deflection

$$\% = 100 \left[\frac{K_1 L_1 P_s + K_1 P_L}{\left(\frac{2EP}{3}\right)\left(\frac{1}{SDR-1}\right)^3 + (.061 \cdot F_s \cdot E_1)} \right]$$

Where K_1 = Bedding Factor, .1 (Drisco Manual)
L_1 = Deflection Lag Factor, 1.5 (Drisco Manual)
F_s = soil support Factor, 2.0 (PPI Handbook)
P_L = Live Load

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767.06
SHEET NO. 4 OF 6
CALCULATED BY RAC DATE 1/21/08
CHECKED BY EAS DATE 2/12/08
SCALE Not to Scale

For SDR-17

$$\% = 100\left[\frac{.1 \cdot 1.5 \cdot 120.4\ psi}{\frac{2 \cdot 28{,}200}{3}\left(\frac{1}{17-1}\right)^3 + .061 \cdot 2 \cdot 1500 psi}\right]$$

18.06

= 9.6% ✓ 18,800 (0.0002) + 183 = 186.8

using same equation and variables, except change SDR

→ SDR-11 = 8.9% ✓

SDR-9 = 8.2% ✓

use SDR-17 because SDR-11 and SDR-9 offer marginal increase in strength ✓

Final System

Loading: A40 D Grader/Loader with 2' of Cover (Loading Conditions apply for interim system at time of installion)

Soil load = γH, γ = 115 lb/ft³ (Barrier Protection material)
= 115 PcF · 2' = 230 lb/ft²

A40 Load → gross weight = 150,507 lb
Load at one wheel = 150,507/6 = 37,628 lb

Live load; $P_L = \frac{3 z^3 W_L}{2 \pi R^5}$ where z = R = 2 (distance from load to pipe crown)

$$= \frac{3 \cdot 2^3 \cdot 37{,}628\ lb}{2 \cdot \pi \cdot 2^5} = 4{,}492\ lb/ft^2 / 144\ in^2/ft^2$$ ✓

= 31.2 psi ✓

P_T = 31.2 psi + 230/144 = 32.8 psi

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767.06
SHEET NO. 5 OF 6
CALCULATED BY RAC DATE 1/21/08
CHECKED BY EQ DATE 2/13/08
SCALE Not to Scale

Wall crushing

$S_A = 32.8\ psi \cdot \frac{17-1}{2}$ (for SDR-17)

$= 262.4\ psi$

$SF = \frac{1{,}500\ psi}{262.4\ psi} = 5.7$ (OK) ✓

Wall Buckling

For SDR-17, $P_{cb} = 113.1\ psi$

$SF = 113.1/32.8 = 3.4$ (OK) ✓

Ring Deflection

$$\% = 100\left[\frac{.1 \cdot 1.5 \cdot (230/144) + .1 \cdot 31.2\ psi}{\frac{2 \cdot 28{,}200}{3}\left(\frac{1}{17-1}\right)^3 + .061 \cdot 2 \cdot 1500\ psi}\right]$$

$= 1.8\%$ (OK) ✓

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 327670.6
SHEET NO. 6 OF 6
CALCULATED BY RAC DATE 1/21/08
CHECKED BY EAS DATE 7/10/08
SCALE Not to Scale

Interim System (wall Buckling Controls)

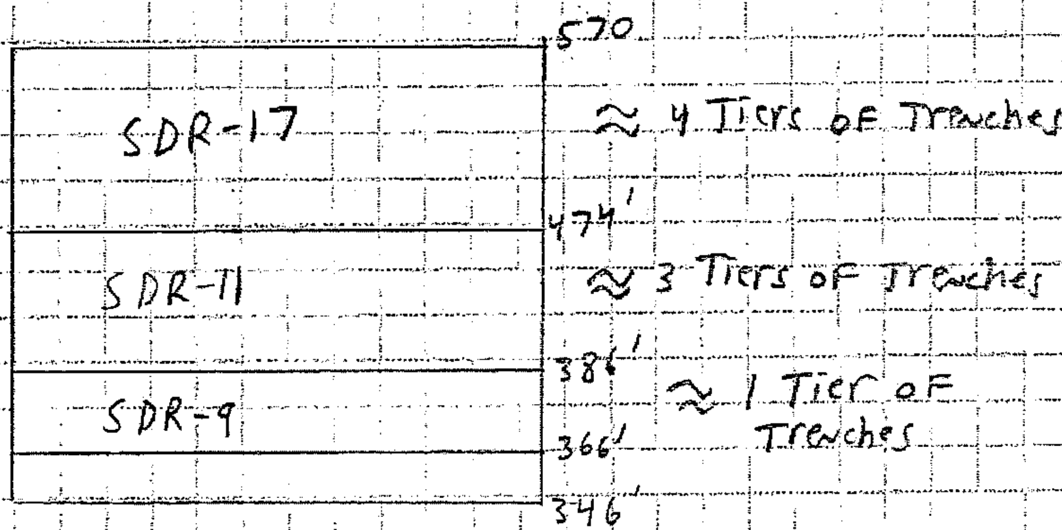


Table 7-7 Bureau of Reclamation Average E' Values for Iowa Formula (Initial Deflection)

Soil type – pipe bedding material (Unified Classification)†	*E' for Degree of Bedding Compaction, lb/in²*			
	Dumped	*Slight (<85% Proctor <40% relative density)*	*Moderate (48%-95% Proctor 40%-70% relative density)*	*High (>95% Proctor >70% relative density)*
Fine-grained soils (LL>50)‡ Soils with medium to high plasticity CH, MH, CH-MH	No data available; consult a competent soils engineer; otherwise, use E' = 0.			
Fine-grained soils (LL<50) Soils with medium to no plasticity CL, ML, CL-ML, with <25% coarse grained particles	50	200	400	1000
Fine-grained soils (LL<50) Soils with medium to no plasticity CL, ML, CL-ML, with >25% coarse grained particles Coarse-grained soils with fines GM, GC, SM, SC◊ contains >12% fines	100	400	1000	2000
Coarse-grained soils with little or no fines GW, GP, SW, SP◊ contains <12% fines	200	1000	2000	3000
Crushed rock	1000	3000	3000	3000
Accuracy in terms of percentage deflection▼	±2%	±2%	±1%	±0.5%

† ASTM D 2487; USBR Designation E-3. ‡ LL = Liquid limit. ◊ Or any borderline soil beginning with one of these symbols, i.e., GM-GC, GC-SC. ▼For ±1% accuracy and predicted deflection of 3%, actual deflection would be between 2% and 4%.

Note – Values applicable only for fills less than 50 ft (15 m). No safety factor included in table values. For use in predicting initial deflections only; appropriate Deflection Lag Factor must be applied for long-term deflections. If bedding falls on the borderline between two compaction categories, select the lower E' value or average the two values. Percentage Proctor based on laboratory maximum dry density from test standards using 12,500 ft-lb/ft³ (598,000 J/m³) (ASTM D 698, AASHTO T-99, USBR Designation E-11). 1 lb/in² = 6.895 kPa.

Table 7-8 Duncan-Hartley Soil Reaction Modulus

Type of Soil	Depth of Cover, ft	E' for Standard AASHTO Relative Compaction, lb.in²			
		85%	90%	95%	100%
Fine-grained soils with <25% sand content (CL, ML, CL-ML)	0-5	500	700	1000	1500
	5-10	600	1000	1400	2000
	10-15	700	1200	1600	2300
	15-20	800	1300	1800	2600
Coarse-grained soils with fines (SM, SC)	0-5	600	1000	1200	1900
	5-10	900	1400	1800	2700
	10-15	1000	1500	2100	3200
	15-20	1100	1600	1400	3700
Coarse-grained soils with little or no fines (SP, SW, GP, GW)	0-5	700	1000	1600	2500
	5-10	1000	1500	2200	3300
	10-15	1050	1600	2400	3600
	15-20	1100	1700	2500	3800

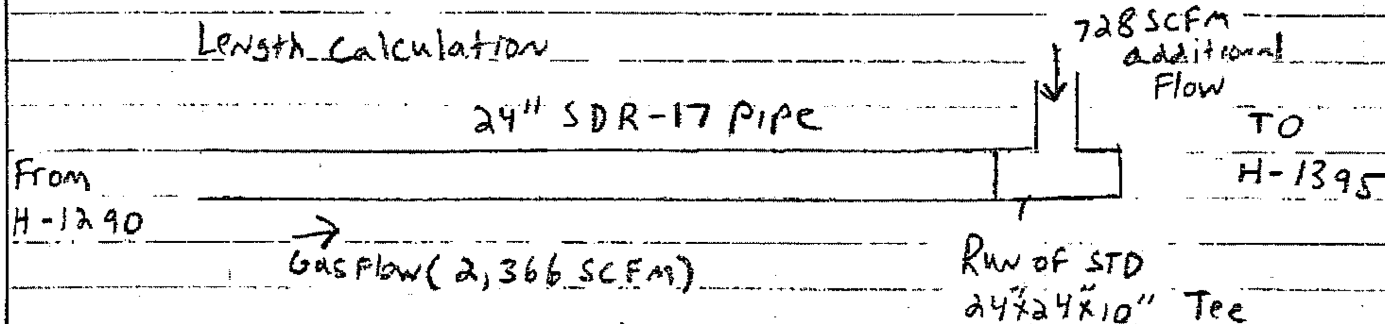
GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767.06
SHEET NO. 1 OF 2
CALCULATED BY RAC DATE 1/28/08
CHECKED BY EAS DATE 2/12/08
SCALE Not to Scale

Example Headloss Calculation
From Pathway A, using per well Flow method

Length calculation



Length = (1395' − 1290') + 70' (equivalent Length of Fitting, From attached chart)
= 175'

Mean Velocity = Q/A = $\frac{(2,366 + 728 \text{ SCFM})}{\frac{\pi \cdot (21.063/12)^2}{4}}$ = $\frac{3094 \text{ SCFM}}{2.42 \text{ Ft}^2}$

(I.D. of 24" SDR 17 = (21.063"))

= 1,279 FPM / 60 = 21.3 FPS

Specific gravity = .94 (constant)

Spitglass Equation

$$\Delta H_L = \frac{Q^2 \cdot SG \cdot L \cdot (1 + 3.6/d + .03d)}{3550^2 \cdot d^5}$$

$$= \frac{(3,094 \text{ SCFM} \cdot 60 \text{ m/hr})^2 \cdot .94 \cdot 175' \cdot (1 + 3.6/21.063" + .03(21.063))}{3550^2 \cdot (21.063)^5}$$

(1.0220×10^{13}; 5.2247×10^{13})

$$= \frac{1.02 \times 10^{13}}{5.22 \times 10^{13}}$$ ≈ .195 ft of head loss

GZA
GeoEnvironmental, Inc.
140 Broadway
Providence, Rhode Island
401-421-4140
Fax 401-751-8613
http://www.gza.com

Engineers and Scientists

JOB 32767.06
SHEET NO. 2 OF 2
CALCULATED BY RAC DATE 1/28/08
CHECKED BY EAS DATE 2/12/08
SCALE Not to scale

Mueller Equation

$$\Delta H_L = \left(\frac{Q \cdot S_g^{.425}}{2971 \cdot D^{2.725}}\right)^{1.74} \cdot L$$

$$= \left(\frac{\overset{180{,}821.85}{3{,}094\ \text{SCFM} \cdot 60\ \text{m/hr} \cdot .94^{.425}}}{\underset{12{,}008{,}685}{2{,}971 \cdot 21.063^{2.725}}}\right)^{1.74} \cdot 175'$$

$$= .118'$$ ✓

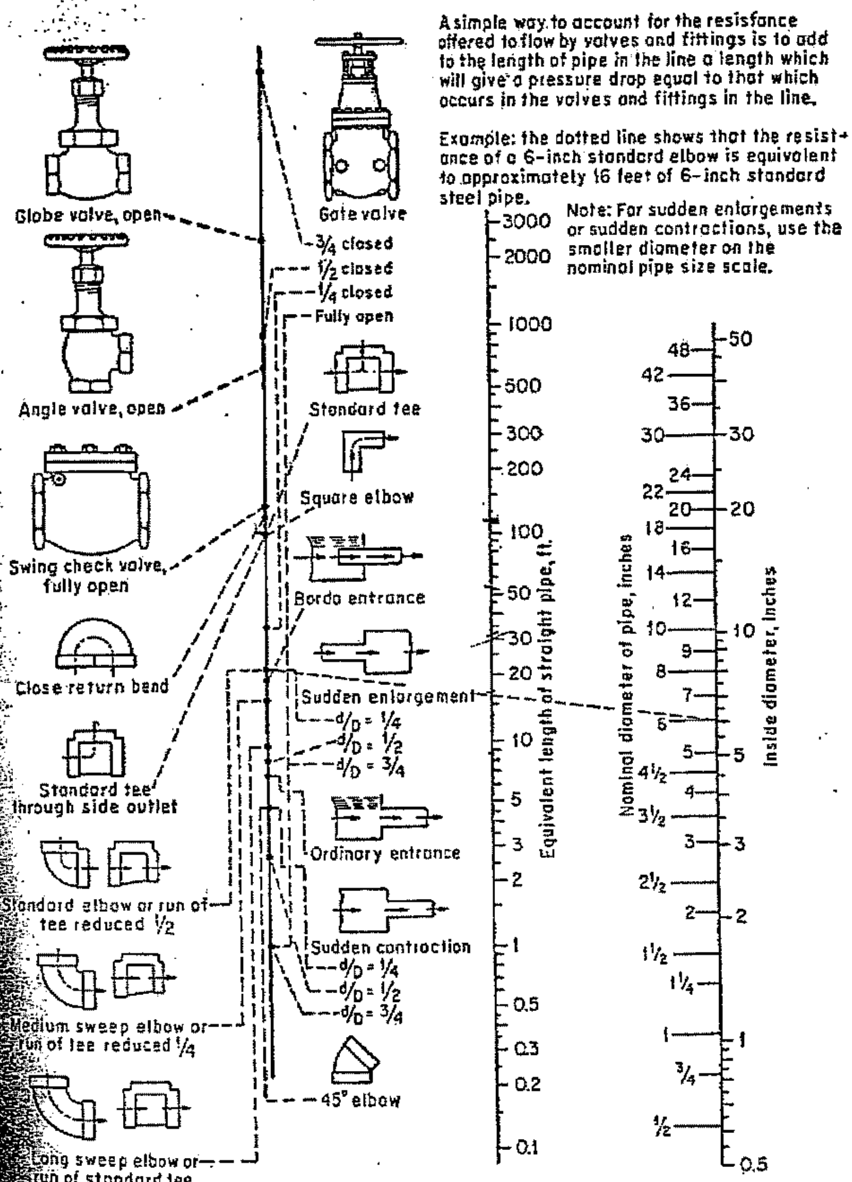


FIG. 16-3. Resistance of valves and fittings to the flow of fluids. (*Courtesy of the Crane Co.*)

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS USING SPITZGLASS EQUATION - PATH A (COLLECTION WELL 111 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	PER FT.	CUMM.	Available Vacuum
WELL 111	Non run of Std 6x6x6 tee	180	30	210	5.814	91	initial flow	91	8.2	0.94	0.126	0.00060	0.000	83.911
H- 180	Run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.456	0.00240	0.582	84.037
H- 360	Run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	1.027	0.00540	1.609	84.494
H- 540	Run of Std 6x6x8 tee (with expansion)	180	33	213	7.570	91	1 well	364	19.4	0.94	0.519	0.00244	2.128	85.520
H- 720	Run of Std 8x8x6 tee	45	15	60	7.570	91	1 well	455	24.3	0.94	0.228	0.00381	2.356	86.039
H- 765	Non Run of Std 18x18x8 tee and Valve	225	114	339	15.797	728	8 wells	1,183	14.5	0.94	0.220	0.00065	2.577	86.268
H- 990	Run of Std 18x18x8 tee	90	30	120	15.797	546	6 wells	1,729	21.2	0.94	0.167	0.00139	2.743	86.488
H- 1080	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	637	7 wells	2,366	16.3	0.94	0.209	0.00065	2.953	86.655
H- 1290	Run of Std 24x24x10 tee	105	70	175	21.063	728	8 wells	3,094	21.3	0.94	0.196	0.00112	3.148	86.864
H- 1395	Run of Std 24x24x10 tee	135	70	205	21.063	728	8 wells	3,822	26.3	0.94	0.350	0.00171	3.498	87.059
H- 1530	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	1,183	13 wells	5,005	25.3	0.94	0.297	0.00141	3.795	87.409
H- 1670	Run of Std 28x28x10 tee	135	70	205	24.574	728	8 wells	5,733	29.0	0.94	0.380	0.00186	4.175	87.706
H- 1805	Non run of Std 48x36x36[3] tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	9,828	108 wells	15,561	26.8	0.94	1.902	0.00115	6.077	88.086
H- 3037	End at Gas Cleanup Station	---	10	10	42.126			15,561	26.8	0.94	0.012	0.00115	6.089	89.988
SUBTOTAL: Head loss through Pathway "A" from well 111 to Gas Mover Station													6.089	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x8 - 15'), (18x18x8 - 30'), (24x24x8 - 60'), (24x24x10 - 60'), (28x28x10 - 70'), (28x28x12 - 70')
Non-run of standard tees: (6x6x6 - 30'), (18x18x6 - 100'), (48x36x36-300')
Expansion joints: (6" to 18" - 18')(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH SPITZGLASS EQUATION - PATH B (COLLECTION WELL 103 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	91	initial flow	91	8.2	0.94	0.126	0.00060	0.000	74.029
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.456	0.00240	0.582	74.155
H- 360	run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	1.027	0.00540	1.609	74.611
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	91	1 well	364	32.9	0.94	2.056	0.00961	3.665	75.638
H- 720	run of Std. 10x10x6 tee	180	16	196	9.435	91	1 well	455	15.6	0.94	0.243	0.00124	3.907	77.694
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	546	6 wells	1,001	24.4	0.94	0.585	0.00254	4.492	77.936
H- 1110	Valve and Non-run std 18x18x12 tee	225	114	339	15.797	1,547	17 wells	2,548	31.2	0.94	1.022	0.00302	5.514	78.521
H- 1335	Non run of Std. 24x24x18 tee	765	130	895	21.063			2,548	17.6	0.94	0.678	0.00076	6.193	79.543
H- 2100	run of Std. 24x24x18 tee	323	70	393	21.063	1,638	18 wells	4,186	28.8	0.94	0.804	0.00205	6.997	80.222
H- 2423	Run of Std. 28x28x8 tee (with expansion)	116	140	256	24.574	455	5 wells	4,641	23.5	0.94	0.311	0.00122	7.308	81.026
H- 2539	Run of Std. 28x28x6 tee	555	70	625	24.574	273	3 wells	4,914	24.9	0.94	0.852	0.00136	8.160	81.337
H- 3094	Run of Std. 28x28x6 tee	735	70	805	24.574	273	3 wells	5,187	26.2	0.94	1.222	0.00152	9.382	82.189
H- 3829	Run of Std. 36x36x18 tee (with expansion)	1620	160	1780	31.595	1,729	19 wells	6,916	21.2	0.94	1.497	0.00084	10.879	83.411
H- 5449	Run of Std. 36x36x8 tee	480	165	645	31.595	546	6 wells	7,462	22.8	0.94	0.632	0.00098	11.511	84.908
H- 5929	Run of Std. 36x36x10 tee	72	165	237	31.595	728	8 wells	8,190	25.1	0.94	0.280	0.00118	11.790	85.540
H- 6001	Run of Std. 36x36x12 tee	660	75	735	31.595	1,183	13 wells	9,373	28.7	0.94	1.135	0.00154	12.926	85.820
H- 6661	Run of Std. 36x36x8 tee	825	75	900	31.595	455	5 wells	9,828	30.1	0.94	1.529	0.00170	14.455	86.955
H- 7486	Run of Std. 48x36x36³ tee	1232	75	1307	42.126	5,733	63 wells	15,561	26.8	0.94	1.505	0.00115	15.959	88.484
H- 8718	End at Gas Mover Station	--	10	10	42.126			15,561	26.8	0.94	0.012	0.00115	15.971	89.988
SUBTOTAL: Head loss through Header line "B" from well 103 to Gas Mover Station													15.971	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fittings are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x10 - 10') (10x10x6 - 16'), (12x10x10 - 20'), (18x18x10 - 30'), (24x24x18 - 60'), (28x28x6 - 70'), (28x28x8 - 70'), (36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75'), (36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (18x18x12 - 100'), (24x24x18 - 130')
Expansion joints: (6" to 12" - 20')(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH SPITZGLASS EQUATION - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	PER FT.	CUMM.	Available Vacuum
WELL 79	Non run of Std. 6x6x6 tee	180	30	210	5.814	91	initial well flow	91	8.2	0.9	0.126	0.00060	0.000	-4.163
H- 180	Run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.456	0.00240	0.582	-4.037
H- 360	Run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	1.027	0.00540	1.609	-3.581
H- 540	Run of Std. 8x8x6 tee (with expansion)	180	33	213	7.570	91	1 well	364	19.4	0.94	0.519	0.00244	2.128	-2.554
H- 720	Run of Std. 8x8x6 tee	165	15	180	7.570	91	1 well	455	24.3	0.94	0.685	0.00381	2.813	-2.035
H- 885	Run of Std. 10x10x6 tee (with expansion)	195	16	211	9.435	91	1 well	546	18.7	0.94	0.376	0.00178	3.189	-1.350
H- 1080	Run of Std. 10x10x6 tee	216	16	232	9.435	91	1 well	637	21.9	0.94	0.563	0.00243	3.752	-0.973
H- 1296	Run of Std. 10x10x6 tee	72	16	88	9.435	91	1 well	728	25.0	0.94	0.279	0.00317	4.031	-0.411
H- 1368	Non run of Std. 24x24x10 tee and valve	90	140	230	9.435			728	25.0	0.94	0.729	0.00317	4.760	-0.132
H- 1458	Run of Std. 24x24x12 tee	135	60	195	21.063	1,183	13 wells	1,911	13.2	0.94	0.083	0.00043	4.843	0.597
H- 1593	Run of Std. 24x24x10 tee	105	60	165	21.063	728	8 wells	2,639	18.2	0.94	0.134	0.00081	4.977	0.680
H- 1698	Run of Std. 24x24x10 tee	210	60	270	21.063	728	8 wells	3,367	23.2	0.94	0.357	0.00132	5.334	0.814
H- 1908	Run of Std. 24x24x10 tee	90	60	150	21.063	637	7 wells	4,004	27.6	0.94	0.281	0.00187	5.615	1.172
H- 1998	Run of Std. 18x18x10 tee (with contraction)	210	80	290	15.797	546	6 wells	4,550	55.7	0.94	2.789	0.00962	8.404	1.452
H- 2208	Run of Std. 18x18x8 tee	68	30	98	15.797	455	5 wells	5,005	61.3	0.94	1.140	0.01164	9.545	4.241
H- 2276	Run of Std. 18x18x6 tee	180	30	210	15.797	364	4 wells	5,369	65.7	0.94	2.812	0.01339	12.357	5.382
H- 2456	Run of Std. 18x18x6 tee	120	30	150	15.797	182	2 wells	5,551	68.0	0.94	2.147	0.01431	14.504	8.194
H- 2576	Run of Std. 18x18x6 tee	566	30	596	15.797	182	2 wells	5,733	70.2	0.94	9.100	0.01527	23.603	10.341
H- 3142	Run of Std. 18x18x6 tee	165	30	195	15.797	91	1 well	5,824	71.3	0.94	3.072	0.01576	26.676	19.440
H- 3307	Run of Std. 18x18x6 tee[4]	173	58	231	15.797	182	2 wells	6,006	73.5	0.94	3.871	0.01676	30.546	22.513
H- 3480	Run of Std. 18x18x6 tee	158	30	188	15.797	273	3 wells	6,279	76.9	0.94	3.443	0.01831	33.989	26.383
H- 3638	Run of Std. 18x18x6 tee	251	30	281	15.797	364	4 wells	6,643	81.3	0.94	5.760	0.02050	39.750	29.827
H- 3889	Run of Std. 18x18x8 tee	158	30	188	15.797	546	6 wells	7,189	88.0	0.94	4.513	0.02401	44.263	35.587
H- 4047	Run of Std. 18x18x12 tee and valve	240	44	284	15.797	1,092	12 wells	8,281	101.4	0.94	9.047	0.03185	53.310	40.100
H- 4287	Non run of Std. 24x24x18 tee	765	100	865	21.063			8,281	57.0	0.94	6.926	0.00801	60.236	49.147
H- 5052	run of Std. 24x24x18 (with expansion) tee	323	130	453	21.063	1,638	18 wells	9,919	68.3	0.94	5.204	0.01149	65.440	56.073
H- 5375	Run of Std. 28x28x8 tee (with expansion)	116	140	256	21.063	455	5 wells	10,374	71.5	0.94	3.217	0.01257	68.657	61.278
H- 5491	Run of Std. 28x28x6 tee	555	70	625	24.574	273	3 wells	10,647	53.9	0.94	3.999	0.00640	72.656	64.495
H- 6046	Run of Std. 28x28x6 tee	735	70	805	24.574	273	3 wells	10,920	55.3	0.94	5.418	0.00673	78.075	68.494
H- 6781	Run of Std. 36x36x18 tee (with expansion)	1620	160	1780	31.595	1,729	19 wells	12,649	38.7	0.94	5.008	0.00281	83.082	73.912
H- 8401	Run of Std. 36x36x8 tee	480	165	645	31.595	546	6 wells	13,195	40.4	0.94	1.975	0.00306	85.057	78.920
H- 8881	Run of Std. 36x36x10 tee	72	165	237	31.595	728	8 wells	13,923	42.6	0.94	0.808	0.00341	85.865	80.894
H- 8953	Run of Std. 36x36x12 tee	660	75	735	31.595	1,183	13 wells	15,106	46.2	0.94	2.949	0.00401	88.814	81.702
H- 9613	Run of Std. 36x36x8 tee	825	75	900	31.595	455	5 wells	15,561	47.6	0.94	3.832	0.00426	92.646	84.651
H- 10438	Run of Std. 48x36x36[3] tee	1232	75	1307	42.126			15,561	26.8	0.94	1.505	0.00115	94.151	88.484
H- 11670	End at Gas Mover Station	--	10	10	42.126			15,561	26.8	0.94	0.012	0.00115	94.163	89.988

SUBTOTAL: Head loss through Pathway "C" from well 79 to Gas Mover Station — 94.163 in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout) — 90.000 in w.c.

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH SPITZGLASS EQUATION - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.
4.) Includes 2 valves on either side of header high point

Assumes all wells from main interior header flow north to northern portion of the perimeter header (valves at high point open).
Assumes flow split in other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the perimeter header,
and gas wells to the south of the high point flow south through the interior header(s) to the perimeter header. This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned
to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (18x18x6 - 30'), (18x18x8 - 30'), (18x18x10 - 30'), (18x18x12 - 30'), (18x18x18 - 30') (24x24x6 - 60'), (24x24x10 - 60') (24x24x12 - 60') (24x24x18 - 60'), (28x28x6 - 70') (28x28x8 - 70'), (36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75')(36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (24x24x10 - 130'), (24x24x18 - 130')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15'), (24" to 18" - 30')

CENTRAL LANDFILL - PHASE VI

LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN

HEAD LOSS CALCULATIONS WITH SPITZGLASS EQUATION - PATH D (COLLECTION WELL 103 TO GAS MOVER STATION)

ASSUMES EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	91	initial well flow	91	8.2	0.9	0.126	0.00060	0.000	60.938
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.456	0.00240	0.582	61.064
H- 360	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	1.027	0.00540	1.609	61.520
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	91	1 well	364	32.9	0.94	2.056	0.00961	3.665	62.547
H- 720	run of Std. 10x10x6 tee	180	16	196	7.570	91	1 well	455	24.3	0.94	0.746	0.00381	4.411	64.602
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	546	6 wells	1,001	24.4	0.94	0.585	0.00254	4.995	65.348
H- 1110	Non run of Std. 18x18x12 tee and 2 valves	158	128	286	15.797	91	1 well	1,092	13.4	0.94	0.158	0.00055	5.154	65.933
H- 1268	Run of Std. 18x18x8 tee	251	30	281	15.797	546	6 wells	1,638	20.1	0.94	0.350	0.00125	5.504	66.092
H- 1519	Run of Std. 18x18x6 tee	165	30	195	15.797	364	4 wells	2,002	24.5	0.94	0.363	0.00186	5.867	66.442
H- 1684	Run of Std. 18x18x6 tee	165	30	195	15.797	273	3 wells	2,275	27.9	0.94	0.469	0.00240	6.336	66.805
H- 1849	Run of Std. 18x18x6 tee	165	30	195	15.797	182	2 wells	2,457	30.1	0.94	0.547	0.00280	6.883	67.274
H- 2014	Run of Std. 18x18x6 tee	75	30	105	15.797	91	1 well	2,548	31.2	0.94	0.317	0.00302	7.199	67.820
H- 2089	Run of Std. 18x18x10 tee	300	30	330	15.797	1,638	18 wells	4,186	51.3	0.94	2.686	0.00814	9.886	68.137
H- 2389	Run of Std. 18x18x6 tee	120	30	150	15.797	182	2 wells	4,368	53.5	0.94	1.329	0.00886	11.215	70.823
H- 2509	Run of Std. 18x18x6 tee	285	30	315	15.797	182	2 wells	4,550	55.7	0.94	3.029	0.00962	14.244	72.153
H- 2794	Run of Std. 18x18x6 tee	75	30	105	15.797	364	4 wells	4,914	60.2	0.94	1.178	0.01122	15.422	75.182
H- 2869	Run of Std. 18x18x8 tee	225	30	255	15.797	455	5 wells	5,369	65.7	0.94	3.415	0.01339	18.837	76.360
H- 3094	Run of Std 18x18x8 tee	90	30	120	15.797	546	6 wells	5,915	72.4	0.94	1.950	0.01625	20.787	79.774
H- 3184	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	637	7 wells	6,552	45.1	0.94	1.604	0.00501	22.391	81.725
H- 3394	Run of Std 24x24x10 tee	105	70	175	21.063	728	8 wells	7,280	50.1	0.94	1.083	0.00619	23.474	83.329
H- 3499	Run of Std 24x24x10 tee	135	70	205	21.063	728	8 wells	8,008	55.2	0.94	1.535	0.00749	25.009	84.412
H- 3634	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	1,183	13 wells	9,191	46.5	0.94	1.001	0.00477	26.010	85.947
H- 3774	Run of Std 28x28x10 tee	135	70	205	24.574	728	8 wells	9,919	50.2	0.94	1.138	0.00555	27.149	86.948
H- 3909	Non run of Std 48x36x36[3] tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	5,642	62 wells	15,561	26.8	0.94	1.902	0.00115	29.051	88.086
H- 5141	End at Gas Mover Station	---	10	10	42.126			15,561	26.8	0.94	0.012	0.00115	29.062	89.988
SUBTOTAL: Head loss through Pathway "D" from well 103 to Gas Mover Station													29.062	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes all wells from main interior header flow south to perimeter header (valves at high point open). This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned ranges to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (12x10x10 - 20'), (18x18x6 - 30'), (18x18x8 - 30'), (24x24x6 - 60'), (24x24x8 - 60'), (24x24x10 - 60') (28x28x10 - 70'), (28x28x12 - 70') (36x36x6 - 75'), (36x36x8 - 75'), (36x36x18 - 75')
Non-run of standard tees; (6x6x6 - 30'), (24x24x10 - 130'), (18x18x12 - 100'), (48x36x36 - 300')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15), (24" to 18" - 30')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH SPITZGLASS EQUATION - PATH A (COLLECTION WELL 111 TO GAS MOVER STATION)
FLOW BY LENGTH OF WELL SCREEN

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	PER FT.	CUMM.	Available Vacuum
WELL 111	Non run of Std 6x6x6 tee	180	30	210	5.814	108	initial flow	108	9.8	0.94	0.178	0.00085	0.000	80.234
H- 180	Run of Std 6x6x6 tee	180	10	190	5.814	108	1 well	216	19.5	0.94	0.643	0.00338	0.820	80.411
H- 360	Run of Std 6x6x6 tee	180	10	190	5.814	108	1 well	324	29.3	0.94	1.446	0.00761	2.266	81.054
H- 540	Run of Std 6x6x8 tee (with expansion)	180	33	213	5.814	108	1 well	432	39.1	0.94	2.882	0.01353	5.148	82.500
H- 720	Run of Std 8x8x6 tee	45	15	60	7.570	108	1 well	540	28.8	0.94	0.322	0.00536	5.470	85.382
H- 765	Non Run of Std 18x18x8 tee and Valve	225	114	339	15.797	864	8 wells	1,404	17.2	0.94	0.310	0.00092	5.780	85.704
H- 990	Run of Std 18x18x8 tee	90	30	120	15.797	648	6 wells	2,052	25.1	0.94	0.235	0.00196	6.015	86.014
H- 1080	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	756	7 wells	2,808	19.3	0.94	0.295	0.00092	6.310	86.249
H- 1290	Run of Std 24x24x10 tee	105	70	175	21.063	811	8 wells	3,619	24.9	0.94	0.268	0.00153	6.577	86.543
H- 1395	Run of Std 24x24x10 tee	135	70	205	21.063	801	8 wells	4,420	30.4	0.94	0.468	0.00228	7.045	86.811
H- 1530	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	944	13 wells	5,364	27.1	0.94	0.341	0.00162	7.386	87.279
H- 1670	Run of Std 28x28x10 tee	135	70	205	24.574	695	8 wells	6,059	30.7	0.94	0.425	0.00207	7.811	87.620
H- 1805	Non run of Std 48x36x36' tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	9,671	108 wells	15,730	27.1	0.94	1.944	0.00118	9.754	88.045
H- 3037	End at Gas Cleanup Station	---	10	10	42.126			15,730	27.1	0.94	0.012	0.00118	9.766	89.988
SUBTOTAL: Head loss through Pathway "A" from well 111 to Gas Mover Station													9.766	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Flow assumed at 1.35 scfm/ft of screen, maximum 80 feet of screen corresponding to a flow of 108 scfm, based on on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (Total well screen equals 11, 472 ft-flow per foot of well screen equals 15,500/11,472, equals 1.35 scfm/ft). Difference between this flow and total flow from worksheet due to rounding error.
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x8 - 15'), (18x18x8 - 30'), (24x24x8 - 60'), (24x24x10 - 60'), (28x28x10 - 70'), (28x28x12 - 70')
Non-run of standard tees: (6x6x6 - 30'), (18x18x6 - 100'), (48x36x36-300')
Expansion joints: (6" to 18" - 18')(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS - PATH B (COLLECTION WELL 103 TO GAS MOVER STATION)
FLOW BY LENGTH OF WELL SCREEN

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	PER FT.	CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	67	initial flow	67	6.1	0.94	0.068	0.00033	0.000	73.864
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	108	1 well	175	15.8	0.94	0.422	0.00222	0.490	73.932
H- 360	run of Std. 6x6x6 tee	180	10	190	5.814	103	1 well	278	25.1	0.94	1.065	0.00560	1.555	74.354
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	100	1 well	378	34.2	0.94	2.217	0.01036	3.772	75.419
H- 720	run of Std. 10x10x6 tee	180	16	196	9.435	108	1 well	486	16.7	0.94	0.277	0.00141	4.048	77.636
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	306	6 wells	792	19.3	0.94	0.366	0.00159	4.414	77.912
H- 1110	Valve and Non-run std 18x18x12 tee	225	114	339	15.797	1,788	17 wells	2,580	31.6	0.94	1.048	0.00309	5.462	78.278
H- 1335	Non run of Std. 24x24x18 tee	765	130	895	21.063			2,580	17.8	0.94	0.696	0.00078	6.158	79.327
H- 2100	run of Std. 24x24x18 tee	323	70	393	21.063	1,843	18 wells	4,423	30.5	0.94	0.898	0.00228	7.056	80.022
H- 2423	Run of Std. 28x28x8 tee (with expansion)	116	140	256	24.574	483	5 wells	4,906	24.8	0.94	0.348	0.00136	7.404	80.920
H- 2539	Run of Std. 28x28x6 tee	555	70	625	24.574	205	3 wells	5,111	25.9	0.94	0.922	0.00147	8.325	81.268
H- 3094	Run of Std. 28x28x6 tee	735	70	805	24.574	157	3 wells	5,268	26.7	0.94	1.261	0.00157	9.586	82.189
H- 3829	Run of Std. 36x36x18 tee (with expansion)	1620	160	1780	31.595	1,735	19 wells	7,003	21.4	0.94	1.535	0.00086	11.121	83.450
H- 5449	Run of Std. 36x36x8 tee	480	165	645	31.595	317	6 wells	7,320	22.4	0.94	0.608	0.00094	11.729	84.985
H- 5929	Run of Std. 36x36x10 tee	72	165	237	31.595	688	8 wells	8,008	24.5	0.94	0.267	0.00113	11.996	85.593
H- 6001	Run of Std. 36x36x12 tee	660	75	735	31.595	1,260	13 wells	9,268	28.4	0.94	1.110	0.00151	13.106	85.860
H- 6661	Run of Std. 36x36x8 tee	825	75	900	31.595	403	5 wells	9,671	29.6	0.94	1.480	0.00164	14.586	86.970
H- 7486	Run of Std. 48x36x36' tee	1232	75	1307	42.126	6,059	63 wells	15,730	27.1	0.94	1.538	0.00118	16.124	88.450
H- 8718	End at Gas Mover Station	--	10	10	42.126			15,730	27.1	0.94	0.012	0.00118	16.136	89.988

SUBTOTAL: Head loss through Header line "B" from well 103 to Gas Mover Station — 16.136 in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout) — 90.000 in w.c.

NOTES:

1.) Flow assumed at 1.35 scfm/ft of screen, maximum 80 feet of screen corresponding to a flow of 108 scfm, based on on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (Total well screen equals 11,472 ft-flow per foot of well screen equals 15,500/11,472, equals 1.35 scfm/ft). Difference between this flow and total flow from worksheet due to rounding error.
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x10 - 10') (10x10x6 - 16), (12x10x10 - 20'), (18x18x10 - 30'), (24x24x18 - 60'), (28x28x6 - 70'), (28x28x8 - 70'), (36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75'), (36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (18x18x12 - 100'), (24x24x18 - 130')
Expansion joints: (6" to 12" - 20')(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
FLOW BY LENGTH OF WELL SCREEN

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 79	Non run of Std. 6x6x6 tee	180	30	210	5.814	108	initial well flow	108	9.8	0.9	0.178	0.00085	0.000	-13.196
H- 180	Run of Std. 6x6x6 tee	180	10	190	5.814	108	1 well	216	19.5	0.94	0.643	0.00338	0.820	-13.018
H- 360	Run of Std. 6x6x6 tee	180	10	190	5.814	108	1 well	324	29.3	0.94	1.446	0.00761	2.266	-12.376
H- 540	Run of Std. 8x8x6 tee (with expansion)	180	33	213	7.570	108	1 well	432	23.0	0.94	0.731	0.00343	2.997	-10.930
H- 720	Run of Std. 8x8x6 tee	165	15	180	7.570	108	1 well	540	28.8	0.94	0.965	0.00536	3.963	-10.199
H- 885	Run of Std. 10x10x6 tee (with expansion)	195	16	211	9.435	85	1 well	625	21.5	0.94	0.493	0.00234	4.455	-9.233
H- 1080	Run of Std. 10x10x6 tee	216	16	232	9.435	43	1 well	668	22.9	0.94	0.619	0.00267	5.074	-8.741
H- 1296	Run of Std. 10x10x6 tee	72	16	88	9.435	27	1 well	695	23.9	0.94	0.254	0.00289	5.328	-8.122
H- 1368	Non run of Std. 24x24x10 tee and valve	90	140	230	9.435			695	23.9	0.94	0.664	0.00289	5.993	-7.868
H- 1458	Run of Std. 24x24x12 tee	135	60	195	21.063	944	13 wells	1,639	11.3	0.94	0.061	0.00031	6.054	-7.203
H- 1593	Run of Std. 24x24x10 tee	105	60	165	21.063	801	8 wells	2,440	16.8	0.94	0.115	0.00070	6.168	-7.142
H- 1698	Run of Std. 24x24x10 tee	210	60	270	21.063	811	8 wells	3,251	22.4	0.94	0.333	0.00123	6.502	-7.028
H- 1908	Run of Std. 24x24x10 tee	90	60	150	21.063	756	7 wells	4,007	27.6	0.94	0.281	0.00187	6.783	-6.694
H- 1998	Run of Std. 18x18x10 tee (with contraction)	210	80	290	15.797	648	6 wells	4,655	57.0	0.94	2.919	0.01007	9.702	-6.413
H- 2208	Run of Std. 18x18x8 tee	68	30	98	15.797	540	5 wells	5,195	63.6	0.94	1.229	0.01254	10.931	-3.494
H- 2276	Run of Std. 18x18x6 tee	180	30	210	15.797	432	4 wells	5,627	68.9	0.94	3.089	0.01471	14.019	-2.265
H- 2456	Run of Std. 18x18x6 tee	120	30	150	15.797	216	2 wells	5,843	71.5	0.94	2.379	0.01586	16.398	0.823
H- 2576	Run of Std. 18x18x6 tee	566	30	596	15.797	216	2 wells	6,059	74.2	0.94	10.164	0.01705	26.562	3.202
H- 3142	Run of Std. 18x18x6 tee	165	30	195	15.797	108	1 well	6,167	75.5	0.94	3.445	0.01767	30.007	13.366
H- 3307	Run of Std. 18x18x6 tee[4]	173	58	231	15.797	216	2 wells	6,383	78.2	0.94	4.372	0.01893	34.379	16.811
H- 3480	Run of Std. 18x18x6 tee	158	30	188	15.797	324	3 wells	6,707	82.1	0.94	3.928	0.02090	38.307	21.183
H- 3638	Run of Std. 18x18x6 tee	251	30	281	15.797	432	4 wells	7,139	87.4	0.94	6.653	0.02367	44.960	25.111
H- 3889	Run of Std. 18x18x8 tee	158	30	188	15.797	608	6 wells	7,747	94.9	0.94	5.241	0.02788	50.201	31.764
H- 4047	Run of Std. 18x18x12 tee and valve	240	44	284	15.797	819	12 wells	8,566	104.9	0.94	9.680	0.03409	59.881	37.005
H- 4287	Non run of Std. 24x24x18 tee	765	100	865	21.063			8,566	59.0	0.94	7.411	0.00857	67.293	46.685
H- 5052	run of Std. 24x24x18 (with expansion) tee	323	130	453	21.063	1,843	18 wells	10,409	71.7	0.94	5.731	0.01265	73.024	54.097
H- 5375	Run of Std. 28x28x8 tee (with expansion)	116	140	256	21.063	483	5 wells	10,892	75.0	0.94	3.546	0.01385	76.570	59.828
H- 5491	Run of Std. 28x28x6 tee	555	70	625	24.574	205	3 wells	11,097	56.2	0.94	4.344	0.00695	80.914	63.374
H- 6046	Run of Std. 28x28x6 tee	735	70	805	24.574	157	3 wells	11,254	56.9	0.94	5.755	0.00715	86.669	67.718
H- 6781	Run of Std. 36x36x18 tee (with expansion)	1620	160	1780	31.595	1,735	19 wells	12,989	39.8	0.94	5.281	0.00297	91.950	73.473
H- 8401	Run of Std. 36x36x8 tee	480	165	645	31.595	317	6 wells	13,306	40.7	0.94	2.008	0.00311	93.958	78.754
H- 8881	Run of Std. 36x36x10 tee	72	165	237	31.595	688	8 wells	13,994	42.8	0.94	0.816	0.00344	94.774	80.762
H- 8953	Run of Std. 36x36x12 tee	660	75	735	31.595	1,260	13 wells	15,254	46.7	0.94	3.007	0.00409	97.781	81.578
H- 9613	Run of Std. 36x36x8 tee	825	75	900	31.595	403	5 wells	15,657	47.9	0.94	3.880	0.00431	101.661	84.585
H- 10438	Run of Std. 48x36x36[3] tee	1232	75	1307	42.126			15,657	27.0	0.94	1.523	0.00117	103.184	88.465
H- 11670	End at Gas Mover Station	–	10	10	42.126			15,657	27.0	0.94	0.012	0.00117	103.196	89.988

SUBTOTAL: Head loss through Pathway "C" from well 79 to Gas Mover Station — 103.196 in w.c.

Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout) — 90.000 in w.c.

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
FLOW BY LENGTH OF WELL SCREEN

NOTES:

1.) Flow assumed at 1.35 scfm/ft of screen, maximum 80 feet of screen corresponding to a flow of 108 scfm, based on on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety
(Total well screen equals 11, 472 ft-flow per foot of well screen equals 15,500/11,472, equals 1.35 scfm/ft). Difference between this flow and total flow from worksheet due to rounding error
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.
4.) Includes 2 valves on either side of header high point

Assumes all wells from main interior header flow north to northern portion of the perimeter header (valves at high point open).
Assumes flow split in other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the perimeter header,
and gas wells to the south of the high point flow south through the interior header(s) to the perimeter header. This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned
to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (18x18x6 - 30'), (18x18x8 - 30'), (18x18x10 - 30'), (18x18x12 - 30'), (18x18x18 - 30') (24x24x6 - 60'), (24x24x10 - 60') (24x24x12 - 60') (24x24x18 - 60'), (28x28x6 - 70') (28x28x8 - 70'),
(36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75')(36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (24x24x10 - 130'), (24x24x18 - 130')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15), (24" to 18" - 30')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS - PATH D (COLLECTION WELL 103 TO GAS MOVER STATION)
FLOW BY LENGTH OF WELL SCREEN

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	67	initial well flow	67	6.1	0.9	0.068	0.00033	0.000	58.489
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	108	1 well	175	15.8	0.94	0.422	0.00222	0.490	58.557
H- 360	run of Std. 6x6x6 tee	180	10	190	5.814	103	1 well	278	25.1	0.94	1.065	0.00560	1.555	58.979
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	100	1 well	378	34.2	0.94	2.217	0.01036	3.772	60.044
H- 720	run of Std. 10x10x6 tee	180	16	196	7.570	108	1 well	486	25.9	0.94	0.851	0.00434	4.623	62.260
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	306	6 wells	792	19.3	0.94	0.366	0.00159	4.989	63.112
H- 1110	Non run of Std. 18x18x12 tee and 2 valves	158	128	286	15.797	27	1 well	819	10.0	0.94	0.089	0.00031	5.078	63.478
H- 1268	Run of Std. 18x18x8 tee	251	30	281	15.797	608	6 wells	1,427	17.5	0.94	0.266	0.00095	5.344	63.567
H- 1519	Run of Std. 18x18x6 tee	165	30	195	15.797	432	4 wells	1,859	22.8	0.94	0.313	0.00161	5.657	63.833
H- 1684	Run of Std. 18x18x6 tee	165	30	195	15.797	324	3 wells	2,183	26.7	0.94	0.432	0.00221	6.089	64.146
H- 1849	Run of Std. 18x18x6 tee	165	30	195	15.797	216	2 wells	2,399	29.4	0.94	0.521	0.00267	6.610	64.577
H- 2014	Run of Std. 18x18x6 tee	75	30	105	15.797	108	1 well	2,507	30.7	0.94	0.307	0.00292	6.916	65.099
H- 2089	Run of Std. 18x18x10 tee	300	30	330	15.797	1,843	18 wells	4,350	53.3	0.94	2.901	0.00879	9.817	65.405
H- 2389	Run of Std. 18x18x6 tee	120	30	150	15.797	216	2 wells	4,566	55.9	0.94	1.453	0.00968	11.270	68.306
H- 2509	Run of Std. 18x18x6 tee	285	30	315	15.797	216	2 wells	4,782	58.6	0.94	3.346	0.01062	14.616	69.759
H- 2794	Run of Std. 18x18x6 tee	75	30	105	15.797	432	4 wells	5,214	63.8	0.94	1.326	0.01263	15.942	73.105
H- 2869	Run of Std. 18x18x8 tee	225	30	255	15.797	540	5 wells	5,754	70.5	0.94	3.922	0.01538	19.864	74.431
H- 3094	Run of Std 18x18x8 tee	90	30	120	15.797	648	6 wells	6,402	78.4	0.94	2.285	0.01904	22.148	78.353
H- 3184	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	756	7 wells	7,158	49.3	0.94	1.914	0.00598	24.063	80.637
H- 3394	Run of Std 24x24x10 tee	105	70	175	21.063	811	8 wells	7,969	54.9	0.94	1.298	0.00742	25.361	82.552
H- 3499	Run of Std 24x24x10 tee	135	70	205	21.063	801	8 wells	8,770	60.4	0.94	1.841	0.00898	27.202	83.849
H- 3634	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	944	13 wells	9,714	49.2	0.94	1.118	0.00533	28.320	85.691
H- 3774	Run of Std 28x28x10 tee	135	70	205	24.574	695	8 wells	10,409	52.7	0.94	1.254	0.00612	29.574	86.809
H- 3909	Non run of Std 48x36x36[3] tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	5,248	62 wells	15,657	27.0	0.94	1.926	0.00117	31.499	88.063
H- 5141	End at Gas Mover Station	—	10	10	42.126			15,657	27.0	0.94	0.012	0.00117	31.511	89.988
SUBTOTAL: Head loss through Pathway "D" from well 103 to Gas Mover Station													31.511	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Flow assumed at 1.35 scfm/ft of screen, maximum 80 feet of screen corresponding to a flow of 108 scfm, based on on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (Total well screen equals 11, 472 ft-flow per foot of well screen equals 15,500/11,472, equals 1.35 scfm/ft). Difference between this flow and total flow from worksheet due to rounding error.
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes all wells from main interior header flow south to perimeter header (valves at high point open). This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned ranges to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (12x10x10 - 20'), (18x18x6 - 30'), (18x18x8 - 30'), (24x24x6 - 60'), (24x24x8 - 60'), (24x24x10 - 60') (28x28x10 - 70'), (28x28x12 - 70') (36x36x6 - 75'), (36x36x8 - 75'), (36x36x18 - 75')
Non-run of standard tees: (6x6x6 - 30'), (24x24x10 - 130'), (18x18x12 - 100'), (48x36x36 - 300')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15), (24" to 18" - 30')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH MUELLER EQUATION - PATH A (COLLECTION WELL 111 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 111	Non run of Std 6x6x6 tee	180	30	210	5.814	91	initial flow	91	8.2	0.94	0.137	0.00065	0.000	86.193
H- 180	Run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.415	0.00218	0.552	86.331
H- 360	Run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	0.840	0.00442	1.392	86.745
H- 540	Run of Std 6x6x8 tee (with expansion)	180	33	213	7.570	91	1 well	364	19.4	0.94	0.444	0.00209	1.836	87.585
H- 720	Run of Std 8x8x6 tee	45	15	60	7.570	91	1 well	455	24.3	0.94	0.185	0.00308	2.021	88.029
H- 765	Non Run of Std 18x18x8 tee and Valve	225	114	339	15.797	728	8 wells	1,183	14.5	0.94	0.168	0.00050	2.189	88.214
H- 990	Run of Std 18x18x8 tee	90	30	120	15.797	546	6 wells	1,729	21.2	0.94	0.115	0.00096	2.304	88.382
H- 1080	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	637	7 wells	2,366	16.3	0.94	0.135	0.00042	2.439	88.497
H- 1290	Run of Std 24x24x10 tee	105	70	175	21.063	728	8 wells	3,094	21.3	0.94	0.118	0.00067	2.557	88.633
H- 1395	Run of Std 24x24x10 tee	135	70	205	21.063	728	8 wells	3,822	26.3	0.94	0.200	0.00097	2.757	88.751
H- 1530	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	1,183	13 wells	5,005	25.3	0.94	0.158	0.00075	2.915	88.951
H- 1670	Run of Std 28x28x10 tee	135	70	205	24.574	728	8 wells	5,733	29.0	0.94	0.195	0.00095	3.110	89.108
H- 1805	Non run of Std 48x36x36[3] tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	9,828	108 wells	15,561	26.8	0.94	0.693	0.00042	3.802	89.303
H- 3037	End at Gas Cleanup Station	---	10	10	42.126			15,561	26.8	0.94	0.004	0.00042	3.807	89.996
SUBTOTAL: Head loss through Pathway "A" from well 111 to Gas Mover Station													3.807	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" - 12'), (18" - 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x8 - 15'), (18x18x8 - 30'), (24x24x8 - 60'), (24x24x10 - 60'), (28x28x10 - 70'), (28x28x12 - 70')
Non-run of standard tees: (6x6x6 - 30'), (18x18x6 - 100'), (48x36x36-300')

CENTRAL LANDFILL - PHASE VI

LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN

HEAD LOSS CALCULATIONS WITH MUELLER EQUATION - PATH B (COLLECTION WELL 103 TO GAS MOVER STATION)

ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	91	initial flow	91	8.2	0.94	0.137	0.00065	0.000	80.766
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.415	0.00218	0.552	80.903
H- 360	run of Std 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	0.840	0.00442	1.392	81.317
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	91	1 well	364	32.9	0.94	1.560	0.00729	2.952	82.157
H- 720	run of Std. 10x10x6 tee	180	16	196	9.435	91	1 well	455	15.6	0.94	0.212	0.00108	3.164	83.718
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	546	6 wells	1,001	24.4	0.94	0.437	0.00190	3.602	83.930
H- 1110	Valve and Non-run std 18x18x12 tee	225	114	339	15.797	1,547	17 wells	2,548	31.2	0.94	0.639	0.00188	4.240	84.367
H- 1335	Non run of Std. 24x24x18 tee	765	130	895	21.063			2,548	17.6	0.94	0.431	0.00048	4.671	85.006
H- 2100	run of Std. 24x24x18 tee	323	70	393	21.063	1,638	18 wells	4,186	28.8	0.94	0.449	0.00114	5.120	85.437
H- 2423	Run of Std. 28x28x8 tee (with expansion)	116	140	256	24.574	455	5 wells	4,641	23.5	0.94	0.168	0.00066	5.288	85.885
H- 2539	Run of Std. 28x28x6 tee	555	70	625	24.574	273	3 wells	4,914	24.9	0.94	0.454	0.00073	5.743	86.054
H- 3094	Run of Std. 28x28x6 tee	735	70	805	24.574	273	3 wells	5,187	26.2	0.94	0.643	0.00080	6.385	86.508
H- 3829	Run of Std. 36x36x18 tee (with expansion)	1620	160	1780	31.595	1,729	19 wells	6,916	21.2	0.94	0.712	0.00040	7.098	87.151
H- 5449	Run of Std. 36x36x8 tee	480	165	645	31.595	546	6 wells	7,462	22.8	0.94	0.295	0.00046	7.392	87.863
H- 5929	Run of Std. 36x36x10 tee	72	165	237	31.595	728	8 wells	8,190	25.1	0.94	0.127	0.00054	7.519	88.158
H- 6001	Run of Std. 36x36x12 tee	660	75	735	31.595	1,183	13 wells	9,373	28.7	0.94	0.499	0.00068	8.018	88.285
H- 6661	Run of Std. 36x36x8 tee	825	75	900	31.595	455	5 wells	9,828	30.1	0.94	0.664	0.00074	8.682	88.784
H- 7486	Run of Std. 48x36x36' tee	1232	75	1307	42.126	5,733	63 wells	15,561	26.8	0.94	0.548	0.00042	9.230	89.448
H- 8718	End at Gas Mover Station	—	10	10	42.126			15,561	26.8	0.94	0.004	0.00042	9.234	89.996
SUBTOTAL: Head loss through Header line "B" from well 103 to Gas Mover Station													9.234	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes flow split at high point of main interior header (valves closed) and other interior headers which cross highpoint; gas wells to the north of the high point flow north through interior header(s) to the northern perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the southern perimeter header.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18'), (36"-30')
Run of standard tees (6x6x6 - 10'), (6x6x10 - 10') (10x10x6 - 16), (12x10x10 - 20'), (18x18x10 - 30'), (24x24x18 - 60'), (28x28x6 - 70'), (28x28x8 - 70'), (36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75'), (36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (18x18x12 - 100'), (24x24x18 - 130')
Expansion joints: (6" to 12" - 20')(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH MUELLER EQUATION - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)		To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 79	Non run of Std. 6x6x6 tee		180	30	210	5.814	91	initial well flow	91	8.2	0.9	0.137	0.00065	0.000	44.624
H- 180	Run of Std. 6x6x6 tee		180	10	190	5.814	91	1 well	182	16.5	0.94	0.415	0.00218	0.552	44.761
H- 360	Run of Std. 6x6x6 tee		180	10	190	5.814	91	1 well	273	24.7	0.94	0.840	0.00442	1.392	45.176
H- 540	Run of Std. 8x8x6 tee (with expansion)		180	33	213	7.570	91	1 well	364	19.4	0.94	0.444	0.00209	1.836	46.016
H- 720	Run of Std. 8x8x6 tee		165	15	180	7.570	91	1 well	455	24.3	0.94	0.554	0.00308	2.390	46.460
H- 885	Run of Std. 10x10x6 tee (with expansion)		195	16	211	9.435	91	1 well	546	18.7	0.94	0.314	0.00149	2.703	47.014
H- 1080	Run of Std. 10x10x6 tee		216	16	232	9.435	91	1 well	637	21.9	0.94	0.451	0.00194	3.155	47.328
H- 1296	Run of Std. 10x10x6 tee		72	16	88	9.435	91	1 well	728	25.0	0.94	0.216	0.00245	3.370	47.779
H- 1368	Non run of Std. 24x24x10 tee and valve		90	140	230	9.435			728	25.0	0.94	0.564	0.00245	3.934	47.995
H- 1458	Run of Std. 24x24x12 tee		135	60	195	21.063	1,183	13 wells	1,911	13.2	0.94	0.057	0.00029	3.991	48.559
H- 1593	Run of Std. 24x24x10 tee		105	60	165	21.063	728	8 wells	2,639	18.2	0.94	0.084	0.00051	4.076	48.616
H- 1698	Run of Std. 24x24x10 tee		210	60	270	21.063	728	8 wells	3,367	23.2	0.94	0.211	0.00078	4.287	48.700
H- 1908	Run of Std. 24x24x10 tee		90	60	150	21.063	637	7 wells	4,004	27.6	0.94	0.159	0.00106	4.446	48.911
H- 1998	Run of Std. 18x18x10 tee (with contraction)		210	80	290	15.797	546	6 wells	4,550	55.7	0.94	1.498	0.00517	5.944	49.070
H- 2208	Run of Std. 18x18x8 tee		68	30	98	15.797	455	5 wells	5,005	61.3	0.94	0.598	0.00610	6.541	50.568
H- 2276	Run of Std. 18x18x6 tee		180	30	210	15.797	364	4 wells	5,369	65.7	0.94	1.447	0.00689	7.988	51.165
H- 2456	Run of Std. 18x18x6 tee		120	30	150	15.797	182	2 wells	5,551	68.0	0.94	1.095	0.00730	9.083	52.612
H- 2576	Run of Std. 18x18x6 tee		566	30	596	15.797	182	2 wells	5,733	70.2	0.94	4.603	0.00772	13.687	53.708
H- 3142	Run of Std. 18x18x6 tee		165	30	195	15.797	91	1 well	5,824	71.3	0.94	1.548	0.00794	15.234	58.311
H- 3307	Run of Std. 18x18x6 tee[4]		173	58	231	15.797	182	2 wells	6,006	73.5	0.94	1.935	0.00837	17.169	59.859
H- 3480	Run of Std. 18x18x6 tee		158	30	188	15.797	273	3 wells	6,279	76.9	0.94	1.701	0.00905	18.870	61.793
H- 3638	Run of Std. 18x18x6 tee		251	30	281	15.797	364	4 wells	6,643	81.3	0.94	2.804	0.00998	21.674	63.494
H- 3889	Run of Std. 18x18x8 tee		158	30	188	15.797	546	6 wells	7,189	88.0	0.94	2.153	0.01145	23.827	66.299
H- 4047	Run of Std. 18x18x12 tee and valve		240	44	284	15.797	1,092	12 wells	8,281	101.4	0.94	4.159	0.01464	27.986	68.451
H- 4287	Non run of Std. 24x24x18 tee		765	100	865	21.063			8,281	57.0	0.94	3.218	0.00374	31.224	72.610
H- 5052	run of Std. 24x24x18 (with expansion) tee		323	130	453	21.063	1,638	18 wells	9,919	68.3	0.94	2.321	0.00512	33.545	75.848
H- 5375	Run of Std. 28x28x8 tee (with expansion)		116	140	256	21.063	455	5 wells	10,374	71.5	0.94	1.418	0.00554	34.964	78.170
H- 5491	Run of Std. 28x28x6 tee		555	70	625	24.574	273	3 wells	10,647	53.9	0.94	1.744	0.00279	36.708	79.588
H- 6046	Run of Std. 28x28x6 tee		735	70	805	24.574	273	3 wells	10,920	55.3	0.94	2.348	0.00292	39.056	81.332
H- 6781	Run of Std. 36x36x18 tee (with expansion)		1620	160	1780	31.595	1,729	19 wells	12,649	38.7	0.94	2.036	0.00114	41.092	83.680
H- 8401	Run of Std. 36x36x8 tee		480	165	645	31.595	546	6 wells	13,195	40.4	0.94	0.794	0.00123	41.886	85.716
H- 8881	Run of Std. 36x36x10 tee		72	165	237	31.595	728	8 wells	13,923	42.6	0.94	0.320	0.00135	42.206	86.510
H- 8953	Run of Std. 36x36x12 tee		660	75	735	31.595	1,183	13 wells	15,106	46.2	0.94	1.145	0.00156	43.351	86.830
H- 9613	Run of Std. 36x36x8 tee		825	75	900	31.595	455	5 wells	15,561	47.6	0.94	1.476	0.00164	44.828	87.975
H- 10438	Run of Std. 48x36x36[3] tee		1232	75	1307	42.126			15,561	26.8	0.94	0.548	0.00042	45.376	89.452
	End at Gas Mover Station		—	10	10	42.126									

SUBTOTAL: Head loss through Pathway "C" from well 79 to Gas Mover Station — 45.376 in w.c.

Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout) — 90.000 in w.c.

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH MUELLER EQUATION - PATH C (COLLECTION WELL 79 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 = 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.
4.) Includes 2 valves on either side of header high point

Assumes all wells from main interior header flow north to northern portion of the perimeter header (valves at high point open).
Assumes flow split in other interior headers which cross highpoint: gas wells to the north of the high point flow north through interior header(s) to the perimeter header, and gas wells to the south of the high point flow south through the interior header(s) to the perimeter header. This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18"- 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (18x18x6 - 30'), (18x18x8 - 30'), (18x18x10 - 30'), (18x18x12 - 30'), (18x18x18 - 30') (24x24x6 - 60'), (24x24x10 - 60') (24x24x12 - 60') (24x24x18 - 60'), (28x28x6 - 70') (28x28x8 - 70'), (36x36x6 - 75'), (36x36x8 - 75'), (36x36x10 - 75'), (36x36x12 - 75')(36x36x18 - 75'), (48x36x36 - 75')
Non-run of standard tees: (6x6x6 - 30'), (24x24x10 - 130'), (24x24x18 - 130')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15), (24" to 18" - 30')

CENTRAL LANDFILL - PHASE VI
LANDFILL GAS COLLECTION SYSTEM PIPING DESIGN
HEAD LOSS CALCULATIONS WITH MUELLER EQUATION - PATH D (COLLECTION WELL 103 TO GAS MOVER STATION)
ASSUMING EQUAL FLOW FROM EACH WELL

From (1)	To (2)	Length (feet)	Fittings (feet)	TOTAL (feet)	Pipe I.D (inches)	Flow (scfm)	Added well/trench	Flow (scfm)	Velocity (fps)	Specific Gravity	Head Loss (in w.c.) TOTAL	Head Loss (in w.c.) PER FT.	Head Loss (in w.c.) CUMM.	Available Vacuum
WELL 103	Non-run std 6x6x6 tee	180	30	210	5.814	91	initial well flow	91	8.2	0.9	0.137	0.00065	0.000	73.673
H- 180	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	182	16.5	0.94	0.415	0.00218	0.552	73.810
H- 360	run of Std. 6x6x6 tee	180	10	190	5.814	91	1 well	273	24.7	0.94	0.840	0.00442	1.392	74.225
H- 540	run of Std. 6x6x10 tee (with expansion)	180	34	214	5.814	91	1 well	364	32.9	0.94	1.560	0.00729	2.952	75.065
H- 720	run of Std. 10x10x6 tee	180	16	196	7.570	91	1 well	455	24.3	0.94	0.603	0.00308	3.555	76.625
H- 900	run of Std. 12x10x10 tee	210	20	230	11.190	546	6 wells	1,001	24.4	0.94	0.437	0.00190	3.992	77.228
H- 1110	Non run of Std. 18x18x12 tee and 2 valves	158	128	286	15.797	91	1 well	1,092	13.4	0.94	0.123	0.00043	4.116	77.665
H- 1268	Run of Std. 18x18x8 tee	251	30	281	15.797	546	6 wells	1,638	20.1	0.94	0.245	0.00087	4.361	77.789
H- 1519	Run of Std. 18x18x6 tee	165	30	195	15.797	364	4 wells	2,002	24.5	0.94	0.241	0.00124	4.602	78.034
H- 1684	Run of Std. 18x18x6 tee	165	30	195	15.797	273	3 wells	2,275	27.9	0.94	0.302	0.00155	4.904	78.276
H- 1849	Run of Std. 18x18x6 tee	165	30	195	15.797	182	2 wells	2,457	30.1	0.94	0.345	0.00177	5.249	78.577
H- 2014	Run of Std. 18x18x6 tee	75	30	105	15.797	91	1 well	2,548	31.2	0.94	0.198	0.00188	5.447	78.922
H- 2089	Run of Std. 18x18x10 tee	300	30	330	15.797	1,638	18 wells	4,186	51.3	0.94	1.475	0.00447	6.921	79.120
H- 2389	Run of Std. 18x18x6 tee	120	30	150	15.797	182	2 wells	4,368	53.5	0.94	0.722	0.00481	7.643	80.594
H- 2509	Run of Std. 18x18x6 tee	285	30	315	15.797	182	2 wells	4,550	55.7	0.94	1.627	0.00517	9.270	81.316
H- 2794	Run of Std. 18x18x6 tee	75	30	105	15.797	364	4 wells	4,914	60.2	0.94	0.620	0.00591	9.890	82.943
H- 2869	Run of Std. 18x18x8 tee	225	30	255	15.797	455	5 wells	5,369	65.7	0.94	1.757	0.00689	11.647	83.564
H- 3094	Run of Std 18x18x8 tee	90	30	120	15.797	546	6 wells	5,915	72.4	0.94	0.979	0.00815	12.626	6.535
H- 3184	Run of Std 24x24x8 tee (with expansion)	210	110	320	21.063	637	7 wells	6,552	45.1	0.94	0.797	0.00249	13.423	5.738
H- 3394	Run of Std 24x24x10 tee	105	70	175	21.063	728	8 wells	7,280	50.1	0.94	0.524	0.00299	13.946	5.214
H- 3499	Run of Std 24x24x10 tee	135	70	205	21.063	728	8 wells	8,008	55.2	0.94	0.724	0.00353	14.670	4.490
H- 3634	Run of Std 28x28x12 tee (with expansion)	140	70	210	24.574	1,183	13 wells	9,191	46.5	0.94	0.454	0.00216	15.124	4.037
H- 3774	Run of Std 28x28x10 tee	135	70	205	24.574	728	7 wells	9,919	50.2	0.94	0.506	0.00247	15.630	3.531
H- 3909	Non run of Std 48x36x36[3] tee and valve (with expansion from 28" to 36")	1232	420	1652	42.126	5,642	63 wells	15,561	26.8	0.94	0.693	0.00042	16.323	2.838
H- 5141	End at Gas Mover Station	—	10	10	42.136			15,561	26.8	0.94	0.004	0.00042	16.327	2.834
SUBTOTAL: Head loss through Pathway "D" from well 103 to Gas Mover Station													16.327	in w.c.
Vacuum available at Gas Mover Station before blower (-90" w.c. assuming gas movers have a 100" capacity and 10" of headloss occurs at the primary knockout)													90.000	in w.c.

NOTES:

1.) Used 91 SCFM for standard trench/wellhead flow which is based on a total modeled flow of 15,561 scfm for the recoverable portion of the accelerated case times a 1.5 factor of safety (171 wells/15,561 ~ 91 scfm per well
2.) H= Horizontal design length (equivalent fitting length NOT added in) in linear feet from start point (1) to end point (2).
3.) Plans call for two 36" pipes to run to cleanup plant. A 48" pipe was used to simplify headloss calculations.

Assumes all wells from main interior header flow south to perimeter header (valves at high point open). This is considered an emergency flow path utilized for short periods of maintenance/repairs and therefore piping was not redesigned ranges to bring velocities and headloss within target ranges.

Values used for equivalent pipe lengths for fitting are extremely conservative.

Valves: (6" - 8'), (8" - 10'), (12" -12'), (18" - 14'), (24" - 18')
Run of standard tees (6x6x6 - 10'), (8x8x6 - 15'), (10x10x6 - 16'), (12x10x10 - 20'), (18x18x6 - 30'), (18x18x8 - 30'), (24x24x6 - 60'), (24x24x8 - 60'), (24x24x10 - 60') (28x28x10 - 70'), (28x28x12 - 70') (36x36x6 - 75'), (36x36x8 - 75'), (36x36x18 - 75')
Non-run of standard tees: (6x6x6 - 30'), (24x24x10 - 130'), (18x18x12 - 100'), (48x36x36 - 300')
Expansion joints: (6" to 8" - 18')(8" to 10" - 25'), (10" to 18" - 25'),(18" to 24" - 50'), (24" to 28" - 70'), (28" to 36" - 90')
Sudden Contractions: (18" to 10" - 15), (24" to 18" - 30')