CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS
TCEQ PERMIT NO. MSW-2293C

MAJOR PERMIT AMENDMENT APPLICATION

VOLUME 2 OF 6

Prepared for

Meadow Landfill, LLC

August 2024

STATE OF TEXAS
KYLE D. GOULD
106018
LICENSED
PROFESSIONAL ENGINEER

08/05/2024

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0120-809-11-05

This document is intended for permitting purposes only.

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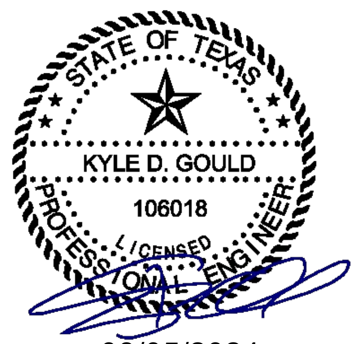
CONTENTS



08/05/2024

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS
TCEQ PERMIT NO. MSW-2293C

MAJOR PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIB
ALTERNATIVE LINER POINT OF COMPLIANCE DEMONSTRATION

Prepared for

Meadow Landfill, LLC

August 2024

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
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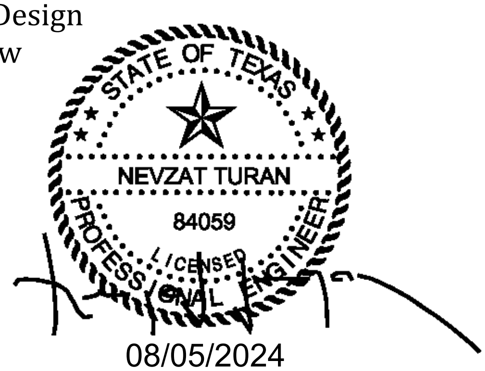
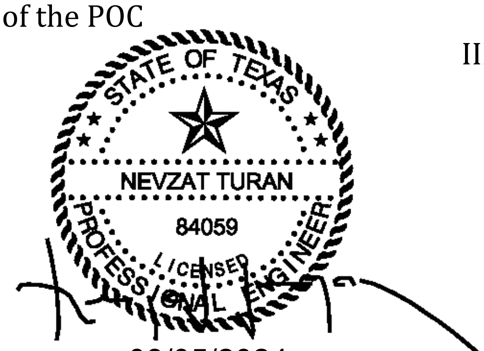


STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

TABLES



08/05/2024

1 INTRODUCTION

1.1 Purpose and Scope

The proposed development of the City of Meadow Landfill includes an alternative liner for the subtitle D lined areas of the landfill. The purpose of this appendix is to demonstrate that the proposed alternative liner system meets the point of compliance (POC) requirement set forth in Title 30 TAC §330.331(a), which is:

> *"a design that ensures that the concentration values listed in Table 1 of this paragraph will not be exceeded in the uppermost aquifer at the point of compliance."*

This is achieved by demonstrating that the predicted concentrations of selected leachate chemical constituents do not exceed the maximum contaminant levels (MCLs) listed in Table 1 in §330.331(a)(1) in the uppermost aquifer at the POC.

Section 1.2 provides a description of the alternative liner system design, and Section 1.3 provides an overview of the alternative liner POC demonstration.

1.2 Proposed Alternative Liner Design

The alternative liner system design is shown on Figure 1-2. As shown on Figure 1-2, the proposed alternative liner system for future cells will consist of a 60-mil HDPE geomembrane placed over a geosynthetic clay liner (GCL). A geocomposite leachate collection layer consisting of a 200-mil-thick geonet with a 6 oz/sy non-woven geotextile heat-bonded to both sides for sideslopes and to one side for the floor grades will be placed above the geomembrane and will be covered with a 2-foot-thick layer of protective cover soil.

Details for the alternative liner system are provided in Appendix IIIA-A – Liner and Final Cover System Details. The design of the leachate collection is presented in Appendix IIIC – Leachate and Contaminated Water Management Plan. The stability of the liner system is analyzed in Appendix IIIE-A and the liner settlement analysis is provided in Appendix IIIE-B.

1.3 POC Demonstration Overview

The purpose of the POC demonstration is to show that the proposed alternative liner system design will meet the POC requirements set forth in §330.331(a)(1). This is achieved by demonstrating that the predicted concentration of a wide range of leachate chemical constituents does not exceed allowable values at the POC.

The proposed design (i.e., alternative liner system shown on Figure 1-2) will minimize leachate seepage into the groundwater below the containment system; therefore, current groundwater conditions at the site will be unaffected and will remain below the constituent parameters listed in Table 1 of §330.331(a)(1).

Section 2 provides a discussion of the site's geology, groundwater quality, and leachate quality. The landfill configurations analyzed and the POC demonstration methods are discussed further in Section 3. A summary of the POC demonstration is provided in Section 4.

0 300 600
SCALE IN FEET

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMIT OF WASTE
- N 7180000 — STATE PLANE COORDINATE SYSTEM
- 3300 — EXISTING CONTOUR
- 3280 — TOP OF LINER CONTOUR
- SECTOR BOUNDARY
- LEACHATE COLLECTION PIPE
- LEACHATE COLLECTION SUMP
- LEACHATE RISER PIPE
- MW-1 PROPOSED OBSERVATION/GROUNDWATER MONITORING WELL
- GMP-5 PROPOSED LANDFILL GAS MONITORING PROBE
- GMP-2 EXISTING LANDFILL GAS MONITORING PROBE

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. ELEVATIONS SHOWN HEREON ARE RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988.
3. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.
4. EXCAVATION SLOPES AND SLOPES OUTSIDE THE LIMIT OF WASTE (e.g., CHANNELS) ARE TYPICALLY 3H:1V.
5. REFER TO APPENDIX IIIC FOR LEACHATE STORAGE INFORMATION.
6. ELEVATION OF DEEPEST EXCAVATION AT THE LCS SUMP IS 3251.0 FT-MSL.
7. SEQUENCE OF SITE DEVELOPMENT IS PROVIDED IN PARTS I/II, APPENDIX I/IIA DRAWINGS I/IIA.4 THROUGH I/IIA.7.

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DATE: 08/2024
FILE: 0120-809-11
CAD: FIG 1-1 TOP OF LINER PLAN.DWG

DRAWN BY: RAA
DESIGN BY: JPI
REVIEWED BY: NT

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
TOP OF LINER PLAN

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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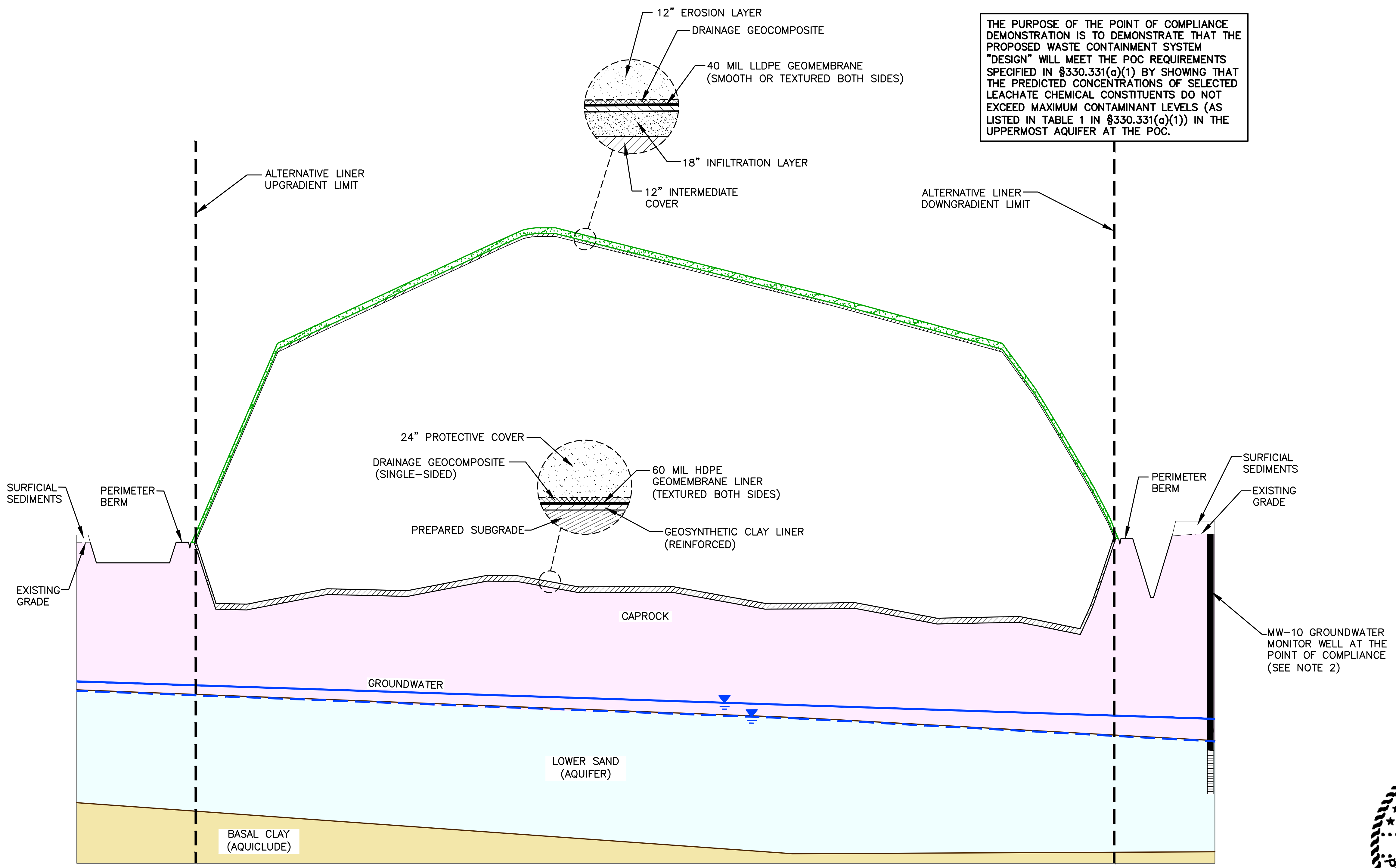
FIGURE 1-1

SHEET IIIB-2A

O:\0120\809\EXPANSION 2023\PART III\IIIB\FIG 1-1 TOP OF LINER PLAN.dwg, jpuhr, 1:2

THE PURPOSE OF THE POINT OF COMPLIANCE DEMONSTRATION IS TO DEMONSTRATE THAT THE PROPOSED WASTE CONTAINMENT SYSTEM "DESIGN" WILL MEET THE POC REQUIREMENTS SPECIFIED IN §330.331(a)(1) BY SHOWING THAT THE PREDICTED CONCENTRATIONS OF SELECTED LEACHATE CHEMICAL CONSTITUENTS DO NOT EXCEED MAXIMUM CONTAMINANT LEVELS (AS LISTED IN TABLE 1 IN §330.331(a)(1)) IN THE UPPERMOST AQUIFER AT THE POC.



NOTES:

1. TYPICAL GEOLOGIC PROFILE DEVELOPED FROM CROSS-SECTIONS INCLUDED IN APPENDIX IIIG.
2. THE MODEL IS DEVELOPED CONSERVATIVELY USING THE DOWNGRADIENT MONITORING WELL THAT IS CLOSEST TO THE LIMIT OF WASTE AND THE LARGEST TWO-DIMENSIONAL WASTE FILL AREA (I.E., LONGEST DISTANCE LEACHATE BETWEEN THE UPGRADIENT AND DOWNGRADIENT LIMIT OF WASTE).
3. GROUNDWATER ELEVATIONS MEASURED BY WCG IN APRIL 2024 AND POSTED BY MEASUREMENT LOCATIONS IN FT-MSL. GROUNDWATER CONTOURS INTERPOLATED BETWEEN MEASUREMENT LOCATIONS. ACTUAL GROUNDWATER ELEVATIONS MAY VARY FROM THOSE ILLUSTRATED IN THIS FIGURE.
4. DUE TO THE SEMI-CONFINED NATURE OF THE AQUIFER ACROSS THE SITE, THE MODELED GROUNDWATER SURFACE REPRESENTS THE EXPECTED FLOW OF GROUNDWATER BETWEEN THE BASAL CLAY AQUICLUDE AND THE CAPROCK.

LEGEND

- LIMITS OF WASTE
- APPROXIMATE GROUNDWATER POTENTIOMETRIC SURFACE (SEE NOTE 3)
- MODELED GROUNDWATER SURFACE (SEE NOTE 4)

TYPICAL SECTION A

0 200 400
HORIZONTAL SCALE IN FEET

0 20 40
VERTICAL SCALE IN FEET

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DATE: 08/2024
FILE: 0120-809-11
CAD: FIG 1-2 WASTE CONTAINMENT.DWG

DRAWN BY: SRF
DESIGN BY: JPI
REVIEWED BY: NT

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
WASTE CONTAINMENT SYSTEM
ALTERNATIVE LINER

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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FIGURE 1-2

SHEET IIIB-2B

O:\0120\809\EXPANSION 2023\PART III\IIIB\FIG 1-2 WASTE CONTAINMENT.dwg, jpuhr, 1:2

2 SITE INFORMATION

This section describes the site information related to the POC demonstration, including a discussion on the geologic conditions, groundwater quality, and leachate quality.

2.1 Site Geology

The subsurface characterization of the site is supported by data from 30 borings at locations shown Figure IIIG-B-1 in Appendix IIIG – Geology Report. The borings were advanced during two drilling events conducted in March and August-September of 2023 and are further discussed in Section 3.3 of Appendix IIIG. The subsurface investigation data and geologic cross-sections indicate that the facility's geology can be divided into four site-specific stratigraphic units (Surficial Sediments, Caprock, Lower Sand, and Basal Clay) each unit is described below.

2.1.1 Surficial Sediments

At ground surface lies the Surficial Sediments site-specific stratum which is comprised of predominately loose windblown sand and sediments. These sediments exhibit a high degree of compositional homogeneity with little to no change in material composition, and a predevelopment average thickness of six feet across the site.

2.1.2 Caprock

Beneath the Surficial Sediments lies the Caprock stratum which is comprised of upper Ogallala Formation sediments that are continuous boundary across the permit and is composed predominately of caliche, sand, and silt sediments, with lesser clay and chert. The Caprock unit exhibits an average thickness of approximately 50-feet.

2.1.3 Lower Sand

Beneath the Caprock lies the Lower Sand stratum. The Lower Sand is comprised of Ogallala Formation sediments that are continuous beneath the permit boundary and comprised of unconsolidated, dense to very dense, and moist to wet coarse-grained sediments with an average thickness of approximately 25-feet. The Lower Sand is composed predominately of sand and silt with lesser clay and caliche gravel. The

Lower Sand stratum contains the facility's uppermost monitorable groundwater zone which is commensurate with the regional Ogallala Aquifer.

2.1.4 Basal Clay

The Lower Sand aquifer sediments are underlain by low permeability fine-grained, dry to moist, clayey sediments of the Basal Clay stratum that functions as the Lower Confining Unit to groundwater. The Basal Clay is comprised predominately of hard interbedded clays, silty clay, shaley clay, and sandy clay. The facility's geology and hydrogeology are discussed further in Appendix IIIG – Geology Report.

2.2 Uppermost Aquifer

The uppermost monitorable groundwater zone within the landfill permit boundary is encountered within Lower Sand sediments which transmit groundwater within the subsurface and above the underlying Basal Clay stratum. Lower Sand groundwater exhibits confined conditions with greater confining potential in the northwest (where Lower Sand sediments are overlain by greater thicknesses of Caprock stratum sediments) and lesser confined conditions downgradient to the south nearing the Ogallala Formation outcrop approaching Rich Lake. The Lower Sand constitutes the Uppermost Aquifer beneath the Site.

2.3 Groundwater Monitoring System

The facility is an existing Type IAE and Type IVAE landfill (MSW Permit No. 2293) with no groundwater monitoring system. A groundwater monitoring network design is proposed to accommodate the facility's proposed waste footprint expansion as a Type I MSW Landfill. The proposed groundwater monitoring system network buildout is illustrated on Figure IIIH-A-2 and IIIH-A-3 in Appendix IIH. The groundwater monitoring system design is further discussed in the Groundwater Sampling and Analysis Plan provided in Appendix IIIH.

The MCL's listed in §330.331(a)(1) and the current groundwater constituent levels are listed in Table 2-1. As shown in the table, current constituent levels at the site are below the MCLs set forth in §330.331(a)(1).

Table 2-1
Chemical Constituent MCLs and Current Groundwater Conditions

Constituent	MCL Listed in §330.331(a)(1) (mg/l)	Site Groundwater Concentrations[1] (mg/l)
Arsenic	0.05	0.0476
Barium	1.0	0.415
Benzene[2]	0.005	0.0005
Cadmium[2]	0.01	0.001
Carbon tetrachloride[2]	0.005	0.0025
Chromium (hexavalent)[2]	0.05	0.01
2,4-Dichlorophenoxy acetic acid	0.1	--
1,4-Dichlorobenzene[2]	0.075	0.001
1,2-Dichloroethane[2]	0.005	0.0005
1,1-Dichloroethylene	0.007	--
Endrin	0.0002	--
Fluoride	4	--
Lindane	0.004	--
Lead[2]	0.05	0.0284
Mercury	0.002	--
Methoxychlor	0.1	--
Nitrate	10	--
Selenium[2]	0.01	0.005
Silver[2]	0.05	0.005
Toxaphene	0.005	--
1,1,1-Trichloroethane	0.2	0.0005
Trichloroethylene[2]	0.005	--
2,4,5-Trichlorophenoxy acetic acid	0.01	--
Vinyl Chloride[2]	0.002	0.001

1 Current Groundwater concentrations are reproduced from analytical testing performed in April 2023 by WCG.
2 For constituents not detected at reporting limits, one-half of the reporting limit is listed.

2.4 Leachate Quality

The demonstration was conducted by showing that the alternative liner design will not allow the concentrations of the 24 EPA listed chemical constituents shown in Table 2-2 (the same constituents listed in Table 1 of Title 30 TAC §330.331(a)(l)) to be exceeded at the relevant point of compliance. This is done by modeling a Dilution Attenuation Factor (DAF), defined as the initial input leachate concentration, C_O, divided by the concentration at the POC, C_P:

$$DAF = \frac{C_O\text{, Initial Constituent Concentration of Leachate within the Landfill}}{C_P\text{, Constituent Concentration at the POC}}$$

The input leachate concentrations are based on recommended input concentrations from USEPA's "Draft Background Summary of Data on Municipal Solid Waste Landfill Leachate Characteristics: July 1988", and the Toxicity Characteristic Leaching Procedure (TCLP) in 40 CFR 261.62. The greater of the two values for each constituent was used as the recommended input concentration. Table 2-2 lists these data. As noted in the above equation, the DAF represents the factor by which the constituent concentration is expected to decrease between the landfill and the POC. As shown in Table 2-2, the required DAFs range from less than 100 to 260. When the constituent's concentration is divided by the model predicted DAF, the resulting concentration must be less than the allowable maximum contaminant levels (MCLs) in groundwater for the chemical parameters listed in Table 1 included in Title 30 TAC §330.331(a)(1).

The highest listed DAF is 260, which indicates that if a trichloroethylene concentration of 1.3 mg/l exists within the landfill, then the concentration would have to be reduced by a factor of 260 prior to the constituent reaching the POC to meet the 0.005 mg/l MCL for this constituent $(DAF = \frac{1.3 mg/l}{0.005 mg/l} = 260)$. A DAF of 260 has been the historical standard used in POC demonstrations approved by the TCEQ and is the standard discussed in the original TCEQ guidance document for POC demonstrations (*Texas Water Commission Alternate Liner Design Handbook*, August 1993). A substantial amount of leachate quality data has been generated from Subtitle D landfills since 1993. Based on WCG's experience in Texas, the initial concentrations for the 24 constituents shown on Table 2-2 are conservative compared to leachate quality at other Texas MSW landfills.

Table 2-2
Chemical Constituent Concentrations in Leachate

Constituent	MCL (mg/L) Listed in §330.331(a)(1)	Leachate Quality Information Historically Used for POC Demonstrations in Texas (mg/L)	Minimum Required DAF in Guidance[1]
Arsenic	0.05	5.0	100
Barium	1.0	100.0	100
Benzene	0.005	0.814	163
Cadmium	0.01	1.0	100
Carbon tetrachloride	0.005	0.5	100
Chromium[1] (hexavalent)	0.05	5.0	100
2,4-Dichlorophenoxy acetic acid	0.1	10.0	100
1,4-Dichlorobenzene	0.075	7.5	100
1,2-Dichloroethane	0.005	0.5	100
1-1-Dichloroethylene	0.007	0.7	100
Endrin	0.0002	0.05	250
Fluoride	4	--	--
Lindane	0.004	0.4	100
Lead	0.05	5.0	100
Mercury	0.002	0.2	100
Methoxychlor	0.1	--	--
Nitrate	10	--	--
Selenium	0.01	1.0	100
Silver	0.05	5.0	100
Toxaphene	0.005	0.5	100
1,1,1-Trichloroethane	0.2	--	--
Trichloroethylene	0.005	1.3	260
2,4,5-Trichlorophenoxy acetic acid	0.01	1.0	100
Vinyl Chloride	0.002	0.2	100

[1] Minimum DAF required for each constituent based on the input concentrations recommended in the 1993 Texas Water Commission Alternate Liner Design Handbook.

3 POINT OF COMPLIANCE DEMONSTRATION METHODS

This section describes the point of compliance (POC) demonstration using (1) the HELP model to estimate leachate percolation through the alternative liner system and (2) MODFLOW to perform pollutant fate and transport simulations between the landfill and the point of compliance. The following subsections discuss the landfill configurations analyzed and the POC demonstration methods using the HELP and MODFLOW models. The demonstration set forth in this appendix is applicable to the entire undeveloped alternative liner area.

3.1 Landfill Configurations Analyzed

3.1.1 Section Development

The location of Sections A and B were developed to represent the area that will receive the alternative liner system and the distance between the liner area and the POC, which is shown on Figure 3-1. Sections A and B were selected to represent the shortest, downgradient distance within the uppermost aquifer between the alternative liner area and the POC. Groundwater at the site flows outward from the southwestern permit boundary northeast towards monitor well MW-10 and southeast towards monitoring well MW-20.

Figure 3-2 is presented to show how Section A is developed. In the waste disposal area, Figure 3-2 shows each element of the containment system (e.g., alternative liner system and Subtitle D final cover system). In addition, the site-specific subsurface soils and hydrogeologic information reproduced from Appendix IIIG are shown in the section for the area between the landfill and the POC. The information shown is input into the MODFLOW model to estimate the fate and transport of leachate constituents in the unlikely event that there is a release from the landfill.

As shown on Figure 3-2, the model is divided into three zones to estimate percolation and groundwater recharge throughout the active life of the landfill and throughout the postclosure period. Zone I is located within the limits of the landfill footprint where alternative liner may be installed. The estimated percolation rate during the life of the landfill footprint is discussed in detail in Section 3.3. However, one conservative assumption is the percolation through the alternative liner system was assumed to flow directly to groundwater (i.e., unsaturated zone between the bottom of the liner and the top of the saturated zone is not included). This assumption ignores travel time, absorption, and consumption of water that occurs within the in-situ subsurface soils. The in-situ caprock stratum is comprised of loose to very dense caliche with low hydraulic conductivity that is expected to allow no recharge to the uppermost aquifer. Therefore, no recharge was modeled for the offsite areas. It is assumed that no recharge occurs in Zone II (i.e., perimeter berm), located between the groundwater recharge zone and the limits of waste. The percolation zones are summarized in Table 3-1.

Table 3-1
Summary of Percolation Zones

Percolation Zone	Description
Zone I (Alternative Liner Area)	This percolation zone models the impact of percolation through the alternative liner system.
Zone II (Perimeter Berm)	This percolation zone represents the perimeter berm area. The berm is considered well-drained where no recharge occurs.
Zone III (Offsite Area)	This percolation zone models the in-situ soils offsite. The in-situ soils (caprock stratum) is classified as loose to very dense caliche where no recharge is expected to occur.

3.1.2 Sequence of Site Development

As shown on Figure 3-2, the alternative liner area is expected to receive waste between 2025 and 2121. Therefore, three timeframes are considered: (1) the active case, which represents the time period beginning when waste is first placed and is expected to last 1 year, (2) the interim case, which represents the time period between the active case until final cover is installed and is expected to last 97 years, and (3) the closed case, which represents the period after final cover is placed and is modeled for 30 years. Sequencing plans for the site are presented in Appendix I/IIA.

3.2 HELP Model Demonstration

3.2.1 HELP Model

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07, is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the landfill. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, run-off, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage. The HELP Model was used to estimate the rate of percolation through the alternative liner system. The percolation rate was determined for various landfill configurations, as discussed in Section 3.2.2.

3.2.2 Configurations Modeled in HELP

A HELP model simulation was performed to obtain an assumed current leachate percolation rate through the bottom of the alternative liner area. This simulation assumes the maximum waste column thickness (130 feet) to determine a worst-case percolation rate. Three HELP Model simulations were performed to obtain percolation rates through the alternative liner system. Table 3-2 summarizes the landfill configurations modeled using HELP.

Table 3-2
HELP Model Configurations

Area	Case	Description
Alternative Liner Area (Zone I)	Active, 10 ft waste	The alternative liner area models the impact of percolation through the alternative liner system under expected filling conditions for both active, interim, and closed conditions.
	Interim, 130 ft waste	
	Closed, 130 ft waste	

3.2.3 HELP Model Input

Each case listed in Table 3-2 was modeled for various periods with synthetically generated precipitation data using normal mean monthly precipitation data from the National Oceanic and Atmospheric Administration (NOAA) from the Brownfield #2, Texas weather station for the years 1991 through 2020. Temperature and solar radiation data were also synthetically generated by the HELP Model using program defaults for Midland, Texas.

The active and interim conditions for the alternative liner area were modeled for 1 year and 10 years respectively, based on the expected conditions over the life of the site for the alternative liner area, as discussed in Section 3.1.2. The closed cases were modeled for 30 years to represent the postclosure period. The National Resources Conservation Service (NRCS) runoff curve numbers were calculated by HELP based on soil data and expected ground cover, surface slope, and slope length.

Additional HELP input information is provided in Appendix IIIB-A.

3.3 Percolation Rate Summary

The percolation rates for Zones I through III, which include the results for the HELP cases listed in Section 3.2.2, are summarized below in Table 3-3. The output files and HELP summary table are included in Appendix IIIB-A.

Table 3-3
Percolation Rate Summary

Percolation Zone	Case	Leachate Generation Rate[1]	Percolation Rate
Zone I (Alternative Liner Area)	Active Case (10 ft waste)	0.0 gal/ac/yr	0.0000 mm/yr
	Interim Case (130 ft waste)	16,505.5 gal/ac/yr	0.0001 mm/yr
	Closed Case (130 ft waste)	3,691.5 gal/ac/yr	0.00002 mm/yr
Zone II (Perimeter Berm)	N/A	N/A	0.0 mm/yr
Zone III (Off-Site Recharge)	In-situ Soil	N/A	0.0 mm/yr

1 Leachate generation rate (i.e., lateral drainage collected) and percolation rate values are reproduced from the HELP Version 3.07 output included in Appendix IIIB-A.

As shown in the results included in Table 3-3, there is a small amount of percolation predicted by the HELP model for the alternative liner area. Therefore, the percolation rates shown in Table 3-3 will be utilized in the fate and transport modeling discussed in Section 3.4.

3.4 MODFLOW

Various computer programs are available to model contaminant transport for point of compliance (POC) demonstrations. The model selected to support this additional POC demonstration is MODFLOW. MODFLOW is a USGS modular finite-difference flow model, which is a computer code that solves the groundwater flow equation. The program is used to simulate the flow of groundwater through aquifers. Visual MODFLOW, developed by Waterloo Hydrogeolic, has been used for the simulations included in this appendix.

3.4.1 Leachate Quality

A single simulation can account for all 24 constituents by assuming the constituents act as particles that do not experience carbon absorption or chemical or biological decay. This very conservative assumption discounts natural attenuation processes that normally act to reduce chemical concentrations. If the input leachate concentration is assumed to be 1 mg/l, then the DAF at the POC becomes the reciprocal of the output concentration calculated by MODFLOW. The reciprocal of the MODFLOW result must then equal or exceed the most critical DAF to meet TCEQ requirements.

Table 2-2 presents a summary of the MCLs listed in Table 1 of §330.331(a)(1), in addition to the leachate quality input data historically used for POC demonstrations in Texas. As noted in Table 2-2, the DAFs range from less than 100 to 260. Refer to Section 2.3 for a detailed discussion.

3.4.2 Groundwater Flow Analysis

The Preconditioned Conjugate-Gradient 2 (PCG2) solver was selected for the POC demonstration to solve transient (i.e., non-steady state) flow produced with varying percolation values with respect to time. The PCG2 solver works on a two-tier approach to a solution at one time step, inner and outer iterations. Outer iterations are used to vary the preconditioned parameter matrix in an approach toward the solution. An outer iteration is where the hydrogeological parameters of the flow system are updated (i.e., transmissivity, saturated thickness, storativity) in the preconditioned set of matrices. The inner iterations continue until the final convergence criteria are met. The PCG2 solver is described in the USGS Water-Resources Investigations Report 90-4048 (Hill, 1990). PCG2 is a numerical engine in MODFLOW that solves the groundwater flow portion of the MODFLOW simulation. MODFLOW processes the data sets by combining similar durations of input (e.g., recharge and percolation) into "stress periods." A stress period represents a time period of constant input data. For this demonstration, the stress periods consist of the following:

- Active Landfill Condition. The projected year waste filling begins in the expansion area for 1 year.
- Interim Landfill Condition. The projected year of waste filling operations in the expansion area after the first year through the projected year of Subtitle D final cover construction over the alternative liner area (e.g., 97 years).
- Closed Landfill Condition. The projected year of Subtitle D final cover construction over the alternative liner area through the projected year of the end of the postclosure care period for the landfill (i.e., 30 years).

The model divides each stress period into "time steps" which are incremental steps between each landfill condition. The time step factor of 10, the default factor in MODFLOW, is used in the simulations. For example, the time step for a 50-year stress period is 5 years, which is calculated by MODFLOW by dividing the stress period of 50 years by 10. During each time step, the model applies percolation and recharge to the groundwater surface. Percolation and recharge are input into the model by defining cells in the uppermost grid layer; however, the model applies the percolating water to the existing groundwater surface, bypassing unsaturated zones. The uppermost grid layer represents the plan view of the two-dimensional model; therefore, the model receives any percolation from this layer. PCG2 achieves a mass balance for each time step by performing simultaneous iterations for each saturated cell until the program converges. For example, mass balance is achieved when the resulting drain boundary discharge is equal to the drain boundary capacity, which is established by the program utilizing the hydrogeologic characteristics of the model. Additionally, at each time step, the program establishes the groundwater surface that is in balance with (1) the groundwater surface in the previous time step, (2) percolating water entering the model, and (3) water leaving the cell during the time step or water draining out of the model at the drain boundary cells. Once this step is complete for each cell and for the entire model simulation period, the model is ready to run the fate and transport module.

3.4.3 Fate and Transport Model Analysis

The fate and transport modeling has the capability to track the concentration of contaminants in groundwater with respect to time. The fate and transport model is also capable of modeling sources (e.g., defined boundaries of contaminated groundwater and percolation. Developed by Zheng in 1990 for the United States Environmental Protection Agency (EPA), MT3D code (which is a module in MODFLOW) is the primary model for fate and transport.

MT3D Code

MT3D (Modular 3-Dimensional Transport Model) is a transport model for simulating advection, dispersion, and chemical reactions of contaminants in groundwater flow systems. MT3D code solves the transport equation after the flow solution has been obtained from the groundwater flow model (i.e., PCG2). Various versions of MT3D code have been commonly used in contaminant transport modeling and remediation assessment studies (e.g., MT3Dv1.1, MT3Dv1.5, MT3Dv1.86, MT3D96, MT3D99, and MT3DMS).

The partial differential equation describing the fate and transport of contaminants of species k in three-dimensional, transient (i.e. non-steady state) groundwater flow systems can be written as follows:

$$\frac{\partial(\theta C^k)}{\partial t} = \frac{\partial}{\partial x_i}\left(\theta D_{ij}\frac{\partial C^k}{\partial x_j}\right) - \frac{\partial}{\partial x_i}\left(\theta v_i C^k\right) + q_s C_s^k + \sum R_n$$

where

C^k	is the dissolved concentration of species k, ML^{-3};
θ	is the porosity of the subsurface medium, dimensionless;
t	is time, T;
x_i	is the distance along the respective Cartesian coordinate axis, L;
D_{ij}	is the hydrodynamic dispersion coefficient tensor, L^2T^{-1};
v_i	is the seepage or linear pore water velocity; LT^{-1}; it is related to the specific discharge or Darcy flux through the relationship, $v_i = q_i / \theta$
q_s	is the volumetric flow rate per unit volume of aquifer representing fluid sources
C_s^k	(positive) and sinks negative, T^{-1};

is the concentration of the source or sink flux for species k, ML^{-3};

$\sum R_n$ is the chemical reaction term, $ML^{-3}T^{-1}$.

MT3DMS Solver Selection

MT3DMS (Modular 3-Dimensional Multispecies Transport Model) was selected for the POC demonstration to simulate changes in concentrations of miscible contaminants in groundwater considering advection and dispersion with various types of boundary conditions and external sources or sinks. Zheng and Wang developed this multi-species transport model in June 1998 for the US Army Corps of Engineers (USACE). MT3DMS can accommodate very general spatial discretization schemes and boundary conditions, including: 1) confined, unconfined or variably confined/unconfined aquifer layers; 2) inclined model layers and variable cell thickness within the same layer; 3) specified concentration or mass flux boundaries; and 4) the solute fate and transport effects of external hydraulic sources (i.e., percolation). Note that various decay processes were not included in this demonstration to provide a conservative analysis. These decay processes include chemical and biological decay as well as adsorption.

MT3DMS Solution Method

The Method of Characteristics (MOC) module is available in all versions of MT3D. MOC uses a conventional particle tracking technique based on a mixed Eulerian-Lagrangian method for solving the advection term. The dispersion, sink/source mixing and chemical reaction terms are solved with the finite difference method, which tracks a large number of moving particles forward in time and keeps track of the concentration and position of each particle.

For this demonstration, the amount of leachate (i.e., source) that percolates from the landfill to the subsurface is established using the HELP model (discussed in Section 3.2). An initial constituent concentration is then assigned to the leachate that is predicted to percolate from the landfill (refer to Appendix IIIB-A for the HELP model simulations).

MODFLOW uses a water balance methodology for the saturated soils within the area defined by the groundwater surface at the top, no flow boundary at the bottom, and upgradient and downgradient boundary conditions to determine the final concentration of the leachate constituents at the POC. The leachate that is modeled to percolate from the landfill enters the subsurface. The constituents in the leachate are modeled to mix with groundwater and are simulated to change in concentration due to leachate moving into groundwater (i.e., advection) and dispersion. It is important to note that the leachate constituents will also be reduced or attenuated during the time that the leachate is modeled to travel from the landfill to the POC due to (1) adsorption within the subsurface soil matrix and (2) biological and chemical decay. However, these factors were not included in the demonstration to provide a conservative analysis.

Fate and Transport Output

Fate and transport results and outputs are discussed in Section 4. The MT3DMS fate and transport modeling was performed for a period of 127 years (1 year active, 97 years interim, and 30 years closed landfill condition). The resulting DAF contours represent the ratio of dilution factor of 260 to represent the extent of 260 DAF contours, which stands for the minimum acceptable DAF value. The DAF contours are the result of attenuation of constituents due to (1) advective flow and (2) dispersion of constituents in the groundwater.

3.4.4 Parameter Selection

The following summarizes the model input key parameters.

- **Landfill Area Modeled.** The entire alternative liner area is modeled in the two-dimensional MODFLOW simulations as a section.
- **Time Frame.** The alternative liner area is expected to be in the active and interim condition (i.e., without final cover) for approximately 97 years. The modeling is performed for the duration from the initial placement of waste on the alternative liner area (starting the year of 2025 as shown on Figure 3-2) to the closure of the site, the year 2121 (final postclosure year 2151).
- **Percolation Rates.** The percolation rates were estimated as discussed in Section 3.3.
- **Subsurface Information.** The site geology and hydrogeology information is reproduced from Appendix IIIG. The key MODFLOW input parameters are listed in Table 3-4.
- **Groundwater.** Starting groundwater contours have been obtained from the groundwater contours generated based on the groundwater measurements obtained from the site on April 2024 as presented on Figure 3-1.

Table 3-4
MODFLOW Model Input Parameters

Layer	Maximum Hydraulic Conductivity (cm/s)[1]		Specific Storage (1/ft)[2]	Specific Yield[3]	Effective Porosity[1]	Total Porosity[3]
Lower Sand Layer	$K_{x,y}$	$1.08x10^{-3}$	$3.28x10^{-5}$	.30	.30	.45
	K_z	$2.80X10^{-3}$				

1 Maximum hydraulic conductivity and effective values for subsurface soils obtained from Appendix IIIG.
2 Specific storage values for subsurface soils obtained from Domenico and Mifflin (1965).
3 Specific yield and total porosity values for subsurface soils obtained from the Morrison and Johnson (1967).

4 POINT OF COMPLIANCE DEMONSTRATION RESULTS

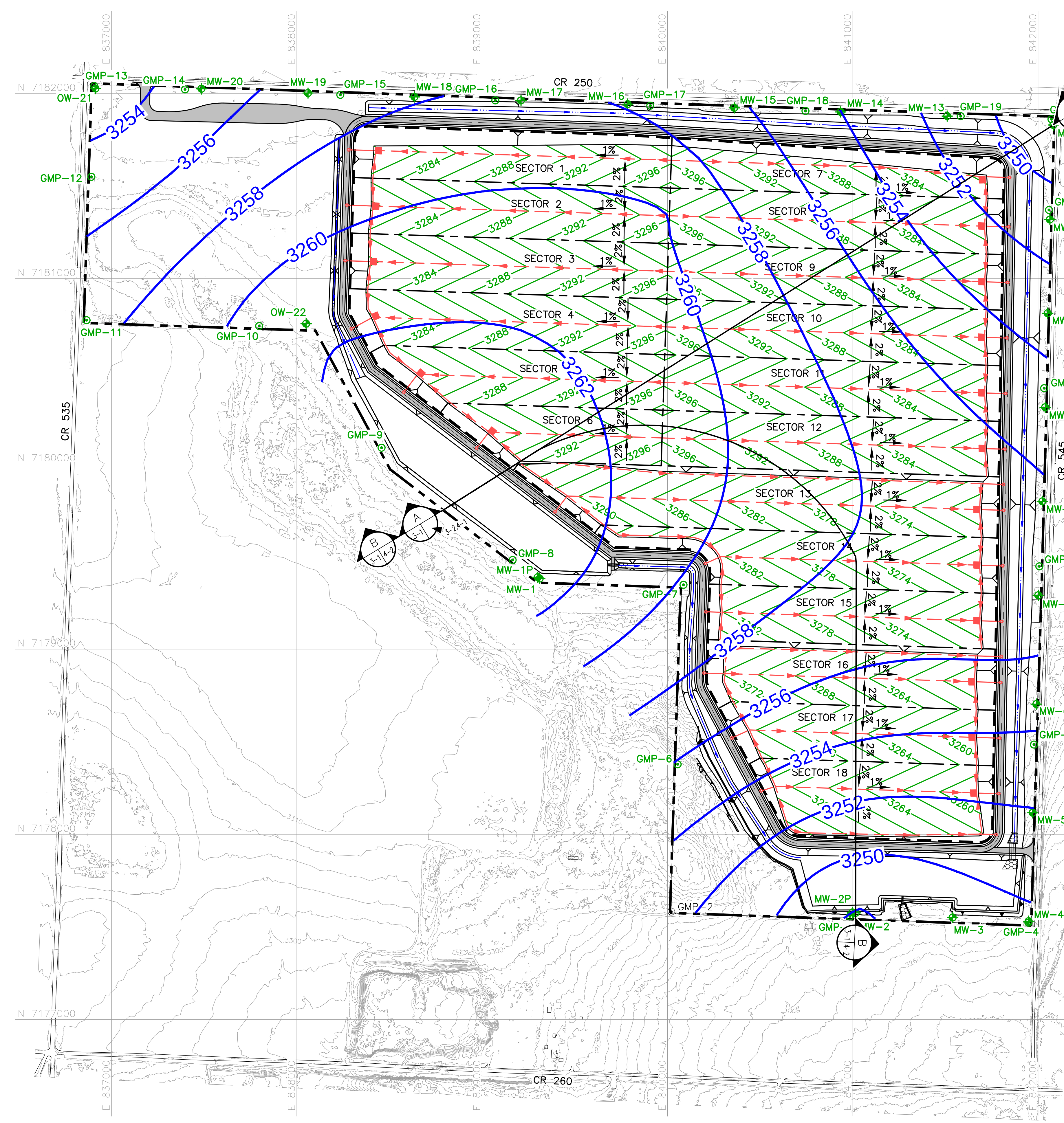
The results of the POC demonstration are summarized in Table 4-1 and graphically illustrated on Figure 4-1. The demonstration results in a DAF well in excess of the minimum required value of 260 and is expected that only natural groundwater background levels will be detected on the POC. Based on the model simulation results, it is concluded that the "waste containment system design" included in this permit amendment application meets or exceeds the requirements of Title 30 TAC §330.331(a)(1).

Table 4-1
Summary of MODFLOW Simulation Results

Model Section	Calculated DAF	Minimum Required DAF	Design Compliant with §330.331(a)(1)
Section A	$3.5x10^7$	260	Yes
Section B	$3.9x10^7$	260	Yes

Tables 4-2 and 4-3 have been developed to further illustrate how the DAF is used to determine the constituent level at the POC. As summarized on Tables 4-2 and 4-3, the concentration at the POC (combined total of background concentration and constituent concentration at the POC) is less than the MCL listed in §330.331(a)(1).

As shown in Tables 4-1 through 4-3, the waste containment system produces DAFs that are well above the required minimum value.



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0 300 600
SCALE IN FEET

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMIT OF WASTE
- N 7180000 — STATE PLANE COORDINATE SYSTEM
- 3300 — EXISTING CONTOUR
- 3280 — TOP OF LINER CONTOUR
- SECTOR BOUNDARY
- LEACHATE COLLECTION PIPE
- LEACHATE COLLECTION SUMP
- LEACHATE RISER PIPE
- MW-1 PROPOSED OBSERVATION/GROUNDWATER MONITORING WELL
- GMP-5 PROPOSED LANDFILL GAS MONITORING PROBE
- GMP-2 EXISTING LANDFILL GAS MONITORING PROBE
- 3260 GROUNDWATER POTENTIOMETRIC SURFACE CONTOUR IN FT-MSL

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. ELEVATIONS SHOWN HEREON ARE RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988.
3. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.
4. EXCAVATION SLOPES AND SLOPES OUTSIDE THE LIMIT OF WASTE (e.g., CHANNELS) ARE TYPICALLY 3H:1V.
5. REFER TO APPENDIX IIIC FOR LEACHATE STORAGE INFORMATION.
6. ELEVATION OF DEEPEST EXCAVATION AT THE LCS SUMP IS 3251.0 FT-MSL.
7. SEQUENCE OF SITE DEVELOPMENT IS PROVIDED IN PARTS I/II, APPENDIX I/IIA DRAWINGS I/IIA.4 THROUGH I/IIA.7.
8. GROUNDWATER POTENTIOMETRIC SURFACE CONTOURS ARE INTERPOLATED BETWEEN MEASUREMENT LOCATIONS; ACTUAL CONDITIONS MAY VARY.
9. GROUNDWATER ELEVATIONS MEASURED BY WCG IN APRIL 2024 AND POSTED BY MEASUREMENT LOCATIONS IN FT-MSL. GROUNDWATER CONTOURS INTERPOLATED BETWEEN MEASUREMENT LOCATIONS. ACTUAL GROUNDWATER ELEVATIONS MAY VARY FROM THOSE ILLUSTRATED IN THIS FIGURE.

SHEET IIIB-16A

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CAD: FIG 3-1 GROUNDWATER CONTOUR.DWG

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DESIGN BY: JPI
REVIEWED BY: NT

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MAJOR PERMIT AMENDMENT
APRIL 2024
GROUNDWATER CONTOUR MAP

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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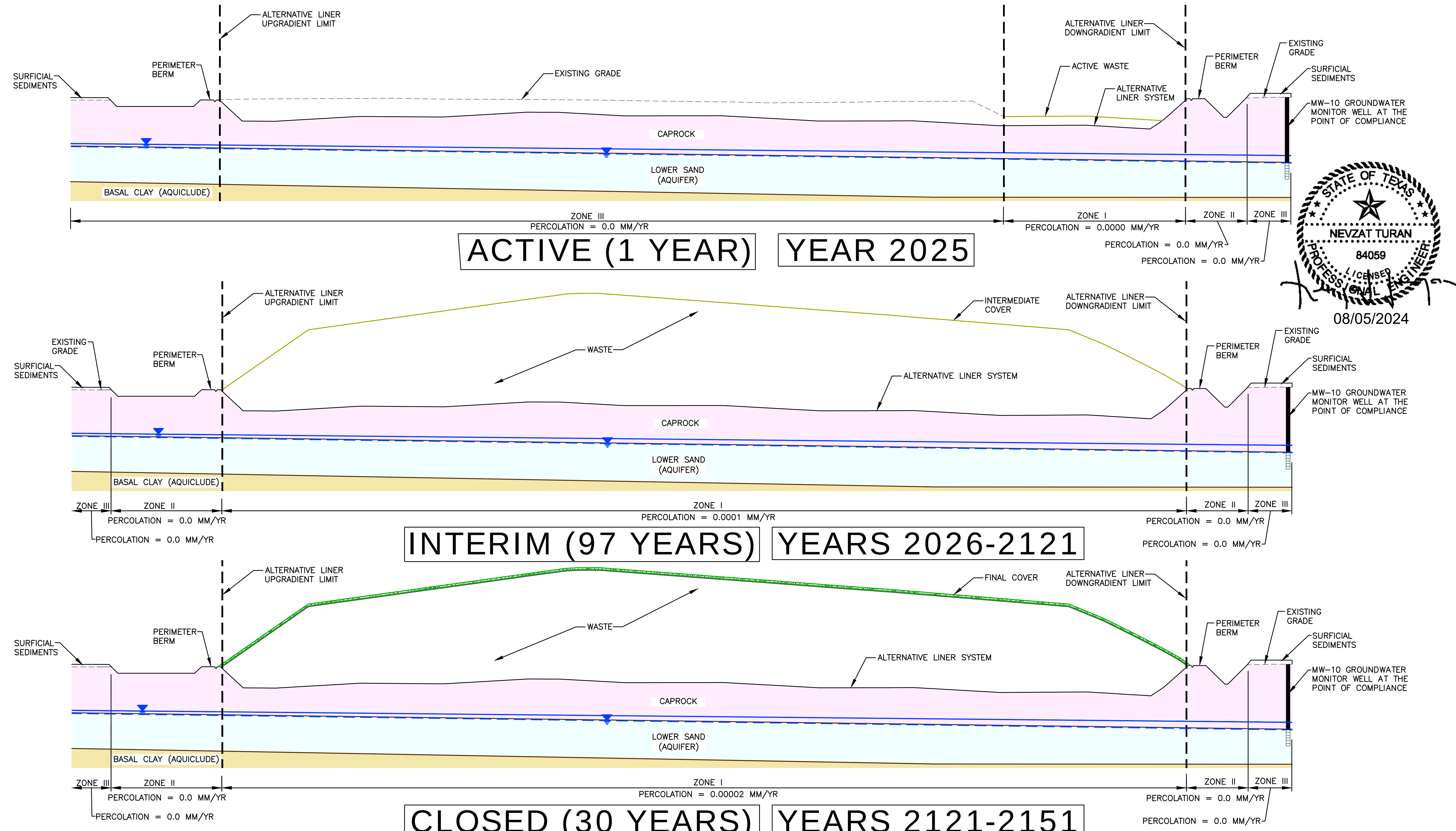
FIGURE 3-1

O:\0120\809\EXPANSION 2023\PART III\IIIB\FIG 3-1 GROUNDWATER CONTOUR MAP.dwg, jpuhr, 1:2



LEGEND

- LIMITS OF WASTE
- APPROXIMATE GROUNDWATER POTENTIOMETRIC SURFACE
- MODELED GROUNDWATER SURFACE

SECTION A (A, 3-1, 3-2)

HORIZONTAL SCALE IN FEET: 0, 150, 300

VERTICAL SCALE IN FEET: 0, 50, 100

SHEET IIIB-16B

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DATE: 08/2024
FILE: 0120-809-11
CAD: FIG 3-2-SECTION A.DWG

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DESIGN BY: JPI
REVIEWED BY: NT

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TYPICAL SEQUENCE OF EVENTS

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TERRY COUNTY, TEXAS

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FIGURE 3-2

Table 4-2
Summary of Constituent Levels at the POC
(Section A)

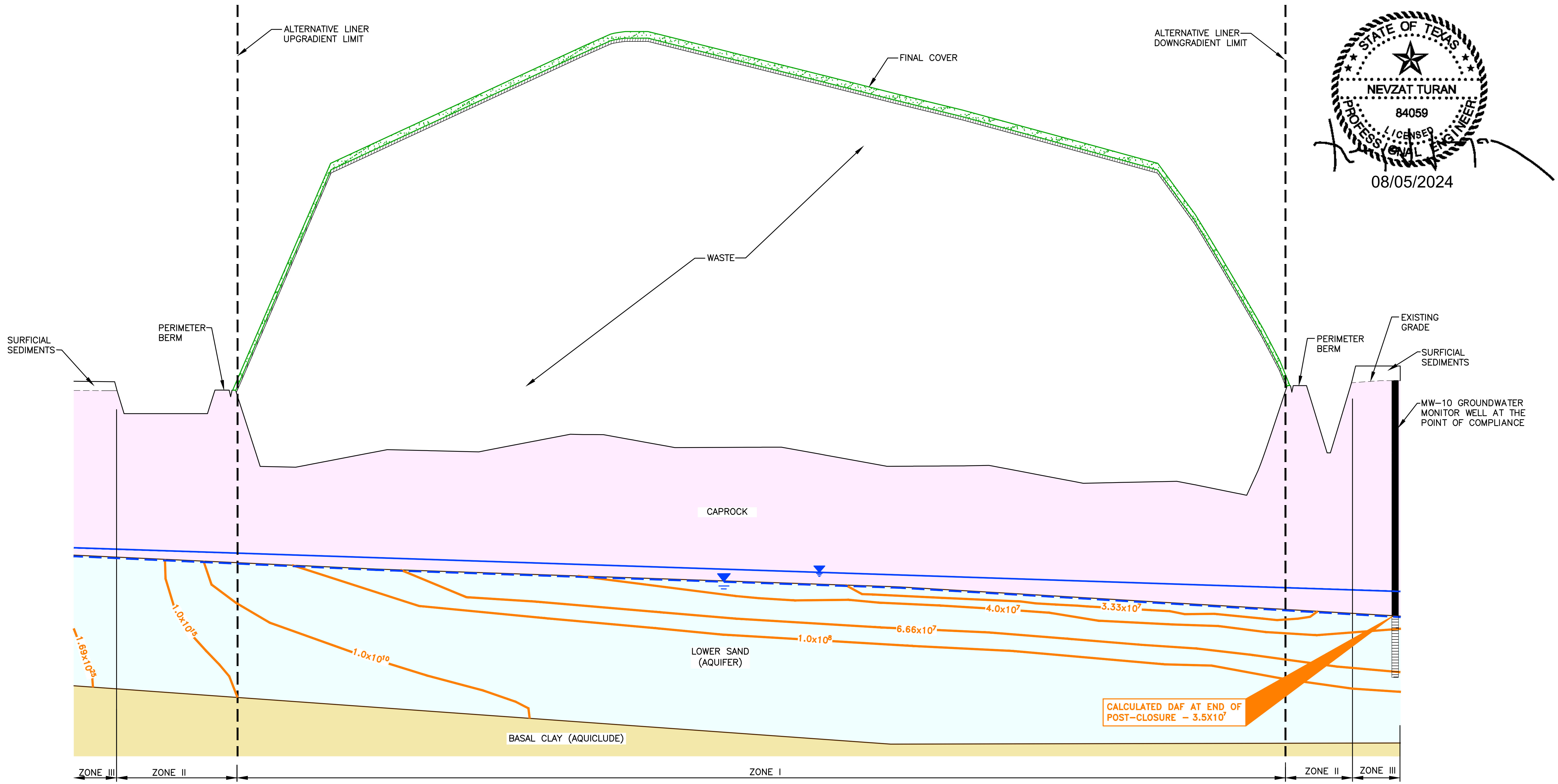
Constituent	C_{BG}, Background Concentration[1] (mg/l)	C_O[2]		DAF[3] (mg/l)	=	CP (mg/l) (Constituent Concentration at the POC due to Estimated Leachate Percolation)	$C_{BG} + C_P = C_T$ at POC (mg/l)	MCL (mg/l) Listed in §330.331(a)(1)	C_T at POC < MCL
Arsenic	0.0476	5.0	/	3.5E+07	=	1.4E-07	0.0476	0.05	YES
Barium	0.415	100	/	3.5E+07	=	2.9E-06	0.4150	1	YES
Benzene	0.0005	0.5	/	3.5E+07	=	1.4E-08	0.0005	0.005	YES
Cadmium	0.001	1.0	/	3.5E+07	=	2.9E-08	0.0010	0.01	YES
Carbon tetrachloride	0.0025	0.5	/	3.5E+07	=	1.4E-08	0.0025	0.005	YES
Chromium (hexavalent)	0.01	5.0	/	3.5E+07	=	1.4E-07	0.0100	0.05	YES
2,4-Dichlorophenoxy acetic acid	--	10.0	/	3.5E+07	=	2.9E-07	2.9E-07	0.1	YES
1,4-Dichlorobenzene	0.001	7.5	/	3.5E+07	=	2.2E-07	0.0010	0.075	YES
1,2-Dichloroethane	0.0005	0.5	/	3.5E+07	=	1.4E-08	0.0005	0.005	YES
1,1-Dichloroethylene	--	0.7	/	3.5E+07	=	2.0E-08	2.0E-08	0.007	YES
Endrin	--	0.02	/	3.5E+07	=	5.7E-10	5.7E-10	0.0002	YES
Fluoride	--	--	/	3.5E+07	=	--	--	4	--
Lindane	--	0.4	/	3.5E+07	=	1.1E-08	1.1E-08	0.004	YES
Lead	0.0284	5.0	/	3.5E+07	=	1.4E-07	0.0284	0.05	YES
Mercury	--	0.2	/	3.5E+07	=	5.7E-09	5.7E-09	0.002	YES
Methoxychlor	--	--	/	3.5E+07	=	--	--	0.1	--
Nitrate	---	--	/	3.5E+07	=	--	--	10	--
Selenium	0.005	1	/	3.5E+07	=	2.9E-08	0.0050	0.01	YES
Silver	0.005	5.0	/	3.5E+07	=	1.4E-07	0.0050	0.05	YES
Toxaphene	--	0.5	/	3.5E+07	=	1.4E-08	1.4E-08	0.005	YES
1,1,1-Trichloroethane	0.0005	--	/	3.5E+07	=	--	--	0.2	--
Trichloroethylene	--	0.5	/	3.5E+07	=	1.4E-08	1.4E-08	0.005	YES
2,4,5-Trichlorophenoxy acetic acid	--	1.0	/	3.5E+07	=	2.9E-08	2.9E-08	0.01	YES
Vinyl Chloride	0.001	0.2	/	3.5E+07	=	5.7E-09	0.0010	0.002	YES

1 Background concentrations have been obtained from Table 2-1.
2 Initial concentrations, C_O, has been reproduced from historical standard information utilized by TCEQ as discussed in Section 2.3 and provided in Table 2-2.
3 DAF value for Section A is presented on Figure 4-1.

Table 4-3
Summary of Constituent Levels at the POC
(Section B)

Constituent	C_{BG}, Background Concentration[1] (mg/l)	C_O[2]		DAF[3] (mg/l)	=	CP (mg/l) (Constituent Concentration at the POC due to Estimated Leachate Percolation)	$C_{BG} + C_P = C_T$ at POC (mg/l)	MCL (mg/l) Listed in §330.331(a)(1)	C_T at POC < MCL
Arsenic	0.0476	5.0	/	3.9E+07	=	1.3E-07	0.0476	0.05	YES
Barium	0.415	100	/	3.9E+07	=	2.6E-06	0.4150	1	YES
Benzene	0.0005	0.5	/	3.9E+07	=	1.3E-08	0.0005	0.005	YES
Cadmium	0.001	1.0	/	3.9E+07	=	2.6E-08	0.0010	0.01	YES
Carbon tetrachloride	0.0025	0.5	/	3.9E+07	=	1.3E-08	0.0025	0.005	YES
Chromium (hexavalent)	0.01	5.0	/	3.9E+07	=	1.3E-07	0.0100	0.05	YES
2,4-Dichlorophenoxy acetic acid	--	10.0	/	3.9E+07	=	2.6E-07	2.6E-07	0.1	YES
1,4-Dichlorobenzene	0.001	7.5	/	3.9E+07	=	1.9E-07	0.0010	0.075	YES
1,2-Dichloroethane	0.0005	0.5	/	3.9E+07	=	1.3E-08	0.0005	0.005	YES
1,1-Dichloroethylene	--	0.7	/	3.9E+07	=	1.8E-08	1.8E-08	0.007	YES
Endrin	--	0.02	/	3.9E+07	=	5.2E-10	5.2E-10	0.0002	YES
Fluoride	--	--	/	3.9E+07	=	--	--	4	--
Lindane	--	0.4	/	3.9E+07	=	1.0E-08	1.0E-08	0.004	YES
Lead	0.0075	5.0	/	3.9E+07	=	1.3E-07	0.0284	0.05	YES
Mercury	--	0.2	/	3.9E+07	=	5.2E-09	5.2E-09	0.002	YES
Methoxychlor[4]	--	--	/	3.9E+07	=	--	--	0.1	--
Nitrate[4]	---	--	/	3.9E+07	=	--	--	10	--
Selenium	0.005	1.0	/	3.9E+07	=	2.6E-08	0.0050	0.01	YES
Silver	0.005	5.0	/	3.9E+07	=	1.3E-07	0.0050	0.05	YES
Toxaphene	--	0.5	/	3.9E+07	=	1.3E-08	1.3E-08	0.005	YES
1,1,1-Trichloroethane	--	--	/	3.9E+07	=	--	--	--	--
Trichloroethylene	0.0025	0.5	/	3.9E+07	=	1.3E-08	1.3E-08	0.005	YES
2,4,5-Trichlorophenoxy acetic acid	--	1.0	/	3.9E+07	=	2.6E-08	2.6E-08	0.01	YES
Vinyl Chloride	0.01	0.2	/	3.9E+07	=	5.2E-09	0.0010	0.002	YES

1 Background concentrations have been obtained from Table 2-1.
2 Initial concentrations, C_0, has been reproduced from historical standard information utilized by TCEQ as discussed in Section 2.3 and provided in Table 2-2.
3 DAF value for Section B is presented on Figure 4-2.



NOTES:

1. TYPICAL GEOLOGIC PROFILE DEVELOPED FROM CROSS-SECTIONS INCLUDED IN APPENDIX IIIG.
2. THE MODEL IS DEVELOPED CONSERVATIVELY USING THE DOWNGRADIENT MONITORING WELL THAT IS CLOSEST TO THE LIMIT OF WASTE AND THE LARGEST TWO-DIMENSIONAL WASTE FILL AREA (I.E., LONGEST DISTANCE LEACHATE BETWEEN THE UPGRADIENT AND DOWNGRADIENT LIMIT OF WASTE).
3. GROUNDWATER ELEVATIONS MEASURED BY WCG IN APRIL 2024 AND POSTED BY MEASUREMENT LOCATIONS IN FT-MSL. GROUNDWATER CONTOURS INTERPOLATED BETWEEN MEASUREMENT LOCATIONS. ACTUAL GROUNDWATER ELEVATIONS MAY VARY FROM THOSE ILLUSTRATED IN THIS FIGURE.
4. DUE TO THE SEMI-CONFINED NATURE OF THE AQUIFER ACROSS THE SITE, THE MODELED GROUNDWATER SURFACE REPRESENTS THE EXPECTED FLOW OF GROUNDWATER BETWEEN THE BASAL CLAY AQUICLUDE AND THE CAPROCK.

LEGEND

- LIMITS OF WASTE
- APPROXIMATE GROUNDWATER POTENTIOMETRIC SURFACE (SEE NOTE 3)
- MODELED GROUNDWATER SURFACE (SEE NOTE 4)
- $1.0X10^{15}$ DAF CONTOUR AT END OF POSTCLOSURE

SECTION A (A, 3-1, 4-1)

0 150 300 HORIZONTAL SCALE IN FEET

0 15 30 VERTICAL SCALE IN FEET

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DESIGN BY: JPI
REVIEWED BY: NT

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MAJOR PERMIT AMENDMENT
MODFLOW RESULTS
SECTION A

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FIGURE 4-1

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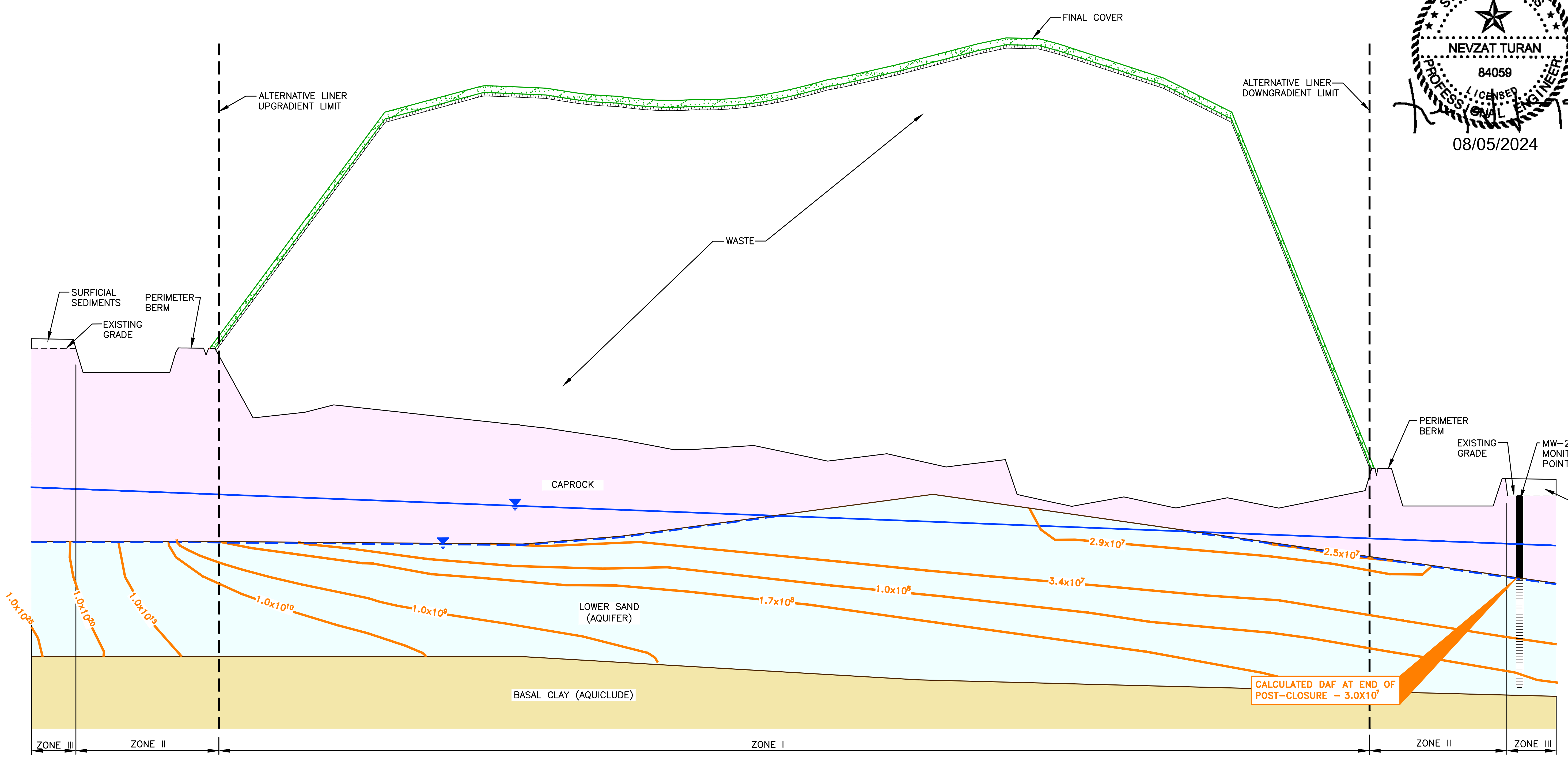

SECTION B (B 3–1/4–2)

0 150 300
HORIZONTAL SCALE IN FEET

0 15 30
VERTICAL SCALE IN FEET

NOTES:

1. TYPICAL GEOLOGIC PROFILE DEVELOPED FROM CROSS–SECTIONS INCLUDED IN APPENDIX IIIG.
2. THE MODEL IS DEVELOPED CONSERVATIVELY USING THE DOWNGRADIENT MONITORING WELL THAT IS CLOSEST TO THE LIMIT OF WASTE AND THE LARGEST TWO–DIMENSIONAL WASTE FILL AREA (I.E., LONGEST DISTANCE LEACHATE BETWEEN THE UPGRADIENT AND DOWNGRADIENT LIMIT OF WASTE).
3. GROUNDWATER ELEVATIONS MEASURED BY WCG IN APRIL 2024 AND POSTED BY MEASUREMENT LOCATIONS IN FT–MSL. GROUNDWATER CONTOURS INTERPOLATED BETWEEN MEASUREMENT LOCATIONS. ACTUAL GROUNDWATER ELEVATIONS MAY VARY FROM THOSE ILLUSTRATED IN THIS FIGURE.
4. DUE TO THE SEMI–CONFINED NATURE OF THE AQUIFER ACROSS THE SITE, THE MODELED GROUNDWATER SURFACE REPRESENTS THE EXPECTED FLOW OF GROUNDWATER BETWEEN THE BASAL CLAY AQUICLUDE AND THE CAPROCK.

LEGEND

- LIMITS OF WASTE
- APPROXIMATE GROUNDWATER POTENTIOMETRIC SURFACE (SEE NOTE 3)
- MODELED GROUNDWATER SURFACE (SEE NOTE 4)
- 1.0X10¹⁵ DAF CONTOUR AT END OF POSTCLOSURE

SHEET IIIB–18B

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CAD: FIG 4–2–SECTION B MODFLOW.DWG	REVIEWED BY: NT

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MAJOR PERMIT AMENDMENT
MODFLOW RESULTS
SECTION B

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FIGURE 4–2

APPENDIX IIIB-A

HELP MODEL ANALYSIS

Includes pages IIIB-A-1 through IIIB-A-30

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HELP MODEL ANALYSIS

The following HELP model simulations were run to obtain percolation rates through the undeveloped Subtitle D alternative liner.

Table 1
Landfill Configurations

Case	Description
Case 1: Active, 10 ft Waste	Active landfill with 10 feet of waste modeled for 1 year.
Case 2: Interim, 130 ft Waste	Interim landfill with 130 feet of waste above the liner modeled for 10 years.
Case 3: Closed, 130 ft Waste	Closed landfill with 130 feet of waste above the liner modeled for 30 years.

For input information such as climate data, field capacity and moisture content, and landfill profile information, refer to Appendix IIIC-A.

Alternative Liner System

The proposed alternative liner system for future sectors will consist of a 60-mil HDPE geomembrane placed over a geosynthetic clay liner (GCL). A geocomposite leachate collection layer consisting of a 200-mil-thick geonet with a 6 oz/sy non-woven geotextile heat-bonded to both sides for sideslopes and a geotextile heat-bonded to one side for the floor grades will be placed above the geomembrane and will be covered with a 2-foot-thick layer of protective cover soil.

Help Output

The HELP summaries and output files are presented starting on page IIIB-A-2.

CITY OF MEADOW LANDFILL
0120-809-11-06
HELP VERSION 3.07 SUMMARY SHEET
POINT OF COMPLIANCE DEMONSTRATION

			ACTIVE (10 FT WASTE)	Interim (130 FT WASTE)	CLOSED (130 FT WASTE)
GENERAL INFORMATION		Case No.	1	2	3
		Output Page	IIIB-A-4	IIIB-A-12	IIIB-A-20
		No. of Years	1	10	30
		Ground Cover	FAIR	GOOD	GOOD
		SCS Runoff Curve No.	79.7	85.6	80.6
		Model Area (acre)	1	1	1
		Runoff Area (%)	0	90	100
		Maximum Leaf Area Index	0.0	2.0	4.5
		Evaporative Zone Depth (inch)	12	12	12
Final Cover	TOPSOIL LAYER (Texture = 10)	Thickness (in)			12
		Porosity (vol/vol)			0.3980
		Field Capacity (vol/vol)			0.2440
		Wilting Point (vol/vol)			0.1360
		Init. Moisture Content (vol/vol)			0.2440
		Hyd. Conductivity (cm/s)			1.2E-04
	GEOCOMPIOSITE DRAINAGE LAYER (Texture = 0)	Thickness (in)			0.250
		Porosity (vol/vol)			0.8500
		Field Capacity (vol/vol)			0.0100
		Wilting Point (vol/vol)			0.0050
		Init. Moisture Content (vol/vol)			0.0100
		Hyd. Conductivity (cm/s)			6.63
		Slope (%)			5
		Slope Length (ft)			350
	FLEXIBLE MEMBRANE LINER (Texture = 36)	Thickness (in)			0.04
		Hyd. Conductivity (cm/s)			4.0E-13
		Pinhole Density (holes/acre)			1
		Install. Defects (holes/acre)			4
		Placement Quality			GOOD
	INFILTRATION LAYER (Texture = 0)	Thickness (in)			18.00
		Porosity (vol/vol)			0.4270
		Field Capacity (vol/vol)			0.4180
		Wilting Point (vol/vol)			0.3670
		Init. Moisture Content (vol/vol)			0.4270
		Hyd. Conductivity (cm/s)			1.0E-05
Intermediate Cover	INTERMEDIATE COVER (Texture = 10)	Thickness (in)		12	12
		Porosity (vol/vol)		0.3980	0.3980
		Field Capacity (vol/vol)		0.2440	0.2440
		Wilting Point (vol/vol)		0.1360	0.1360
		Init. Moisture Content (vol/vol)		0.2440	0.2440
		Hyd. Conductivity (cm/s)		1.2E-04	1.2E-04
Waste	WASTE TOP[1] (Texture = 0)	Thickness (in)	120	1200	1200
		Porosity (vol/vol)	0.6649	0.6277	0.6277
		Field Capacity (vol/vol)	0.5262	0.5156	0.5156
		Wilting Point (vol/vol)	0.0770	0.0770	0.0770
		Init. Moisture Content (vol/vol)	0.2500	0.3000	0.3000
		Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03
	WASTE BOTTOM[1] (Texture = 0)	Thickness (in)		360	360
		Porosity (vol/vol)		0.5740	0.5740
		Field Capacity (vol/vol)		0.5004	0.5004
		Wilting Point (vol/vol)		0.0770	0.0770
		Init. Moisture Content (vol/vol)		0.3000	0.3000
		Hyd. Conductivity (cm/s)		1.0E-04	1.0E-04
Liner	PROTECTIVE COVER (Texture = 10)	Thickness (in)	24	24	24
		Porosity (vol/vol)	0.3980	0.3980	0.3980
		Field Capacity (vol/vol)	0.2440	0.2440	0.2440
		Wilting Point (vol/vol)	0.1360	0.1360	0.1360
		Init. Moisture Content (vol/vol)	0.2440	0.2440	0.2440
		Hyd. Conductivity (cm/s)	1.2E-04	1.2E-04	1.2E-04
	LEACHATE COLLECTION LAYER (Texture = 0)	Thickness (in)	0.199	0.172	0.171
		Porosity (vol/vol)	0.8500	0.8500	0.8500
		Field Capacity (vol/vol)	0.0100	0.0100	0.0100
		Wilting Point (vol/vol)	0.0050	0.0050	0.0050
		Init. Moisture Content (vol/vol)	0.0100	0.0100	0.0100
		Hyd. Conductivity (cm/s)	0.90	0.19	0.19
		Slope[3] (%)	2.2	2.2	2.2
		Slope Length (ft)	275	275	275
	FLEXIBLE MEMBRANE LINER (Texture = 36)	Thickness (in)	0.06	0.06	0.06
		Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13
		Pinhole Density (holes/acre)	1	1	1
		Install. Defects (holes/acre)	4	4	4
		Placement Quality	GOOD	GOOD	GOOD
	GEOSYNTHETIC CLAY LINER (Texture = 0)	Thickness (in)	0.06	0.06	0.06
		Porosity (vol/vol)	0.7500	0.7500	0.7500
		Field Capacity (vol/vol)	0.7470	0.7470	0.7470
		Wilting Point (vol/vol)	0.4000	0.4000	0.4000
		Init. Moisture Content (vol/vol)	0.7500	0.7500	0.7500
		Hyd. Conductivity (cm/s)	5.0E-09	5.0E-09	5.0E-09
PRECIPITATION		Average Annual (in)	26.32	20.14	17.93
RUNOFF		Average Annual (in)	0.00	0.76	0.23
EVAPOTRANSPIRATION		Average Annual (in)	24.73	17.84	16.47
HEAD ON LINER		Average Annual (in)	0.000	0.019	0.004
LEACHATE GENERATION		Average Annual (cf/yr)	0.0	2,206.5	493.5
		Average Annual (gal/yr)	0.0	16,505.5	3,691.5
PERCOLATION THROUGH			Alternative Liner	Alternative Liner	Alternative Liner
PERCOLATION VALUES		Average Annual (ft^3/yr)	0.00000	0.014	0.00300
		Average Annual (mm/yr)	0.0000	0.0001	0.00002

Notes: [1] The field capacity and porosity values for the waste layer were obtained from: Zornberg, Jorge G. et. al, *Retention of Free Liquids in Landfills Undergoing Vertical Expansion.* Journal of Geotechnical and Geoenvironmental Engineering, July 1999, pp. 583-594.

HELP MODEL OUTPUT

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


PRECIPITATION DATA FILE:    C:\MEADOW\B\AC\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\B\AC\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\B\AC\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\B\AC\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\B\AC\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\B\AC\OUTDATA.OUT


TIME:  13:18     DATE:   4/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-ACTIVE 10 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                        TYPE 1 - VERTICAL PERCOLATION LAYER
                            MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =    120.00   INCHES
```

```
POROSITY                    =      0.6649 VOL/VOL
FIELD CAPACITY              =      0.5262 VOL/VOL
WILTING POINT               =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
```

```
                        LAYER  2
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
```

```
                        LAYER  3
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.899999976000     CM/SEC
SLOPE                       =      2.20   PERCENT
DRAINAGE LENGTH             =    275.0    FEET
```

```
                        LAYER  4
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
```

```
   INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
   FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
   FML PLACEMENT QUALITY       =  3 - GOOD
```

```
                       LAYER  5
                       --------

             TYPE 3 - BARRIER SOIL LINER
             MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =      0.06   INCHES
   POROSITY                    =      0.7500 VOL/VOL
   FIELD CAPACITY              =      0.7470 VOL/VOL
   WILTING POINT               =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
          A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER              =     79.70
FRACTION OF AREA ALLOWING RUNOFF     =      0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      3.000  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      7.979  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.924  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     35.903  INCHES
TOTAL INITIAL WATER                  =     35.903  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

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

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 25 THROUGH 25

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.58	0.53	1.16	2.07	3.93	4.76
	5.38	3.78	1.20	0.52	0.22	2.19
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.492	0.544	1.577	0.840	3.738	4.290
	5.111	4.019	1.055	0.468	0.352	1.247
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 25 THROUGH 25

	INCHES	CU. FEET	PERCENT
PRECIPITATION	26.32 (0.000)	95541.6	100.00
RUNOFF	0.000 (0.0000)	0.00	0.000
EVAPOTRANSPIRATION	24.733 (0.0000)	89779.02	93.969
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.00000 (0.00000)	0.001	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000 (0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 4	0.000 (0.000)		
CHANGE IN WATER STORAGE	1.587 (0.0000)	5762.60	6.032

****

****

PEAK DAILY VALUES FOR YEARS 25 THROUGH 25

	(INCHES)	(CU. FT.)
PRECIPITATION	1.67	6062.100

RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.00000	0.00028
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 4	0.000	
MAXIMUM HEAD ON TOP OF LAYER 4	0.035	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.94	3421.4011

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3369

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1086

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

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

****

****

FINAL WATER STORAGE AT END OF YEAR 25

LAYER	(INCHES)	(VOL/VOL)
1	31.5874	0.2632
2	5.8560	0.2440
3	0.0020	0.0100
4	0.0000	0.0000

```
            5          0.0450        0.7500

        SNOW WATER     0.000

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


PRECIPITATION DATA FILE:    C:\MEADOW\B\I130\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\B\I130\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\B\I130\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\B\I130\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\B\I130\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\B\I130\OUTDATA.OUT


TIME:  15: 9     DATE:   3/21/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 130 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                    =    12.00   INCHES
```

```
  POROSITY                        =      0.3980 VOL/VOL
  FIELD CAPACITY                  =      0.2440 VOL/VOL
  WILTING POINT                   =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT      =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.       =  0.119999997000E-03 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                       =   1200.00   INCHES
  POROSITY                        =      0.6277 VOL/VOL
  FIELD CAPACITY                  =      0.5156 VOL/VOL
  WILTING POINT                   =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT      =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.       =  0.100000005000E-02 CM/SEC


                          LAYER  3
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                       =    360.00   INCHES
  POROSITY                        =      0.5740 VOL/VOL
  FIELD CAPACITY                  =      0.5004 VOL/VOL
  WILTING POINT                   =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT      =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.       =  0.999999975000E-04 CM/SEC


                          LAYER  4
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  10
  THICKNESS                       =     24.00   INCHES
  POROSITY                        =      0.3980 VOL/VOL
  FIELD CAPACITY                  =      0.2440 VOL/VOL
  WILTING POINT                   =      0.1360 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC


                        LAYER  5
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.17   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.189999998000     CM/SEC
SLOPE                       =      2.20   PERCENT
DRAINAGE LENGTH             =    275.0    FEET


                        LAYER  6
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  7
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
         FAIR STAND OF GRASS, A SURFACE SLOPE OF  2.%
         AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     85.60
FRACTION OF AREA ALLOWING RUNOFF    =     90.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.928  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.776  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.632  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    476.973  INCHES
TOTAL INITIAL WATER                 =    476.973  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         MIDLAND                TEXAS

     STATION LATITUDE                          =  32.00 DEGREES
     MAXIMUM LEAF AREA INDEX                   =   2.00
     START OF GROWING SEASON (JULIAN DATE)     =     67
     END OF GROWING SEASON (JULIAN DATE)       =    317
     EVAPORATIVE ZONE DEPTH                    =  12.0  INCHES
     AVERAGE ANNUAL WIND SPEED                 =  11.10 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY     =  52.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY     =  50.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY     =  55.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY     =  58.00 %


NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
```

COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.010	0.003	0.037	0.235

	0.293	0.018	0.119	0.040	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.020	0.007	0.047	0.466
	0.519	0.042	0.184	0.105	0.000	0.007

EVAPOTRANSPIRATION

TOTALS	0.752	0.797	1.013	1.478	2.390	2.131
	2.369	1.387	2.845	1.143	0.951	0.579
STD. DEVIATIONS	0.397	0.433	0.617	1.060	0.893	1.336
	1.422	0.838	0.934	0.893	0.565	0.307

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0467	0.0491	0.0556	0.0540	0.0550	0.0461
	0.0419	0.0501	0.0524	0.0514	0.0508	0.0547
STD. DEVIATIONS	0.0653	0.0623	0.0719	0.0700	0.0714	0.0636
	0.0633	0.0668	0.0682	0.0671	0.0658	0.0707

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0175	0.0202	0.0208	0.0209	0.0206	0.0179
	0.0157	0.0188	0.0203	0.0193	0.0197	0.0205
STD. DEVIATIONS	0.0245	0.0256	0.0269	0.0271	0.0267	0.0246
	0.0237	0.0250	0.0264	0.0251	0.0255	0.0265

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2 THROUGH 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.14 (3.835)	73111.8	100.00
RUNOFF	0.757 (0.5939)	2746.66	3.757
EVAPOTRANSPIRATION	17.836 (2.7384)	64744.97	88.556
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.60784 (0.71967)	2206.458	3.01792
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00000 (0.00000)	0.014	0.00002
AVERAGE HEAD ON TOP OF LAYER 6	0.019 (0.023)		
CHANGE IN WATER STORAGE	0.940 (1.2148)	3413.72	4.669

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PEAK DAILY VALUES FOR YEARS 2 THROUGH 11

	(INCHES)	(CU. FT.)
PRECIPITATION	4.19	15209.700
RUNOFF	1.325	4810.4985
DRAINAGE COLLECTED FROM LAYER 5	0.00595	21.61378
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000000	0.00013
AVERAGE HEAD ON TOP OF LAYER 6	0.069	
MAXIMUM HEAD ON TOP OF LAYER 6	0.137	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	2.4 FEET	
SNOW WATER	0.46	1655.6732

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3724

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1360

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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8516	0.1543
2	374.2077	0.3118
3	104.1541	0.2893
4	5.9363	0.2473
5	0.0401	0.2332
6	0.0000	0.0000
7	0.1875	0.7500
SNOW WATER	0.000	

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****

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


PRECIPITATION DATA FILE:    C:\MEADOW\B\CL\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\B\CL\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\B\CL\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\B\CL\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\B\CL\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\B\CL\OUTDATA.OUT


TIME:  13:16     DATE:   4/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-CLOSED 130 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER  10
           THICKNESS                   =     12.00   INCHES
```

```
  POROSITY                   =     0.3980 VOL/VOL
  FIELD CAPACITY             =     0.2440 VOL/VOL
  WILTING POINT              =     0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT =     0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.



                            LAYER  2
                            --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =     0.25   INCHES
  POROSITY                   =     0.8500 VOL/VOL
  FIELD CAPACITY             =     0.0100 VOL/VOL
  WILTING POINT              =     0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =     0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =   6.63000011000     CM/SEC
  SLOPE                      =     5.00   PERCENT
  DRAINAGE LENGTH            =   350.0    FEET



                            LAYER  3
                            --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  36
  THICKNESS                  =     0.04   INCHES
  POROSITY                   =     0.0000 VOL/VOL
  FIELD CAPACITY             =     0.0000 VOL/VOL
  WILTING POINT              =     0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.399999993000E-12 CM/SEC
  FML PINHOLE DENSITY        =     1.00   HOLES/ACRE
  FML INSTALLATION DEFECTS   =     4.00   HOLES/ACRE
  FML PLACEMENT QUALITY      =  3 - GOOD



                            LAYER  4
                            --------

                TYPE 3 - BARRIER SOIL LINER
```

```
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     18.00   INCHES
POROSITY                     =      0.4270 VOL/VOL
FIELD CAPACITY               =      0.4180 VOL/VOL
WILTING POINT                =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-05 CM/SEC


                          LAYER  5
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  10
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC


                          LAYER  6
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =   1200.00   INCHES
POROSITY                     =      0.6277 VOL/VOL
FIELD CAPACITY               =      0.5156 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                          LAYER  7
                          --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    360.00   INCHES
POROSITY                     =      0.5740 VOL/VOL
FIELD CAPACITY               =      0.5004 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC


                        LAYER  8
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  10
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC


                        LAYER  9
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.17   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.189999998000     CM/SEC
SLOPE                       =      2.20   PERCENT
DRAINAGE LENGTH             =    275.0    FEET


                        LAYER 10
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      1.00   HOLES/ACRE
```

```
FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD
```

```
                     LAYER 11
                     --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.25   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  5.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER              =     80.60
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      2.928  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      4.776  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      1.632  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =    487.590  INCHES
TOTAL INITIAL WATER                  =    487.590  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          MIDLAND                TEXAS
```

```
STATION LATITUDE                         =  32.00 DEGREES
MAXIMUM LEAF AREA INDEX                  =   4.50
START OF GROWING SEASON (JULIAN DATE)    =     67
END OF GROWING SEASON (JULIAN DATE)      =    317
EVAPORATIVE ZONE DEPTH                   =  12.0  INCHES
AVERAGE ANNUAL WIND SPEED                =  11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  58.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.69	0.55	1.29	1.32	1.96	2.54
	2.67	1.56	2.49	1.40	0.90	0.57
STD. DEVIATIONS	0.64	0.33	1.02	0.82	1.05	2.04
	1.97	1.09	1.58	1.26	0.60	0.60
RUNOFF						
TOTALS	0.000	0.000	0.001	0.000	0.003	0.080
	0.108	0.002	0.024	0.010	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.004	0.000	0.008	0.205
	0.271	0.006	0.066	0.039	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.638	0.543	0.946	1.790	1.914	2.164
	2.281	1.514	2.192	0.984	0.849	0.650
STD. DEVIATIONS	0.403	0.375	0.719	0.900	1.044	1.514
	1.449	1.012	1.307	0.720	0.464	0.421
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.0356	0.0084	0.0811	0.0416	0.0118	0.2721
	0.3466	0.0211	0.1873	0.2096	0.0307	0.0293
STD. DEVIATIONS	0.1049	0.0324	0.2176	0.1034	0.0387	0.6090
	0.6202	0.0972	0.4689	0.6370	0.0726	0.1175
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 9						
TOTALS	0.0111	0.0121	0.0141	0.0138	0.0143	0.0134
	0.0100	0.0098	0.0094	0.0094	0.0089	0.0095
STD. DEVIATIONS	0.0368	0.0373	0.0432	0.0423	0.0436	0.0412

	0.0367	0.0373	0.0359	0.0359	0.0339	0.0363

PERCOLATION/LEAKAGE THROUGH LAYER 11

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0002	0.0001	0.0008	0.0003	0.0001	0.0087
	0.0202	0.0002	0.0027	0.0034	0.0002	0.0002
STD. DEVIATIONS	0.0006	0.0002	0.0027	0.0006	0.0002	0.0233
	0.0558	0.0012	0.0076	0.0116	0.0005	0.0007

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0042	0.0050	0.0053	0.0053	0.0053	0.0052
	0.0037	0.0037	0.0036	0.0035	0.0034	0.0036
STD. DEVIATIONS	0.0138	0.0155	0.0162	0.0164	0.0163	0.0159
	0.0137	0.0140	0.0139	0.0135	0.0131	0.0136

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	17.93	(4.448)	65096.8	100.00
RUNOFF	0.227	(0.3408)	822.80	1.264
EVAPOTRANSPIRATION	16.465	(3.7223)	59766.44	91.812
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1.27516	(1.06066)	4628.840	7.11070

```
 PERCOLATION/LEAKAGE THROUGH     0.00009 (  0.00014)         0.325     0.00050
   LAYER  4

 AVERAGE HEAD ON TOP             0.003 (    0.005)
   OF LAYER  3

 LATERAL DRAINAGE COLLECTED      0.13595 (  0.43532)       493.481    0.75807
   FROM LAYER  9

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.003     0.00000
   LAYER 11

 AVERAGE HEAD ON TOP             0.004 (    0.014)
   OF LAYER 10

 CHANGE IN WATER STORAGE        -0.169   (  0.8768)       -614.78     -0.944

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               PEAK DAILY VALUES FOR YEARS    1 THROUGH   30
   ------------------------------------------------------------------------
                                                  (INCHES)      (CU. FT.)
                                                 ----------   -------------
      PRECIPITATION                                4.67         16952.100

      RUNOFF                                       1.192         4326.7114

      DRAINAGE COLLECTED FROM LAYER  2             1.33907       4860.82568

      PERCOLATION/LEAKAGE THROUGH LAYER  4         0.000438         1.59150

      AVERAGE HEAD ON TOP OF LAYER  3              6.402

      MAXIMUM HEAD ON TOP OF LAYER  3             11.221

      LOCATION OF MAXIMUM HEAD IN LAYER  2
            (DISTANCE FROM DRAIN)                 42.6 FEET

      DRAINAGE COLLECTED FROM LAYER  9             0.00595         21.61378

      PERCOLATION/LEAKAGE THROUGH LAYER 11         0.000000         0.00013

      AVERAGE HEAD ON TOP OF LAYER 10              0.069
```

```
MAXIMUM HEAD ON TOP OF LAYER 10          0.137

LOCATION OF MAXIMUM HEAD IN LAYER  9
      (DISTANCE FROM DRAIN)              2.4 FEET

SNOW WATER                               0.94          3421.4011


MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.3762

MINIMUM VEG. SOIL WATER (VOL/VOL)                0.1360

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

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

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              FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
```

LAYER	(INCHES)	(VOL/VOL)
1	1.9229	0.1602
2	0.0025	0.0100
3	0.0000	0.0000
4	7.6860	0.4270
5	2.8960	0.2413
6	360.0346	0.3000
7	103.9216	0.2887
8	5.8560	0.2440
9	0.0017	0.0100

10	0.0000	0.0000
11	0.1875	0.7500
SNOW WATER	0.000	

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****

CITY OF MEADOW LANDFILL
TERRY COUNTY
TCEQ PERMIT NO. MSW-2293C

MAJOR PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIIC
LEACHATE AND CONTAMINATED WATER MANAGEMENT PLAN

Prepared for

Meadow Landfill, LLC

August 2024

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

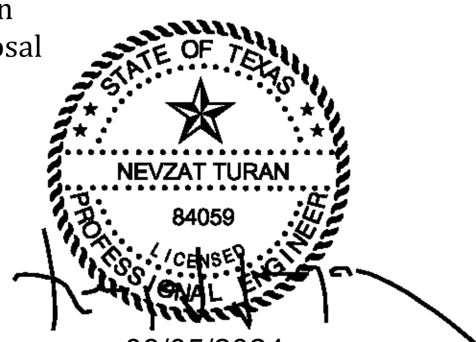
Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Blvd., Suite 206
Fort Worth, Texas 76109
817-735-9770

WCG Project No. 0120-809-11-05

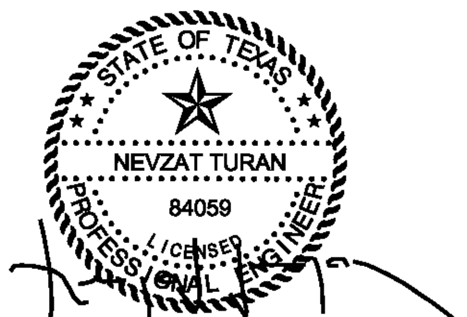
This document is intended for permitting purposes only.

CONTENTS



08/05/2024

CONTENTS (Continued)



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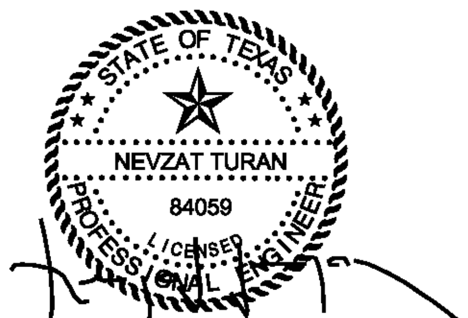


08/05/2024

1 PURPOSE AND SCOPE

This Leachate and Contaminated Water Management Plan for the City of Meadow Landfill was prepared consistent with Title 30 Texas Administrative Code (TAC) §§330.305(c), 330.305(g), 330.177, 330.207, and 330.333. This plan provides the details of the collection, storage, and disposal of contaminated water, and leachate generated during the active and postclosure periods of the landfill.

This appendix addresses §§330.305(g), 330.177, 330.207 and 330.333.

The landfill will be developed with a Subtitle D liner system and the historic waste fill area will be relocated to Subtitle D lined areas. Refer to Section 4.25 of the Site Operating Plan for the waste relocation plan. The design details for the liner and final cover systems are included in Part III, Appendix IIIA-A – Liner and Final Cover System Details. The top of liner plan and landfill completion plan are also included in Part III, Appendix IIIA-A. Additionally, Figure 3-1 includes the top of liner plan showing the leachate collection system layout.

2 LEACHATE AND CONTAMINATED WATER GENERATION

2.1 Generation Process

Leachate is generated when water percolates through the layers of solid waste as moisture is released from high moisture content waste. The capacity of solid waste to absorb moisture is known as field capacity. When the field capacity is exceeded, leachate is generated. However, leachate may also flow within the landfill through preferential pathways; therefore, some downward flow of leachate will occur before the field capacity of waste is reached. The quantity of leachate produced will depend upon the climate, site topography, type of cover, construction and landfilling procedures, and waste characteristics.

Contaminated water is defined in Title 30 TAC §330.3(36) as "leachate, gas condensate, or water that has come into contact with waste." Contaminated water is therefore generated when stormwater runoff has come into contact with solid waste at the working face of the landfill or any other area at the site where water contacts solid waste, leachate, or gas condensate.

2.2 Leachate Generation and Contaminated Stormwater Modeling

The Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.07, was used to estimate the amount of leachate that will be generated at the City of Meadow Landfill. The HELP model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil-moisture storage, recirculation, evapotranspiration, and lateral drainage.

Leachate generation was evaluated for both active and closed landfill conditions. An explanation of the assumed conditions, methodologies, models and printouts of the results are included as Appendix IIIC-A. As discussed in Section 6, the leachate generation rates produced by HELP are used for the leachate collection system design.

The Rational Method was used to estimate the volume of contaminated water that must be contained around the working face. The design calculations and the size of the diversion and containment berms required around the working face for a 25-year, 24-hour storm event are provided in Appendix IIIC-C.

2.3 Stormwater Management

The City of Meadow Landfill will manage stormwater throughout the active life of the landfill to minimize the amount of stormwater that will come in contact with waste or leachate. Uncontaminated surface water will be controlled through the use of diversion berms and stormwater diversion ditches. To promote runoff and prevent ponding, the operational cover will be graded and maintained. The use of drainage swales, diversion berms, and the containment berm is illustrated in Parts I/II, Appendix I/IIA, Drawings I/IIA.4 through I/IIA.6 – Cell Development Plans.

Stormwater that comes into contact with waste will be considered contaminated water and handled consistent with Title 30 TAC §330.207. Contaminated water will be contained by the containment berm at the working face as shown in Appendix IIIC-C. At no time will contaminated water be allowed to discharge into waters of the United States. Storage of contaminated water and its disposal are discussed in Sections 4 and 5 of this appendix, respectively.

The final cover has been designed to minimize infiltration and promote runoff. Uncontaminated surface water will be managed throughout the active life of the landfill to minimize infiltration into the filled areas and to minimize contact with solid waste. Also, daily and intermediate soil cover areas will be graded and maintained to promote runoff and prevent ponding as described in Part IV – Site Operating Plan (SOP).

Procedures for verifying the adequacy of daily cover placement to cover all waste material is discussed in Part IV – SOP, Section 4.18.2. Runoff generated from fill areas covered with a minimum 6 inches of earthen daily cover having no exposed waste or 12 inches of intermediate cover will be considered as uncontaminated and allowed to drain to the perimeter drainage system. In the event that the 6 inches of daily cover does not prevent stormwater from contacting solid waste or leachate, this stormwater will be collected and managed as contaminated and disposed of in an authorized manner. Uncontaminated surface water runoff will be diverted around the working face as shown in Appendix IIIC-C.

3 LEACHATE COLLECTION SYSTEM

3.1 System Layout and Design Criteria

3.1.1 Introduction

The leachate collection system (LCS) for the Subtitle D area consists of: (1) a collection layer placed over the liner system, (2) the leachate collection piping, and (3) the leachate collection sumps and pumps. The plan for the LCS piping and grading is shown on Figure 3-1 and in Part III, Appendix IIIA-A, Drawing A.1. LCS details are also provided in Part III, Appendix IIIA-A – Liner and Final Cover System Details.

3.1.2 Design Criteria

The leachate management system is designed and operated to collect and remove leachate from each sector, maintain leachate levels below 12 inches (or 30 cm) above the liner systems, channel leachate to designated collection sumps, and effectively manage leachate through storage and disposal. The system is designed to eliminate potential migration of landfill leachate into the environment and to meet the requirements of Title 30 TAC §330.333, namely:

- constructed of materials that are chemically resistant to the leachate expected to be generated;
- of sufficient strength and thickness to prevent collapse under the pressures exerted by overlying wastes, waste cover materials, and by equipment used at the facility; and
- designed to function through the scheduled closure and post-closure period of the facility.

The LCS is designed to maintain the maximum leachate depth on the liner to less than 12 inches, in accordance with Title 30 TAC §330.331(a)(2) by the monitoring of head levels and timely recovery of leachate. This is accomplished by setting the control level for the automatic sump pumps at a level less than 12 inches above the lip of the sump. The drainage geocomposite leachate collection layer is designed to convey the estimated peak leachate flow rate without the leachate level within the geocomposite exceeding the thickness of the geocomposite. The operation of the leachate sump and the conveyance capacity of the geocomposite leachate collection layer work in tandem to maintain compliance with the design standard listed in Title 30 TAC §330.331(a)(2). The leachate collection system piping network is designed to convey collected leachate to the leachate collection sumps. The LCS piping is designed for post-settlement slopes and to meet each of the three criteria listed within the bullets on the previous page.

In addition, the leachate collection system for the Subtitle D areas is designed to manage leachate that may be recirculated at the working face. Section 5.2 includes a leachate recirculation plan. Also, Appendix IIIC-A (page IIIC-A-3 and IIIC-A-4) provides a discussion regarding how the estimated additional leachate load due to recirculation was determined.

The geotextiles used for the geocomposite drainage layer utilize 100% continuous-filament polyester or polypropylene. Extensive testing, including EPA 9090 for chemical resistance, has demonstrated that polyester and polypropylene are resistant to a wide range of chemical classes encountered in soil and to typical leachate. The LCS piping and the geonet portion of the geocomposite are constructed of high density polyethylene (HDPE). HDPE is an industry standard material and is resistant to a wide range of chemical constituents, including those typically found in leachate.

3.1.3 Leachate Collection System Layout

The leachate collection system layout is shown on Figure 3-1. For the Subtitle D sectors, the leachate collection layer includes a geocomposite placed over the liner system to collect and transfer leachate to the leachate collection pipes and sumps. The proposed leachate collection system has been evaluated considering the leachate collection layer and leachate collection header pipe grades under the proposed landfill final conditions (i.e., after landfill foundation settlement – refer to Appendix IIIE). Leachate collection layer slopes and slope lengths have been estimated for the proposed closed landfill conditions. Table 3-1 provides a design summary for the Subtitle D sectors. As shown in each case, the maximum depth of leachate that occurs in the liner system is less than 12 inches and the flow depth is less than the thickness of the drainage geocomposite.

There is no existing leachate collection system at the site. Type IAE and Type IVAE facilities are exempt from providing a leachate collection system in accordance with 30 TAC §330.57(a). With this major permit amendment, a leachate collection system will be installed in all proposed sectors in accordance with 30 TAC §330.333. Waste from the existing trenches will be relocated into lined areas with a leachate collection system. Refer to Section 4.25 of Part IV – Site Operating Plan for the Waste Relocation Plan.

The leachate collection layer will be placed directly over the liner system. The leachate collection layer has been designed for the estimated overburden pressure that will be created by the proposed final waste fill thicknesses over the LCS. The LCS material specifications are included in the following subsections for these sectors. Table 3-1 shows that the maximum leachate depth for these sectors is less than 12 inches and the flow depth is less than the thickness of the drainage geocomposite. Table 3-1 presents a summary of the initial and post-settlement/design slope for each Subtitle D sector and also the maximum depth of leachate over the liner based on the HELP generated peak flow.

Table 3-1
Subtitle D Leachate Collection System Design Summary
Maximum Depth of Leachate on Liner

Sector[3]	Location	Initial Slope	Post-Settlement Slope[4]	Slope Used for Design	Maximum Depth of Leachate on Liner Using Peak Flow Rate Generated by HELP[1]	Flow Depth Less than Thickness of Drainage Geocomposite
Sectors 1 through 18	Slope between cell ridgeline and leachate collection pipe	2.2%	2.2%	2.2%	0.137 inches	Yes
	Slope of leachate collection pipe	1.0%	0.8%	0.8%	Peak flow less than the capacity of the collection pipe[2]	--

1 Maximum depth of leachate on liner was determined using the post settlement slope. Refer to Appendices IIIC-A, IIIC-A.1, and IIIC-B for additional information.
2 The leachate collection pipe is a 6-inch-diameter pipe.
3 The leachate collection layer for Sectors 1 through 18 – 200-mil-thick single-sided geocomposite (floors) and 200-mil-thick double-sided geocomposite (sideslopes).
4 Foundation settlement is discussed in Appendix IIIE.

3.2 Leachate Collection Layer

The leachate collection layer will be placed directly over the liner system to collect and transfer leachate to the leachate collection system pipes and sumps. The leachate collection layer placed over the floor grades will consist of a 200-mil-thick HDPE geonet with a 6 oz/sy (minimum) non-woven geotextile heat bonded to the top side of the HDPE geonet. The geocomposite was selected to maintain less than 12 inches of head above the bottom liner. The leachate collection layer placed over the sideslopes will consist of an HDPE geonet with a geotextile heat bonded to both sides. Calculations indicating the required properties of the geocomposite drainage layers (after accounting for losses due to clogging) are presented in Appendix IIIC-A and IIIC-A.1. The drainage geocomposite will comply with the specifications listed in Table 3-2. Geocomposites with higher thickness may be utilized. Also, double sided geocomposites meeting all the requirements of this design grades may be utilized on the floor.

3.2.1 Chimney Drains

The chimney drains will be installed above the LCS pipes and the top of the chimney drain gravel will be extended to (or may exceed) the top of protective cover grades. The chimney drains will be constructed with drainage material having a hydraulic conductivity of 1.0 cm/s or greater and will be covered by a geotextile to restrict migration of the protective cover soil into the LCS. The chimney drains will allow leachate to flow into the LCS without a buildup of head above the protective cover layer. Calculations demonstrating the adequacy of the chimney drain design are provided in Appendix IIIC-B.

3.3 Leachate Collection Piping

The liner and overlying leachate collection layer will slope to drain toward the LCS trenches, which will contain a perforated leachate collection pipe surrounded by drainage stone and separated from the adjacent protective cover and waste layers by a geotextile fabric (i.e., chimney drain). The leachate collection pipe will direct the leachate to the landfill sumps. The proposed leachate collection pipes will be SDR 17 HDPE smooth wall pipe (refer to Appendix IIIC-B for LCS pipe design). As shown in Table 3-1, the LCS pipes are designed for after settlement slopes.

The geotextile fabric and pipe perforations are designed to prevent clogging of the fabric or pipe. The leachate collection system is designed with cleanout risers at the end of each of the collection pipes to allow cleaning. Leachate collection pipe design calculations are provided in Appendix IIIC-B. These calculations demonstrate the adequacy of the pipes to convey leachate to the sumps, the structural stability of the pipes, and the satisfaction of the perforation requirements. Details of the LCS layer and pipe trench are shown in Part III, Appendix IIIA-A – Liner and Final Cover System Details.

3.4 Leachate Sumps and Pumps

The leachate collection sumps and pumps have been sized to comply with the regulatory design standard listed in Title 30 TAC §330.331(a)(2). The leachate collection sumps and pumps have been designed to maintain less than 30 cm (12 inches) depth of leachate on the liner system at the sump lip. The leachate sump operating plan is included in Table 3-2.

Each leachate sump is sized based on the amount of leachate generation taking into consideration the contributing area draining to each sump. The size and capacity of the sumps for all sectors are presented in Appendix IIIC-B. Sumps will be backfilled with drainage stone meeting the gradation in accordance with ASTM D 448, size number 467 (nominal aggregate size is 2 inches to 3/16 inches). Other gradients will require hydraulic conductivity testing to demonstrate that 1.0 cm/s hydraulic conductivity is provided by the drainage stone. Each sump will be emptied by a submersible pump located in an 18-inch nominal diameter sidewall riser pipe which extends into the bottom of the sump and is perforated in the sump. Pumps will be operated either manually or automatically by pressure transducers. Control levels for an automatic pump will be set to maintain sump liquid levels between the lip of the sump and pump intake. The objective of the pump operation is to ensure that a free-flowing condition is maintained in the LCS layer. If the pump malfunctions, the pump will be removed, repaired, and replaced, or a new pump will be used (see Table 3-2 for additional information). The leachate depth monitoring procedure and leachate removal will be the same for all disposal areas. The depth of leachate in the sump may be monitored by the pressure transducer which will be calibrated to provide direct read-out of the leachate level in the sump (e.g., typically the leachate level is shown on a continuous digital display at the sump as the pressure transducers provide a constant determination of the leachate levels in the sump). These automatic control levels will be inspected every day the facility is in operation and accepting waste. As noted in Part IV – SOP, Section 4.23, the leachate levels for each sump will be recorded in the Site Operating Record once per week. If the pressure transducers are not functioning, the pumps will be operated manually (once per day) until the automatic system is repaired. Details of the leachate sump are provided in Appendix IIIA-A – Liner and Final Cover System Details.

The specified pump for each sector as specified in Table 4-1 will have the capacity to remove leachate to maintain less than 12 inches of head on the liner. The maximum estimated flow to be pumped from the largest sector (Sector 13 with a contributing area of 18.5 acres) is approximately 880.3 gpd (refer to Appendix IIIC-B). If the specified leachate sump pumps are not able to empty the sump and maintain less than 12 inches of head on the liner at reasonable cycle times, then a pump with more capacity will be used (refer to Section 4.1 for more information).

Table 3-2
Leachate Sump Operating Plan

<table>
<tr><th>Leachate Level Description</th><th>Condition</th><th>Action Required</th></tr>
<tr><td>Leachate level between lip of sump and pump intake at the bottom of the sump.</td><td>System is functioning as designed. The leachate sump controls will be set to turn on once the leachate level reaches the lip of the sump. The drainage geocomposite leachate collection layer installed on the floor of the landfill is designed to convey the estimated peak leachate flow rate without the leachate level within the geocomposite exceeding the thickness of the geocomposite. The operation of the leachate sump and the conveyance capacity of the geocomposite leachate collection layer work in tandem to maintain compliance with the design standard listed in §330.331(a)(2).</td><td>The depth of leachate in the sump is monitored by a pressure transducer which is calibrated to provide direct read-out of the leachate level in the sump (e.g., typically the leachate level is shown on a continuous digital display near the sump riser, as the pressure transducers provide a constant determination of the leachate levels in the sump). These automatic control levels will be inspected every day the facility is in operation and accepting waste. As noted in Part IV – SOP, Section 4.23, the leachate levels for each sump will be recorded in the Site Operating Record once per week.
Leachate flow to the sump required, sump pump capacity, and range of pump operating times are listed in Appendix IIIC, Table 4-1. The sump design is discussed in Appendix IIIC, Section 3.4 and detailed sump design calculations are provided in Appendix IIIC-B.</td></tr>
<tr><td>Leachate level between the lip of the sump and 30 cm (or 12 inches) above the lip of the sump.</td><td>The pump is not able to maintain the leachate levels at or below the lip of the sump. However, the 12-inch design standard listed in §330.331(a)(2) has not been exceeded.</td><td rowspan="2">For these two conditions, the sump operation will be monitored daily to determine if this leachate level is the result of a short-term situation (e.g., significant storm event during initial waste filling operations of a Cell, temporary loss of power at the site, etc.) or if there is a maintenance issue with the pump or pump controls. For both conditions, the leachate levels in the sump will be recorded daily (as discussed in Part IV – SOP, Section 4.23). If the leachate sump pumps are not able to maintain the leachate level below the lip of the sump at reasonable cycle times, then a pump with more capacity will be used to maintain the leachate level below the lip of the sump. If the pump has to operate close to 24 hours per day for a significant period of time, then it is approaching the pump capacity limits and a larger pump will need to be installed.
As noted in the EPA Technical Manual Solid Waste Disposal Facility Criteria, EPA530-R-93-017, “The 30-cm head allowance is a design standard and the [EPA] recognizes that this design standard may be exceeded for relatively short periods of time during the active life of the unit.” To address this requirement, adequately sized sump pumps will be set to initiate pumping when leachate levels reach the lip of the sump. After the sump pump has been evaluated and found to be operating inadequately, the issue will be noted in the site operating record and the pump will be repaired or replaced within 5 business days from the discovery of the leachate/level pumping issues when practicable.</td></tr>
<tr><td>Leachate level over 12 inches above the lip of the sump.</td><td>System not functioning as designed and the design standard listed in §330.331(a)(2) has been exceeded.</td></tr>
</table>

3.5 Drainage Stone (Coarse Aggregate)

Granular drainage material around the leachate collection pipes and in the LCS sumps in the Subtitle D areas will consist of typical (e.g., unit weight of 90 to 110 pcf) or lightweight (e.g., unit weight less than 70 pcf) materials that comply with the following criteria. The aggregate will have a loss of mass due to calcium carbonate of less than 15 percent (in accordance with JLT-S-105-89 or ASTM D3042 method modified to use a solution of hydrochloric acid having a pH of 5). The drainage stone will meet the following gradation in accordance with ASTM D448, size number 467.

Sieve Size Square Opening	Percent Passing
2 inches	100
1½ inches	95 - 100
¾ inch	35 - 70
3/8 inch	10 - 30
No. 4 (3/16 inch)	0 - 5

Drainage materials not complying with the above gradations may also be approved by the POR if demonstrated to have a hydraulic conductivity of at least 1.0 cm/s and meet the gradation requirements of the filter and leachate collection pipe (in no case will the maximum rock size be greater than 2 inches). At a minimum, the drainage stone will meet the following size criteria:

For circular holes:

$$\frac{\text{85 Percent Size of Filter Material}}{\text{Hole Diameter}} > 1.7$$

For slots:

$$\frac{\text{85 Percent Size of Filter Material}}{\text{Slot Width}} > 2.0$$

The drainage stone will be covered by a geotextile to maintain separation of drainage stone from the overlying layers. The geotextile will be resistant to commonly encountered chemicals, hydrocarbons and mildew, and will be rot resistant. Geotextile design calculations are presented in Appendix IIIC-B.

0 300 600
SCALE IN FEET

LEGEND

— · —	PROPOSED PERMIT BOUNDARY
— — —	PROPOSED LIMIT OF WASTE
N 7180000	STATE PLANE COORDINATE SYSTEM
3300	EXISTING CONTOUR
3280	TOP OF LINER CONTOUR
— - —	SECTOR BOUNDARY
— ◄ —	LEACHATE COLLECTION PIPE
■	LEACHATE COLLECTION SUMP
—•	LEACHATE RISER PIPE

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. ELEVATIONS SHOWN HEREON ARE RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988.
3. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.
4. ELEVATION OF DEEPEST EXCAVATION AT THE LCS SUMP IS 3251.0 FT–MSL.
5. REFER TO FIGURE 4–1 FOR THE LCS FORCEMAIN AND LCS STORAGE TANK INFORMATION.

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: 3-1 LEACHATE COLLECTION.DWG

DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: NT

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
LEACHATE COLLECTION SYSTEM PLAN

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

WWW.WCGRP.COM

FIGURE 3–1

SHEET IIIC–10A

O:\0120\809\EXPANSION 2023\PART III\IIIC\3-1 LEACHATE COLECTION.dwg, jpuhr, 1:2

4 LEACHATE AND CONTAMINATED WATER STORAGE

4.1 Leachate Storage

Temporary leachate storage will be provided in the leachate collection sumps. The leachate collection sump size and pump requirements have been based on the amount of leachate generated. The site may utilize a combination of onsite above-ground storage tanks and evaporation ponds for additional storage as described in Section 4.3. Table 4-1 summarizes the estimated leachate flow into the sump and the daily pump operating time provided by two representative sectors/areas. The estimated leachate generation rate is based on the average leachate generation estimated by the HELP model analysis. Table 4-1 also includes the expected leachate generation and pump operating times which are based on site specific leachate generation values. Sump volume calculations are provided in Appendix IIIC-B. Details of the leachate sumps are provided in Appendix IIIA-A – Liner and Final Cover System Details.

Leachate levels in the sumps will be measured and recorded to evaluate leachate production and fluctuations. A form to record leachate measurements will be kept in the Site Operating Record and will be used to evaluate the effectiveness of leachate monitoring and control facilities. The sumps will be emptied by submersible pumps located within the sump section of the sidewall riser pipes to meet the design objective as required by the Leachate Sump Operating Plan presented in Table 3-2. Disposal of leachate is discussed in Section 5. Leachate will be pumped to the leachate storage tank, evaporation ponds, or recirculated at the working face. The design and operation of the onsite storage tank and evaporation ponds is discussed in Section 4.3. The location of the leachate storage area is shown on Figure 4-1. The storage tank and evaporation pond calculations are presented in Appendix IIIC-D.

The forcemain that connects the sumps to the leachate storage area will consist of a 2-inch minimum diameter pipe encased in a 4-inch minimum diameter carrier pipe. The carrier pipe will provide leak detection and containment. The forcemain will be extended to serve each sector as landfill development progresses. The location of the leachate forcemain and the leachate storage area is shown on Figure 4-1. Details of the connection between the 18-inch riser and forcemain are presented on Figure 4-2, and the forcemain capacity calculations are presented in Appendix IIIC-D.

Table 4-1
Sump Flow and Pump Operating Times

Sump Storage Summary			
Condition	Sectors 1 through 18[1]		
	Flow (gpd)	Pump Operating Time (hours/day)	Pump Capacity (gpm)
	Average[2]	Average[2]	
Active	353.9	0.6	10
Interim	880.3	1.5	10
Closed	187.1	0.3	10

[1] Sumps draining the largest LCS layer areas are shown. Refer to Appendix IIIC-B, Sheet IIIC-B-38 – Sump Drainage Areas for Sector layout and areas draining to each sump.
[2] Refer to Appendix IIIC-B, page IIIC-B-34 for sump design calculations.

4.2 Contaminated Water Management

Contaminated water will be contained at the working face as shown in Appendix IIIC-C. A vacuum truck or similar vehicle will remove contaminated water from this area. Contaminated water will then be transported via tanker trucks to a properly permitted offsite wastewater treatment facility or recirculated back into the landfill, as discussed in Section 5.

4.3 Onsite Storage Tank(s) and Evaporation Ponds

The proposed minimum 21,000-gallon leachate storage tank and evaporation ponds will provide enough storage capacity for the leachate expected to be generated at the site. Contaminated water and landfill gas condensate will also be stored in the leachate tank or evaporation ponds as discussed in Sections 5.3 and 5.4. The storage tank and evaporation ponds will be emptied, as required, to maintain capacity for the leachate currently generated at the site. The leachate level in the tank will be managed to provide a minimum of 2,500 gallons of emergency backup storage capacity. The leachate level in the evaporation pond will be managed to provide a minimum of 1 foot of freeboard.

Leachate storage capacity calculations are provided in Appendix IIIC-D. The tank is equipped with a liquid-level sensor and a high-level alarm to prevent overfill. When the high level alarm is triggered, a light on the tank will start flashing, which will alert site personnel of the high level in the tank. Additionally, the alarm will activate an electronic signal that will be sent to the leachate sump pumps to shut them down until the issue is resolved. Site personnel will then take appropriate actions to reduce the leachate level in the tank. The storage tank will be emptied consistent with the leachate storage system operation plan detailed in Section 5.

The minimum 21,000-gallon tank will be dual contained or located within a secondary containment area consisting of a 2-foot-high (minimum) earthen berm. The design is sufficient to control and contain a worst case spill or release. As shown in Appendix IIIC-D, the design of the unenclosed containment area that surrounds the tank accounts for precipitation from the 25-year, 24-hour storm. Leachate spillage within the containment area, should it occur, will be manually pumped back into the storage tank.

The evaporation ponds will be operated to maintain a minimum of 2 foot of freeboard. The limit of the maximum operating level (2 foot vertically down from the top of the pond) will be clearly marked with paint, or a bead of HDPE, or some other appropriate marking so that the operating level may be easily checked. The leachate level will be maintained at or below the maximum operating level. The level in the pond will be checked weekly and after rainfall events greater than four inches. If the leachate level exceeds the maximum operating level because of an excessive rainfall event, the pond content will be loaded into tanker trucks for off-site disposal or placed in the onsite leachate tank. The evaporation pond will be lined with a double liner system including geomembrane and geosynthetic clay composite liner using the same materials specified for the landfill liner and constructed in accordance with Appendix IIID – Liner Quality Control Plan. Design and calculations showing projected pond performance and design requirements are contained in Appendix IIID-D.

Table 4-2
Proposed Leachate Storage

Designation	Storage Capacity[1] (Total, gal)	Freeboard[2] (ft)	Overfill Protection	Construction	Dimensions	Secondary Containment Description	Leak Detection	Secondary Containment Capacity (gallons)	Discharge
Storage Tank L1[1]	Minimum 21,000 (total) 4,918 (working)	1	Yes, high level sensor within tank with actuated shutoff valve and visual alarm. Alarm set at or below freeboard height.	Single contained, dual contained or on concrete foundation. Closed top.	31-ft by 10-foot base 9-ft height	Dual contained tank or 2-foot-high containment berm	Visual inside secondary containment.	Minimum 21,000 (provides containment for working volume plus 1-ft freeboard)	Discharge by tanker truck
Evaporation Pond L2[2]	597,981 (working)	1	Maximum operating level will be marked and checked weekly or after rainfall events greater than four inches.	Primary 60-mil HDPE geomembrane overlaying a primary geosynethetic clay liner (GCL) and a secondary 60-mil HDPE geomembrane overlaying a secondary GCL.	135 ft by 135 ft top 10-ft deep	Secondary Liner System	Visual	Minimum (provides containment for working volume plus 1-ft freeboard)	Discharge by tanker truck
Evaporation Pond L3[2]	597,981 (working)	1	Maximum operating level will be marked and checked weekly or after rainfall events greater than four inches.	Primary 60-mil HDPE geomembrane overlaying a primary geosynethetic clay liner (GCL) and a secondary 60-mil HDPE geomembrane overlaying a secondary GCL.	135 ft by 135 ft top 10-ft deep	Secondary Liner System	Visual	Minimum (provides containment for working volume plus 1-ft freeboard)	Discharge by tanker truck

1 Tank total storage capacity in table includes storage and freeboard volumes combined. Working storage capacity does not include freeboard storage.

2 In all instances freeboard depth exceeds the 25-year, 24-hour storm event depth of 5.26 inches (reference: Appendix IIIC-C, Page IIIC-C-2).

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. ELEVATIONS SHOWN HEREON ARE RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988.
3. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

☐ DRAFT
☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: 4-1 LEACHATE STORAGE.DWG

DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: KDG

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
FORCEMAIN AND STORAGE TANK PLAN

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

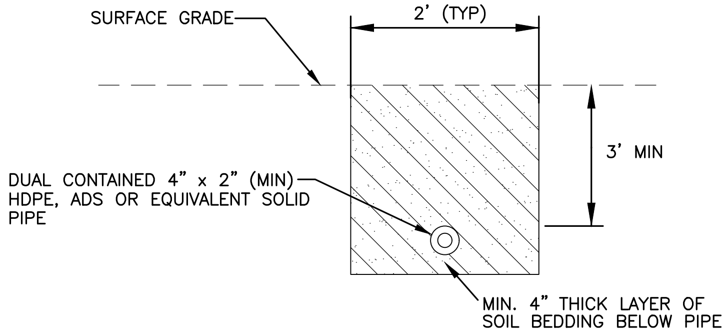
Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

WWW.WCGRP.COM

FIGURE 4-1

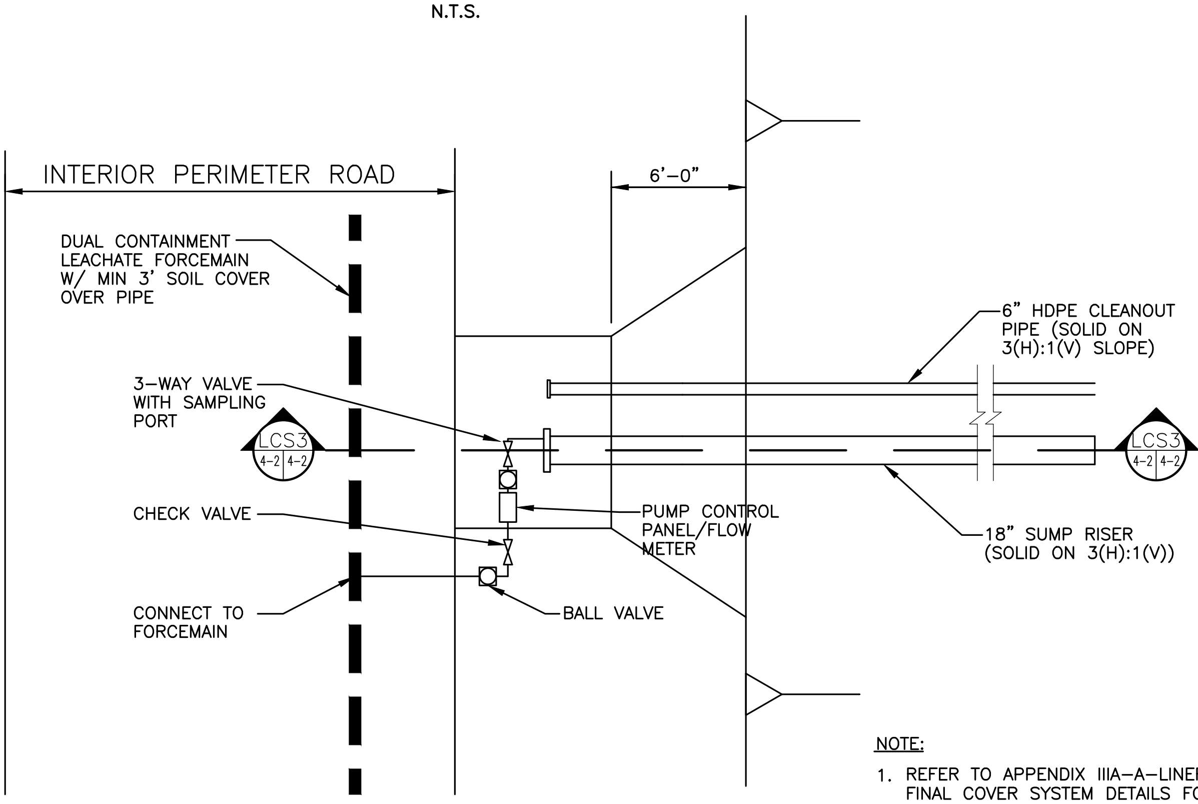
SHEET IIIC-14A

O:\0120\809\EXPANSION 2023\PART III\IIIC14-1 FORCEMAIN.dwg, jpuhr, 1:2



LEACHATE FORCEMAIN (DUAL CONTAINED) LCS1 4-2 4-2
N.T.S.

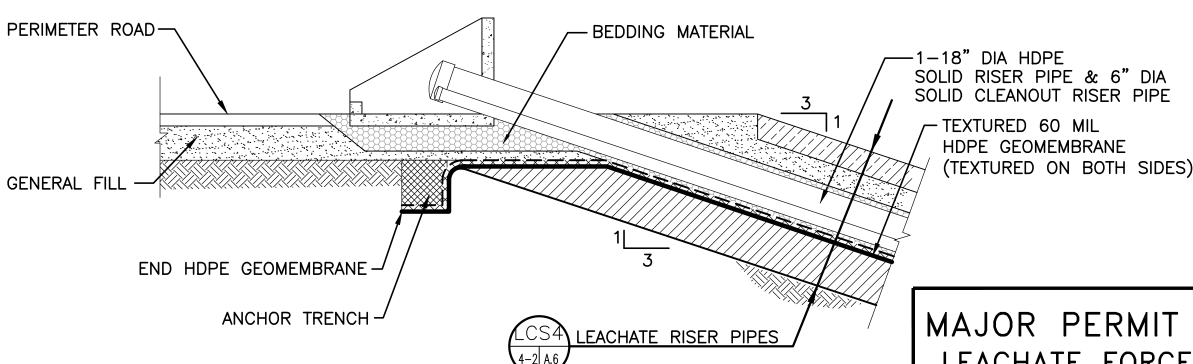
STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024



NOTE:

1. REFER TO APPENDIX IIIA-A-LINER AND FINAL COVER SYSTEM DETAILS FOR LINER INFORMATION.
2. MULTIPLE 6" CLEANOUT RISERS MAY BE INSTALLED DEPENDING ON THE NUMBER OF LCS PIPE DRAINING TO THE SUMP.

FORCEMAIN CONNECTION LCS2 4-1 4-2
N.T.S.



LEACHATE RISER/CLEANOUT LCS3 4-2 4-2

0 4 8
SCALE IN FEET

SHEET IIIC-14B

MAJOR PERMIT AMENDMENT
LEACHATE FORCEMAIN DETAILS

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

DRAWN BY: BPY	DATE: 08/2024	FILE: 0120-809-11
REVIEWED BY: BPY	CAD: 4-2 FORCEMAIN DTLS.DWG	FIGURE 4-2

O:\0120\809\EXPANSION 2023\PART III\IIIC\4-2 FORCEMAIN DETAILS.dwg, jpuhr, 1:1

5 LEACHATE AND CONTAMINATED WATER DISPOSAL

5.1 Leachate Storage System Operation and Disposal

Leachate that is generated at the site will be conveyed to the leachate collection sumps. Leachate levels in the sumps are measured and recorded to evaluate leachate production and fluctuations. A form to record leachate measurements is kept in the Site Operating Record and is used to evaluate the effectiveness of the leachate monitoring and control facilities. The depth of leachate in the sump will be monitored by the pressure transducer which will be calibrated to provide direct read-out of the leachate level in the sump (e.g., typically the leachate level is shown on a continuous digital display at the sump, as the pressure transducers provide a constant determination of the leachate levels in the sump). As noted in Part IV – SOP, Section 4.23, the leachate levels for each sump will be recorded in the Site Operating Record once per week at a minimum. Leachate will be pumped from the leachate sumps and transferred to the leachate storage tank or evaporation ponds via the forcemain (see Figure 4-1 for location).

The storage tank and evaporation pond capacity calculations are presented in Appendix IIIC-D. As noted in Appendix IIIC-D, the storage tank(s) will provide approximately 4 days of leachate storage and the evaporation ponds will provide approximately 222 days of leachate storage.

The collected leachate will be transported by tanker trucks to a properly permitted off-site treatment facility or recirculated back into the landfill (refer to Section 5.2). For leachate that is transferred to tanker trucks, sampling and analysis will be based on the disposal facility's requirements.

The leachate tank will be equipped with a liquid-level indicator. Leachate levels in the storage tanks will be controlled to prevent capacity exceedance. The leachate levels in the ponds will be monitored as discussed in Section 4.3 to prevent capacity exceedance. The quantity of leachate pumped from the system is also recorded on a monthly basis. This information is maintained in the Site Operating Record. When the high level alarm is triggered, a light on the tank will start flashing, which will alert site personnel of the high level in the tank. Additionally, the alarm will activate an electronic signal that will be sent to the leachate sump pumps to shut them down until the issue is resolved. Site personnel will then take appropriate actions (e.g., increase leachate discharge via pumping or tanker trucks) to reduce the leachate level in the tank.

5.2 Leachate Recirculation Plan

The main purpose of recirculating leachate at this facility is to enhance the ability to manage and control leachate. Additionally, in an effort to promote an increase in waste compaction, leachate recirculation will provide the opportunity to create a uniform moisture content throughout the waste at the working face. The additional moisture will help stabilize the waste mass, thus providing for an increased compaction of the waste. The leachate will be better managed because the recirculation of leachate through the waste mass allows for treatment of the leachate to occur through physical, biological, and chemical interactions with the organic and some inorganic portions of the waste. This increases the rate of waste decomposition and stabilization, as well as increasing the rate of landfill gas recovery. Recirculation of leachate also facilitates dust control at the working face.

Consistent with Title 30 TAC §330.177, recirculation of leachate will only occur over areas underlain by a Subtitle D liner system (no recirculation will occur over the areas with alternative liner). Leachate will be recirculated by surface spraying at the working face. Leachate will be distributed from a water truck or other comparable equipment using a spray bar or hose to distribute leachate back to the working face (i.e., within the active waste fill area that is contained by the containment berm).

The following performance standards will govern the application rate of leachate recirculation.

- The rate of leachate recirculation will not exceed the moisture holding capacity of the landfill. For example, the application rate will be applied so that no seeps or ponding is observed in the vicinity of the recirculation area. In addition, leachate recirculation over a specific sector will cease if the leachate flow rate to a sump approaches the capacity of the pump within the sump. For the purposes of this plan, if the leachate pump is constantly having to pump leachate more than 16 hours in a day, then the capacity of the sump has been reached. The quantity of leachate pumped from each sump will be monitored on a monthly basis. If the pump begins to operate near capacity, then the pump operating time will be monitored on a daily basis to determine if leachate recirculation needs to be reduced over the sector that flows to the sump which contains the pump that is operating near capacity. If this occurs, recirculation activities will move to another sector. The site can recirculate up to 71 gallons/day/acre.
- Leachate recirculation will not occur immediately before, during, or immediately after rainfall events, or during freezing temperatures that could affect the holding capacity of the waste.
- Leachate recirculation will not occur during high wind events.

- Refer to Part IV – SOP, Section 4.10 for additional information regarding the plan to be followed if odors due to leachate recirculation become an issue.

Contaminated stormwater will not be recirculated into the waste.

5.3 Contaminated Water Disposal

Contaminated water that collects behind the containment berm will be pumped into tanker trucks and transported to the leachate tank, evaporation ponds, or a properly permitted treatment facility. Contaminated water will be removed as soon as practicable from the area inside the containment berm (refer to Section 4.23 of the SOP for additional information and record keeping requirements). Contaminated water may also be transported to the leachate storage tank. When contaminated water is stored in the leachate storage tank, no leachate recirculation will occur, and a sign will be posted on the tank stating "No Recirculation." When the tank containing the contaminated water is emptied, the sign will be removed.

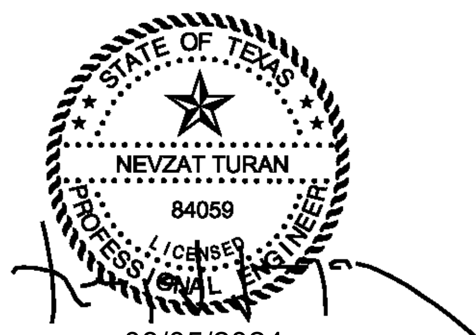
5.4 Landfill Gas Condensate

Consistent with Title 30 TAC §330.177 and §330.207(e), landfill gas condensate will be pumped to the onsite leachate storage tank or evaporation ponds. It will then be handled and disposed of consistent with Section 5.1 or recirculated consistent with Section 5.2.

APPENDIX IIIC-A

LEACHATE GENERATION MODEL

Includes pages IIIC-A-1 through IIIC-A-52



08/05/2024

LEACHATE GENERATION MODEL

HELP MODEL

The Hydrologic Evaluation of Landfill Performance (HELP) Model, Version 3.07 was used to estimate quantity of leachate that will be generated during the active life and postclosure period of the City of Meadow Landfill. The HELP Model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of the landfill. The model uses climate, soil, and landfill design data to perform a solution technique that accounts for the effects of surface storage, runoff, infiltration, percolation, soil moisture storage, evapotranspiration, and lateral drainage.

MODEL SETUP

The site was modeled as a 1-acre unit area for the following stages of landfill development in Sectors 1 through 18:

- Working face with 10 feet of waste
- 50 feet of waste with intermediate cover
- 100 feet of waste with intermediate cover
- 130 feet of waste with intermediate cover
- 130 feet of waste with final cover

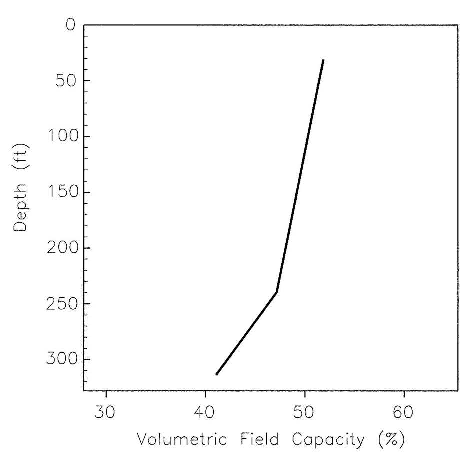
The active stage was modeled for one year with no intermediate or daily cover. The interim stages with intermediate cover were modeled for various lengths of time selected based on the projected duration each condition is likely to occur. The closed landfill condition was modeled for 30 years. The evaporative zone depth was selected to be 12 inches for the active, interim, and closed cases. The leaf area index was selected to be 0 for the active case, 2 for the interim cases and 4.5 for the closed case based on the selected ground area. The USDA National Resources Conservation Service (NRCS) runoff curve numbers were calculated by HELP based on soil data and expected ground cover, surface slope, and slope length. The active case models a curve number of 79.7 and percent runoff area of zero, which is representative given that this condition assumes complete infiltration (minus evapotranspiration). The interim cases utilize the default curve number assigned by the HELP model which is 85.6 and corresponds to "fair" ground cover. The percent runoff area used varies between 70 to 90. This is representative of the intermediate cover, which will be 12 inches of compacted soil with 60 percent or more vegetation coverage. The final case models a curve number of 80.6 and percent runoff area of 100, which corresponds to “good” ground cover. This is representative of the final cover, which will have a minimum 90 percent vegetation coverage.

MOISTURE CONTENT AND FIELD CAPACITY

For a conservative analysis, the initial moisture content was set at field capacity for all profile layers except the compacted clay barrier layer and the waste layer. HELP automatically sets the initial moisture content for a compacted clay barrier layer at porosity (i.e., fully saturated). The initial moisture content for the waste layer was selected to be 25 percent for the 10-foot-thick and 50-foot-thick waste column cases. A moisture content of 25 percent is typical for recently placed waste. For the remaining cases, the initial moisture content for the waste layer was selected to be 30 percent to account for the fact that the waste will be in place for a longer period of time and the moisture content could increase.

Default values for the field capacity of each profile layer, other than the waste layer, were used. The field capacity values for the waste layer were obtained from “Retention of Free Liquids in Landfills Undergoing Vertical Expansion” (Zornberg, Jorge G., et al., 1999) and varies based on average waste column thickness. The relationship used is shown in the following graph.

VOLUMETRIC FIELD CAPACITY AS A
FUNCTION OF
WASTE DEPTH



CLIMATE DATA INPUT

Precipitation and temperature data was synthetically generated by the HELP model program using normal mean monthly precipitation data and temperature date from the National Oceanic Atmospheric Administration (NOAA) for the Brownfield #2, Texas weather station. The average annual precipitation over the modeled 30-year period was 17.93 inches. Solar radiation data were synthetically generated by the HELP model using program defaults for Midland, Texas.

LANDFILL PROFILE

The landfill profiles for various stages of the landfill development are presented in the attached HELP Model summary sheets. The profile presented below includes a composite liner with a standard Subtitle D final cover system.

Liner Systems

The Subtitle D composite liner consists of a 60-mil high-density polyethylene (HDPE) geomembrane placed over a 24-inch-thick compacted clay liner with a hydraulic conductivity of $1x10^{-7}$ cm/s. The geomembrane liner was modeled for good installation quality, with 0 installation defect and 0 pinhole per acre. Default characteristics from the HELP model were selected for the HDPE geomembrane hydraulic conductivity. Default soil characteristics from the HELP model were also selected for the compacted clay liner.

Leachate Collection System

Sectors 1 through 18 will be constructed with an LCS that includes a 200-mil-thick single-sided geocomposite (floor grades). The required transmissivity of the 200-mil-thick geocomposite was determined using HELP model. The slope length was determined from post-settlement slopes as analyzed in Appendix IIIE-B. The 200-mil-thick geocomposite calculations are shown on pages IIIC-A-5 through IIIC-A-9. The double-sided geocomposite used on sideslopes is analyzed in Appendix IIIC-A.1.

In HELP model demonstrations 10 percent recirculation is used. This is a conservative assumption since that recirculation will only occur at the working face, which will move on a daily basis. For example, the HELP Model analysis is based on a 1-acre "unit" area. Therefore, the area that receives additional leachate due to recirculation is limited to the working face area which constantly moves within the area defined by the waste fill footprint. As a result, the majority of the time most of the waste footprint area does not experience any recirculation, and for the purpose of this analysis it is assumed that the "unit" acre will experience recirculation 10 percent of the time. Refer to Appendix IIIC, Section 5.2 for specific guidance regarding leachate recirculation. Consistent with Subtitle D regulations, leachate will only be recirculated over areas underlain by a Subtitle D compliant liner system that is consistent with 30 TAC §330.331(b).

Waste Layers

Various waste thicknesses were modeled to represent the various stages of landfill development. A default wilting point was selected from HELP to represent municipal solid waste. The waste column was split into two layers. The top 100-foot layer was modeled with a hydraulic conductivity of $1x10^{-3}$ cm/s. A lower hydraulic conductivity of $1x10^{-4}$ cm/s was used for the bottom layer because the additional overburden pressure will cause additional consolidation to this layer that will likely lower the hydraulic conductivity. The moisture content, field capacity, and porosity values were selected as discussed previously.

Intermediate Cover

The intermediate cover consists of a 12-inch-thick layer of soil placed over the waste. Default soil characteristics were selected from HELP to represent the available onsite soils with a hydraulic conductivity of $1.2x10^{-4}$ cm/s.

Final Cover

The composite final cover over the landfill consists of a 12-inch erosion layer with the top 6 inches capable of sustaining growth of vegetation, a geocomposite drainage layer, a 40-mil LLDPE geomembrane liner, and an 18-inch infiltration layer. The geomembrane liner was modeled for good installation quality, 4 construction defects per acre, and a pinhole density of 1 hole per acre. The infiltration layer consists of compacted soil with a hydraulic conductivity of $1x10^{-5}$ cm/s.

HELP MODEL OUTPUT

The HELP summary tables and output files for the various stages of the landfill development are presented beginning on page IIIC-A-10.

Required: Determine the minimum requirements of the 200-mil geocomposite leachate collection layer for Sectors 1 through 18.

Method:

1. Determine the 200-mil geocomposite leachate collection layer thickness under the expected loading conditions.
2. Use HELP model to determine the minimum required hydraulic conductivity of the 200-mil geocomposite leachate collection layer at the expected loading conditions.
3. Determine factors of safety for strength and environmental conditions based on the expected duration of each stage of landfill development.
4. Compute the design transmissivity of the 200-mil geocomposite leachate collection layer for each stage of landfill development using the calculated thicknesses, the hydraulic conductivity, and the reduction factors.
5. Specify the geocomposite properties for the leachate collection layer.

References:

1. Koerner, R.M., Designing With Geosynthetics, Third Edition, 1994.
2. Gray, Donald H., Koerner, Robert M., Qian, Xuede, Geotechnical Aspects of Landfill Design and Construction , 2002.
3. Geosynthetic Institute, GRI Standard GC-8, 2001.
4. GSE Drainage Design Manual, Second Edition, June 2007.
5. Acar, Yalcin B.& Daniel, David E., *Geoenvironment 2000 Characterization, Containment, Remediation, and Performance in Environmental Geotechnics,* Volume 2, American Society of Civil Engineers, 1995.

Solution:

1. Determine the 200-mil geocomposite leachate collection layer thickness under the expected loading conditions.

   Assume the geocomposite leachate collection layer will undergo compression due to the weight of soil (in the form of intermediate cover, protective cover, or final cover) and waste.

Unloaded Geocomposite Thickness (200 mil) = 0.20 in
Unit Weight of Soil = 108 pcf

Table 1 - Geocomposite Thickness for Subtitle D Areas

Fill Condition	d_W[1] (ft)	d_S[2] (ft)	γ[3] (pcf)	P[4] (psf)	t[5] (in)	t[5] (cm)
Active - 10'	10	2	51	726	0.199	0.504
Interim - 50'	50	3	51	2,874	0.190	0.484
Interim - 100'	100	3	57	6,024	0.179	0.454
Interim - 130'	130	3	61	8,254	0.171	0.435
Closed - 130'	130	5.5	61	8,524	0.170	0.433

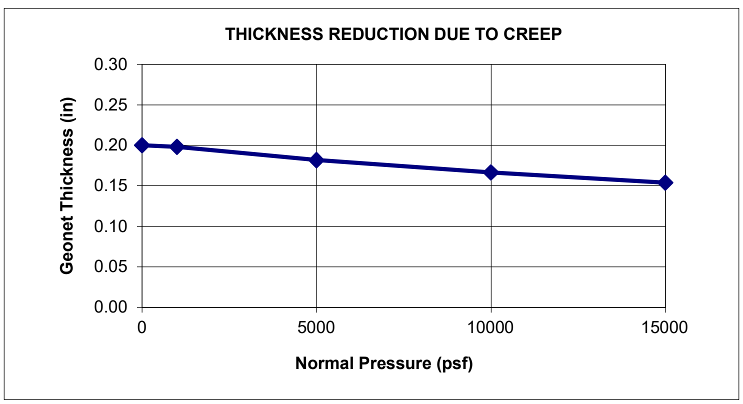
1 d_W is the depth of waste and daily cover soil above the geocomposite leachate collection layer.

2 d_S is the depth of soil (protective cover, intermediate cover, and final cover) above the geocomposite leachate collection layer.

3 The unit weight of waste/soil is selected at the midpoint of the waste column thickness using the Unit Weight Profile for MSW graph provided in Ref 5.

4 P is the pressure on the geocomposite leachate collection layer due to the weight of the waste and soil.

5 t is the thickness of the geocomposite leachate collection layer after being subjected to compression based on the chart below adapted from Reference 4.



2. Use HELP model to determine the minimum required hydraulic conductivity of the 200-mil geocomposite leachate collection layer at the expected loading conditions. HELP model results are shown in Sheet IIIC-A-10

3. Determine factors of safety for strength and environmental conditions based on the expected duration of each stage of landfill development.

Table 2 - Reduction Factors and Factor of Safety

Reduction Factors[1]		Fill Condition: Active (10' Waste)	Interim (50' Waste)	Interim (100' Waste)	Interim (130' Waste)	Closed
RF_{IN}	Delayed Intrusion	1.1	1.1	1.1	1.1	1.1
RF_{CC}	Chemical Clogging	1.0	1.3	1.5	1.9	2.0
RF_{BC}	Biological Clogging	1.0	1.1	1.2	1.2	1.3
Total Reduction Factor[2]		1.10	1.57	1.98	2.51	2.86

Overall Factor of Safety to Account For Uncertainties	2.0	2.0	2.0	2.0	2.0
Overall Reduction Factor (ORF)[3]	2.20	3.15	3.96	5.02	5.72

[1] Values are obtained from References 1, 2, and 3.

[2] The Total Reduction Factors are a product of all the reduction factors for each fill condition.

[3] The Overall Reduction Factors are a product of the Total Reduction Factor and Overall Factor of Safety to Account For Uncertainties for each fill condition.

4. Compute the design transmissivity of the 200-mil geocomposite leachate collection layer for each stage of landfill development using the calculated thicknesses, the hydraulic conductivity, and the reduction factors.

Table 3 - Required Transmissivity for Subtitle D Areas

Fill Condition	d_W[1] (ft)	P[2] (psf)	t[3] (cm)	k[4] (cm/s)	T_{DES}[5] (m^2/s)	ORF[6]	T[7] (m^2/s)
Active - 10'	10	726	0.504	0.90	4.55E-05	2.20	1.00E-04
Interim - 50'	50	2,874	0.484	0.53	2.54E-05	3.15	8.00E-05
Interim - 100'	100	6,024	0.454	0.33	1.52E-05	3.96	6.00E-05
Interim - 130'	130	8,254	0.435	0.19	8.26E-06	5.02	4.14E-05
Closed - 130'	130	8,524	0.433	0.19	8.23E-06	5.72	4.71E-05

[1] d_W is the depth of waste above the geocomposite leachate collection layer.

[2] P is the pressure on the geocomposite leachate collection layer due to the weight of the waste and soil from Table 1.

[3] t is the calculated geocomposite leachate collection layer thickness from Table 1.

[4] k is obtained from the HELP model design as shown on Sheet IIIC-A-10

[5] T_{DES} is the design transmissivity value calculated using the following equation:

$$T_{DES} = (k * t) / 100^2$$

[6] ORF is the Overall Reduction Factor obtained from Table 2.

[7] T is the design transmissivity value calculated using the following equation:

$$T = T_{DES} * ORF$$

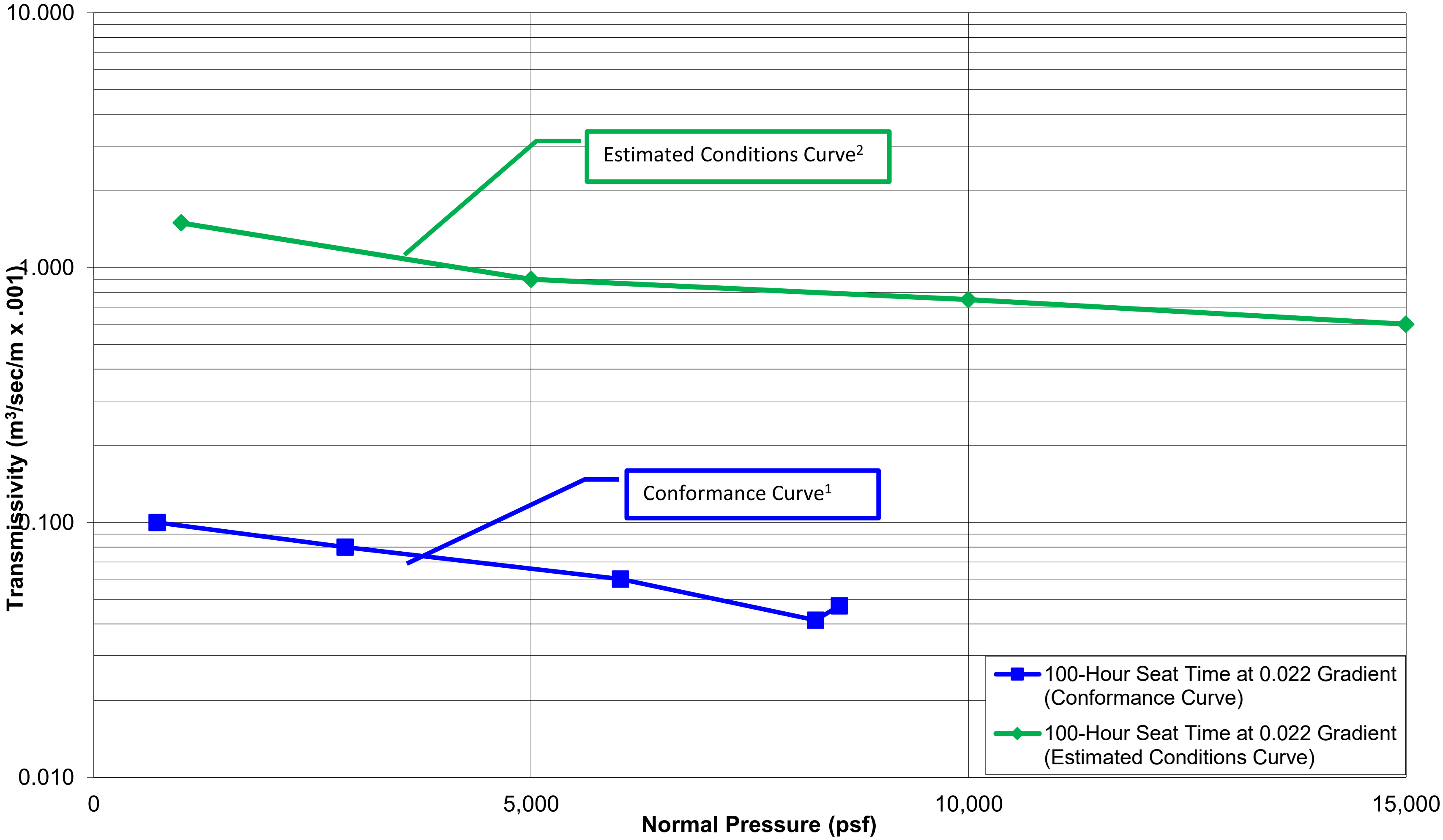
5. Specify Drainage Geocomposite Properties for the Leachate Collection Layer

As shown on the HELP model summary sheets, a geocomposite with characteristics similar to the conformance curve on the graph shown on Sheet IIIC-A-9 will provide a drainage layer that will maintain less than twelve inches of head on the liner system. The estimated conditions curve was developed based on engineering judgement and experience with similar geocomposite products at numerous MSW sites in Texas and is provided to verify the selected drainage geocomposite transmissivity provides greater conveyance than the specified transmissivity in these calculations.
The drainage geocomposite required transmissivity values will be measured at a gradient of 0.022 under normal pressures of 1,000, 10,000 and 8,254 psf (or higher), boundary conditions consisting of soil/geocomposite/geomembrane with minimum seat time of 100 hours and will be run for the first 100,000 square feet of liner construction. For each additional 100,000 square feet of single-sided geocomposite placement area, one additional transmissivity test will be run under the maximum normal stress (i.e., 8,524 psf) with all the same assumptions as the first three tests.

Refer to the conformance curve plotted on Sheet IIIC-A-9 for the minimum transmissivity requirements.

Note:
Reference to "geocomposite thickness" within these calculations refers to thickness of geonet, not the overall thickness of geocomposite. Actual manufacturer's specified thickness for a geocomposite incorporating the specified geonet thickness may be greater.

TRANSMISSIVITY OF SINGLE-SIDED GEOCOMPOSITE
6 oz/sy Polypropylene Geotextile with 200-mil Drainage Net
(Soil/Geocomposite/Geomembrane)



[1] The transmissivity shall be greater than the Conformace Curve to be considered passing.
[2] These values are developed based on engineering judgement and experience with similar geocomposite products at numerous MSW sites in Texas and is provided to verify the selected drainage geocomposite transmissivity provides greater conveyance than the specified transmissivity in these calculations.

HELP VERSION 3.07 SUMMARY SHEET
SECTORS 1-18

		ACTIVE (10 FT WASTE)	INTERIM (50 FT WASTE)	INTERIM (100 FT WASTE)	INTERIM (130 FT WASTE)	CLOSED (130 FT WASTE)
GENERAL	Case No.	1	2	3	4	5
INFORMATION	Output Page	IIIC-A-12	IIIC-A-20	IIIC-A-29	IIIC-A-38	IIIC-A-47
INFORMATION	No. of Years	1	10	10	10	30
	Ground Cover	BARE	FAIR	FAIR	FAIR	GOOD
	SCS Runoff Curve No.	79.7	85.6	85.6	85.6	80.6
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	0	70	80	90	100
	Maximum Leaf Area Index	0.0	2.0	2.0	2.0	4.5
	Evaporative Zone Depth (inch)	12	12	12	12	12
TOPSOIL	Thickness (in)					12
LAYER	Porosity (vol/vol)					0.3980
(Texture = 10)	Field Capacity (vol/vol)					0.2440
	Wilting Point (vol/vol)					0.1360
	Init. Moisture Content (vol/vol)					0.2440
	Hyd. Conductivity (cm/s)					1.2E-04
GEOCOMPIOSITE	Thickness (in)					0.250
DRAINAGE	Porosity (vol/vol)					0.8500
LAYER	Field Capacity (vol/vol)					0.0100
(Texture = 0)	Wilting Point (vol/vol)					0.0050
	Init. Moisture Content (vol/vol)					0.0100
	Hyd. Conductivity (cm/s)					6.63
	Slope (%)					5.0
	Slope Length (ft)					350
FLEXIBLE	Thickness (in)					0.04
MEMBRANE	Hyd. Conductivity (cm/s)					4.0E-13
LINER	Pinhole Density (holes/acre)					1
(Texture = 36)	Install. Defects (holes/acre)					4
	Placement Quality					GOOD
COMPACTED	Thickness (in)					18.00
CLAY LINER	Porosity (vol/vol)					0.4270
(Texture = 0)	Field Capacity (vol/vol)					0.4180
	Wilting Point (vol/vol)					0.3670
	Init. Moisture Content (vol/vol)					0.4270
	Hyd. Conductivity (cm/s)					1.0E-05
INTERMEDIATE	Thickness (in)		12	12	12	12
COVER	Porosity (vol/vol)		0.3980	0.3980	0.3980	0.3980
(Texture = 10)	Field Capacity (vol/vol)		0.2440	0.2440	0.2440	0.2440
	Wilting Point (vol/vol)		0.1360	0.1360	0.1360	0.1360
	Init. Moisture Content (vol/vol)		0.2440	0.2440	0.2440	0.2440
	Hyd. Conductivity (cm/s)		1.2E-04	1.2E-04	1.2E-04	1.2E-04
WASTE TOP[2]	Thickness (in)	120	600	1200	1200	1200
(Texture = 0)	Porosity (vol/vol)	0.6649	0.6483	0.6277	0.6277	0.6277
	Field Capacity (vol/vol)	0.5262	0.5215	0.5156	0.5156	0.5156
	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
	Init. Moisture Content (vol/vol)	0.2500	0.2500	0.3000	0.3000	0.3000
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
WASTE BOTTOM[2]	Thickness (in)				360	360
(Texture = 0)	Porosity (vol/vol)				0.5740	0.5740
	Field Capacity (vol/vol)				0.5004	0.5004
	Wilting Point (vol/vol)				0.0770	0.0770
	Init. Moisture Content (vol/vol)				0.3000	0.3000
	Hyd. Conductivity (cm/s)				1.0E-04	1.0E-04
PROTECTIVE	Thickness (in)	24	24	24	24	24
COVER	Porosity (vol/vol)	0.3980	0.3980	0.3980	0.3980	0.3980
(Texture = 10)	Field Capacity (vol/vol)	0.2440	0.2440	0.2440	0.2440	0.2440
	Wilting Point (vol/vol)	0.1360	0.1360	0.1360	0.1360	0.1360
	Init. Moisture Content (vol/vol)	0.2440	0.2440	0.2440	0.2440	0.2440
	Hyd. Conductivity (cm/s)	1.2E-04	1.2E-04	1.2E-04	1.2E-04	1.2E-04
LEACHATE	Thickness (in)	0.199	0.190	0.179	0.172	0.171
COLLECTION	Porosity (vol/vol)	0.8500	0.8500	0.8500	0.8500	0.8500
LAYER	Field Capacity (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
(Texture = 0)	Wilting Point (vol/vol)	0.0050	0.0050	0.0050	0.0050	0.0050
	Init. Moisture Content (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
	Hyd. Conductivity (cm/s)	0.90	0.53	0.33	0.19	0.19
	Slope (%)	2.2	2.2	2.2	2.2	2.2
	Slope Length (ft)	275	275	275	275	275
FLEXIBLE	Thickness (in)	0.06	0.06	0.06	0.06	0.06
MEMBRANE	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
LINER	Pinhole Density (holes/acre)	0	0	0	0	0
(Texture = 35)	Install. Defects (holes/acre)	0	0	0	0	0
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
COMPACTED	Thickness (in)	24	24	24	24	24
CLAY LINER	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
(Texture = 16)	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	26.32	20.14	20.14	20.14	17.93
RUNOFF	Average Annual (in)	0.00	0.59	0.67	0.76	0.23
EVAPOTRANSPIRATION	Average Annual (in)	24.73	17.82	17.79	17.83	16.47
LATERAL	Average Annual (cf/year)	0.0	0.0	1,287.5	2,322.0	493.5
DRAINAGE COLLECTED[1]	Peak Daily (cf/day)	0.0	0.0	25.8	21.7	21.6
LATERAL	Average Annual (cf/year)		0.0	128.7	232.2	
DRAINAGE RECIRCULATED	Peak Daily (cf/day)		0.0	2.6	2.2	
HEAD ON LINER	Average Annual (in)	0.00	0.00	0.006	0.020	0.004
	Peak Daily (in)	0.035	0.036	0.094	0.137	0.137

[1] Drainage collected includes actual leachate pumped by the leachate pumps (i.e., the total of the collected and recirculated leachate).

[2] The field capacity and porosity values for the waste layer were obtained from: Zornberg, Jorge G. et. al, *Retention of Free Liquids in Landfills Undergoing Vertical Expansion.* Journal of Geotechnical and Geoenvironmental Engineering, July 1999, pp. 583-594.

HELP MODEL OUTPUT
(SECTORS 1 THROUGH 18)

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


PRECIPITATION DATA FILE:    C:\MEADOW\A10\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\A10\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\A10\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\A10\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\A10\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\A10\OUTDATA.OUT


TIME:  32:44     DATE:   2/22/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-ACTIVE 10 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =    120.00   INCHES
           POROSITY                   =      0.6649 VOL/VOL
           FIELD CAPACITY             =      0.5262 VOL/VOL
           WILTING POINT              =      0.0770 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2500 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
```

```
                        LAYER  2
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  10
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.3980 VOL/VOL
FIELD CAPACITY              =      0.2440 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC


                        LAYER  3
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.899999976000     CM/SEC
SLOPE                       =      2.20   PERCENT
DRAINAGE LENGTH             =    275.0    FEET


                        LAYER  4
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  5
```

```
              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.4270 VOL/VOL
FIELD CAPACITY             =      0.4180 VOL/VOL
WILTING POINT              =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

```
NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     79.70
FRACTION OF AREA ALLOWING RUNOFF    =      0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.000  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      7.979  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.924  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     46.106  INCHES
TOTAL INITIAL WATER                 =     46.106  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

```
NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         MIDLAND               TEXAS

     STATION LATITUDE                        =  32.00 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   0.00
     START OF GROWING SEASON (JULIAN DATE)   =     67
     END OF GROWING SEASON (JULIAN DATE)     =    317
     EVAPORATIVE ZONE DEPTH                  =  12.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =  11.10 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  52.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  50.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  55.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  58.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 25 THROUGH 25

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.58	0.53	1.16	2.07	3.93	4.76
	5.38	3.78	1.20	0.52	0.22	2.19
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

```
  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

 EVAPOTRANSPIRATION
 ------------------
  TOTALS                 1.492    0.544    1.577    0.840    3.738    4.290
                         5.111    4.019    1.055    0.468    0.352    1.247

  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

 LATERAL DRAINAGE COLLECTED FROM LAYER  3
 ----------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER  5
 ------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
  AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   25 THROUGH   25
-------------------------------------------------------------------------------
                                    INCHES            CU. FEET       PERCENT
                              -------------------   -------------   ---------
 PRECIPITATION                  26.32    (   0.000)      95541.6     100.00

 RUNOFF                          0.000   (  0.0000)          0.00      0.000
```

```
 EVAPOTRANSPIRATION             24.733   (  0.0000)      89779.02     93.969

 LATERAL DRAINAGE COLLECTED      0.00000 (  0.00000)         0.001    0.00000
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.000     0.00000
   LAYER  5

 AVERAGE HEAD ON TOP             0.000 (    0.000)
   OF LAYER  4

 CHANGE IN WATER STORAGE         1.587   (  0.0000)       5762.60      6.032

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



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

               PEAK DAILY VALUES FOR YEARS   25 THROUGH   25
   ------------------------------------------------------------------------
                                            (INCHES)      (CU. FT.)
                                           ----------   -------------
      PRECIPITATION                          1.67          6062.100

      RUNOFF                                 0.000            0.0000

      DRAINAGE COLLECTED FROM LAYER  3       0.00000          0.00028

      PERCOLATION/LEAKAGE THROUGH LAYER  5   0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER  4        0.000

      MAXIMUM HEAD ON TOP OF LAYER  4        0.035

      LOCATION OF MAXIMUM HEAD IN LAYER  3
            (DISTANCE FROM DRAIN)            0.0 FEET

      SNOW WATER                             0.94          3421.4011


      MAXIMUM VEG. SOIL WATER (VOL/VOL)              0.3369

      MINIMUM VEG. SOIL WATER (VOL/VOL)              0.1086

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

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

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FINAL WATER STORAGE AT END OF YEAR 25

LAYER	(INCHES)	(VOL/VOL)
1	31.5874	0.2632
2	5.8560	0.2440
3	0.0020	0.0100
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

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****

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


PRECIPITATION DATA FILE:    C:\MEADOW\I50\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\I50\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\I50\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\I50\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\I50\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\I50\OUTDATA.OUT


TIME:  32:20     DATE:   2/22/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 50 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3980 VOL/VOL
           FIELD CAPACITY             =      0.2440 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
```

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



                          LAYER  2
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =    600.00   INCHES
  POROSITY                   =      0.6483 VOL/VOL
  FIELD CAPACITY             =      0.5215 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
         IS RECIRCULATED INTO THIS LAYER.



                          LAYER  3
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  10
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.3980 VOL/VOL
  FIELD CAPACITY             =      0.2440 VOL/VOL
  WILTING POINT              =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC



                          LAYER  4
                          --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.19   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.529999971000     CM/SEC
  SLOPE                      =      2.20   PERCENT
  DRAINAGE LENGTH            =    275.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.
```

LAYER 5

TYPE 4 - FLEXIBLE MEMBRANE LINER
MATERIAL TEXTURE NUMBER 35

THICKNESS	=	0.06	INCHES
POROSITY	=	0.0000	VOL/VOL
FIELD CAPACITY	=	0.0000	VOL/VOL
WILTING POINT	=	0.0000	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0000	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.199999996000E-12	CM/SEC
FML PINHOLE DENSITY	=	0.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	0.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	3 - GOOD	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16

THICKNESS	=	24.00	INCHES
POROSITY	=	0.4270	VOL/VOL
FIELD CAPACITY	=	0.4180	VOL/VOL
WILTING POINT	=	0.3670	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4270	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000001000E-06	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A FAIR STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 350. FEET.

SCS RUNOFF CURVE NUMBER	=	85.60	
FRACTION OF AREA ALLOWING RUNOFF	=	70.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.928	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.776	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.632	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	169.034	INCHES
TOTAL INITIAL WATER	=	169.034	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.008	0.002	0.029	0.183
	0.233	0.014	0.093	0.031	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.016	0.006	0.037	0.363
	0.414	0.033	0.144	0.081	0.000	0.005
EVAPOTRANSPIRATION						
TOTALS	0.753	0.796	1.013	1.471	2.383	2.139
	2.377	1.387	2.843	1.132	0.927	0.593
STD. DEVIATIONS	0.403	0.431	0.625	1.062	0.886	1.344
	1.443	0.845	0.932	0.897	0.518	0.291
LATERAL DRAINAGE RECIRCULATED INTO LAYER 2						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE RECIRCULATED FROM LAYER 4						
TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2 THROUGH 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.14 (3.835)	73111.8	100.00
RUNOFF	0.594 (0.4671)	2155.85	2.949
EVAPOTRANSPIRATION	17.815 (2.7085)	64667.97	88.451
DRAINAGE RECIRCULATED INTO LAYER 2	0.00000 (0.00000)	0.000	0.00000
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.00000 (0.00000)	0.000	0.00000
DRAINAGE RECIRCULATED FROM LAYER 4	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.000 (0.000)		
CHANGE IN WATER STORAGE	1.732 (1.2331)	6288.01	8.601

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PEAK DAILY VALUES FOR YEARS 2 THROUGH 11

	(INCHES)	(CU. FT.)
PRECIPITATION	4.19	15209.700
RUNOFF	1.031	3741.9133
DRAINAGE RECIRCULATED INTO LAYER 2	0.00000	0.00002
DRAINAGE COLLECTED FROM LAYER 4	0.00000	0.00015
DRAINAGE RECIRCULATED FROM LAYER 4	0.00000	0.00002
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.000	
MAXIMUM HEAD ON TOP OF LAYER 5	0.036	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.46	1655.6732

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3905

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1360

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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8478	0.1540
2	168.4025	0.2807
3	5.8560	0.2440
4	0.0019	0.0100
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\MEADOW\I100\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\I100\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\I100\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\I100\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\I100\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\I100\OUTDATA.OUT


TIME:  32:34     DATE:   2/22/2024


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     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 100 FT

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                    LAYER  1
                                    --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3980 VOL/VOL
           FIELD CAPACITY             =      0.2440 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
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NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.



                          LAYER  2
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =   1200.00   INCHES
  POROSITY                   =      0.6277 VOL/VOL
  FIELD CAPACITY             =      0.5156 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
         IS RECIRCULATED INTO THIS LAYER.



                          LAYER  3
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER  10
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.3980 VOL/VOL
  FIELD CAPACITY             =      0.2440 VOL/VOL
  WILTING POINT              =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC



                          LAYER  4
                          --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.18   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.330000013000     CM/SEC
  SLOPE                      =      2.20   PERCENT
  DRAINAGE LENGTH            =    275.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.
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                     LAYER  5
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               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER  35
   THICKNESS                  =      0.06   INCHES
   POROSITY                   =      0.0000 VOL/VOL
   FIELD CAPACITY             =      0.0000 VOL/VOL
   WILTING POINT              =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
   FML INSTALLATION DEFECTS   =      0.00   HOLES/ACRE
   FML PLACEMENT QUALITY      =  3 - GOOD


                     LAYER  6
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                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  16
   THICKNESS                  =     24.00   INCHES
   POROSITY                   =      0.4270 VOL/VOL
   FIELD CAPACITY             =      0.4180 VOL/VOL
   WILTING POINT              =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF  2.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER            =     85.60
FRACTION OF AREA ALLOWING RUNOFF   =     80.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH             =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.928  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.776  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.632  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    379.034  INCHES
TOTAL INITIAL WATER                =    379.034  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.009	0.002	0.033	0.209
	0.262	0.016	0.106	0.035	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.018	0.005	0.042	0.415
	0.464	0.037	0.164	0.093	0.000	0.006
EVAPOTRANSPIRATION						
TOTALS	0.725	0.766	0.977	1.508	2.394	2.139
	2.382	1.387	2.842	1.148	0.923	0.598
STD. DEVIATIONS	0.339	0.450	0.637	1.080	0.884	1.341
	1.428	0.839	0.932	0.903	0.526	0.298
LATERAL DRAINAGE RECIRCULATED INTO LAYER 2						
TOTALS	0.0030	0.0017	0.0027	0.0041	0.0029	0.0016
	0.0018	0.0034	0.0032	0.0033	0.0035	0.0043
STD. DEVIATIONS	0.0063	0.0044	0.0056	0.0066	0.0053	0.0050
	0.0048	0.0058	0.0060	0.0069	0.0064	0.0070
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0269	0.0153	0.0246	0.0370	0.0263	0.0145
	0.0158	0.0304	0.0288	0.0294	0.0315	0.0387
STD. DEVIATIONS	0.0568	0.0394	0.0506	0.0598	0.0479	0.0453
	0.0433	0.0526	0.0543	0.0618	0.0576	0.0628
LATERAL DRAINAGE RECIRCULATED FROM LAYER 4						
TOTALS	0.0030	0.0017	0.0027	0.0041	0.0029	0.0016
	0.0018	0.0034	0.0032	0.0033	0.0035	0.0043
STD. DEVIATIONS	0.0063	0.0044	0.0056	0.0066	0.0053	0.0050
	0.0048	0.0058	0.0060	0.0069	0.0064	0.0070

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0065	0.0041	0.0059	0.0092	0.0063	0.0036
	0.0038	0.0073	0.0071	0.0070	0.0078	0.0093
STD. DEVIATIONS	0.0136	0.0104	0.0121	0.0148	0.0115	0.0112
	0.0104	0.0126	0.0134	0.0148	0.0143	0.0151

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2 THROUGH 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.14 (3.835)	73111.8	100.00
RUNOFF	0.674 (0.5289)	2446.81	3.347
EVAPOTRANSPIRATION	17.789 (2.7837)	64572.93	88.321
DRAINAGE RECIRCULATED INTO LAYER 2	0.03547 (0.05961)	128.746	0.17610
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.31921 (0.53646)	1158.717	1.58486
DRAINAGE RECIRCULATED FROM LAYER 4	0.03547 (0.05961)	128.746	0.17610
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.003	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.006 (0.011)		
CHANGE IN WATER STORAGE	1.359 (1.3160)	4933.20	6.747

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PEAK DAILY VALUES FOR YEARS 2 THROUGH 11

	(INCHES)	(CU. FT.)
PRECIPITATION	4.19	15209.700
RUNOFF	1.178	4275.9409
DRAINAGE RECIRCULATED INTO LAYER 2	0.00071	2.57902
DRAINAGE COLLECTED FROM LAYER 4	0.00639	23.21121
DRAINAGE RECIRCULATED FROM LAYER 4	0.00071	2.57902
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.047	
MAXIMUM HEAD ON TOP OF LAYER 5	0.094	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	1.4 FEET	
SNOW WATER	0.46	1655.6732

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3832

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1360

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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8483	0.1540
2	374.5284	0.3121
3	5.9709	0.2488
4	0.0282	0.1578
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\MEADOW\I130\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\I130\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\I130\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\I130\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\I130\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\I130\OUTDATA.OUT


TIME:  13:59     DATE:   2/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 130 FT

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3980 VOL/VOL
           FIELD CAPACITY             =      0.2440 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
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NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  3.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =   1200.00   INCHES
  POROSITY                   =      0.6277 VOL/VOL
  FIELD CAPACITY             =      0.5156 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 5
         IS RECIRCULATED INTO THIS LAYER.


                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =    360.00   INCHES
  POROSITY                   =      0.5740 VOL/VOL
  FIELD CAPACITY             =      0.5004 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC


                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.3980 VOL/VOL
  FIELD CAPACITY             =      0.2440 VOL/VOL
  WILTING POINT              =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                          LAYER  5
                          --------
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              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.17   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.189999998000     CM/SEC
  SLOPE                      =      2.20   PERCENT
  DRAINAGE LENGTH            =    275.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
        LAYER IS RECIRCULATED INTO LAYER #  2.


                        LAYER  6
                        --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
  THICKNESS                  =      0.06   INCHES
  POROSITY                   =      0.0000 VOL/VOL
  FIELD CAPACITY             =      0.0000 VOL/VOL
  WILTING POINT              =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
  FML INSTALLATION DEFECTS   =      0.00   HOLES/ACRE
  FML PLACEMENT QUALITY      =  3 - GOOD


                        LAYER  7
                        --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  16
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.4270 VOL/VOL
  FIELD CAPACITY             =      0.4180 VOL/VOL
  WILTING POINT              =      0.3670 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 350. FEET.

SCS RUNOFF CURVE NUMBER	=	85.60	
FRACTION OF AREA ALLOWING RUNOFF	=	90.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.928	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.776	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.632	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	487.034	INCHES
TOTAL INITIAL WATER	=	487.034	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.010	0.003	0.037	0.235
	0.293	0.018	0.119	0.040	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.020	0.007	0.047	0.466
	0.519	0.042	0.184	0.105	0.000	0.007
EVAPOTRANSPIRATION						
TOTALS	0.755	0.794	1.021	1.473	2.393	2.136
	2.367	1.392	2.842	1.134	0.927	0.594
STD. DEVIATIONS	0.403	0.431	0.618	1.055	0.897	1.337
	1.424	0.843	0.931	0.897	0.521	0.290
LATERAL DRAINAGE RECIRCULATED INTO LAYER 2						
TOTALS	0.0046	0.0049	0.0057	0.0062	0.0057	0.0053
	0.0046	0.0057	0.0053	0.0054	0.0052	0.0055
STD. DEVIATIONS	0.0065	0.0063	0.0071	0.0068	0.0072	0.0069
	0.0065	0.0065	0.0067	0.0070	0.0067	0.0071

```
  LATERAL DRAINAGE COLLECTED FROM LAYER  5
  ----------------------------------------
    TOTALS                 0.0416   0.0438   0.0510   0.0554   0.0514   0.0476
                           0.0414   0.0515   0.0473   0.0487   0.0468   0.0492

    STD. DEVIATIONS        0.0585   0.0569   0.0642   0.0612   0.0646   0.0617
                           0.0588   0.0589   0.0605   0.0629   0.0606   0.0637

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  5
  -------------------------------------------
    TOTALS                 0.0046   0.0049   0.0057   0.0062   0.0057   0.0053
                           0.0046   0.0057   0.0053   0.0054   0.0052   0.0055

    STD. DEVIATIONS        0.0065   0.0063   0.0071   0.0068   0.0072   0.0069
                           0.0065   0.0065   0.0067   0.0070   0.0067   0.0071

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES               0.0173   0.0200   0.0212   0.0238   0.0214   0.0205
                           0.0172   0.0214   0.0203   0.0202   0.0201   0.0205

    STD. DEVIATIONS        0.0244   0.0260   0.0267   0.0263   0.0269   0.0265
                           0.0245   0.0245   0.0260   0.0262   0.0260   0.0265

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


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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    2 THROUGH   11
-------------------------------------------------------------------------------
                                        INCHES           CU. FEET      PERCENT
                                   -------------------  -------------  ---------
 PRECIPITATION                       20.14    (   3.835)     73111.8    100.00

 RUNOFF                               0.757   (  0.5939)      2746.79     3.757

 EVAPOTRANSPIRATION                  17.828   (  2.7124)     64716.08    88.517

 DRAINAGE RECIRCULATED                0.06397 (  0.07328)      232.202   0.31760
```

```
   INTO LAYER  2

 LATERAL DRAINAGE COLLECTED      0.57571 (  0.65952)      2089.818    2.85838
   FROM LAYER  5

 DRAINAGE RECIRCULATED           0.06397 (  0.07328)       232.202    0.31760
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.005     0.00001
   LAYER  7

 AVERAGE HEAD ON TOP             0.020 (    0.023)
   OF LAYER  6

 CHANGE IN WATER STORAGE         0.980   (  1.2157)       3559.16      4.868

*******************************************************************************
```

```
******************************************************************************

             PEAK DAILY VALUES FOR YEARS    2 THROUGH   11
   ------------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                             4.19         15209.700

      RUNOFF                                    1.325         4810.4126

      DRAINAGE RECIRCULATED INTO LAYER  2       0.00060          2.16139

      DRAINAGE COLLECTED FROM LAYER  5          0.00536         19.45247

      DRAINAGE RECIRCULATED FROM LAYER  5       0.00060          2.16139

      PERCOLATION/LEAKAGE THROUGH LAYER  7      0.000000         0.00003

      AVERAGE HEAD ON TOP OF LAYER  6           0.069

      MAXIMUM HEAD ON TOP OF LAYER  6           0.137

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)               2.7 FEET

      SNOW WATER                                0.46          1655.6732


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.3724

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1360


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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8479	0.1540
2	374.5248	0.3121
3	104.2426	0.2896
4	5.9328	0.2472
5	0.0424	0.2466
6	0.0000	0.0000
7	10.2480	0.4270
SNOW WATER	0.000	

****
****

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


PRECIPITATION DATA FILE:    C:\MEADOW\CL130\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\CL130\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\CL130\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\CL130\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\CL130\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\CL130\OUTDATA.OUT


TIME:  14: 2     DATE:   2/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-CLOSED 130 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                   =     12.00   INCHES
           POROSITY                    =      0.3980 VOL/VOL
           FIELD CAPACITY              =      0.2440 VOL/VOL
           WILTING POINT               =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
```

```
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.25   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =   6.63000011000     CM/SEC
  SLOPE                      =      5.00   PERCENT
  DRAINAGE LENGTH            =    350.0    FEET


                          LAYER  3
                          --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  36
  THICKNESS                  =      0.04   INCHES
  POROSITY                   =      0.0000 VOL/VOL
  FIELD CAPACITY             =      0.0000 VOL/VOL
  WILTING POINT              =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.399999993000E-12 CM/SEC
  FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
  FML INSTALLATION DEFECTS    =      4.00   HOLES/ACRE
  FML PLACEMENT QUALITY       =  3 - GOOD


                          LAYER  4
                          --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =     18.00   INCHES
  POROSITY                   =      0.4270 VOL/VOL
  FIELD CAPACITY             =      0.4180 VOL/VOL
  WILTING POINT              =      0.3670 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-05 CM/SEC
```

```
                        LAYER  5
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                      =     12.00   INCHES
POROSITY                       =      0.3980 VOL/VOL
FIELD CAPACITY                 =      0.2440 VOL/VOL
WILTING POINT                  =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.119999997000E-03 CM/SEC


                        LAYER  6
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =   1200.00   INCHES
POROSITY                       =      0.6277 VOL/VOL
FIELD CAPACITY                 =      0.5156 VOL/VOL
WILTING POINT                  =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.100000005000E-02 CM/SEC


                        LAYER  7
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =    360.00   INCHES
POROSITY                       =      0.5740 VOL/VOL
FIELD CAPACITY                 =      0.5004 VOL/VOL
WILTING POINT                  =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.999999975000E-04 CM/SEC


                        LAYER  8
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                      =     24.00   INCHES
POROSITY                       =      0.3980 VOL/VOL
FIELD CAPACITY                 =      0.2440 VOL/VOL
WILTING POINT                  =      0.1360 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC



                        LAYER  9
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.17   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.189999998000     CM/SEC
SLOPE                       =      2.20   PERCENT
DRAINAGE LENGTH             =    275.0    FEET



                        LAYER 10
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD



                        LAYER 11
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 350. FEET.

SCS RUNOFF CURVE NUMBER	=	80.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.928	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.776	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.632	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	497.650	INCHES
TOTAL INITIAL WATER	=	497.650	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM MIDLAND TEXAS

STATION LATITUDE	=	32.00	DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50	
START OF GROWING SEASON (JULIAN DATE)	=	67	
END OF GROWING SEASON (JULIAN DATE)	=	317	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.69	0.55	1.29	1.32	1.96	2.54
	2.67	1.56	2.49	1.40	0.90	0.57
STD. DEVIATIONS	0.64	0.33	1.02	0.82	1.05	2.04
	1.97	1.09	1.58	1.26	0.60	0.60
RUNOFF						
TOTALS	0.000	0.000	0.001	0.000	0.003	0.080
	0.108	0.002	0.024	0.010	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.004	0.000	0.008	0.205
	0.271	0.006	0.066	0.039	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.638	0.543	0.946	1.790	1.914	2.164
	2.281	1.514	2.192	0.984	0.849	0.650
STD. DEVIATIONS	0.403	0.375	0.719	0.900	1.044	1.514
	1.449	1.012	1.307	0.720	0.464	0.421

LATERAL DRAINAGE COLLECTED FROM LAYER 2

```
    TOTALS                 0.0356   0.0084   0.0811   0.0416   0.0118   0.2721
                           0.3466   0.0211   0.1873   0.2096   0.0307   0.0293

    STD. DEVIATIONS        0.1049   0.0324   0.2176   0.1034   0.0387   0.6090
                           0.6202   0.0972   0.4689   0.6370   0.0726   0.1175

  PERCOLATION/LEAKAGE THROUGH LAYER  4
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0001
                           0.0001   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER  9
  ----------------------------------------
    TOTALS                 0.0111   0.0121   0.0141   0.0138   0.0143   0.0134
                           0.0100   0.0098   0.0094   0.0094   0.0089   0.0095

    STD. DEVIATIONS        0.0368   0.0373   0.0432   0.0423   0.0436   0.0412
                           0.0367   0.0373   0.0359   0.0359   0.0339   0.0363

  PERCOLATION/LEAKAGE THROUGH LAYER 11
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  3
  -------------------------------------
    AVERAGES               0.0002   0.0001   0.0008   0.0003   0.0001   0.0087
                           0.0202   0.0002   0.0027   0.0034   0.0002   0.0002

    STD. DEVIATIONS        0.0006   0.0002   0.0027   0.0006   0.0002   0.0233
                           0.0558   0.0012   0.0076   0.0116   0.0005   0.0007

  DAILY AVERAGE HEAD ON TOP OF LAYER 10
  -------------------------------------
    AVERAGES               0.0042   0.0050   0.0053   0.0053   0.0053   0.0052
                           0.0037   0.0037   0.0036   0.0035   0.0034   0.0036

    STD. DEVIATIONS        0.0138   0.0155   0.0162   0.0164   0.0163   0.0159
                           0.0137   0.0140   0.0139   0.0135   0.0131   0.0136

*******************************************************************************
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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES		CU. FEET	PERCENT
PRECIPITATION	17.93	(4.448)	65096.8	100.00
RUNOFF	0.227	(0.3408)	822.80	1.264
EVAPOTRANSPIRATION	16.465	(3.7223)	59766.44	91.812
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1.27516	(1.06066)	4628.840	7.11070
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00009	(0.00014)	0.325	0.00050
AVERAGE HEAD ON TOP OF LAYER 3	0.003	(0.005)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.13595	(0.43532)	493.483	0.75808
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000	(0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.004	(0.014)		
CHANGE IN WATER STORAGE	-0.169	(0.8768)	-614.78	-0.944

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	4.67	16952.100
RUNOFF	1.192	4326.7114
DRAINAGE COLLECTED FROM LAYER 2	1.33907	4860.82568
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000438	1.59150
AVERAGE HEAD ON TOP OF LAYER 3	6.402	
MAXIMUM HEAD ON TOP OF LAYER 3	11.221	

```
LOCATION OF MAXIMUM HEAD IN LAYER  2
      (DISTANCE FROM DRAIN)              42.6 FEET

DRAINAGE COLLECTED FROM LAYER  9          0.00595         21.61386

PERCOLATION/LEAKAGE THROUGH LAYER 11      0.000000         0.00003

AVERAGE HEAD ON TOP OF LAYER 10           0.069

MAXIMUM HEAD ON TOP OF LAYER 10           0.137

LOCATION OF MAXIMUM HEAD IN LAYER  9
      (DISTANCE FROM DRAIN)               2.7 FEET

SNOW WATER                                0.94          3421.4011


MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.3762

MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1360

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

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

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




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

              FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
```

LAYER	(INCHES)	(VOL/VOL)
1	1.9229	0.1602
2	0.0025	0.0100
3	0.0000	0.0000
4	7.6860	0.4270
5	2.8960	0.2413
6	360.0346	0.3000

7	103.9216	0.2887
8	5.8560	0.2440
9	0.0017	0.0100
10	0.0000	0.0000
11	10.2480	0.4270
SNOW WATER	0.000	

****
****

APPENDIX IIIC-A.1

SUMMARY OF LEACHATE GENERATION MODEL FOR SIDESLOPES

Includes pages IIIC-A.1-1 through IIIC-A.1-49

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER

08/05/2024

INTRODUCTION

This appendix contains the analysis of the sideslope geocomposite. This appendix includes the following:

- Sheets IIIC-A.1-2 through IIIC-A.1-7. Double-sided geocomposite calculations, required properties, and HELP model summary sheet.

As shown in the following HELP model summary sheets, the geocomposite incorporated into the LCS design is adequate (i.e., the calculated head on the liner is within the compressed thickness of the LCS geocomposite).

Required: Determine the minimum requirements of the 200-mil geocomposite leachate collection layer for Sectors 1 through 18 sideslopes.

Method:

1. Determine the 200-mil geocomposite leachate collection layer thickness under the expected loading conditions.
2. Use HELP model to determine the minimum required hydraulic conductivity of the 200-mil geocomposite leachate collection layer at the expected loading conditions.
3. Determine factors of safety for strength and environmental conditions based on the expected duration of each stage of landfill development.
4. Compute the design transmissivity of the 200-mil geocomposite leachate collection layer for each stage of landfill development using the calculated thicknesses, the hydraulic conductivity, and the reduction factors.
5. Specify the geocomposite properties for the leachate collection layer.

References:

1. Koerner, R.M., Designing With Geosynthetics, Third Edition, 1994.
2. Gray, Donald H., Koerner, Robert M., Qian, Xuede, Geotechnical Aspects of Landfill Design and Construction, 2002.
3. Geosynthetic Institute, GRI Standard GC-8, 2001.
4. GSE Drainage Design Manual, Second Edition, June 2007.
5. Acar, Yalcin B.& Daniel, David E., *Geoenvironment 2000 Characterization, Containment, Remediation, and Performance in Environmental Geotechnics,* Volume 2, American Society of Civil Engineers, 1995.

Solution:

1. Determine the 200-mil geocomposite leachate collection layer thickness under the expected loading conditions.

Assume the geocomposite leachate collection layer will undergo compression due to the weight of soil (in the form of intermediate cover, protective cover, or final cover) and waste.

Unloaded Geocomposite Thickness (200 mil) =	0.20	in
Unit Weight of Soil =	108	pcf

Table 1 - Geocomposite Thickness for Subtitle D Areas

Fill Condition	d_W[1] (ft)	d_S[2] (ft)	γ[3] (pcf)	P[4] (psf)	t[5] (in)	t[5] (cm)
Active - 10'	10	2	51	726	0.199	0.504
Interim - 50'	50	3	51	2,874	0.190	0.484
Interim - 100'	100	3	57	6,024	0.179	0.454
Interim - 130'	130	3	61	8,254	0.172	0.437
Closed - 130'	130	5.5	61	8,524	0.171	0.435

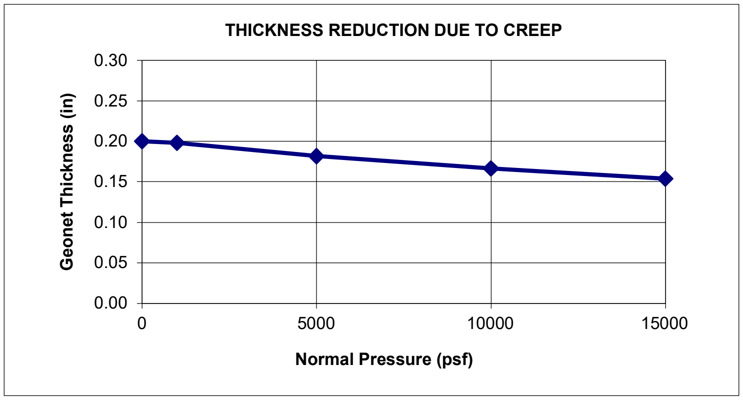
[1] d_W is the depth of waste and daily cover soil above the geocomposite leachate collection layer.

[2] d_S is the depth of soil (protective cover, intermediate cover, and final cover) above the geocomposite leachate collection layer.

[3] The unit weight of waste/soil is selected at the midpoint of the waste column thickness using the Unit Weight Profile for MSW graph provided in Ref 5.

[4] P is the pressure on the geocomposite leachate collection layer due to the weight of the waste and soil.

[5] t is the thickness of the geocomposite leachate collection layer after being subjected to compression based on the chart below adapted from Reference 4.



2. Use HELP model to determine the minimum required hydraulic conductivity of the 200-mil geocomposite leachate collection layer at the expected loading conditions. HELP model results are shown on Sheet IIIC-A.1-7

3. Determine factors of safety for strength and environmental conditions based on the expected duration of each stage of landfill development.

Table 2 - Reduction Factors and Factor of Safety

Reduction Factors[1]		Fill Condition				
		Active (10' Waste)	Interim (50' Waste)	Interim (100' Waste)	Interim (130' Waste)	Closed
RF_{IN}	Delayed Intrusion	1.1	1.1	1.1	1.1	1.1
RF_{CC}	Chemical Clogging	1.0	1.3	1.5	1.9	2.0
RF_{BC}	Biological Clogging	1.0	1.1	1.2	1.2	1.3
Total Reduction Factor[2]		1.10	1.57	1.98	2.51	2.86

Overall Factor of Safety to Account For Uncertainties	2.0	2.0	2.0	2.0	2.0
Overall Reduction Factor (ORF)[3]	2.20	3.15	3.96	5.02	5.72

[1] Values are obtained from References 1, 2, and 3.

[2] The Total Reduction Factors are a product of all the reduction factors for each fill condition.

[3] The Overall Reduction Factors are a product of the Total Reduction Factor and Overall Factor of Safety to Account For Uncertainties for each fill condition.

4. Compute the design transmissivity of the 200-mil geocomposite leachate collection layer for each stage of landfill development using the calculated thicknesses, the hydraulic conductivity, and the reduction factors.

Table 3 - Required Transmissivity for Subtitle D Areas

Fill Condition	d_W[1] (ft)	P[2] (psf)	t[3] (cm)	k[4] (cm/s)	T_{DES}[5] (m^2/s)	ORF[6]	T[7] (m^2/s)
Active - 10'	10	726	0.504	0.14	7.12E-06	2.20	1.57E-05
Interim - 50'	50	2,874	0.484	0.07	3.55E-06	3.15	1.12E-05
Interim - 100'	100	6,024	0.454	0.04	1.83E-06	3.96	7.27E-06
Interim - 130'	130	8,254	0.437	0.03	1.17E-06	5.02	5.89E-06
Closed - 130'	130	8,524	0.435	0.02	1.00E-06	5.72	5.74E-06

[1] d_W is the depth of waste above the geocomposite leachate collection layer.

[2] P is the pressure on the geocomposite leachate collection layer due to the weight of the waste and soil from Table 1.

[3] t is the calculated geocomposite leachate collection layer thickness from Table 1.

[4] k is obtained the HELP model design as shown on Sheet IIIC-A.1-7.

[5] T_{DES} is the design transmissivity value calculated using the following equation:

$$T_{DES} = (k * t)/100^2$$

[6] ORF is the Overall Reduction Factor obtained from Table 2.

[7] T is the design transmissivity value calculated using the following equation:

$$T = T_{DES} * ORF$$

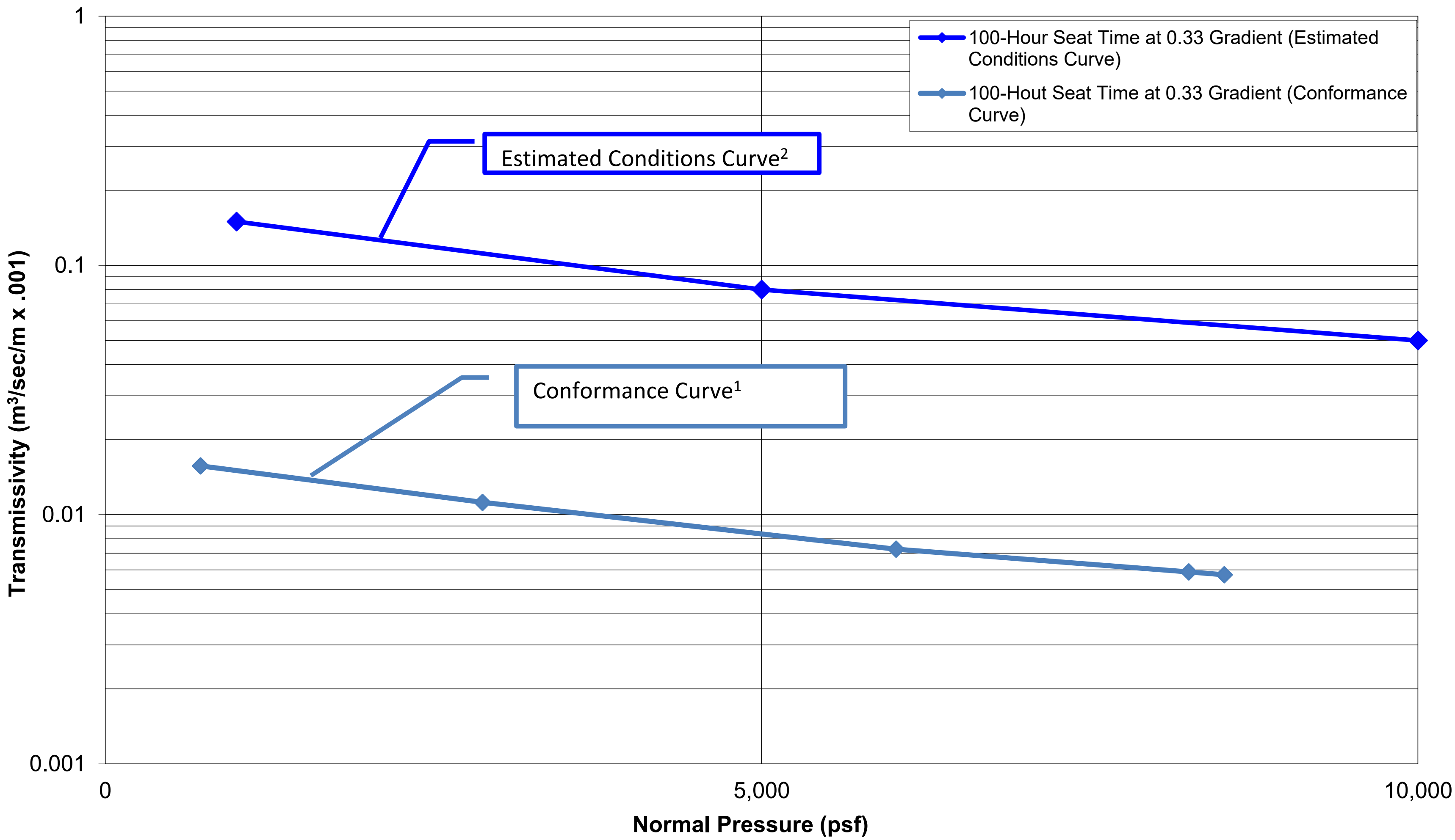
5. Specify Drainage Geocomposite Properties for the Leachate Collection Layer

As shown on the HELP model summary sheets, a geocomposite with characteristics similar to the conformance curve on the graph shown on Sheet IIIC-A.1-6 will provide a drainage layer that will maintain less than twelve inches of head on the liner system. The estimated conditions curve was developed based on engineering judgement and experience with similar geocomposite products at numerous MSW sites in Texas and is provided to verify the selected drainage geocomposite transmissivity provides greater conveyance than the specified transmissivity in these calculations.
The drainage geocomposite required transmissivity values will be measured at a gradient of 0.33 under normal pressures of 1,000, 10,000 and 8,524 psf (or higher), boundary conditions consisting of soil/geocomposite/geomembrane with minimum seat time of 100 hours and will be run for the first 100,000 square feet of liner construction. For each additional 100,000 square feet of single-sided geocomposite placement area, one additional transmissivity test will be run under the maximum normal stress (i.e., 8,524 psf) with all the same assumptions as the first three tests.

Refer to the conformance curve plotted on Sheet IIIC-A.1-6 for the minimum transmissivity requirements.

Note:
Reference to "geocomposite thickness" within these calculations refers to thickness of geonet, not the overall thickness of geocomposite. Actual manufacturer's specified thickness for a geocomposite incorporating the specified geonet thickness may be greater.

TRANSMISSIVITY OF DOUBLE-SIDED GEOCOMPOSITE
8 oz/sy Polypropylene Geotextiles with 200-mil Drainage Net
(Soil/Geocomposite/Geomembrane)



[1] The transmissivity shall be greater than the Conformace Curve to be considered passing.
[2] These values are developed based on engineering judgement and experience with similar geocomposite products at numerous MSW sites in Texas and is provided to verify the selected drainage geocomposite transmissivity provides greater conveyance than the specified transmissivity in these calculations.

CITY OF MEADOW LANDFILL
0120-809-11-05
HELP VERSION 3.07 SUMMARY SHEET
SECTORS 1-18 - SIDESLOPES

		ACTIVE (10 FT WASTE)	INTERIM (50 FT WASTE)	INTERIM (100 FT WASTE)	INTERIM (130 FT WASTE)	CLOSED (130 FT WASTE)
GENERAL INFORMATION	Case No.	1	2	3	4	6
	Output Page	IIIC-A.2-15	IIIC-A.2-23	IIIC-A.2-32	IIIC-A.2-41	IIIC-A.2-50
	No. of Years	1	10	10	10	30
	Ground Cover	BARE	FAIR	FAIR	FAIR	GOOD
	SCS Runoff Curve No.	79.7	85.6	85.6	85.6	80.8
	Model Area (acre)	1	1	1	1	1
	Runoff Area (%)	0	70	80	90	100
	Maximum Leaf Area Index	0.0	2.0	2.0	2.0	4.5
	Evaporative Zone Depth (inch)	10	10	10	10	12
TOPSOIL LAYER (Texture = 10)	Thickness (in)					12
	Porosity (vol/vol)					0.3980
	Field Capacity (vol/vol)					0.2440
	Wilting Point (vol/vol)					0.1360
	Init. Moisture Content (vol/vol)					0.2440
	Hyd. Conductivity (cm/s)					1.2E-04
GEOCOMPIOSITE DRAINAGE LAYER (Texture = 0)	Thickness (in)					0.250
	Porosity (vol/vol)					0.8500
	Field Capacity (vol/vol)					0.0100
	Wilting Point (vol/vol)					0.0050
	Init. Moisture Content (vol/vol)					0.0100
	Hyd. Conductivity (cm/s)					6.63
	Slope (%)					5.0
	Slope Length (ft)					350
FLEXIBLE MEMBRANE LINER (Texture = 36)	Thickness (in)					0.04
	Hyd. Conductivity (cm/s)					4.0E-13
	Pinhole Density (holes/acre)					1
	Install. Defects (holes/acre)					4
	Placement Quality					GOOD
COMPACTED CLAY LINER (Texture = 0)	Thickness (in)					18.00
	Porosity (vol/vol)					0.4270
	Field Capacity (vol/vol)					0.4180
	Wilting Point (vol/vol)					0.3670
	Init. Moisture Content (vol/vol)					0.4270
	Hyd. Conductivity (cm/s)					1.0E-05
INTERMEDIATE COVER (Texture = 10)	Thickness (in)		12	12	12	12
	Porosity (vol/vol)		0.3980	0.3980	0.3980	0.3980
	Field Capacity (vol/vol)		0.2440	0.2440	0.2440	0.2440
	Wilting Point (vol/vol)		0.1360	0.1360	0.1360	0.1360
	Init. Moisture Content (vol/vol)		0.2440	0.2440	0.2440	0.2440
	Hyd. Conductivity (cm/s)		1.2E-04	1.2E-04	1.2E-04	1.2E-04
WASTE TOP[2] (Texture = 0)	Thickness (in)	120	600	1200	1200	1200
	Porosity (vol/vol)	0.6649	0.6483	0.6277	0.6277	0.6277
	Field Capacity (vol/vol)	0.5262	0.5215	0.5156	0.5156	0.5156
	Wilting Point (vol/vol)	0.0770	0.0770	0.0770	0.0770	0.0770
	Init. Moisture Content (vol/vol)	0.2500	0.2500	0.3000	0.3000	0.3000
	Hyd. Conductivity (cm/s)	1.0E-03	1.0E-03	1.0E-03	1.0E-03	1.0E-03
WASTE BOTTOM[2] (Texture = 0)	Thickness (in)				360	360
	Porosity (vol/vol)				0.5740	0.5740
	Field Capacity (vol/vol)				0.5004	0.5004
	Wilting Point (vol/vol)				0.0770	0.0770
	Init. Moisture Content (vol/vol)				0.3000	0.3000
	Hyd. Conductivity (cm/s)				1.0E-04	1.0E-04
PROTECTIVE COVER (Texture = 10)	Thickness (in)	24	24	24	24	24
	Porosity (vol/vol)	0.3980	0.3980	0.3980	0.3980	0.3980
	Field Capacity (vol/vol)	0.2440	0.2440	0.2440	0.2440	0.2440
	Wilting Point (vol/vol)	0.1360	0.1360	0.1360	0.1360	0.1360
	Init. Moisture Content (vol/vol)	0.2440	0.2440	0.2440	0.2440	0.2440
	Hyd. Conductivity (cm/s)	1.2E-04	1.2E-04	1.2E-04	1.2E-04	1.2E-04
LEACHATE COLLECTION LAYER (Texture = 0)	Thickness (in)	0.199	0.190	0.179	0.172	0.171
	Porosity (vol/vol)	0.8500	0.8500	0.8500	0.8500	0.8500
	Field Capacity (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
	Wilting Point (vol/vol)	0.0050	0.0050	0.0050	0.0050	0.0050
	Init. Moisture Content (vol/vol)	0.0100	0.0100	0.0100	0.0100	0.0100
	Hyd. Conductivity (cm/s)	0.14	0.07	0.04	0.03	0.02
	Slope (%)	33.0	33.0	33.0	33.0	33.0
	Slope Length (ft)	115	115	115	115	115
FLEXIBLE MEMBRANE LINER (Texture = 35)	Thickness (in)	0.06	0.06	0.06	0.06	0.06
	Hyd. Conductivity (cm/s)	2.0E-13	2.0E-13	2.0E-13	2.0E-13	2.0E-13
	Pinhole Density (holes/acre)	0	0	0	0	0
	Install. Defects (holes/acre)	0	0	0	0	0
	Placement Quality	GOOD	GOOD	GOOD	GOOD	GOOD
COMPACTED CLAY LINER (Texture = 16)	Thickness (in)	24	24	24	24	24
	Porosity (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Field Capacity (vol/vol)	0.4180	0.4180	0.4180	0.4180	0.4180
	Wilting Point (vol/vol)	0.3670	0.3670	0.3670	0.3670	0.3670
	Init. Moisture Content (vol/vol)	0.4270	0.4270	0.4270	0.4270	0.4270
	Hyd. Conductivity (cm/s)	1.0E-07	1.0E-07	1.0E-07	1.0E-07	1.0E-07
PRECIPITATION	Average Annual (in)	26.32	20.14	20.14	20.14	17.93
RUNOFF	Average Annual (in)	0.00	0.59	0.67	0.76	0.23
EVAPOTRANSPIRATION	Average Annual (in)	24.73	17.82	17.79	17.81	16.47
LATERAL DRAINAGE COLLECTED[1]	Average Annual (cf/year)	0.0	0.0	1,189.7	2,209.0	493.5
	Peak Daily (cf/day)	0.0	0.0	132.2	245.4	25.4
LATERAL DRAINAGE RECIRCULATED	Average Annual (cf/year)		0.0	26.2	23.9	
	Peak Daily (cf/day)		0.0	2.9	2.7	
HEAD ON LINER	Average Annual (in)	0.000	0.000	0.002	0.004	0.001
	Peak Daily (in)	0.014	0.017	0.060	0.062	0.068

[1] Drainage collected includes actual leachate pumped by the leachate pumps (i.e., the total of the collected and recirculated leachate).

[2] The field capacity and porosity values for the waste layer were obtained from: Zornberg, Jorge G. et. al, *Retention of Free Liquids in Landfills Undergoing Vertical Expansion.* Journal of Geotechnical and Geoenvironmental Engineering, July 1999, pp. 583-594.

SIDESLOPE
HELP MODEL OUTPUT
(SECTORS 1 THROUGH 18)

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


PRECIPITATION DATA FILE:    C:\MEADOW\SS\A10\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\SS\A10\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\SS\A10\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\SS\A10\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\SS\A10\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\SS\A10\OUTDATA.OUT


TIME:  13:42     DATE:   2/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-ACTIVE 10 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =    120.00   INCHES
           POROSITY                    =      0.6649 VOL/VOL
           FIELD CAPACITY              =      0.5262 VOL/VOL
           WILTING POINT               =      0.0770 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2500 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
```

```
                        LAYER  2
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                  =     24.00   INCHES
POROSITY                   =      0.3980 VOL/VOL
FIELD CAPACITY             =      0.2440 VOL/VOL
WILTING POINT              =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                        LAYER  3
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.20   INCHES
POROSITY                   =      0.8500 VOL/VOL
FIELD CAPACITY             =      0.0100 VOL/VOL
WILTING POINT              =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.140000001000     CM/SEC
SLOPE                      =     33.00   PERCENT
DRAINAGE LENGTH            =    115.0    FEET


                        LAYER  4
                        --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER  35
THICKNESS                  =      0.06   INCHES
POROSITY                   =      0.0000 VOL/VOL
FIELD CAPACITY             =      0.0000 VOL/VOL
WILTING POINT              =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  3 - GOOD


                        LAYER  5
```

```
                            --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  16
   THICKNESS                  =     24.00   INCHES
   POROSITY                   =      0.4270 VOL/VOL
   FIELD CAPACITY             =      0.4180 VOL/VOL
   WILTING POINT              =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC




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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE #18 WITH BARE
         GROUND CONDITIONS, A SURFACE SLOPE OF  2.% AND
         A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     79.70
FRACTION OF AREA ALLOWING RUNOFF    =      0.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      3.000  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      7.979  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      0.924  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     46.106  INCHES
TOTAL INITIAL WATER                 =     46.106  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR




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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
         MIDLAND               TEXAS

     STATION LATITUDE                         =  32.00 DEGREES
     MAXIMUM LEAF AREA INDEX                  =   0.00
     START OF GROWING SEASON (JULIAN DATE)    =     67
     END OF GROWING SEASON (JULIAN DATE)      =    317
     EVAPORATIVE ZONE DEPTH                   =  12.0  INCHES
     AVERAGE ANNUAL WIND SPEED                =  11.10 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY    =  52.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY    =  50.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY    =  55.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY    =  58.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 25 THROUGH 25

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.58	0.53	1.16	2.07	3.93	4.76
	5.38	3.78	1.20	0.52	0.22	2.19
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

```
  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

 EVAPOTRANSPIRATION
 ------------------
  TOTALS                 1.492    0.544    1.577    0.840    3.738    4.290
                         5.111    4.019    1.055    0.468    0.352    1.247

  STD. DEVIATIONS        0.000    0.000    0.000    0.000    0.000    0.000
                         0.000    0.000    0.000    0.000    0.000    0.000

 LATERAL DRAINAGE COLLECTED FROM LAYER  3
 ----------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

 PERCOLATION/LEAKAGE THROUGH LAYER  5
 ------------------------------------
  TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
              AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


 DAILY AVERAGE HEAD ON TOP OF LAYER  4
 -------------------------------------
  AVERAGES               0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                         0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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


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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS   25 THROUGH   25
-------------------------------------------------------------------------------
                                    INCHES           CU. FEET       PERCENT
                              -------------------  -------------   ---------
 PRECIPITATION                  26.32    (   0.000)     95541.6     100.00

 RUNOFF                          0.000   (  0.0000)         0.00      0.000
```

EVAPOTRANSPIRATION	24.733	(0.0000)	89779.02	93.969
LATERAL DRAINAGE COLLECTED FROM LAYER 3	0.00000	(0.00000)	0.001	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.00000	(0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 4	0.000	(0.000)		
CHANGE IN WATER STORAGE	1.587	(0.0000)	5762.60	6.032

****

****

PEAK DAILY VALUES FOR YEARS 25 THROUGH 25

	(INCHES)	(CU. FT.)
PRECIPITATION	1.67	6062.100
RUNOFF	0.000	0.0000
DRAINAGE COLLECTED FROM LAYER 3	0.00000	0.00081
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 4	0.000	
MAXIMUM HEAD ON TOP OF LAYER 4	0.014	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.94	3421.4011

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3369
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1086

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

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

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****

FINAL WATER STORAGE AT END OF YEAR 25

LAYER	(INCHES)	(VOL/VOL)
1	31.5874	0.2632
2	5.8560	0.2440
3	0.0020	0.0100
4	0.0000	0.0000
5	10.2480	0.4270
SNOW WATER	0.000	

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****

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


PRECIPITATION DATA FILE:    C:\MEADOW\SS\I50\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\SS\I50\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\SS\I50\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\SS\I50\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\SS\I50\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\SS\I50\OUTDATA.OUT


TIME:  13:45     DATE:   2/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 50 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3980 VOL/VOL
           FIELD CAPACITY             =      0.2440 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC
```

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



                          LAYER  2
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =    600.00   INCHES
  POROSITY                     =      0.6483 VOL/VOL
  FIELD CAPACITY               =      0.5215 VOL/VOL
  WILTING POINT                =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
         IS RECIRCULATED INTO THIS LAYER.



                          LAYER  3
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  10
  THICKNESS                    =     24.00   INCHES
  POROSITY                     =      0.3980 VOL/VOL
  FIELD CAPACITY               =      0.2440 VOL/VOL
  WILTING POINT                =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC



                          LAYER  4
                          --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =      0.19   INCHES
  POROSITY                     =      0.8500 VOL/VOL
  FIELD CAPACITY               =      0.0100 VOL/VOL
  WILTING POINT                =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.700000003000E-01 CM/SEC
  SLOPE                        =     33.00   PERCENT
  DRAINAGE LENGTH              =    115.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.
```

```
                         LAYER  5
                         --------

             TYPE 4 - FLEXIBLE MEMBRANE LINER
               MATERIAL TEXTURE NUMBER  35
   THICKNESS                  =     0.06   INCHES
   POROSITY                   =     0.0000 VOL/VOL
   FIELD CAPACITY             =     0.0000 VOL/VOL
   WILTING POINT              =     0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY        =     0.00   HOLES/ACRE
   FML INSTALLATION DEFECTS   =     0.00   HOLES/ACRE
   FML PLACEMENT QUALITY      =  3 - GOOD


                         LAYER  6
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER  16
   THICKNESS                  =    24.00   INCHES
   POROSITY                   =     0.4270 VOL/VOL
   FIELD CAPACITY             =     0.4180 VOL/VOL
   WILTING POINT              =     0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT =     0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF  2.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER              =     85.60
FRACTION OF AREA ALLOWING RUNOFF     =     70.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      2.928  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.776  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.632  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =    169.034  INCHES
TOTAL INITIAL WATER                  =    169.034  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

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        AVERAGE MONTHLY VALUES IN INCHES FOR YEARS    2 THROUGH   11
------------------------------------------------------------------------------

                         JAN/JUL  FEB/AUG  MAR/SEP  APR/OCT  MAY/NOV  JUN/DEC
                         -------  -------  -------  -------  -------  -------
  PRECIPITATION
  -------------
    TOTALS                 0.74     0.64     1.30     1.23     2.63     2.60
                           2.87     1.58     3.42     1.57     0.93     0.66

    STD. DEVIATIONS        0.61     0.41     0.98     0.93     0.88     1.97
                           2.32     1.24     1.47     1.47     0.49     0.51

  RUNOFF
  ------
    TOTALS                 0.000    0.000    0.008    0.002    0.029    0.183
                           0.233    0.014    0.093    0.031    0.000    0.002

    STD. DEVIATIONS        0.000    0.000    0.016    0.006    0.037    0.363
                           0.414    0.033    0.144    0.081    0.000    0.005

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.753    0.796    1.013    1.471    2.383    2.139
                           2.377    1.387    2.843    1.132    0.927    0.593

    STD. DEVIATIONS        0.403    0.431    0.625    1.062    0.886    1.344
                           1.443    0.845    0.932    0.897    0.518    0.291

  LATERAL DRAINAGE RECIRCULATED INTO LAYER  2
  -------------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  ----------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  4
  -------------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
```

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2 THROUGH 11

	INCHES	CU. FEET	PERCENT
PRECIPITATION	20.14 (3.835)	73111.8	100.00
RUNOFF	0.594 (0.4671)	2155.85	2.949
EVAPOTRANSPIRATION	17.815 (2.7085)	64667.97	88.451
DRAINAGE RECIRCULATED INTO LAYER 2	0.00000 (0.00000)	0.000	0.00000
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.00000 (0.00000)	0.000	0.00000
DRAINAGE RECIRCULATED FROM LAYER 4	0.00000 (0.00000)	0.000	0.00000
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000 (0.00000)	0.000	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.000 (0.000)		
CHANGE IN WATER STORAGE	1.732 (1.2331)	6288.01	8.601

```
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             PEAK DAILY VALUES FOR YEARS    2 THROUGH   11
   ------------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                             4.19        15209.700

      RUNOFF                                    1.031        3741.9133

      DRAINAGE RECIRCULATED INTO LAYER  2       0.00000         0.00006

      DRAINAGE COLLECTED FROM LAYER  4          0.00000         0.00051

      DRAINAGE RECIRCULATED FROM LAYER  4       0.00000         0.00006

      PERCOLATION/LEAKAGE THROUGH LAYER  6      0.000000        0.00002

      AVERAGE HEAD ON TOP OF LAYER  5           0.000

      MAXIMUM HEAD ON TOP OF LAYER  5           0.017

      LOCATION OF MAXIMUM HEAD IN LAYER  4
            (DISTANCE FROM DRAIN)               0.0 FEET

      SNOW WATER                                0.46         1655.6732


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.3905

      MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1360


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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8478	0.1540
2	168.4025	0.2807
3	5.8560	0.2440
4	0.0019	0.0100
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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


PRECIPITATION DATA FILE:    C:\MEADOW\SS\I100\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\SS\I100\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\SS\I100\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\SS\I100\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\SS\I100\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\SS\I100\OUTDATA.OUT


TIME:  13:47     DATE:   2/23/2024


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

     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 100 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                         TYPE 1 - VERTICAL PERCOLATION LAYER
                             MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =    12.00   INCHES
           POROSITY                   =     0.3980 VOL/VOL
           FIELD CAPACITY             =     0.2440 VOL/VOL
           WILTING POINT              =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
```

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




                          LAYER  2
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =   1200.00   INCHES
  POROSITY                   =      0.6277 VOL/VOL
  FIELD CAPACITY             =      0.5156 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 4
         IS RECIRCULATED INTO THIS LAYER.




                          LAYER  3
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.3980 VOL/VOL
  FIELD CAPACITY             =      0.2440 VOL/VOL
  WILTING POINT              =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC




                          LAYER  4
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.18   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.399999991000E-01 CM/SEC
  SLOPE                      =     33.00   PERCENT
  DRAINAGE LENGTH            =    115.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.
```

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                        LAYER  5
                        --------

                  TYPE 4 - FLEXIBLE MEMBRANE LINER
                    MATERIAL TEXTURE NUMBER  35
   THICKNESS                   =      0.06   INCHES
   POROSITY                    =      0.0000 VOL/VOL
   FIELD CAPACITY              =      0.0000 VOL/VOL
   WILTING POINT               =      0.0000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
   FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
   FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
   FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER  6
                        --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER  16
   THICKNESS                   =     24.00   INCHES
   POROSITY                    =      0.4270 VOL/VOL
   FIELD CAPACITY              =      0.4180 VOL/VOL
   WILTING POINT               =      0.3670 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
          FAIR STAND OF GRASS, A SURFACE SLOPE OF  2.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     85.60
FRACTION OF AREA ALLOWING RUNOFF    =     80.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     12.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      2.928  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      4.776  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      1.632  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    379.034  INCHES
TOTAL INITIAL WATER                 =    379.034  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00 DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	67
END OF GROWING SEASON (JULIAN DATE)	=	317
EVAPORATIVE ZONE DEPTH	=	12.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.009	0.002	0.033	0.209
	0.262	0.016	0.106	0.035	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.018	0.005	0.042	0.415
	0.464	0.037	0.164	0.093	0.000	0.006
EVAPOTRANSPIRATION						
TOTALS	0.725	0.766	0.977	1.508	2.394	2.139
	2.382	1.387	2.842	1.148	0.923	0.598
STD. DEVIATIONS	0.339	0.450	0.637	1.080	0.884	1.341
	1.428	0.839	0.932	0.903	0.526	0.298
LATERAL DRAINAGE RECIRCULATED INTO LAYER 2						
TOTALS	0.0030	0.0018	0.0028	0.0044	0.0025	0.0014
	0.0019	0.0034	0.0031	0.0031	0.0036	0.0045
STD. DEVIATIONS	0.0064	0.0046	0.0056	0.0071	0.0054	0.0045
	0.0046	0.0059	0.0059	0.0065	0.0065	0.0074
LATERAL DRAINAGE COLLECTED FROM LAYER 4						
TOTALS	0.0271	0.0162	0.0252	0.0397	0.0228	0.0127
	0.0169	0.0303	0.0282	0.0277	0.0328	0.0409
STD. DEVIATIONS	0.0575	0.0411	0.0507	0.0641	0.0482	0.0402
	0.0417	0.0530	0.0528	0.0584	0.0583	0.0665
LATERAL DRAINAGE RECIRCULATED FROM LAYER 4						
TOTALS	0.0030	0.0018	0.0028	0.0044	0.0025	0.0014
	0.0019	0.0034	0.0031	0.0031	0.0036	0.0045
STD. DEVIATIONS	0.0064	0.0046	0.0056	0.0071	0.0054	0.0045
	0.0046	0.0059	0.0059	0.0065	0.0065	0.0074

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	0.0017	0.0011	0.0015	0.0025	0.0014	0.0008
	0.0010	0.0018	0.0018	0.0017	0.0021	0.0025
STD. DEVIATIONS	0.0035	0.0028	0.0031	0.0040	0.0029	0.0025
	0.0025	0.0032	0.0033	0.0036	0.0037	0.0041

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 2 THROUGH 11

	INCHES		CU. FEET	PERCENT
PRECIPITATION	20.14	(3.835)	73111.8	100.00
RUNOFF	0.674	(0.5289)	2446.81	3.347
EVAPOTRANSPIRATION	17.789	(2.7837)	64572.93	88.321
DRAINAGE RECIRCULATED INTO LAYER 2	0.03561	(0.06013)	129.282	0.17683
LATERAL DRAINAGE COLLECTED FROM LAYER 4	0.32053	(0.54119)	1163.537	1.59145
DRAINAGE RECIRCULATED FROM LAYER 4	0.03561	(0.06013)	129.282	0.17683
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.002	0.00000
AVERAGE HEAD ON TOP OF LAYER 5	0.002	(0.003)		
CHANGE IN WATER STORAGE	1.358	(1.3147)	4928.33	6.741

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PEAK DAILY VALUES FOR YEARS 2 THROUGH 11

	(INCHES)	(CU. FT.)
PRECIPITATION	4.19	15209.700
RUNOFF	1.178	4275.9409
DRAINAGE RECIRCULATED INTO LAYER 2	0.00080	2.90610
DRAINAGE COLLECTED FROM LAYER 4	0.00721	26.15486
DRAINAGE RECIRCULATED FROM LAYER 4	0.00080	2.90610
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.014	
MAXIMUM HEAD ON TOP OF LAYER 5	0.060	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	0.0 FEET	
SNOW WATER	0.46	1655.6732

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3832

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1360

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

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

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FINAL WATER STORAGE AT END OF YEAR 11

LAYER	(INCHES)	(VOL/VOL)
1	1.8483	0.1540
2	374.5269	0.3121
3	5.9766	0.2490
4	0.0106	0.0593
5	0.0000	0.0000
6	10.2480	0.4270
SNOW WATER	0.000	

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\MEADOW\SS\I130\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\SS\I130\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\SS\I130\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\SS\I130\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\SS\I130\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\SS\I130\OUTDATA.OUT


TIME:  13:38     DATE:   2/23/2024


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     TITLE:  CITY OF MEADOW LANDFILL-INTERIM 130 FT

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


     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
           THICKNESS                  =    12.00   INCHES
           POROSITY                   =     0.3980 VOL/VOL
           FIELD CAPACITY             =     0.2440 VOL/VOL
           WILTING POINT              =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2440 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
```

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




                          LAYER  2
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =   1200.00   INCHES
  POROSITY                   =      0.6277 VOL/VOL
  FIELD CAPACITY             =      0.5156 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM LAYER # 5
         IS RECIRCULATED INTO THIS LAYER.




                          LAYER  3
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =    360.00   INCHES
  POROSITY                   =      0.5740 VOL/VOL
  FIELD CAPACITY             =      0.5004 VOL/VOL
  WILTING POINT              =      0.0770 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.3000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC




                          LAYER  4
                          --------

            TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  10
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.3980 VOL/VOL
  FIELD CAPACITY             =      0.2440 VOL/VOL
  WILTING POINT              =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
  EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC




                          LAYER  5
                          --------
```

```
              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.17   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.299999993000E-01 CM/SEC
  SLOPE                      =     33.00   PERCENT
  DRAINAGE LENGTH            =    115.0    FEET
NOTE:   10.00 PERCENT OF THE DRAINAGE COLLECTED FROM THIS
         LAYER IS RECIRCULATED INTO LAYER #  2.


                          LAYER  6
                          --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  35
  THICKNESS                  =      0.06   INCHES
  POROSITY                   =      0.0000 VOL/VOL
  FIELD CAPACITY             =      0.0000 VOL/VOL
  WILTING POINT              =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.199999996000E-12 CM/SEC
  FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
  FML INSTALLATION DEFECTS   =      0.00   HOLES/ACRE
  FML PLACEMENT QUALITY      =  3 - GOOD


                          LAYER  7
                          --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER  16
  THICKNESS                  =     24.00   INCHES
  POROSITY                   =      0.4270 VOL/VOL
  FIELD CAPACITY             =      0.4180 VOL/VOL
  WILTING POINT              =      0.3670 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.100000001000E-06 CM/SEC


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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
```

SOIL DATA BASE USING SOIL TEXTURE #10 WITH A
FAIR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 350. FEET.

SCS RUNOFF CURVE NUMBER	=	85.60	
FRACTION OF AREA ALLOWING RUNOFF	=	90.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.928	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.776	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.632	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	487.034	INCHES
TOTAL INITIAL WATER	=	487.034	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
MIDLAND TEXAS

STATION LATITUDE	=	32.00	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	67	
END OF GROWING SEASON (JULIAN DATE)	=	317	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIDLAND TEXAS
AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 2 THROUGH 11

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.74	0.64	1.30	1.23	2.63	2.60
	2.87	1.58	3.42	1.57	0.93	0.66
STD. DEVIATIONS	0.61	0.41	0.98	0.93	0.88	1.97
	2.32	1.24	1.47	1.47	0.49	0.51
RUNOFF						
TOTALS	0.000	0.000	0.010	0.003	0.037	0.235
	0.292	0.018	0.119	0.040	0.000	0.002
STD. DEVIATIONS	0.000	0.000	0.020	0.007	0.047	0.466
	0.518	0.042	0.184	0.105	0.000	0.007
EVAPOTRANSPIRATION						
TOTALS	0.730	0.826	0.994	1.465	2.394	2.136
	2.370	1.390	2.849	1.143	0.920	0.593
STD. DEVIATIONS	0.339	0.467	0.634	1.061	0.886	1.336
	1.430	0.844	0.933	0.906	0.524	0.286
LATERAL DRAINAGE RECIRCULATED INTO LAYER 2						
TOTALS	0.0049	0.0053	0.0069	0.0063	0.0063	0.0050
	0.0048	0.0059	0.0053	0.0055	0.0053	0.0055
STD. DEVIATIONS	0.0066	0.0062	0.0069	0.0068	0.0070	0.0065
	0.0065	0.0067	0.0068	0.0071	0.0068	0.0071

```
  LATERAL DRAINAGE COLLECTED FROM LAYER  5
  ----------------------------------------
    TOTALS                 0.0440   0.0476   0.0621   0.0570   0.0570   0.0446
                           0.0429   0.0528   0.0474   0.0495   0.0475   0.0496

    STD. DEVIATIONS        0.0595   0.0554   0.0623   0.0613   0.0626   0.0588
                           0.0585   0.0602   0.0615   0.0639   0.0610   0.0642

  LATERAL DRAINAGE RECIRCULATED FROM LAYER  5
  -------------------------------------------
    TOTALS                 0.0049   0.0053   0.0069   0.0063   0.0063   0.0050
                           0.0048   0.0059   0.0053   0.0055   0.0053   0.0055

    STD. DEVIATIONS        0.0066   0.0062   0.0069   0.0068   0.0070   0.0065
                           0.0065   0.0067   0.0068   0.0071   0.0068   0.0071

  PERCOLATION/LEAKAGE THROUGH LAYER  7
  ------------------------------------
    TOTALS                 0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

    STD. DEVIATIONS        0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000


-------------------------------------------------------------------------------
               AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)
-------------------------------------------------------------------------------


  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES               0.0036   0.0043   0.0051   0.0048   0.0046   0.0038
                           0.0035   0.0043   0.0040   0.0040   0.0040   0.0040

    STD. DEVIATIONS        0.0048   0.0049   0.0051   0.0052   0.0051   0.0049
                           0.0048   0.0049   0.0052   0.0052   0.0051   0.0052

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


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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    2 THROUGH   11
-------------------------------------------------------------------------------
                                         INCHES            CU. FEET       PERCENT
                                   -------------------   -------------   ---------
 PRECIPITATION                       20.14    (   3.835)      73111.8     100.00

 RUNOFF                               0.756   (  0.5930)       2745.70      3.755

 EVAPOTRANSPIRATION                  17.811   (  2.7816)      64654.26     88.432

 DRAINAGE RECIRCULATED                0.06688 (  0.07261)       242.791    0.33208
```

```
  INTO LAYER  2

LATERAL DRAINAGE COLLECTED      0.60196 (  0.65349)      2185.120    2.98874
  FROM LAYER  5

DRAINAGE RECIRCULATED           0.06688 (  0.07261)       242.791    0.33208
  FROM LAYER  5

PERCOLATION/LEAKAGE THROUGH     0.00000 (  0.00000)         0.004     0.00001
  LAYER  7

AVERAGE HEAD ON TOP             0.004 (    0.005)
  OF LAYER  6

CHANGE IN WATER STORAGE         0.972   (  1.1618)       3526.78      4.824

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              PEAK DAILY VALUES FOR YEARS    2 THROUGH   11
   ------------------------------------------------------------------------
                                              (INCHES)      (CU. FT.)
                                             ----------   -------------
      PRECIPITATION                            4.19         15209.700

      RUNOFF                                   1.325         4810.3452

      DRAINAGE RECIRCULATED INTO LAYER  2      0.00073          2.65764

      DRAINAGE COLLECTED FROM LAYER  5         0.00659         23.91872

      DRAINAGE RECIRCULATED FROM LAYER  5      0.00073          2.65764

      PERCOLATION/LEAKAGE THROUGH LAYER  7     0.000000         0.00002

      AVERAGE HEAD ON TOP OF LAYER  6          0.017

      MAXIMUM HEAD ON TOP OF LAYER  6          0.062

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)              0.0 FEET

      SNOW WATER                               0.46          1655.6732


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                0.3724

      MINIMUM VEG. SOIL WATER (VOL/VOL)                0.1360


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

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

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                FINAL WATER STORAGE AT END OF YEAR   11
    ----------------------------------------------------------------------
                 LAYER        (INCHES)       (VOL/VOL)
                 -----        --------       ---------
                   1            1.8484         0.1540

                   2          374.4963         0.3121

                   3          104.2200         0.2895

                   4            5.9275         0.2470

                   5            0.0091         0.0530

                   6            0.0000         0.0000

                   7           10.2480         0.4270

                SNOW WATER      0.000

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**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE              **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)               **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                  **
**                    USAE WATERWAYS EXPERIMENT STATION                    **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY             **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\MEADOW\SS\CL130\DATA4.D4
TEMPERATURE DATA FILE:      C:\MEADOW\SS\CL130\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\MEADOW\SS\CL130\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\MEADOW\SS\CL130\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\MEADOW\SS\CL130\DATA10.D10
OUTPUT DATA FILE:           C:\MEADOW\SS\CL130\OUTDATA.OUT


TIME:  13:52     DATE:   2/23/2024


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     TITLE:  CITY OF MEADOW LANDFILL-CLOSED 130 FT

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     NOTE:  INITIAL MOISTURE CONTENT OF THE LAYERS AND SNOW WATER
              WERE SPECIFIED BY THE USER.


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  10
          THICKNESS                  =     12.00   INCHES
          POROSITY                   =      0.3980 VOL/VOL
          FIELD CAPACITY             =      0.2440 VOL/VOL
          WILTING POINT              =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2440 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC
```

```
NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


                          LAYER  2
                          --------

              TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =      0.25   INCHES
  POROSITY                   =      0.8500 VOL/VOL
  FIELD CAPACITY             =      0.0100 VOL/VOL
  WILTING POINT              =      0.0050 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0100 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =   6.63000011000     CM/SEC
  SLOPE                      =      5.00   PERCENT
  DRAINAGE LENGTH            =    350.0    FEET


                          LAYER  3
                          --------

              TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER  36
  THICKNESS                  =      0.04   INCHES
  POROSITY                   =      0.0000 VOL/VOL
  FIELD CAPACITY             =      0.0000 VOL/VOL
  WILTING POINT              =      0.0000 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.0000 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.399999993000E-12 CM/SEC
  FML PINHOLE DENSITY        =      1.00   HOLES/ACRE
  FML INSTALLATION DEFECTS   =      4.00   HOLES/ACRE
  FML PLACEMENT QUALITY      =  3 - GOOD


                          LAYER  4
                          --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER   0
  THICKNESS                  =     18.00   INCHES
  POROSITY                   =      0.4270 VOL/VOL
  FIELD CAPACITY             =      0.4180 VOL/VOL
  WILTING POINT              =      0.3670 VOL/VOL
  INITIAL SOIL WATER CONTENT =      0.4270 VOL/VOL
  EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-05 CM/SEC
```

```
                        LAYER  5
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.119999997000E-03 CM/SEC


                        LAYER  6
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =   1200.00   INCHES
POROSITY                     =      0.6277 VOL/VOL
FIELD CAPACITY               =      0.5156 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC


                        LAYER  7
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    360.00   INCHES
POROSITY                     =      0.5740 VOL/VOL
FIELD CAPACITY               =      0.5004 VOL/VOL
WILTING POINT                =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.3000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC


                        LAYER  8
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER  10
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.3980 VOL/VOL
FIELD CAPACITY               =      0.2440 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
```

```
INITIAL SOIL WATER CONTENT  =      0.2440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC


                        LAYER  9
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.17   INCHES
POROSITY                    =      0.8500 VOL/VOL
FIELD CAPACITY              =      0.0100 VOL/VOL
WILTING POINT               =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-01 CM/SEC
SLOPE                       =     33.00   PERCENT
DRAINAGE LENGTH             =    115.0    FEET


                        LAYER 10
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  35
THICKNESS                   =      0.06   INCHES
POROSITY                    =      0.0000 VOL/VOL
FIELD CAPACITY              =      0.0000 VOL/VOL
WILTING POINT               =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.199999996000E-12 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =      0.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  3 - GOOD


                        LAYER 11
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER  16
THICKNESS                   =     24.00   INCHES
POROSITY                    =      0.4270 VOL/VOL
FIELD CAPACITY              =      0.4180 VOL/VOL
WILTING POINT               =      0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #10 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 5.% AND A SLOPE LENGTH OF 350. FEET.

SCS RUNOFF CURVE NUMBER	=	80.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.928	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.776	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.632	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	497.650	INCHES
TOTAL INITIAL WATER	=	497.650	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM MIDLAND TEXAS

STATION LATITUDE	=	32.00	DEGREES
MAXIMUM LEAF AREA INDEX	=	4.50	
START OF GROWING SEASON (JULIAN DATE)	=	67	
END OF GROWING SEASON (JULIAN DATE)	=	317	
EVAPORATIVE ZONE DEPTH	=	12.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	11.10	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	52.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	50.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	55.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	58.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR ABILENE TEXAS

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
0.69	0.62	1.07	1.31	2.20	2.67
1.94	1.80	2.56	1.57	0.88	0.74

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
40.90	44.80	52.70	60.60	70.00	78.30
80.60	79.30	72.00	61.80	49.90	41.90

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIDLAND TEXAS AND STATION LATITUDE = 32.00 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 30

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	0.69	0.55	1.29	1.32	1.96	2.54
	2.67	1.56	2.49	1.40	0.90	0.57
STD. DEVIATIONS	0.64	0.33	1.02	0.82	1.05	2.04
	1.97	1.09	1.58	1.26	0.60	0.60
RUNOFF						
TOTALS	0.000	0.000	0.001	0.000	0.003	0.080
	0.108	0.002	0.024	0.010	0.000	0.000
STD. DEVIATIONS	0.000	0.000	0.004	0.000	0.008	0.205
	0.271	0.006	0.066	0.039	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	0.638	0.543	0.946	1.790	1.914	2.164
	2.281	1.514	2.192	0.984	0.849	0.650
STD. DEVIATIONS	0.403	0.375	0.719	0.900	1.044	1.514
	1.449	1.012	1.307	0.720	0.464	0.421

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	0.0356	0.0084	0.0811	0.0416	0.0118	0.2721
	0.3466	0.0211	0.1873	0.2096	0.0307	0.0293
STD. DEVIATIONS	0.1049	0.0324	0.2176	0.1034	0.0387	0.6090
	0.6202	0.0972	0.4689	0.6370	0.0726	0.1175

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
	0.0001	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 9

TOTALS	0.0118	0.0124	0.0142	0.0139	0.0143	0.0128
	0.0096	0.0098	0.0094	0.0093	0.0089	0.0096
STD. DEVIATIONS	0.0379	0.0380	0.0434	0.0424	0.0436	0.0396
	0.0366	0.0373	0.0360	0.0354	0.0339	0.0365

PERCOLATION/LEAKAGE THROUGH LAYER 11

TOTALS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0002	0.0001	0.0008	0.0003	0.0001	0.0087
	0.0202	0.0002	0.0027	0.0034	0.0002	0.0002
STD. DEVIATIONS	0.0006	0.0002	0.0027	0.0006	0.0002	0.0233
	0.0558	0.0012	0.0076	0.0116	0.0005	0.0007

DAILY AVERAGE HEAD ON TOP OF LAYER 10

AVERAGES	0.0013	0.0015	0.0016	0.0016	0.0016	0.0014
	0.0011	0.0011	0.0011	0.0010	0.0010	0.0011
STD. DEVIATIONS	0.0042	0.0046	0.0048	0.0048	0.0048	0.0045
	0.0040	0.0041	0.0041	0.0039	0.0039	0.0040

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 30

	INCHES	CU. FEET	PERCENT
PRECIPITATION	17.93 (4.448)	65096.8	100.00
RUNOFF	0.227 (0.3408)	822.80	1.264
EVAPOTRANSPIRATION	16.465 (3.7223)	59766.44	91.812
LATERAL DRAINAGE COLLECTED FROM LAYER 2	1.27516 (1.06066)	4628.840	7.11070
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00009 (0.00014)	0.325	0.00050
AVERAGE HEAD ON TOP OF LAYER 3	0.003 (0.005)		
LATERAL DRAINAGE COLLECTED FROM LAYER 9	0.13595 (0.43746)	493.483	0.75808
PERCOLATION/LEAKAGE THROUGH LAYER 11	0.00000 (0.00000)	0.001	0.00000
AVERAGE HEAD ON TOP OF LAYER 10	0.001 (0.004)		
CHANGE IN WATER STORAGE	-0.169 (0.8788)	-614.78	-0.944

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	4.67	16952.100
RUNOFF	1.192	4326.7114
DRAINAGE COLLECTED FROM LAYER 2	1.33907	4860.82568
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000438	1.59150
AVERAGE HEAD ON TOP OF LAYER 3	6.402	
MAXIMUM HEAD ON TOP OF LAYER 3	11.221	

```
LOCATION OF MAXIMUM HEAD IN LAYER  2
      (DISTANCE FROM DRAIN)              42.6 FEET

DRAINAGE COLLECTED FROM LAYER  9          0.00700         25.42133

PERCOLATION/LEAKAGE THROUGH LAYER 11      0.000000         0.00002

AVERAGE HEAD ON TOP OF LAYER 10           0.024

MAXIMUM HEAD ON TOP OF LAYER 10           0.068

LOCATION OF MAXIMUM HEAD IN LAYER  9
      (DISTANCE FROM DRAIN)               0.0 FEET

SNOW WATER                                0.94          3421.4011


MAXIMUM VEG. SOIL WATER (VOL/VOL)                 0.3762

MINIMUM VEG. SOIL WATER (VOL/VOL)                 0.1360

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

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

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




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

             FINAL WATER STORAGE AT END OF YEAR   30
    ----------------------------------------------------------------------
              LAYER        (INCHES)        (VOL/VOL)
              -----        --------        ---------
                1            1.9229          0.1602

                2            0.0025          0.0100

                3            0.0000          0.0000

                4            7.6860          0.4270

                5            2.8960          0.2413

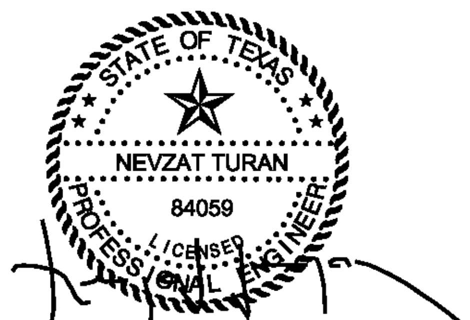
                6          360.0346          0.3000
```

7	103.9216	0.2887
8	5.8560	0.2440
9	0.0017	0.0100
10	0.0000	0.0000
11	10.2480	0.4270
SNOW WATER	0.000	

****
****

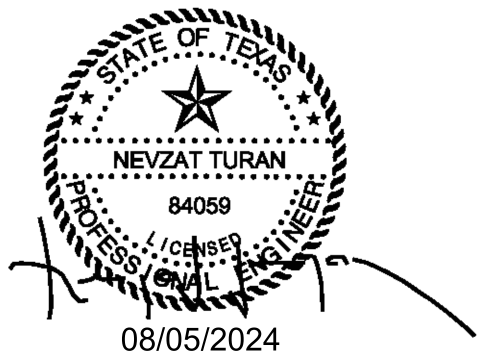
APPENDIX IIIC-B

LEACHATE COLLECTION SYSTEM DESIGN CALCULATIONS



08/05/2024

CONTENTS



STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

LEACHATE COLLECTION PIPE
CAPACITY CALCULATIONS

REQUIRED: Size leachate collection system pipe.

METHOD:

A. Use leachate production rates determined from the HELP model analysis (see Appendix IIIC-A) to size the leachate collection pipes. The largest sector is analyzed to provide for a conservative analysis.

B. Determine required hole size (perforations) based on characteristics of the surrounding drainage media.

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

3. Driscopipe, *Leachate Pipe Systems* , Phillips Drisco Inc., 1992.

SOLUTION:

Determine the peak daily flow rate estimate:

The following tables summarize the fill conditions that are likely to be present and have the greatest contribution of leachate into the LCS. The peak flow rate (lateral drainage in the LCS layer) is shown for each condition.

Sectors 1-18:

From the HELP model results in Appendix IIIC-A (highest leachate generation values used from all HELP runs for undeveloped Sectors.

CONDITION	PEAK[1] cfd/ac	PEAK gpd/ac
Active, 10' Waste	0.0	0.0
Interim, 50' Waste	0.0	0.0
Interim, 100' Waste	25.8	193.0
Interim, 130' Waste	21.7	162.3

[1]This leachate value is the sum of the leachate recirculated and the leachate collected for each condition, if applicable.

For the undeveloped Sectors, the largest area draining to a leachate collection pipe is 18.5 acres (pipe in Sector 13). Note, it is a conservative assumption that all the leachate will drain to a singluar pipe as leachate will likely be split between multiple pipes in Sector 13.

Therefore, the maximum leachate production expected in the leachate collection pipe is predicted to occur assuming the following scenario:

1. Active condition, 10' waste over 4.0 ac
2. Interim condition, 50' waste over 4.8 ac
3. Interim condition, 100' waste over 6.0 ac
4. Interim condition, 130' waste over 3.7 ac

CONDITION	AREA ac	PEAK gpd/ac	PEAK gpd	PEAK cfs
Active, 10' Waste	4.0	0.0	0.0	0.00E+00
Interim, 50' Waste	4.8	0.0	0.0	0.00E+00
Interim, 100' Waste	6.0	193.0	1,157.9	1.79E-03
Interim, 130' Waste	3.7	162.3	600.6	9.29E-04
Total=	18.5		1,758.5	2.72E-03

Undeveloped Sectors Peak Leachate Production = 2.72E-03 cfs

Determination of flow capacity (Q_{full}) for proposed 6-inch SDR 17 perforated pipe:
*Use Undeveloped Cells Peak Leachate Production

Determination of flow capacity (Q_{full}) for a 6-inch perforated pipe:

$$Q_{full} = \frac{1.486}{n} A R^{2/3} S^{1/2}$$

Where:
- A = Cross-sectional area of pipe, with d representing the inside diameter in feet
- R = Hydraulic radius of pipe in feet under full flow conditions
- S = Design slope of pipe
- n = Manning's number

From Pipe Structural Stability Calculations:

Standard Dimension Ratio (SDR) = 17.0

ID = 5.845 in
= 0.487 ft

A = 0.186 sq ft

R = 0.122 ft

S[1] = 0.008 ft / ft

[1]The 0.8 percent slope was chosen as the minimum slope for the leachate collection pipes. Refer to Appendix IIIE-B.

n = Manning's number — n = 0.015

Q_{full} =	0.406	cfs

Compare Peak Q_{max} and Q_{full} for the 6" SDR 17 pipe:

Q_{full} =	0.406	cfs	>>	Q_{max} =	0.0027	cfs

An SDR 17 pipe with a nominal diameter of 6 inches exceeds flow capacity requirements.

B. Perforation configuration for a 6-inch perforated pipes:

Pipe perforations must allow free passage of leachate and also prevent migration of drainage media into collection pipes. Therefore, size of perforations depends on media particle size. Two perforations alternatives are evaluated below:

For leachate collection pipes with slotted perforations:

$$\frac{D_{85}\text{ of Filter}}{\text{Slot Width}} > 2.0$$

Where: D_{85} = Particle size for which 85% of all particles are smaller than

	D_{85} =	25	mm
	=	0.984	in
Standard slot width:	d =	0.125	in

Check values to find that:

$$\frac{D_{85}\text{ of Filter}}{\text{Slot Width}} = 7.9 > 2.0 \quad \text{(acceptable)}$$

For leachate collection pipes with circular holes:

$$\frac{D_{85}\text{ of Filter}}{\text{Hole Diameter}} > 1.7$$

Where: D_{85} = Particle size for which 85% of all particles are smaller than

	D_{85} =	25	mm
	=	0.984	in
Standard hole diameter	d =	0.5	in

$$\frac{D_{85}\text{ of Filter}}{\text{Hole Diameter}} = 2.0 > 1.7 \quad \text{(acceptable)}$$

In Addition:

A minimum open area of 1 square inch per foot of drainage pipe is recommended by the U.S. Soil Conservation Service and the U.S. Bureau of Reclamation. Therefore, the number of 0.5 in diameter holes per foot will be 6 and total slot area provided by the manufacturer will provide documentation that minimum of 1 square inch of total slot area is provided per linear foot of pipe.

LEACHATE COLLECTION PIPE
STRUCTURAL STABILITY

REQUIRED: Analyze structural stability of the 6 inch diameter leachate collection system pipe.

METHOD:

A. Determine the critical load and calculate stress under the following two conditions:

1. Construction loading
2. Overburden loading

B. Use the critical loading pressure to analyze pipe stability under the following three possible failure conditions:

1. Wall crushing
2. Wall buckling
3. Ring deflection

NOTE:

1. The leachate trench details shown on pages IIIC-B-18 and IIIC-B-19 are for illustration purposes only to show parameters used in the following calcualtions. Leachate collection system details can be found in Appendix IIIA-A.

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

3. Phillips 66 Driscopipe, *System Design* , 1991.

4. Landfill Design Series, *Leachate Gas Management Systems Design, Volume 5, Leachate Management and Storage,* Appendix A, 1993.

5. Caterpillar Tractor Company*, Caterpillar Performance Handbook,* Edition 27, October 1996.

6. Quian, Xuede, R.M. Koerner, D. H. Gray, "Geotechnical Aspects of Landfill Design and Construction." Prentice-Hall, Inc., New Jersey, 2002.

7. Advanced Drainage Systems, Inc. *Structural Performance of Corrugated PE Pipe Using the Burns and Richard Solution,* October 2003.

SOLUTION:

A. Determine the critical load and stress:

A.1. Maximum construction loading:

Assume: CAT 637E Series II scraper with an even load distribution

Loaded weight =	190,500	lb
Tire pressure =	80	psi
Number of tires =	4	

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F = Force exerted by one tire (lb)

F =	47,625	lb

Determine area of contact for circular tire imprint:

$$r = (F/\pi p)^{1/2}$$

Where:
r = Radius of contact (in)
F = Force exerted by one tire (lb)
p = Tire pressure (psi)

r =	13.8	in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p\,(1 - ((r/z)^2+1)^{-3/2})$$

Where:
y = Change in vertical stress (psi)
p = Tire pressure (psi)
r = Radius of contact (in)
z = Protective cover thickness (in)

z = 24 in

y =	27.8	psi

Assume only one wheel load on pipe and add 50% for impact loading:

P_L = 1.5y

Where: P_L = Maximum live load (psi)

P_L =	41.7	psi

P_D = (zw)/1728

Where: P_D = Maximum dead load (psi)
z = Protective cover thickness (in)
w = Unit weight of protective cover (pcf)

z =	24	in
w =	108	pcf

P_D =	1.50	psi

P_T = P_L + P_D

Where: P_T = Maximum construction load (psi)

P_T =	43.2	psi

A.2. Overburden loading (postclosure load):

For maximum fill load on pipe:

2.0	ft protective cover @	108	pcf =	216	psf	
3.5	ft final & intrm cover @	108	pcf =	378	psf	
130.0	ft solid waste/soil @	61	pcf =	7,930	psf	Highest waste column thickness
			Σ =	8,524	psf	over a 6" LCS pipe.

P_T =	59.2	psi

Determine critical loading condition:

Construction loading:	P_T =	43.2	psi
Overburden loading:	P_T =	59.2	psi

Overburden loading is most critical to the structural stability of the pipe and will be used to determine the design pipe stress.

Determine design stress:

1. Adjust critical stress to account for loss of strength in the pipe due to perforations:

$$P_{DES1} = 12P_T / (12 - l_p)$$

Where:

	l_p	= Cumulative length of perforations per foot of pipe
	P_T	= Critical pipe stress (psi)
	P_{DES1}	= Pipe stress adjusted for loss of strength (psi)

	6	holes / foot
	0.5	in / hole
l_p =	3.0	in/ft

From determination of critical loading:

P_T =	59.2	psi
P_{DES1} =	78.9	psi

Adjust pipe stress determined above to account for effects of soil arching:

2. The design pipe stress is estimated by accounting for the soil structure interaction between the buried leachate collection pipe and its backfill to obtain a realistic loading condition on the pipe.

2a. For the burial conditions shown on Figure 1 (page IIIC-B-18), the pipe may be classified as a positive projecting conduit.

2b. Because the pipe is flexible and will deflect in the vertical plane as shown on Figure 2 (page IIIC-B-19), the pipe will experience a reduction in loading due to soil arching. Soil arching is present when the soil column over the pipe settles and creates shear stresses in the surrounding soil. Those shear stresses will support the soil column, thereby reducing the load experienced by the pipe (see Figure 3, page IIIC-B-19).

2c. The load on the pipe will be estimated using Marston's Formula:

$$W_c = \gamma C_c B_c^2 \qquad (1)$$

$$C_c = \frac{e^{\pm 2k\mu(H_e/B_c)} - 1}{\pm 2k\mu} + \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu(H_e/B_c)} \qquad (2)$$

Where:
- W_c = Load per unit length of conduit (lb/ft)
- γ = Unit weight of soil above conduit (pcf)
- B_c = Outer diameter of conduit (ft)
- H = Height of fill above conduit (ft)
- H_e = Height of plane of equal settlement above critical plane (ft)
- k = Lateral pressure ratio (earth pressure coefficient)
- μ = tan ϕ
- ϕ = Angle of internal friction of pipe-zone backfill (PZB) (degrees)

$$H_e = \pm r_{sd}\, p \left(\frac{H}{B_c}\right) \qquad (3)$$

Where:
- r_{sd} = Settlement ratio
- p = Ratio of the conduit projection above the compacted soil liner to its diameter

$$r_{sd} = \frac{(S_m + S_g) - (S_f + dc)}{S_m} \qquad (4)$$

Where:
- S_m = Compression deformation of soil column adjacent to conduit
- S_g = Settlement of natural ground adjacent to conduit
- S_f = Settlement of conduit into foundation material
- dc = Vertical deflection of the conduit

It is assumed that for a leachate collection pipe S_g and S_f are equivalent. The equation settlement ratio, therefore, reduces to the following:

$$r_{sd} = \frac{S_m - dc}{S_m} \qquad (5)$$

Since the trench aggregate (PZB) is much stiffer than the pipe, dc is larger than S_m implying that r_{sd} will be negative. Because r_{sd} is negative, the pipe is categorized as an incomplete ditch as specified by Marston. Note that in the above equations, where a + and a - sign are used together, the upper sign corresponds to a positive r_{sd} and a the lower sign to a negative r_{sd}.

2d. Load analysis solution by trial and error

Step 1: Assume a value for the settlement ratio, r_{sd}.

r_{sd} = -0.64

Step 2: Calculate S_m based on the estimated vertical stress at the level of the pipe and the deformation modulus E of the PZB.

$S_m = P_{DES1}\,D / E_s$

Where:

P_{DES1}	= Pipe stress adjusted for loss of strength (psi)
D	= Pipe diameter (in)
E_s	= PZB soil modulus (psi)

P_{DES1} =	78.9	psi
D =	6.625	in
E_s =	3,000	psi

S_m =	0.174	in

Step 3: Calculate dc using Equation (5):

$dc = S_m\,(1 - r_{sd})$

dc =	0.285	in

Step 4: Use the Iowa Formula (provided below) to calculate load per unit length (W_c).

$$W_c = \frac{dc}{(DL)k}\left(\frac{EI}{r^3} + 0.061E'\right)$$

Where:

DL	= Deflection lag factor
k	= Bedding factor
E	= Young's modulus for pipe material (psi)
I	= Moment of inertia for pipe wall = $t^3/12$ (in^4/in)
r	= Pipe radius (in)
E'	= Modulus of soil reaction (psi)

DL =	2.5	(Ref 6)
k =	0.1	(Ref 6)
E =	33,500	psi (refer to chart 25 on page IIIC-B-20, based on PDES1 above)
t =	0.390	in (SDR 17 pipe)
I =	0.005	in^4/in
r =	3.3	in
E' =	3,000	psi

W_c =	214	lb/in

Step 5: Calculate C_c using Equation 1:

$$C_c = \frac{W_c}{\gamma B_c^{\ 2}}$$

Composite unit weight for waste and soil:

5.5	ft soil @	108	pcf =	594	psf
130.0	ft waste @	61	pcf =	7,930	psf
			Total =	8,524	psf

γ =	62.91	pcf (weighted average based on above table)
B_c =	6.625	in

C_c =	133.8	(unitless)

Step 6: Solve for H_e/B_c using Equation 2 in an iterative manner:

	H =	130	ft
	H/B_c =	235.5	
Assume:	H_e/B_c =	2.19	
	$k\mu$ =	0.13	(Ref 4)
	$e^{-2k\mu(He/Bc)}-1$ =	-0.43	
	$-2k\mu$ =	-0.26	
	$(H/B_c - H_e/B_c)$ =	233.3	
	$e^{-2k\mu(He/Bc)}$ =	0.57	

Left-hand-side of equation (LHS) = 134
Right-hand-side of equation (RHS) = 134

Step 7: Substitute H_e/B_c into equation given below to determine if proper value for r_{sd} was used.

$$\left[\frac{1}{2k\mu} \pm \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) \pm \frac{r_{sd}\,p}{3}\right] \frac{e^{\pm 2k\mu (H_e/B_c)} - 1}{\pm 2k\mu} \pm \frac{1}{2}\left(\frac{H_e}{B_c}\right)^2$$
$$\pm \frac{r_{sd}\,p}{3}\left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu (H_e/B_c)} - \frac{1}{2k\mu}\left(\frac{H_e}{B_c}\right) \mp \left(\frac{H}{B_c}\right)\left(\frac{H_e}{B_c}\right) = \pm r_{sd}\,p\left(\frac{H}{B_c}\right)$$

Because r_{sd} is negative for the incomplete ditch condition, the lower signs in the above equation are used.

p =	1
kμ =	0.13
H/B_c =	235.5
H_e/B_c =	2.19
r_{sd} =	-0.64
LHS =	150
RHS =	150

If LHS is not approximately equal to RHS, adjust value for r_{sd} in Step 1 and repeat solution procedure.

2e. Once the solutions to the above equations are determined, the design pipe stress may be calculated and the deflection of the pipe determined.

$P_{DES2} = W_c / D$

Where: P_{DES2} = Load on pipe adjusted to account for effects of soil arching (psi)

W_c =	214	lb/in
D =	6.6	in
P_{DES2} =	32	psi

A summary table for the structural stability analysis is provided on page IIIC-B-17 for the 6-inch-diameter leachate collection pipe. A pipe will be selected from this table for use in the collection system based on the calculated factors of safety for each possible failure condition. An example calculation is provided below that outlines the procedures used to determine the factors of safety for all pipe SDR sizes shown in the summary table.

B. Use the critical loading pressure to analyze pipe stability:

Example pipe structural stability calculations:

SDR	= Standard dimension ratio	=	17	
S_Y	= compressive yield strength	=	1,500	psi
RD_{all}	= allowable ring deflection	=	4.2	%

1. Wall crushing (Ref 3)

$S_A = P_{DES2}$ (SDR - 1) / 2 FS $= S_Y / S_A$

Where:
- S_A = Actual compressive stress (psi)
- SDR = Standard dimension ratio
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- S_Y = Compressive yield strength (psi)
- FS = Factor of safety against wall crushing

P_{DES2} = 32 psi

S_A =	258.2	psi
FS =	5.8	

Compare calculated and suggested factor of safety:	5.8	> 1.0

2. Wall buckling (Ref 3)

$P_{cb} = 0.8\ (E'\ (2.32E / SDR^3))^{1/2}$ FS $= P_{cb} / P_{DES2}$

Where:
- P_{cb} = Critical buckling pressure at top of pipe (psi)
- E' = Soil modulus (psi)
- E = Stress/time dependent tensile modulus for design loading conditions (psi)
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- FS = Factor of safety against wall buckling

E' =	3,000	psi
E =	25,000	psi for 50 years based on SA above (see chart page IIIC-B-20)
P_{DES2} =	32	psi

P_{cb} =	150.6	psi
FS =	4.7	

Compare calculated and suggested factor of safety:	4.7	> 1.0

3. Ring deflection (Ref 3)

$E_S = P_{DES2} / E'$

Where:
- E_S = Soil strain (%)
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- E' = Soil modulus (psi)

P_{DES2} =	32	psi
E' =	3,000	psi

E_S =	1.1	%

Ring deflection for buried HDPE pipe is conservatively the same (no more than) the vertical compression of the soil envelope around the pipe. Therefore, assumed actual ring deflection (RD_{act}) is equal to soil strain.

RD_{act} = 1.1 %

Allowable ring deflection, RD_{all} = 4.20 %

$RD_{act} < RD_{all}$, design is acceptable

Note: An additional factor of safety is inherent to the design of the leachate collection system due to the presence of a gravel envelope surrounding the leachate collection pipe. The gravel layer will transmit leachate in the event that the leachate collection pipe becomes plugged or crushed.

CITY OF MEADOW LANDFILL
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LEACHATE COLLECTION PIPE STRUCTURAL STABILITY
6" DIA PIPE

Adjusted load to account for soil arching = 32 psi

	Wall Crushing			Wall Buckling				Ring Deflection			
SDR	S_Y	S_A	FS_{WC}	E[2]	E'	P_{cb}	FS_{WB}	RD_{all}	E'	RD_{act}	FS_{RD}
32.5	1,500	508.4	3.0	19,000	3,000	49.7	1.5	8.1	3,000	1.1	7.5
26.0	1,500	403.5	3.7	21,500	3,000	73.8	2.3	6.5	3,000	1.1	6.0
21.0	1,500	322.8	4.6	24,000	3,000	107.4	3.3	5.2	3,000	1.1	4.8
19.0	1,500	290.5	5.2	24,500	3,000	126.1	3.9	4.7	3,000	1.1	4.4
17.0 [1]	1,500	258.2	5.8	26,000	3,000	153.5	4.8	4.2	3,000	1.1	3.9
15.5	1,500	234.0	6.4	27,000	3,000	179.7	5.6	3.9	3,000	1.1	3.6
13.5	1,500	201.9	7.4	28,000	3,000	224.9	7.0	3.4	3,000	1.1	3.2
11.0	1,500	161.4	9.3	30,000	3,000	316.9	9.8	2.7	3,000	1.1	2.5

[shaded box] denotes standard size

[1] Select 6-inch-diameter HDPE SDR 17.0 pipe for use in the leachate collection system based on the calculated factors of safety.

[2] Values for the modulus of elasticity were selected from the attached chart (page IIIC-B-20), Reference 3, using the calculated stress in the pipe wall (S_A under the wall crushing heading in the above table) for a 50 year duration (maximum loading is the overburden load on the pipe).

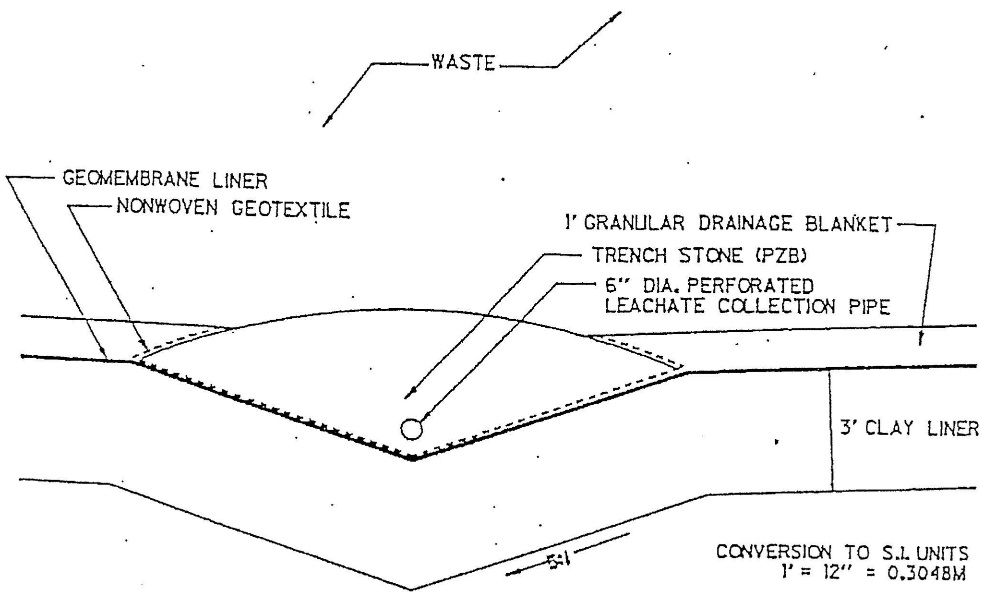


FIGURE 1: TYPICAL V-SHAPED TRENCH FOR LANDFILLS WITH COMPOSITE LINERS

/ol/users/jow/prgetren.dgn

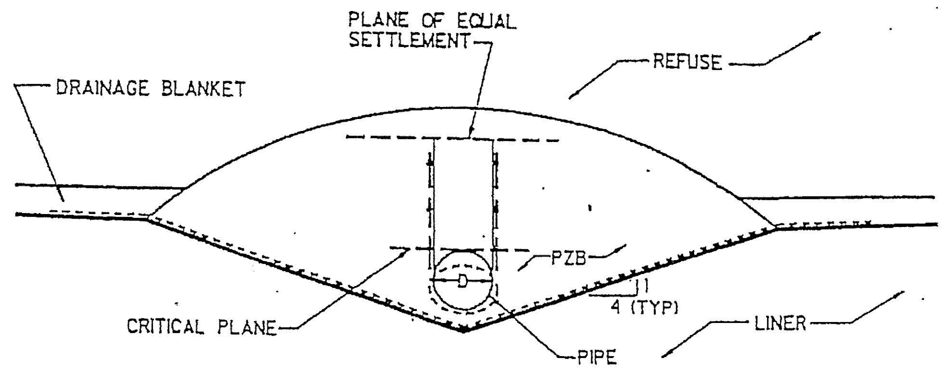


FIGURE 2: SETTLEMENT OF LEACHATE PIPE INDUCING SHEAR STRESSES IN PZB

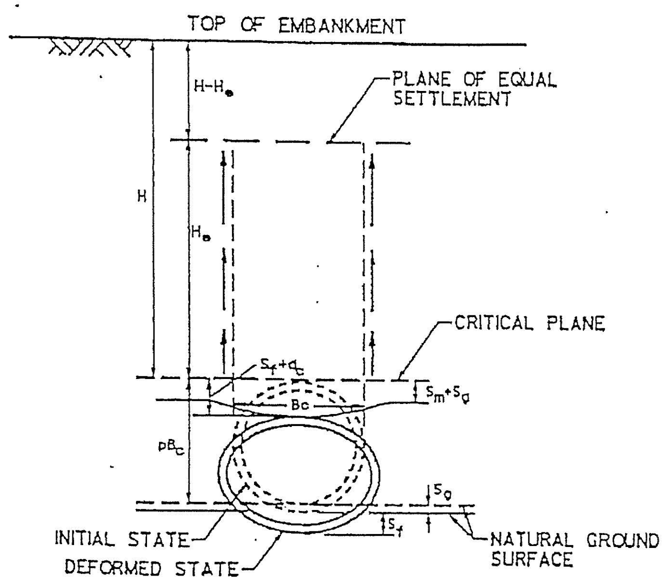


FIGURE 3: CASE OF AN INCOMPLETE DITCH CONDITION FOR A POSITIVE PROJECTING CONDUIT

/dl/users/jow/prgetran.dgn

here: S_A = Actual compressive stress, psi
SDR = Standard Dimension Ratio
P_T = External Pressure, psi

Safety Factor = 1500 psi ÷ S_A where 1500 psi is the Compressive Yield Strength of Driscopipe.

Design by Wall Buckling: Local wall buckling is a longitudinal wrinkling of the pipe wall. Tests of *non-pressurized* Driscopipe show that buckling and collapse do not occur when the soil envelope is in full contact with the pipe and is compacted to a dense state. However, it can be forced to occur over the long term in *non-pressurized* pipe if the total external soil pressure, P_t, is allowed to exceed the pipe-soil system's critical buckling pressure, P_{cb}. If $P_t > P_{cb}$, gradual collapse may occur over the long term. A calculated, conservative value for the critical buckling pressure may be obtained by the following approximate formula. All pipe diameters with the same SDR in the same burial situation have the same critical collapse and critical buckling endurance

$$P_{cb} = 0.8\sqrt{E' \times P_c}$$

Where:

P_t = Total vertical soil pressure at the top of the pipe, psi

P_{cb} = Critical buckling soil pressure at the top of the pipe, psi

E' = Soil modulus in psi calculated as the ratio of the vertical soil pressure to vertical soil strain at a specified density

P_c = Hydrostatic, critical-collapse differential pressure, psi

$$P_c = \frac{2E\,(t/D)^3\,(D_{MIN}/D_{MAX})^3}{(1-\mu^2)}$$

$$P_c = \frac{2.32\,E}{(SDR)^3}$$

Where: $(D_{MIN}/D_{MAX}) = .95$
μ = Poission's Ratio
μ = .45 for Driscopipe
E = stress and time dependent tensile modulus of elasticity, psi

In a direct burial pressurized pipeline, the internal pressure is usually great enough to exceed the external critical-buckling soil pressure. When a pressurized line is to be shut down for a period, wall buckling should be examined.

Design by Wall Buckling Guidelines:
Although wall buckling is seldom the limiting factor in the design of a Driscopipe system, a check of non-pressurized pipelines can be made according to the following steps to insure $P_t < P_{cb}$.

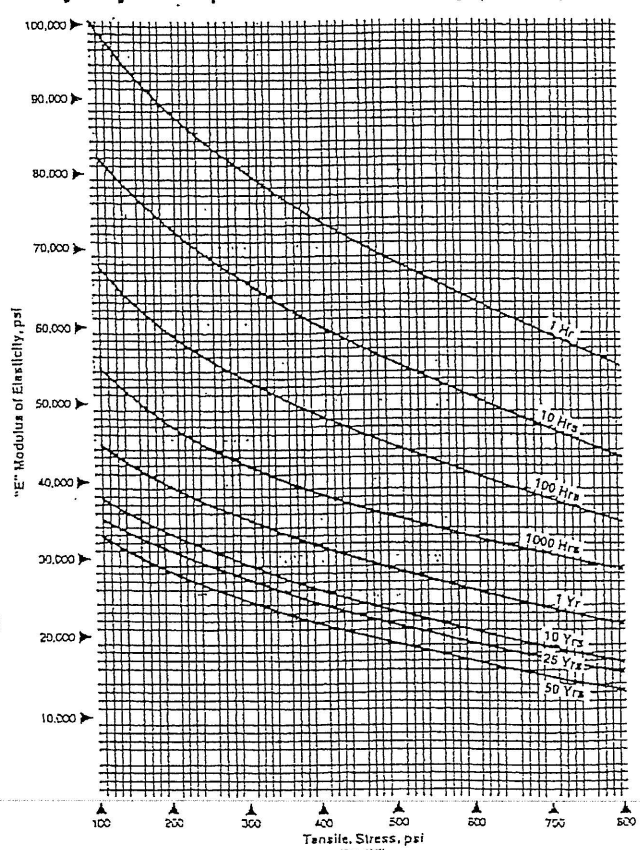
1. Calculate or estimate the total soil pressure, P_t, at the top of the pipe.
2. Calculate the stress "S_A" in the pipe wall according to the formula:

$$S_A = \frac{(SDR - 1)\,P_t}{2}$$

3. Based upon the stress "S_A" and the estimated time duration of non-pressurization, use Chart 25 to find the value of the pipe's modulus of elasticity, E, in psi.

Chart 25

Time Dependent Modulus of Elasticity for Polyethylene Pipe vs. Stress Intensity (73.4°F)



NOTE: The short term modulus of elasticity of Driscopipe per ASTM D 638 is approximately 100,000 psi. Due to the cold flow (creep) characteristic of the pipe material, this modulus is dependent upon the stress intensity and the time duration of the applied stress.

Simplified Burial Design: A conservative estimate of the ability of Driscopipe pipelines to perform in a buried environment is found in Chart 24. It is based on a minimum 2:1 safety factor and 50 year design service life. A detailed burial design starts on page 37. The detailed design should be used for critical or marginal applications or whenever a more precise solution is desired.

Detailed Burial Design:
Design by Wall Crushing: Wall crushing would theoretically occur when the stress in a pipe wall, due to the external vertical pressure, exceeded the long-term compressive strength of the pipe material. To ensure that the Driscopipe wall is strong enough to endure the external pressure the following check should be made:

$$S_A = \frac{(SDR - 1)}{2} P_T$$

Values of E′

Based on Soil Type (ASTM D2321) and Degree of Compaction

Soil Type of Initial Backfill Embedment Material	Description	E′ (psi) for Degree of Compaction (Proctor Density, %) Loose	Slight (70-85%)	Moderate (85-95%)	High (95%)
I	Manufactured angular, granular materials (crushed stone or rock, broken coral, cinders, etc.)	1,000	3,000	3,000	3,000
II	Coarse grained soils with little or no fines	N.R.	1,000	2,000	3,000
III	Coarse grained soils with fines	N.R.	N.R.	1,000	2,000
IV	Fine-grained soils	N.R.	N.R.	N.R.	N.R.
V	Organic soils (peat, muck, clay, etc.)	N.R.	N.R.	N.R.	N.R.

N.R. = Not Recommended for use by ASTM D2321 for pipe wall support

Chart 24

SDR	Maximum Burial Depth, ft. in dry soil of 100 lbs/cu. ft. — Soil Modulus, psi* 1000	2000	3000	Maximum External Pressure psi — Soil Modulus, psi* 1000	2000	3000	Maximum Deflection, % after installation — Soil Modulus, psi* 1000	2000	3000
32.5	25	32	37	17	22	26	1.7	0.9	0.6
26	33	45	52	23	31	36	2.3	1.2	0.8
21	46	61	71	32	42	49	3.2	1.6	1.1
19	52	69	81	36	48	56	3.6	1.8	1.2
17	61	121	181	42	84	126	4.2	2.1	1.4
15.5	56	112	168	39	78	117	3.9	2.0	1.3
13.5	49	98	147	34	68	102	3.4	1.7	1.1
11	39	78	117	27	54	81	2.7	1.4	0.9
9.3	33	68	101	23	47	70	2.3	1.2	0.8
8.3	30	61	89	21	42	62	2.1	1.1	0.7
7.3	26	52	79	18	36	55	1.8	0.9	0.6

*assumes no external loads

CITY OF MEADOW LANDFILL
0120-809-11-05
LEACHATE COLLECTION PIPE STRUCTURAL STABILITY
18"-DIA PIPE

REQUIRED: Analyze structural stability of the 18 inch diameter leachate collection system pipe.

METHOD:

A. Determine the critical load and calculate stress under the following two conditions:

1. Construction loading
2. Overburden loading

B. Use the critical loading pressure to analyze pipe stability under the following three possible failure conditions:

1. Wall crushing
2. Wall buckling
3. Ring deflection

NOTE: The leachate trench details shown on pages IIIC-B-18 and IIIC-B-19 are for illustration purposes only to show parameters used in the following calcualtions. Leachate collection system details can be found in Appendix IIIA-A.

REFERENCES:

1. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.

2. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.

3. Phillips 66 Driscopipe, *System Design* , 1991.

4. Landfill Design Series, *Leachate Gas Management Systems Design, Volume 5, Leachate Management and Storage,* Appendix A, 1993.

5. Caterpillar Tractor Company*, Caterpillar Performance Handbook,* Edition 27, October 1996.

6. Quian, Xuede, R.M. Koerner, D. H. Gray, "Geotechnical Aspects of Landfill Design and Construction." Prentice-Hall, Inc., New Jersey, 2002.

SOLUTION:

A. Determine the critical load and stress:

A.1. Maximum construction loading

Assume: CAT 637E Series II scraper with an even load distribution

Loaded weight =	190,500	lb
Tire pressure =	80	psi
Number of tires =	4	

For a circular tire imprint:

$$F = \frac{\text{Loaded Weight}}{\text{Number of Tires}}$$

Where: F = Force exerted by one tire (lb)

F =	47,625	lb

Determine area of contact for circular tire imprint:

$$r = (F/\pi p)^{1/2}$$

Where:
r = Radius of contact (in)
F = Force exerted by one tire (lb)
p = Tire pressure (psi)

r =	13.8	in

Use Boussinesq's solution to find the stress at a point below a uniformly loaded circular area:

$$y = p\,(1 - ((r/z)^2+1)^{-3/2})$$

Where:
y = Change in vertical stress (psi)
p = Tire pressure (psi)
r = Radius of contact (in)
z = Protective cover thickness (in)

z = 24 in

y =	27.8	psi

Assume only one wheel load on pipe and add 50% for impact loading:

P_L = 1.5y

Where: P_L = Maximum live load (psi)

P_L =	41.7	psi

P_D = (zw)/1728

Where:
P_D = Maximum dead load (psi)
z = Protective cover thickness (in)
w = Unit weight of protective cover (pcf)

z =	24	in
w =	108	pcf

P_D =	1.50	psi

P_T = P_L + P_D

Where: P_T = Maximum construction load (psi)

P_T =	43.2	psi

A.2. Overburden loading (postclosure load):

For maximum fill load on pipe:

2.0	ft gravel & cover @	108	pcf =	216	psf
3.5	ft final & intrm cover @	108	pcf =	378	psf
73	ft solid waste/soil @	52	pcf =	3,796	psf
			Σ =	4,390	psf

P_T =	30.5	psi

Determine critical loading condition:

Construction loading:	P_T =	43.2	psi
Overburden loading:	P_T =	30.5	psi

Construction loading is most critical to the structural stability of the pipe and will be used to determine the design pipe stress.

Determine Desing Stress:

1. Adjust critical stress to account for loss of strength in the pipe due to perforations:

$P_{DES1} = 12P_T / (12 - l_p)$

Where:

l_p	=	Cumulative length of perforations per foot of pipe
P_T	=	Critical pipe stress (psi)
P_{DES1}	=	Pipe stress adjusted for loss of strength (psi)

6	holes / foot
0.5	in / hole

l_p =	3.0	in/ft

From determination of critical loading:

P_T =	43.2	psi
P_{DES1} =	40.6	psi

Adjust pipe stress determined above to account for effects of soil arching:

2. The design pipe stress is estimated by accounting for the soil structure interaction between the buried leachate collection pipe and its backfill to obtain a realistic loading condition on the pipe.

2a. For the burial conditions shown on Figure 1 (page IIIC-B-18), the pipe may be classified as a positive projecting conduit.

2b. Because the pipe is flexible and will deflect in the vertical plane as shown on Figure 2 (page IIIC-B-19), the pipe will experience a reduction in loading due to soil arching. Soil arching is present when the soil column over the pipe settles and creates shear stresses in the surrounding soil. Those shear stresses will support the soil column, thereby reducing the load experienced by the pipe (see Figure 3, page IIIC-B-19).

2c. The load on the pipe will be estimated using Marston's Formula:

$$W_c = \gamma C_c B_c^{\,2} \qquad (1)$$

$$C_c = \frac{e^{\pm 2k\mu(H_e/B_c)} - 1}{\pm 2k\mu} + \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu(H_e/B_c)} \qquad (2)$$

Where:
- W_c = Load per unit length of conduit (lb/ft)
- γ = Unit weight of soil above conduit (pcf)
- B_c = Outer diameter of conduit (ft)
- H = Height of fill above conduit (ft)
- H_e = Height of plane of equal settlement above critical plane (ft)
- k = Lateral pressure ratio (earth pressure coefficient)
- μ = tan ϕ
- ϕ = Angle of internal friction of pipe-zone backfill (PZB) (degrees)

$$H_e = \pm r_{sd}\, p\left(\frac{H}{B_c}\right) \qquad (3)$$

Where:
- r_{sd} = Settlement ratio
- p = Ratio of the conduit projection above the compacted soil liner to its diameter

$$r_{sd} = \frac{\left(S_m + S_g\right) - \left(S_f + dc\right)}{S_m} \qquad (4)$$

Where:
- S_m = Compression deformation of soil column adjacent to conduit
- S_g = Settlement of natural ground adjacent to conduit
- S_f = Settlement of conduit into foundation material
- dc = Vertical deflection of the conduit

It is assumed that for a leachate collection pipe S_g and S_f are equivalent. The equation settlement ratio, therefore, reduces to the following:

$$r_{sd} = \frac{S_m - dc}{S_m} \qquad (5)$$

Since the trench aggregate (PZB) is much stiffer than the pipe, dc is larger than S_m implying that r_{sd} will be negative. Because r_{sd} is negative, the pipe is categorized as an incomplete ditch as specified by Marston. Note that in the above equations, where a + and a - sign are used together, the upper sign corresponds to a positive r_{sd} and a the lower sign to a negative r_{sd}.

2d. Load analysis solution by trial and error

Step 1: Assume a value for the settlement ratio, r_{sd}.

r_{sd} = -0.68

Step 2: Calculate S_m based on the estimated vertical stress at the level of the pipe and the deformation modulus E of the PZB.

$S_m = P_{DES1}\,D / E_s$

Where:
P_{DES1} = Pipe stress adjusted for loss of strength (psi)
D = Pipe diameter (in)
E_s = PZB soil modulus (psi)

P_{DES1} =	40.6	psi
D =	18	in
E_s =	3,000	psi

S_m =	0.244	in

Step 3: Calculate dc using Equation (5):

$dc = S_m\,(1 - r_{sd})$

dc =	0.409	in

Step 4: Use the Iowa Formula (provided below) to calculate load per unit length (W_c).

$$W_c = \frac{dc}{(DL)k}\left(\frac{EI}{r^3} + 0.061E'\right)$$

Where:
DL = Deflection lag factor
k = Bedding factor
E = Young's modulus for pipe material (psi)
I = Moment of inertia for pipe wall = $t^3/12$ (in^4/in)
r = Pipe radius (in)
E' = Modulus of soil reaction (psi)

DL =	2.5	(Ref 6)
k =	0.1	(Ref 6)
E =	33,000	psi (refer to chart 25 on page IIIC-B-20, based on PDES1 above)
t =	1.059	in (SDR 17 pipe)
I =	0.099	in^4/in
r =	9.0	in
E' =	3,000	psi

W_c =	307	lb/in

Step 5: Calculate C_c using Equation 1:

$$C_c = \frac{W_c}{\gamma B_c^{\ 2}}$$

Composite unit weight for waste and soil:

5.5	ft soil @	108	pcf =	594	psf
73.0	ft waste/soil @	52	pcf =	3,796	psf
			Total =	4,390	psf

γ =	55.9	pcf (weighted average based on above table)
B_c =	18	in

C_c =	29.3	(unitless)

Step 6: Solve for H_e/B_c using Equation 2 in an iterative manner:

H =	79	ft
H/B_c =	52.3	

Assume: H_e/B_c = 2.27

kμ =	0.13	(Ref 4)
$e^{-2k\mu(He/Bc)}-1$ =	-0.45	
-2kμ =	-0.26	
$(H/B_c - H_e/B_c)$ =	50.1	
$e^{-2k\mu(He/Bc)}$ =	0.55	

Left-hand-side of equation (LHS) = 29
Right-hand-side of equation (RHS) = 29

Step 7: Substitute H_e/B_c into equation given below to determine if proper value for r_{sd} was used.

$$\left[\frac{1}{2k\mu} \pm \left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) \pm \frac{r_{sd}\,p}{3}\right] \frac{e^{\pm 2k\mu (H_e/B_c)} - 1}{\pm 2k\mu} \pm \frac{1}{2}\left(\frac{H_e}{B_c}\right)^2$$
$$\pm \frac{r_{sd}\,p}{3}\left(\frac{H}{B_c} - \frac{H_e}{B_c}\right) e^{\pm 2k\mu (H_e/B_c)} - \frac{1}{2k\mu}\left(\frac{H_e}{B_c}\right) \mp \left(\frac{H}{B_c}\right)\left(\frac{H_e}{B_c}\right) = \pm r_{sd}\,p\left(\frac{H}{B_c}\right)$$

Because r_{sd} is negative for the incomplete ditch condition, the lower signs in the above equation are used.

p =	1
kμ =	0.13
H/B_c =	52.3
H_e/B_c =	2.265
r_{sd} =	-0.68
LHS =	35
RHS =	35

If LHS is not approximately equal to RHS, adjust value for r_{sd} in Step 1 and repeat solution procedure.

2e. Once the solutions to the above equations are determined, the design pipe stress may be calculated and the deflection of the pipe determined.

$P_{DES2} = W_c / D$

Where: P_{DES2} = Load on pipe adjusted to account for effects of soil arching (psi)

W_c =	307	lb/in
D =	18.0	in
P_{DES2} =	17	psi

A summary table for the structural stability analysis is provided on page IIIC-B-33 for the 18-inch-diameter leachate collection pipe. A pipe will be selected from this table for use in the collection system based on the calculated factors of safety for each possible failure condition. An example calculation is provided below that outlines the procedures used to determine the factors of safety for all pipe SDR sizes shown in the summary table.

B. Use the critical loading pressure to analyze pipe stability:

Example pipe structural stability calculations:

SDR	= Standard dimension ratio	=	17	
S_Y	= compressive yield strength	=	1,500	psi
RD_{all}	= allowable ring deflection	=	4.2	%

1. Wall crushing (Ref 3)

$S_A = P_{DES2} (SDR - 1) / 2$ FS $= S_Y / S_A$

Where:
- S_A = Actual compressive stress (psi)
- SDR = Standard dimension ratio
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- S_Y = Compressive yield strength (psi)
- FS = Factor of safety against wall crushing

P_{DES2} = 17 psi

S_A =	136.4	psi
FS =	11.0	

Compare calculated and suggested factor of safety:	11.0	> 1.0

2. Wall buckling (Ref 3)

$P_{cb} = 0.8 (E' (2.32E / SDR^3))^{1/2}$ FS $= P_{cb} / P_{DES2}$

Where:
- P_{cb} = Critical buckling pressure at top of pipe (psi)
- E' = Soil modulus (psi)
- E = Stress/time dependent tensile modulus for design loading conditions (psi)
- P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
- FS = Factor of safety against wall buckling

E' =	3,000	psi
E =	29,000	psi for 50 years based on SA above (see chart page IIIC-B-20)
P_{DES2} =	17	psi

P_{cb} =	162.2	psi
FS =	9.5	

Compare calculated and suggested factor of safety:	9.5	> 1.0

3. Ring deflection (Ref 3)

$E_S = P_{DES2} / E'$

Where:
E_S = Soil strain (%)
P_{DES2} = Load pipe adjusted to account for effects of soil arching (psi)
E' = Soil modulus (psi)

P_{DES2} =	17	psi
E' =	3,000	psi

E_S =	0.6	%

Ring deflection for buried HDPE pipe is conservatively the same (no more than) the vertical compression of the soil envelope around the pipe. Therefore, assumed actual ring deflection (RDact) is equal to soil strain.

RD_{act} = 0.6 %

Allowable ring deflection, RD_{all} = 4.20 %

$RD_{act} < RD_{all}$, design is acceptable

ROYAL OAKS LANDFILL
0120-076-11-106
SUBTITLE D LEACHATE COLLECTION PIPE STRUCTURAL STABILITY
18"-DIA PIPE

Adjusted load to account for soil arching = 17 psi

	Wall Crushing			Wall Buckling				Ring Deflection			
SDR	S_Y	S_A	FS_{WC}	E[2]	E'	P_{cb}	FS_{WB}	RD_{all}	E'	RD_{act}	FS_{RD}
32.5	1,500	268.5	5.6	25,900	3,000	58.0	3.4	8.1	3,000	0.6	14.3
26.0	1,500	213.1	7.0	27,600	3,000	83.6	4.9	6.5	3,000	0.6	11.4
21.0	1,500	170.5	8.8	29,100	3,000	118.3	6.9	5.2	3,000	0.6	9.1
19.0	1,500	153.5	9.8	30,800	3,000	141.4	8.3	4.7	3,000	0.6	8.3
17.0 [1]	1,500	136.4	11.0	31,000	3,000	167.6	9.8	4.2	3,000	0.6	7.4
15.5	1,500	123.6	12.1	32,000	3,000	195.6	11.5	3.9	3,000	0.6	6.9
13.5	1,500	106.6	14.1	32,900	3,000	243.8	14.3	3.4	3,000	0.6	6.0
11.0	1,500	85.3	17.6	34,000	3,000	337.3	19.8	2.7	3,000	0.6	4.8

(shaded box) denotes standard size

[1] Select 18-inch-diameter HDPE SDR 17.0 pipe for use in the leachate collection system based on the calculated factors of safety.

[2] Values for the modulus of elasticity were selected from the attached chart (page IIIC-B-20), Reference 3, using the calculated stress in the pipe wall (S_A under the wall crushing heading in the above table) for a 50 year duration (maximum loading is the overburden load on the pipe).

LEACHATE SUMP DESIGN

REQUIRED: Size leachate collection sumps.

METHOD:

A. Use leachate production rates from HELP model and the sump drainage areas from Sheet IIIC-B-39. The largest drainage area is analyzed to provide for a conservative analysis. Sump details are provided in Appendix IIIA-A Liner and Final Cover System Details.
B. Determine geometry of sump and its corresponding storage capacity.
C. Assume pump size and determine the average pump cycle time.

REFERENCES:

1. Texas Natural Resource Conservation Commission, *Leachate Collection System Handbook* , 30 TAC 330.201, 1993.
2. Bass, J., *Avoiding Failure of Leachate Collection and Cap Drainage Systems* , Pollution Technology Review No. 138, Noyles Data Corporation, 1986.
3. Phillips 66 Driscopipe, *System Design* , 1991.
4. Heisler, Sanford I., P.E., Wiley Engineer's Desk Reference, John Wiley & Sons, Inc., New York, 1998.

SOLUTION:

A. Average flow rate into sump

A.1 Determine the per acre flow rate for specific leachate collection sumps.

The following tables summarize the fill conditions that are likely to be present within each cell and have the greatest contribution of leachate into the LCS and sump system. The average flow rates (lateral drainage in the LCS layer) are shown for each condition.

Leachate sump drainage areas are shown on Sheet IIIC-B-39 Sump Drainage Areas.

Sectors 1-18

From the HELP model results in Appendix IIIC-A:

The largest area draining to the sump is 18.5 acres (sump located in Sector 13).

For each fill condition, the highest leachate generation rate from the HELP runs were used to be conservative.

Condition	Average[1] cfy/ac	Average gpd/ac
Active, 10' Waste	0.0	0.0
Interim, 50' Waste	0.0	0.0
Interim, 100' Waste	1,287.5	26.4
Interim, 130' Waste	2,322.0	47.6
Closed, 130' Waste	493.5	10.1

[1]The leachate value is the sum of the leachate recirculated and the leachate collected for each condition, if applicable.

Sump for Sectors 1- 18

18.5 acres

Condition	Rate	Active		Inactive		Closed	
	(gpd/ac)	area (ac)	rate (gpd)	area (ac)	rate (gpd)	area (ac)	rate (gpd)
Active, 10' Waste	0.0	2.7	0.0	0.0	0.0	0.0	0.0
Interim, 50' Waste	0.0	3.4	0.0	0.0	0.0	0.0	0.0
Interim, 100' Waste	26.4	4.6	121.4	0.0	0.0	0.0	0.0
Interim, 130' Waste	47.6	4.1	195.1	18.5	880.3	0.0	0.0
Closed, 130' Waste	10.1	3.7	37.4	0.0	0.0	18.5	187.1
Total		18.5	353.9	18.5	880.3	18.5	187.1

B. Required storage capacity of sump

Assumed porosity of drainage stone: P = 0.35

$V_{Daily\ Inflow} = V_C / P$

1. Active

	V_C (gpd)	V_C (cu ft/day)	$V_{Daily\ Inflow}$ (cu ft/day)
Sectors 1-18	353.9	47.3	135.2

2. Inactive with Intermediate Cover

	V_C (gpd)	V_C (cu ft/day)	$V_{Daily\ Inflow}$ (cu ft/day)
Sectors 1-18	880.3	117.7	336.3

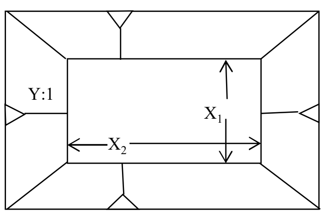
3. Closed

	V_C (gpd)	V_C (cu ft/day)	$V_{Daily\ Inflow}$ (cu ft/day)
Sectors 1-18	187.1	25.0	71.5

Total sump volume:

$$V_{TOT} = 1/3\left(A_1 + A_2 + \sqrt{(A_1 \cdot A_2)}\right)h$$ (Ref. 4, page 17)

Where:
A_1 = Area of bottom of sump
A_2 = Area of top of sump
h = Depth of sump



Y = Slope of sump side walls
$A_1 = X_1 * X_2$
$A_2 = (X_1 + 2(h*Y))*(X_2 + 2(h*Y))$

	X_1 (ft)	X_2 (ft)	Y (ft)	h (ft)	A_1 (ft^2)	A_2 (ft^2)	V_{TOT} (ft^3)
Sectors 1-18	15	15	3	3	225	1,089	1,809

Compute the number of days storage provided for the following:

$$\text{STORAGE (Detention Time)} = \frac{V_{TOT}}{V_{Daily\ Inflow}}$$

1. Active

	$V_{Daily\ Inflow}$ (cu ft/day)	V_{TOT} (cu ft)	Storage (days)
Sectors 1-18	135.2	1,809	13.4

2. Inactive with Intermediate Cover

	$V_{Daily\ Inflow}$ (cu ft/day)	V_{TOT} (cu ft)	Storage (days)
Sectors 1-18	336.3	1,809	5.4

3. Closed

	$V_{Daily\ Inflow}$ (cu ft/day)	V_{TOT} (cu ft)	Storage (days)
Sectors 1-18	71.5	1,809	25.3

C. Estimated rate of leachate removal.

Submersible pump capacity - Sectors 1-18 = 10 gpm

	Production	Average Pump Time	
	(gpd)	(min/day)	(hr/day)
Sectors 1-18			
-Active	353.9	35.4	0.6
-Inactive with Interm. Cover	880.3	88.0	1.5
-Closed	187.1	18.7	0.3

Average pump time is less than 24 hours per day, therefore the design is acceptable. A pump with less capacity may also be used if it can be determined that the actual leachate generation is less than the design flow.

SECTOR SUMMARY	
SECTOR	AREA (ACRES)
SECTOR 1	10.9
SECTOR 2	11.8
SECTOR 3	11.8
SECTOR 4	11.6
SECTOR 5	10.2
SECTOR 6	7.4
SECTOR 7	10.0
SECTOR 8	12.4
SECTOR 9	12.4
SECTOR 10	12.5
SECTOR 11	12.5
SECTOR 12	12.5
SECTOR 13	18.5
SECTOR 14	12.3
SECTOR 15	10.7
SECTOR 16	11.8
SECTOR 17	9.8
SECTOR 18	11.5

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMIT OF WASTE
- N 7180000 — STATE PLANE COORDINATE SYSTEM
- 3300 — EXISTING CONTOUR
- 3280 — TOP OF LINER CONTOUR
- SECTOR BOUNDARY
- LEACHATE COLLECTION PIPE
- LEACHATE COLLECTION SUMP
- LEACHATE RISER PIPE

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. ELEVATIONS SHOWN HEREON ARE RELATIVE TO THE NORTH AMERICAN VERTICAL DATUM OF 1988.
3. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED PROFESSIONAL ENGINEER
08/05/2024

- [ ] DRAFT
- [x] FOR PERMITTING PURPOSES ONLY
- [ ] ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: IIIC-B-39 SUMP DRAINAGE.DWG

DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: BPY

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS		
NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
SUMP DRAINAGE AREAS

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

WWW.WCGRP.COM

SHEET IIIC-B-38

O:\0120\809\EXPANSION 2023\PART III\IIIC\B\IIIC-B-38-SUMP DRAINAGE.dwg, jpuhr, 1:2

GEOTEXTILE DESIGN

REQUIRED: Determine geotextile properties for the following:

A. Geotextile "A" around the chimney drain granular drainage material. This is applicable to the liner systems.

B. Geotextile "B" used as top component of drainage geocomposite. This is applicable to the liner systems.

METHOD: Design geotextiles and determine material property requirements.

REFERENCES:

1. MIRAFI, *Geotextile Filter Design, Application, and Product Selection Guide* , 1991, http://www.tcmirafi.com/pdf/brochures/ef_guidelines.pdf.

2. Koerner, R.M., *Designing With Geosynthetics* , Fifth Edition, 2005.

3. AASHTO Designation: M288-17.

4. GRI White Paper #4, *Reduction Factors (RFs) Used in Geosynthetic Design,* Feb. 3, 2005, revised Mar. 1, 2007.

5. GRI *GRI-GN4 Standard ,* October. 3, 2018, revised Nov. 23, 2020.

SOLUTION:

A. Geotextile "A" Around the Chimney Drain Granular Drainage Material.

The design calculations assume the waste located above the chimney drain will have a hydraulic conductivity of $1.0x10^{-3}$ cm/s and the protective cover soil will consist of soils with a hydraulic conductivity less than $1.2x10^{-4}$ cm/s and percent fines (passing #200 sieve) greater than 20 percent.

If the protective cover material contains less than 20 percent fines, these geotextile calculations will be revised and included in the GLER for a specific sector to demonstrate the adequacy of the material used.

Retention:

Based on Chart 1 - "Soil Retention Criteria," given on page IIIC-B-46, the apparent opening size (O_{95}) may be determined.

O_{95} < 0.21 mm

Permeability:

The required permeability is determined by comparing the permeability of the overlying waste material ($1.0x10^{-3}$ cm/s) and the protective cover ($1.2x10^{-4}$ cm/s) with the permeability of the geotextile after the appropriate reduction factors are applied to the laboratory permeability of the geotextile.

Minimum Laboratory Permeability Specified (k_{ult}) = 0.2 cm/s

To determine the allowable permeability (k_{allow}) of the geotextile, the following reduction factors are used:

Table 1 - Reduction Factors[1]

RF_{SCB} =	Reduction factor for soil clogging and blinding	2.0
RF_{CR} =	Reduction factor for creep reduction of void space	2.0
RF_{IN} =	Reduction factor for adjacent materials intruding into void spaces	1.2
RF_{CC} =	Reduction factor for chemical clogging	1.5
RF_{BC} =	Reduction factor for biological clogging	2.0
	Overall Reduction Factor (ORF) =	14.4

[1] Reduction factors obtained from Ref. 4.

k_{allow} = k_{ult} / ORF = (0.2 cm/s) / 14.4

k_{allow} = 1.4E-02 cm/s

k_{allow} >> k_{waste} ($1.0x10^{-3}$ cm/s) or $k_{protective\ cover}$ ($1.2x10^{-4}$ cm/s).

Specification: Chimney drain geotextile permeability shall be equal to or greater than 0.2 sec^{-1} as determined by ASTM D 4491.

Survivability:

Geotextile properties should be selected considering Class 2 survivability (IIIC-B-46).

Durability:

Chemical compatibility with leachate will be considered during the selection process for the specific geotextile.

Summary of required properties for geotextile "A" (around the chimney drain granular drainage material):

Apparent opening size	<	0.21	mm
Grab tensile strength	>	157	lbs
Elongation	>=	50	%
Puncture strength	>	310	lbs
Trapezoid tear	>	55	lbs
Permitivity	>=	0.2	sec^{-1}

B. Geotextile "B" Used as Top Component of Drainage Geocomposite.

The design calculations assume the protective cover soil will consist of soils with a hydraulic conductivity less than 1.2×10^{-4} cm/s and percent fines (passing #200 sieve) greater than 20 percent.

If the protective cover material contains less than 20 percent fines, these geotextile calculations will be revised and included in the GLER for a specific cell to demonstrate adequacy of material used.

Retention:

Based on Chart 1 - "Soil Retention Criteria," given on page IIIC-B-47, the apparent opening size (O_{95}) may be determined.

O_{95} < 0.21 mm

Permeability:

The required permeability is determined by comparing the permeability of the protective cover (1.2×10^{-4} cm/s) with the permeability of the geotextile after the appropriate reduction factors are applied to the laboratory permeability of the geotextile.

Minimum Laboratory Permeability Specified (k_{ult}) = 0.2 cm/s

To determine the allowable permeability (k_{allow}) of the geotextile, the following reduction factors are used:

Table 2 - Reduction Factors[1]

RF_{SCB} =	Reduction factor for soil clogging and blinding	2.0
RF_{CR} =	Reduction factor for creep reduction of void space	2.0
RF_{IN} =	Reduction factor for adjacent materials intruding into void spaces	1.2
RF_{CC} =	Reduction factor for chemical clogging	1.5
RF_{BC} =	Reduction factor for biological clogging	2.0
	Overall Reduction Factor (ORF) =	14.4

[1] Reduction factors obtained from Ref. 4.

$k_{allow} = k_{ult}$ / ORF = (0.2 cm/s) / 14.4

k_{allow} = 1.4E-02 cm/s

$k_{allow} \gg k_{protective\ cover}$ (1.2×10^{-4} cm/s).

Specification: Geotextile component of geocomposite permeability shall be equal to or greater than 0.2 sec^{-1} as determined by ASTM D 4491.

Survivability:

Geotextile properties should be selected considering Class 2 survivability (IIIC-B-46).

Durability:

Chemical compatibility with leachate will be considered during the selection process for the specific geotextile.

Summary of required properties for geotextile "B" (top component of drainage geocomposite):

Apparent opening size	<	0.21	mm
Grab tensile strength	>	157	lbs
Elongation	>=	50	%
Puncture strength	>	310	lbs
Trapezoid tear	>	55	lbs
Permitivity	>=	0.2	sec^{-1}

Table 1—Geotextile Strength Property Requirements

			Geotextile Class[a,b]						
			Class 1A	Class 1		Class 2		Class 3	
	Test Methods	Units	Elongation <50%	Elongation <50%[c]	Elongation ≥50%[c]	Elongation <50%[c]	Elongation ≥50%[c]	Elongation <50%[c]	Elongation ≥50%[c]
Grab strength	ASTM D4632/ D4632M	N	–[e]	1400	900	1100	700	800	500
Sewn seam strength[d]	ASTM D4632/ D4632M	N	–[e]	1260	810	990	630	720	450
Tear strength	ASTM D4533/ D4533M	N	–[e]	500	350	400[f]	250	300	180
Puncture strength	ASTM D6241	N	–[e]	2750	1925	2200	1375	1650	990
Permittivity	ASTM D4491	sec⁻¹	Refer to Table 6.	Minimum property values for permittivity, AOS, and UV stability are based on geotextile application. Refer to Table 2 for subsurface drainage, Table 3 and Table 4 for separation, Table 5 for stabilization, and Table 7 for permanent erosion control.					
Apparent opening size	ASTM D4751	mm	Refer to Table 6.						
Ultraviolet stability (retained strength)	ASTM D4355/ D4355M	%	Refer to Table 6.	T					

[a] Required geotextile class is designated in Table 2, 3, 4, 5, 6, or 7 for the indicated application. The severity of installation conditions for the application generally dictates the required geotextile class. Class 1A and Class 1 are specified for more severe or harsh installation conditions where there is a greater potential for geotextile damage, and Classes 2 and 3 are specified for less severe conditions.

[b] All numeric values represent MARV in the weaker principal direction. (See Section 8.1.2.)

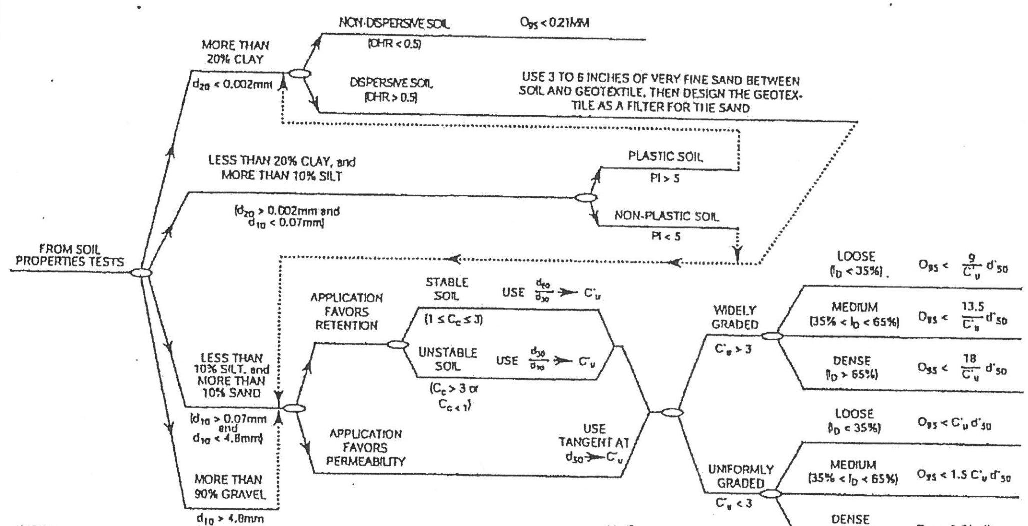
[c] As measured in accordance with ASTM D4632/D4632M.

[d] When sewn seams are required. Refer to Appendix X1 for overlap seam requirements.

[e] Property requirement not applicable to Class 1A. Refer to Table 6 for enhancement for wide width tensile property requirement.

[f] The required MARV tear strength for woven monofilament geotextiles is 250 N.

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



NOTES:

d_x = particle diameter of which size x percent is smaller

$$C'_u = \sqrt{\frac{d'_{100}}{d'_0}}$$

where: d'_{100} and d'_0 are the extremeties of a straight line drawn through the particle-size distribution, as directed above and d'_{50} is the midpoint of this line

$$C_c = \frac{(d_{30})^2}{d_{60} \times d_{10}}$$

I_D = relative density of the soil
PI = plasticity index of the soil
DHR = double-hydrometer ratio of the soil
O_{95} = geotextile opening size

CHIMNEY DRAIN CALCULATIONS

CITY OF MEADOW LANDFILL
0120-809-11-05
SUBTITLE D LEACHATE COLLECTION SYSTEM
CHIMNEY DRAIN CALCULATIONS

Required: Evaluate the adequacy of the chimney drain design along the leachate collection pipe for the maximum leachate impingement rate.

Method:

1. Determine the maximum leachate inflow rate into the chimney drain.
2. Determine the minimum drainage capacity of the chimney drain.
3. Compare the allowable flow rate to the required flow rate.

References:

1. GSE Nonwoven Geotextile (6 oz/sy).
2. GRI White Paper #4, *Reduction Factors (RFs) Used in Geosynthetic Design,* Feb. 3, 2005, revised Mar. 1, 2007.
3. HELP results from Appendix IIIC, Appendix IIIC-A.

Solution:

1. **Determine the maximum leachate inflow rate into the chimney drain.**

A comparison was developed to determine the worst case scenario (i.e., which scenario generates the maximum leachate inflow rate). The peak daily generation rate is from HELP model analyses in Appendix IIIC, Appendix IIIC-A.

Cells	**Peak Daily Generation Rate, q**		**Maximum Drainage Length, L**[1]	**Inflow Rate, Q_{req}**
	(cf/ac/day)	**(cfs/sf)**	**(ft)**	**(cfs)**
Sectors 1 through 18	25.8	6.86E-09	550	3.77E-06

[1] The maximum drainage length as shown takes in to account both sides draining to the chimney drain.

Maximum leachate inflow rate to the chimney drain per unit length (1 ft) is calculated using the following equation:

$$Q_{req} = L * 1 * q$$

where:

Q_{req} = Maximum leachate inflow rate into chimney drain, cfs
L = Maximum length draining to chimney drain from both sides
q = Peak daily leachate generation rate from HELP model listed above, cfs/sf

Maximum Leachate Generation Rate from above table:

Q_{req} =	3.77E-06	cfs

2. Determine the minimum drainage capacity of the chimney drain.

Minimum drainage capacity of the chimney drain per unit length (1 ft):

Q_{ult} = k * i * w * 1

where:

Q_{ult} = Ultimate flow rate
k = Minimum permeability of the geotextile wrap
i = Hydraulic gradient = 1 under free drainage
w = Width of the chimney drain keyed into the waste layer, measured at the top of protective layer, min. 3 ft, as shown in Appendix IIIA-A, Drawing A.4

k = 0.2 cm/s = 6.56E-03 fps (Ref. 1)
i = 1
w = 4 ft

Q_{ult} = 2.62E-02 cfs

To determine the allowable drainage capacity of the geotextile, the following reduction factors are used:

Table 1 - Reduction Factors[1]

RF_{SCB} = Reduction factor for soil clogging and blinding	2.0
RF_{CR} = Reduction factor for creep reduction of void space	2.0
RF_{IN} = Reduction factor for adjacent materials intruding into void spaces	1.2
RF_{CC} = Reduction factor for chemical clogging	1.5
RF_{BC} = Reduction factor for biological clogging	2.0
Overall Reduction Factor (ORF) =	14.4

[1] Reduction factors obtained from Ref. 2.

Q_{allow} = Q_{ult} / ORF

where:

Q_{allow} = Allowable flow rate
Q_{ult} = Ultimate flow rate
ORF = Overall reduction factor from Table 1

Q_{allow} = 1.82E-03 cfs

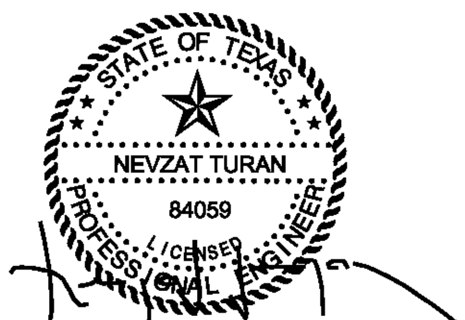
Q_{allow} = 1.82E-03 cfs >> Q_{req} = 3.77E-06 cfs

The predicted flow does not exceed the capacity of the chimney drain geotextile. The chimney drain design is adequate to convey the generated leachate to the leachate collection pipe.

APPENDIX IIIC-C

CONTAINMENT BERM AND DIVERSION BERM CALCULATIONS

Includes pages IIIC-C-1 through IIIC-C-8



08/05/2024

REQUIRED:

1. Determine the height of the contaminated water berm required at the working face.
2. Determine the height of the diversion berm required for run-on control of the working face.

PROCEDURE: **Containment Berm Calculations**

1. Determine the 25-year, 24-hour rainfall.
2. Calculate the volume of water captured behind the containment berm for 25-year, 24-hour rainfall event.
3. Calculate the height of the containment berm required to hold the volume of water calculated in step 2.

Diversion Berm Calculations

1. Determine the 25-year frequency runoff flow rates for the diversion berm run-on drainage areas by the Rational Method.
2. Calculate the capacity of the diversion berm swales at various slopes.
3. Calculate the height of the diversion berm required for the flow rate of run-on surface water.

REFERENCES:

1. NOAA Atlas 14 - Precipitation-Frequency Atlas of the United States, Volume 11, Version 2.0: Texas (U.S. Department of Commerce, National Oceanic and Atmospheric Administration, and National Weather Service, 2018)
2. Texas Department of Highways and Public Transportation, Bridge Division Hydraulic Manual, 3rd Ed, December 1985.
3. Dodson and Associates, Inc., *ProHec-1 Program Documentation* , 1993.

SOLUTION: **Containment Berm Calculations**

1. Based on Reference 1, the 25-year, 24-hour rainfall depth for Terry County is:

$R \approx$ 5.26 in

2. Determine the volume of storage required, V_R.

$V_R = CAR$

Where:				
	C = Runoff coefficient	=	0.5	
	A = Drainage area	=	varies	ac
	R = 25-year, 24-hour rainfall depth =		5.26	in

The storage volume required for varying drainage areas are shown on the attached table.

3. Determine the height of the containment berm for a non-sloping water storage area.

$$H = \frac{V_R}{A_{stor}}$$

Where: A_{stor} = Storage area (sf)

Values for height of the containment berm (H) are listed on Sheet IIIC-C-8 for several storage areas.

4. Determine the height of the berm for a sloping water storage area.

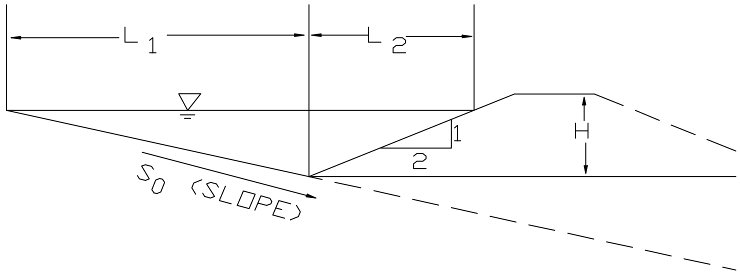
The volume contained by the berm is equal to the cross-sectional storage area multiplied by the width of the berm. The computed volume must be greater than the volume found in step 2.

$V_C = A_s W$

Where: A_s = Cross-sectional storage area (sf)
W = Width (ft)

The minimum width of the downstream berm is 100 feet.

Figure 1. Cross Section of Berm and Storage Area



$$A_s = \frac{(L_1 + L_2)H}{2}$$

Where:

$L_1 = \frac{H}{S_o}$ (ft)

$L_2 =$ 2H (ft)

$S_o =$ Slope of active cell (ft/ft)

<u>Example calculations:</u>

1. Non-sloping water storage area:

Variables:	S_o =	0.00	%	R =	5.26	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Volume: V_R = 4,773 cf

Height: H = 0.438 ft

2. Sloping water storage area:

Variables:						
	S_o =	1.00	%	R =	5.26	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Height: An iterative process is used to determine the height of the berm required to meet the storage volume requirement for a non-sloping storage area.

H = 0.97 ft

Check to ensure that the above berm height is adequate:

L_1 =	97.00	ft
L_2 =	1.94	ft
A_s =	47.99	sf
V_C =	4,799	cf

V_C is larger than V_R; berm has adequate height. See Sheet IIIC-C-5 and page IIIC-C-8 for summary.

3. Sloping water storage area:

Variables:						
	S_o =	2.00	%	R =	5.26	in
	A_{stor} =	0.25	ac	C =	0.5	
	A =	0.50	ac	W =	100	ft

Height: An iterative process is used to determine the height of the berm required to meet the storage volume requirement for a non-sloping storage area.

H = 1.37 ft

Check to ensure that the above berm height is adequate:

L_1 =	68.50	ft
L_2 =	2.74	ft
A_s =	48.80	sf
V_C =	4,880	cf

V_C is larger than V_R; berm has adequate height. See Sheet IIIC-C-5 and page IIIC-C-8 for summary.

CITY OF MEADOW LANDFILL
0120-809-11-05
CONTAINMENT BERM
CALCULATIONS SUMMARY

Drainage Area	Storage Area	Volume Required	Slope	Berm Height	Required Berm Height	Cross Sectional Area	Width	Water Surface Area	Volume Provided	L_1 [1]	L_2 [1]
(ac)	(ac)	(cf)	(%)	(ft)	(ft)	(sf)	(ft)	(ac)	(cf)	(ft)	(ft)
0.5	0.25	4,773	0	0.44	1.44						
			1	0.97	1.97	47.99	100	0.227	4,799	97.0	1.9
			2	1.37	2.37	48.80	100	0.164	4,880	68.5	2.7
1.0	0.50	9,547	0	0.44	1.44						
			1	1.40	2.40	99.96	100	0.328	9,996	140.0	2.8
			2	1.95	2.95	98.87	100	0.233	9,887	97.5	3.9
2.0	1.00	19,094	0	0.44	1.44						
			1	1.95	2.95	193.93	100	0.457	19,393	195.0	3.9
			2	2.75	3.75	196.63	100	0.328	19,663	137.5	5.5
4.0	2.00	38,188	0	0.44	1.44						
			1	2.75	3.75	385.69	100	0.644	38,569	275.0	5.5
			2	3.85	4.85	385.39	100	0.460	38,539	192.5	7.7

[1] L_1 and L_2 are shown on Sheet IIIC-C-3.

Diversion Berm Calculations

- As shown on Sheet IIIC-C-8, several swales were analyzed to determine the adequacy of the swale configuration.
- Hydraulic calculations are summarized on page IIIC-C-8.

The swales were analyzed by the Rational Method.

From Reference 2 for Terry County:

Q = CIA

Where: C= 0.5 (runoff coefficient, Ref 2.)
I = intensity in/hr
A= drainage area, ac

From Ref. 1, for
25-year storm event

t_c is assumed to be 10 min.

I = 7.97 in/hr

Diversion Berm Flow Rate Summary

Area(ac)	Flow Rate (cfs)
0.5	2.0
1	4.0
1.5	6.0
2	8.0
2.5	10.0
3	12.0

CITY OF MEADOW LANDFILL
0120-809-11-05
DIVERSION BERM
CALCULATION SUMMARY

For 33H:1V Diversion Berm Area Slope

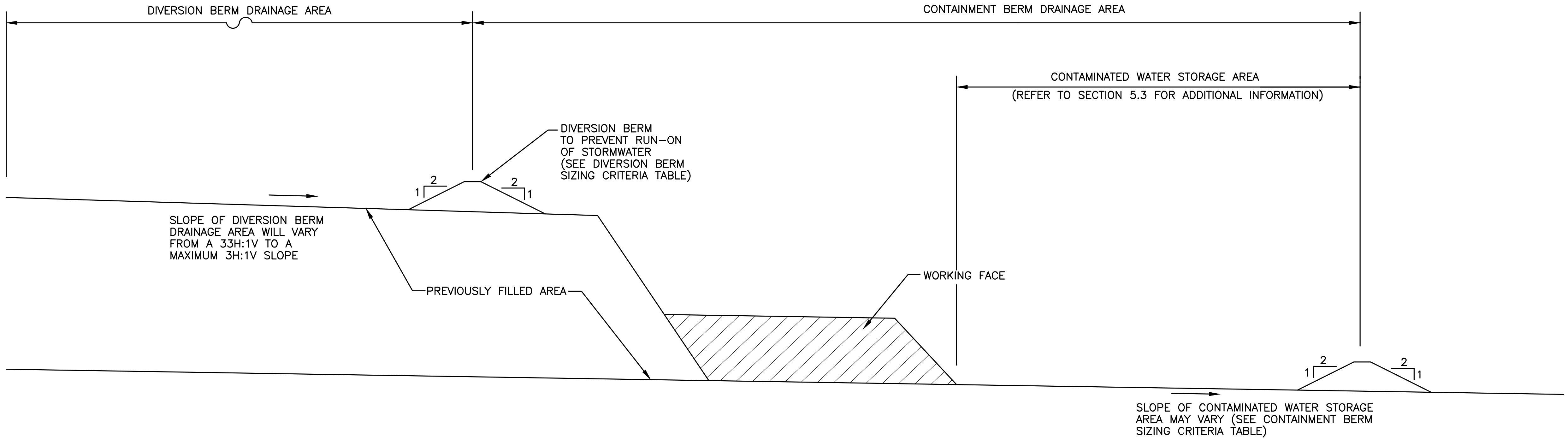
Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width(ft)	Normal Depth(ft)	Flow Vel. (fps)	Froude Number	Velocity Head(ft)	Energy Head(ft)	Flow Area (sf)	Flow Top Width(ft)
0.5	2.0	0.01	0.03	2	33.0	0	0.29	1.37	0.634	0.03	0.32	1.46	10.12
1	4.0	0.01	0.03	2	33.0	0	0.38	1.62	0.661	0.04	0.42	2.46	13.13
1.5	6.0	0.01	0.03	2	33.0	0	0.44	1.80	0.678	0.05	0.49	3.34	15.29
2	8.0	0.01	0.03	2	33.0	0	0.49	1.93	0.690	0.06	0.54	4.15	17.03
2.5	10.0	0.01	0.03	2	33.0	0	0.53	2.04	0.699	0.06	0.59	4.90	18.52
3	12.0	0.01	0.03	2	33.0	0	0.57	2.13	0.707	0.07	0.64	5.62	19.84

Note: Calculations were performed using the HYDROCALC Hydraulics for Windows developed by Dodson and Associates (Version 1.2a, 1996).

For 3H:1V Diversion Berm Area Slope

Drainage Area	Flow Rate (cfs)	Bottom Slope(ft/ft)	Manning's n	Side Slope (left)	Side Slope (right)	Bottom Width(ft)	Normal Depth(ft)	Flow Vel. (fps)	Froude Number	Velocity Head(ft)	Energy Head(ft)	Flow Area (sf)	Flow Top Width(ft)
0.5	2.0	0.01	0.03	2	3	0	0.61	2.14	0.683	0.07	0.68	0.93	3.06
1	4.0	0.01	0.03	2	3	0	0.79	2.54	0.712	0.10	0.89	1.57	3.97
1.5	6.0	0.01	0.03	2	3	0	0.92	2.81	0.728	0.12	1.05	2.14	4.62
2	8.0	0.01	0.03	2	3	0	1.03	3.02	0.742	0.14	1.17	2.65	5.15
2.5	10.0	0.01	0.03	2	3	0	1.12	3.20	0.755	0.16	1.28	3.12	5.59
3	12.0	0.01	0.03	2	3	0	1.20	3.34	0.761	0.17	1.37	3.59	5.99

Note: Calculations were performed using the HYDROCALC Hydraulics for Windows developed by Dodson and Associates (Version 1.2a, 1996).



DIVERSION BERM SIZING CRITERIA *

DIVERSION BERM DRAINAGE AREA (ACRES)	MINIMUM 33%			MAXIMUM 3%		
	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)	FLOW RATE (CFS)	FLOW DEPTH (FT)	REQUIRED MINIMUM DIVERSION BERM HEIGHT (FT)
0.5	2.0	0.29	1.29	2.0	0.61	1.61
1	4.0	0.38	1.38	4.0	0.79	1.79
1.5	6.0	0.44	1.44	6.0	0.92	1.92
2	8.0	0.49	1.49	8.0	1.03	2.03
2.5	10.0	0.53	1.53	10.0	1.12	2.12
3	12.0	0.57	1.57	12.0	1.20	2.20

* DIVERSION BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO CONTAIN STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON PAGES IIIC-C-6 THROUGH IIIC-C-7.

CONTAINMENT BERM SIZING CRITERIA *

CONTAINMENT BERM DRAINAGE AREA (ACRES)	CONTAMINATED WATER STORAGE AREA (ACRES)	FLOOR SLOPE OF CONTAMINATED WATER STORAGE AREA	CALCULATED MINIMUM HEIGHT OF CONTAINMENT BERM (FT)	REQUIRED MINIMUM HEIGHT OF CONTAINMENT BERM (FT)
0.5	0.25	0 % 1 % 2 %	0.44 0.97 1.37	1.44 1.97 2.37
1.0	0.50	0 % 1 % 2 %	0.44 1.40 1.95	1.44 2.40 2.95
2.0	1.00	0 % 1 % 2 %	0.44 1.95 2.75	1.44 2.95 3.75
4.0	2.00	0 % 1 % 2 %	0.44 2.75 3.85	1.44 3.75 4.85

* CONTAINMENT BERM WILL BE SIZED USING THE ABOVE TABLE AS A GUIDELINE TO CONTAIN STORMWATER FROM THE 25 YEAR, 24 HOUR STORM EVENT. SUPPORTING CALCULATIONS ARE INCLUDED ON PAGES IIIC-C-2 THROUGH IIIC-C-5. NOTE THAT THE CRITERIA SET FORTH IN THE ABOVE TABLE IS BASED ON A MINIMUM DOWNSLOPE CONTAINMENT BERM LENGTH OF 100 FEET.

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

- [ ] DRAFT
- [x] FOR PERMITTING PURPOSES ONLY
- [ ] ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: IIIC-C-8 DIVR BERM.DWG
DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: BPY

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

MAJOR PERMIT AMENDMENT
LEACHATE AND CONTAMINATED WATER PLAN

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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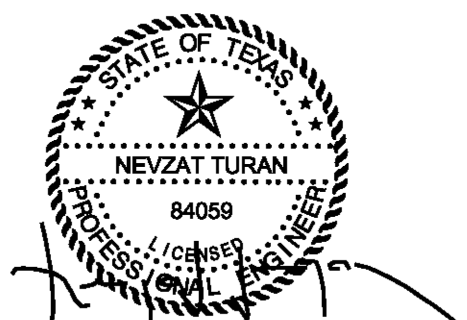
SHEET IIIC-C-8

APPENDIX IIIC-D

STORAGE TANK, EVAPORATION POND, AND FORCEMAIN CAPACITY CALCULATIONS

Includes pages IIIC-D-1 through IIIC-D-13



08/05/2024

Required: Determine the required leachate storage capacity for the site using HELP model results.

Method:

1. Determine the leachate volume using predicted leachate generation values from the HELP model.
2. Design the secondary containment area for the leachate storage tank.

Note: The site will have leachate storage tank(s) with a minimum storage capacity of 21,000 gallons. The following demonstration shows that a minimum of 21,000 gallons of leachate is sufficient to meet the leachate production needs of the site.

Solution: 1. **Determine the leachate volume using predicted leachate generation values from the HELP model.**

Results from the HELP model in Appendix IIIC-A.

Sectors 1-18:

Condition	Average[1] cfy/ac	Average gpd/ac
Active, 10' Waste	0.0	0.0
Interim, 50' Waste	0.0	0.0
Interim, 100' Waste	1,287.5	26.4
Interim, 130' Waste	2,322.0	47.6
Closed, 130' Waste	493.5	10.1

[1]The leachate value is the sum of the leachate recirculated and the leachate collected for each condition, if applicable.

Assume the following fill scenarios:

Storage Tanks		
Condition	Sectors 1 through 18 (210.7 acres)	
	(ac)	(gpd)
Active, 10' Waste	14.0	0
Interim, 50 Waste	36.0	0
Interim, 100' Waste	76.6	2,021
Interim, 130' Waste	54.6	2,598
Closed	29.5	298
Total:	210.7	4,918

Leachate Storage Tank Management Plan

Tank Size	**Leachate Generation, gallons per day**	**Management Plan**
21,000 gallon tank	4,918	The 21,000 gallon storage tank provides approximately 4.27 days of storage. Leachate will be discharged in accordance with Section 5.1 of Appendix IIIC.

2. Design the secondary containment area for the leachate storage tank.

A. Design the secondary containment area for one proposed 21,000 gallon tank.

Note: This calculation is based on a storage tank with the following dimensions. If a different tank is used, this calculation will be updated.

Minimum Tank Dimensions		
Length=	31	ft
Width=	10	ft
Height =	9	ft
Tank Volume =	20,869	gal

1) The layout footprint shown on Sheet IIIC-D-4 is planned for the secondary containment area.

2) Determine Available Secondary Containment Volume, V_{des}.

$V_{des} = 1/3\ (A_1 + A_2 + (A_1 * A_2)^{0.5})\ h$

$A_1 = X_1 * X_2$

$A_2 = (X_1 + 2(h*Y))*(X_2 + 2(h*Y))$

Where:

A_1 =	Area of bottom of containment area	
A_2 =	Area of top of containment area	
h =	Berm height	
X_1 =	Floor width	
X_2 =	Floor length	
Y =	Berm sideslope	

X_1 =	42	ft
X_2 =	34	ft
Y =	2	H:1V
h =	2	ft (without freeboard)
A_1 =	1,428	sf
A_2 =	2,100	sf

V_{des} =	3,506	cf

Note: The berm height provided will be 3 feet, which will allow 1 foot of freeboard.

3) Calculate Required Containment Volume, V_{req}.

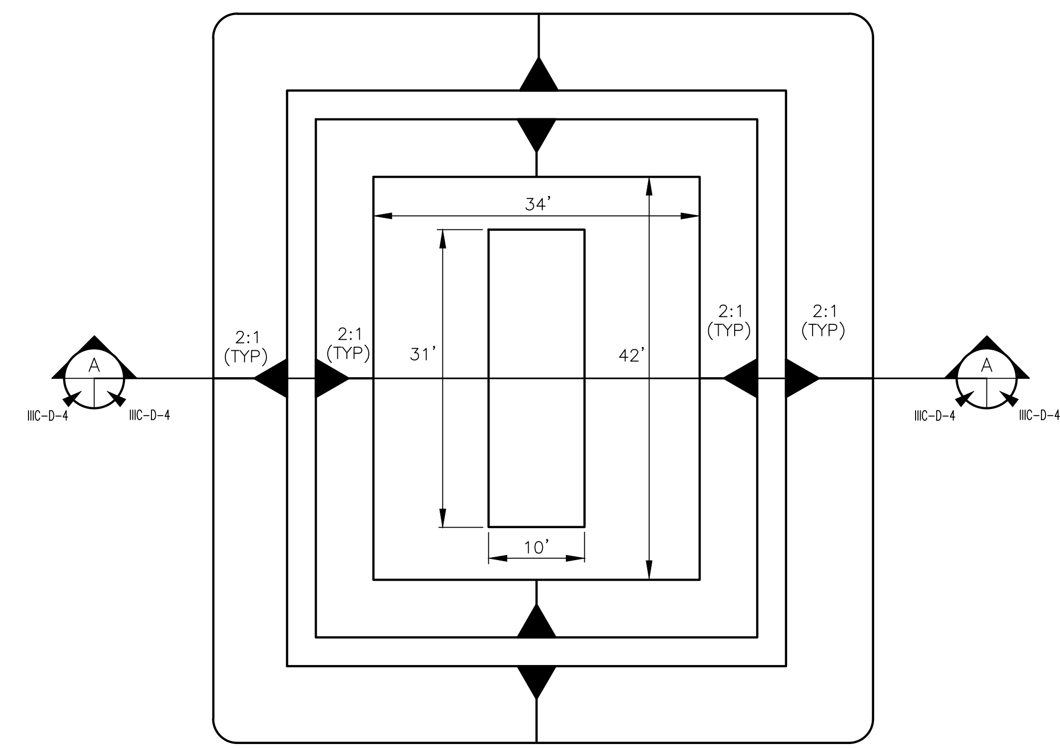
The containment area must be able to hold the volume of one tank and rainfall generated from the 25-year, 24-hour storm event (5.26 inches).

Volume of tank =	20,869	gal
=	2,790	cf
Number of tanks =	1	
Total tank volume =	2,790	cf
Volume of runoff (5.26 inches x A_1) =	626	cf

V_{req} =	3,416	cf

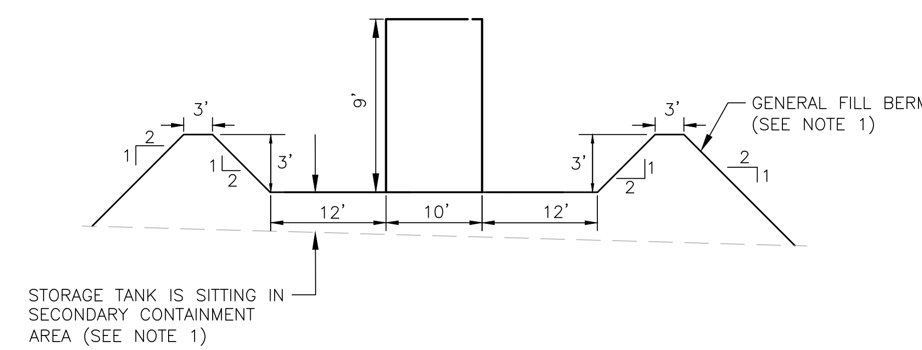
4) Verify that design is acceptable.

V_{des} =	3,506	cf	>	V_{req} =	3,416	cf



TEMPORARY LEACHATE STORAGE PLAN

0 10 20
SCALE IN FEET



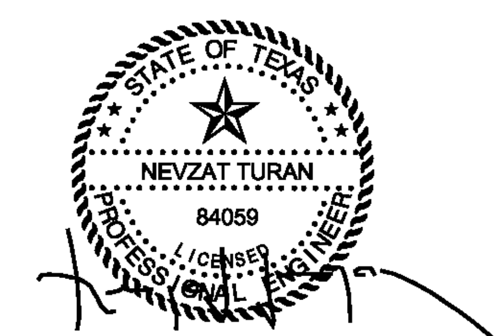
TYPICAL SECTION A IIIC-D-4 IIIC-D-4

0 10 20
SCALE IN FEET
HORIZONTAL

0 5 10
SCALE IN FEET
VERTICAL

NOTE:

1. THE CONTAINMENT BERMS AND FLOOR OF THE STORAGE TANK AREA WILL BE CONSTRUCTED OF CH OR CL MATERIAL AS DEFINED BY THE UNITED SOIL CLASSIFICATION SYSTEM (USCS). THE FLOOR OF THE STORAGE TANK AREA WILL BE A 2-FOOT THICK (MIN) BOTTOM.



08/05/2024

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DATE: 08/2024
FILE: 0120-809-11
CAD: D-4-LEACHATE STORAGE TANK.DWG

DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: BPY

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
LEACHATE STORAGE TANK DETAILS

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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SHEET IIIC-D-4

O:\0120\809\EXPANSION 2023\PART III\IIIC\D\D-4 TANK DETAILS.dwg, jpuhr, 1:2

Required: Evaluate the evaporation pond to demonstrate the working capacity.

Method:

1. Calculate the working capacity of the evaporation pond.
2. Determine the leachate volume using predicted leachate generation values from the HELP model.

Solution:

1. **Calculate the working capacity of the evaporation pond.**

Each pond provides 2 feet of freeboard. The storage volume below elevation 3314 ft-msl is:

Containment Structure	Working Capacity [1] (ft^3)	Working Capacity [1] (gal)
Evaporation Pond L2	79,944	597,981
Evaporation Pond L3	79,944	597,981

[1.] In all instances freeboard depth exceeds the 25-year, 24-hour storm event depth of 5.26 inches.

2. **Determine the leachate volume using predicted leachate generation values from the HELP model.**

Results from the HELP model in Appendix IIIC-A.

Sectors 1-18:

Condition	Average[1] cfy/ac	Average gpd/ac
Active, 10' Waste	0.0	0.0
Interim, 50' Waste	0.0	0.0
Interim, 100' Waste	1,287.5	26.4
Interim, 130' Waste	2,322.0	47.6
Closed, 130' Waste	493.5	10.1

[1]The leachate value is the sum of the leachate recirculated and the leachate collected for each condition, if applicable.

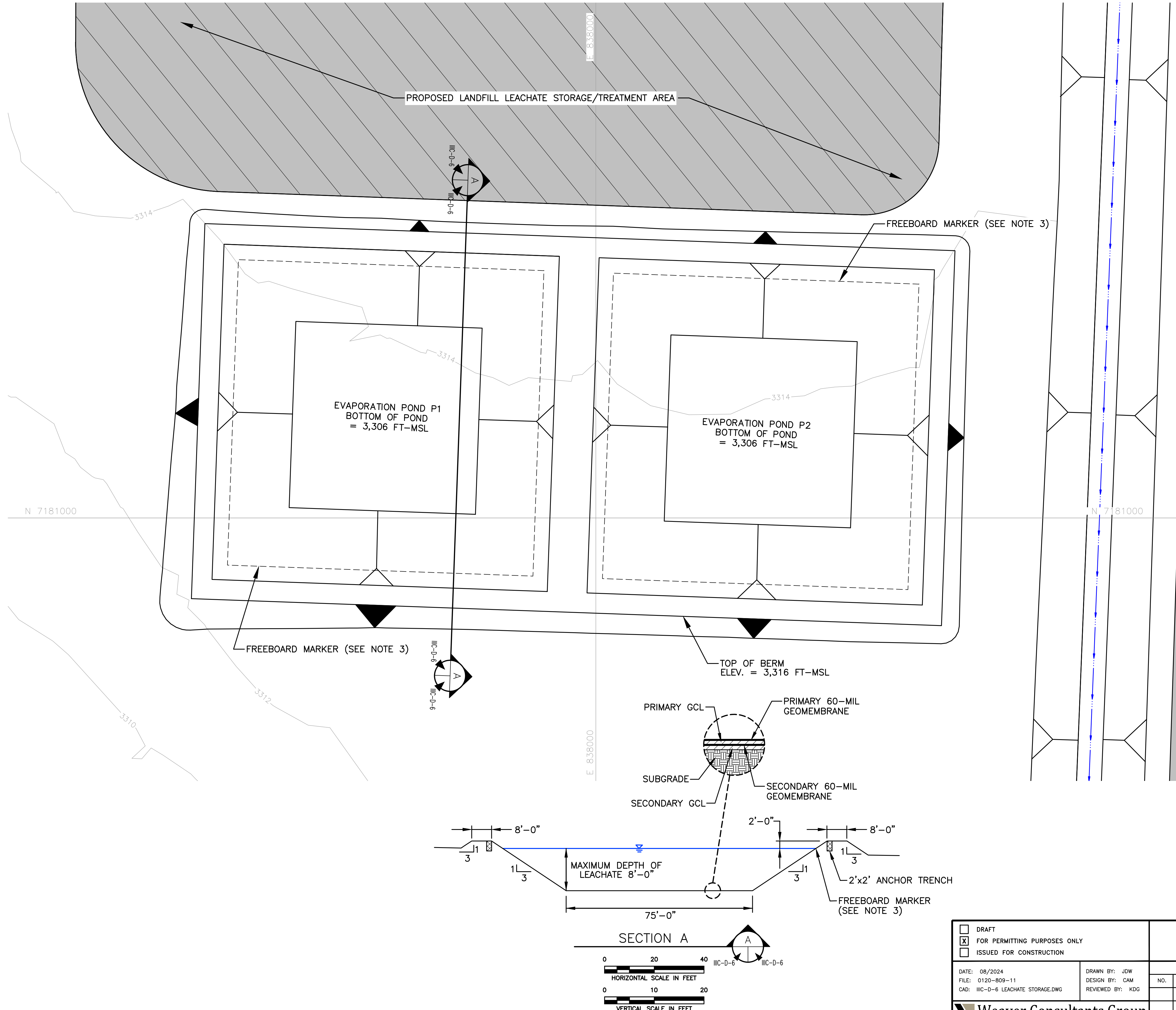
Assume the following fill scenarios:

Condition	Sectors 1 through 18	
	(ac)	(gpd)
Active, 10' Waste	14.0	0
Interim, 50 Waste	36.0	0
Interim, 100' Waste	76.6	2,021
Interim, 130' Waste	54.6	2,598
Closed	29.5	298
Total:	210.7	4,918

Conclusion:

Evaporation Pond Management Plan

Total Pond Working Capacity	**Leachate Generation (gpd)**	**Management Plan**
2 - 597,981 gallon ponds (1,195,962 total)	4,918	The 2 - 597,981 gallon evaporation ponds provides approximately 243 days of storage (121.5 days each). Leachate will be discharged in accordance with Section 5.1 of Appendix IIIC.



SCALE IN FEET (0, 20, 40)

LEGEND

- N 7180000 — STATE PLANE COORDINATE SYSTEM
- 3300 — EXISTING CONTOUR
- CHANNEL CENTERLINE

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. REFER TO LEACHATE POND CAPACITY CALCULATIONS FOR STORAGE INFORMATION.
3. 2 FEET VERTICALLY DOWN FROM THE TOP OF THE POND WILL BE CLEARLY MARKED WITH PAINT, OR A BEAD OF HDPE, OR SOME OTHER APPROPRIATE MARKING.
4. IN ALL INSTANCES FREEBOARD DEPTHS EXCEED THE 25-YEAR, 24-HOUR STORM EVENT DEPTH OF 5.26 INCHES.

STATE OF TEXAS
NEVZAT TURAN
84059
LICENSED
PROFESSIONAL ENGINEER
08/05/2024

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☒ FOR PERMITTING PURPOSES ONLY
☐ ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: IIIC-D-6 LEACHATE STORAGE.DWG

DRAWN BY: JDW
DESIGN BY: CAM
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
EVAPORATION POND DETAILS

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

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SHEET IIIC-D-6

O:\0120\809\EXPANSION 2023\PART III\IIIC\D\D-6 Leachate Storage Pond.dwg, jpuhr, 1:2

REQUIRED: Size the leachate forcemain collection pipe.

METHOD:

A. Use leachate production rates provided in Appendix IIIC-A (based on the HELP model analysis) to determine the required capacity of the leachate collection forcemain pipes.

B. Determine the capacity of the leachate collection system forcemain pipe.

C. Calculate the maximum pressure experienced by the forcemain pipe.

D. Evaluate the flow velocity in the forcemain pipe.

E. Conclusion.

REFERENCES:

1. Driscopipe Systems Design, Phillips 66. 1992 Phillips Driscopipe, Inc. 1235-91 A 01

SOLUTION:

A. Use leachate production rates provided in Appendix IIIC-A to determine the required capacity of the leachate collection forcemain pipe.

West Forcemain (Sectors 3 through 6 - 41.0 acres)

CONDITION	AREA[1]	AVERAGE ANNUAL FLOW		TOTAL FLOW	FLOW
	ac	cfy[2]	gpd/ac	gpd	cfs
10' to 50' Waste	8.0	0	0	0	0.0000
50' to 100' Waste	13.0	644	13	172	0.0003
100' to 130' Waste	20.0	1,805	37	740	0.0011
Total =	41.0				0.0014

East Forcemain (Sectors 1,2 and 7 through 18 - 169.7 acres)

CONDITION	AREA[1]	AVERAGE ANNUAL FLOW		TOTAL FLOW	FLOW
	ac	cfy[2]	gpd/ac	gpd	cfs
10' to 50' Waste	32.0	0	0	0	0.0000
50' to 100' Waste	63.8	644	13	842	0.0013
100' to 130' Waste	73.9	1,805	37	2,733	0.0042
Total =	169.7				0.0055

[1]Total limits of the Subtitle D area conveyed thorough the Forcemain is represented with different waste column thicknesses for demonstration purposes.

[2]The average annual flows in cubic feet per year (cfy) have been obtained from the HELP Model summary tables included on pages IIIC-A-10 and IIIC-A.1-7. The highest values for a given waste thickness have been used for demonstration purposes.

Total maximum leachate production west forcemain = Q = 0.0014 cubic feet per second (cfs)
Q = 1 gallons per minute (gpm)
Q = 911 gallons per day (gpd)

Total maximum leachate production east forcemain = Q = 0.0055 cubic feet per second (cfs)
Q = 2 gallons per minute (gpm)
Q = 3,575 gallons per day (gpd)

Required capacity of leachate forcemain pipe west forcemain = 911 gpd

Required capacity of leachate forcemain pipe east forcemain = 3,575 gpd

B. Determine the capacity of the leachate collection system forcemain pipe.

Capacity of the forcemain is calculated by using the following formula from Ref. 1.

$$\Delta P_{100} = \frac{452 * Q^{1.85}}{C^{1.85} * D^{4.86}} \quad \text{Eq. 1}$$

where:

ΔP_{100} = Friction pressure loss, pounds per square inch per 100 feet of pipe
Q = Rate of flow, gallons per minute
C = Pipe coefficient, See Chart 4 on Page IIIC-D-11
D = Pipe internal diameter, inches

Rearrange Equation 1 to solve for Q.

$$Q = \left(\frac{\Delta P_{100} * C^{1.85} * D^{4.86}}{452} \right)^{(1/1.85)} \quad \text{Eq. 2}$$

Calculate ΔP_{100}:

ΔP_{100} = (P - Δh) / (L/100)

where:

P = Pipe strength, psi
Δh = Geometric head difference, psi
L = Pipe length, ft

P = 160 psi (refer to page IIIC-D-9 for SDR11 pipe)

Calculate Δh:

West forcemain:

Elevation at the low point of forcemain =	3306	ft-msl
Elevation at the high point of forcemain =	3326	ft-msl
Δh =	20	ft

East forcemain:

Elevation at the low point of forcemain =	3286	ft-msl
Elevation at the high point of forcemain =	3326	ft-msl
Δh =	40	ft

Convert units from feet to psi:

Note: 1 psi is equal to 2.31 feet of water column.

Δh (psi) = Δh (ft) / (2.31 ft/psi)

Δh (west forcemain) =	8.67	psi
Δh (east forcemain) =	17.33	psi

Pipe Strength Available for Friction Loss = P - Δh

Pipe Strength for Friction Loss west forcemain=	151.33	psi
Pipe Strength for Friction Loss east forcemain=	142.67	psi

L (west forcemain)=	1,706	ft
L (east forcemain)=	7,732	ft

(Note: Forcemain length is assumed to be the total length encompassing the western and eastern side of the facility (refer to Figure 4-1 in Appendix IIIC for location). This is a conservative assumption given that it is assumed that the design pipe flow travels the maximum distance for estimating the total head loss.)

ΔP_{100} = (160 - 15.17)/(6,100/100)

West forcemain ΔP_{100} =	8.87	psi
East forcemain ΔP_{100} =	1.85	psi

Calculate maximum capacity of the 3-inch pipe by using Equation 2 above:

C = 155 (refer to page IIIC-D-10)
D = 1.943 inches, internal diameter of forcemain (refer to page IIIC-D-9)

$Q = [(\Delta P_{100} C^{1.85} D^{4.86})/452]^{(1/1.85)}$

$Q = [(2.37{*}155^{1.85}{*}2.864^{4.86})/452]^{(1/1.85)}$

West forcemain Q =	106	gpm
West forcemain Q =	152,658	gpd
East forcemain Q =	45	gpm
East forcemain Q =	65,330	gpd

The above calculated value reflects the maximum capacity of the pipe, which is greater than the required capacity (i.e., 152,658 gpd > 911 gpd - west forcemain and 65,330 gpd > 3,575 gdp - east forcemain).

C. Calculate the maximum pressure experienced by the forcemain pipe.

Calculate head loss in the 2-inch diameter forcemain using the following equation from Ref. 1:

$$\Delta P_{100} = \frac{452 * Q^{1.85}}{C^{1.85} * D^{4.86}}$$

West forcemain Q =	1	gpm (from Step A)
East forcemain Q =	2	gpm (from Step A)
C =	155	From Chart 4 on Page IIIC-D-10
D =	1.943	inches, diameter of discharge pipe contained in a 6-inch diameter containment pipe

West forcemain ΔP_{100} =	0.00068	psi
East forcemain ΔP_{100} =	0.00854	psi

Total head loss ($\Sigma\Delta P$) = ΔP_{100} * (L/100) = 0.0 psi x (1706/100)

West forcemain $\Sigma\Delta P$=	0.0116	psi
East forcemain $\Sigma\Delta P$=	0.6605	psi

To account for local head losses (elbows, etc.) multiply the calculated total head loss with a factor of safety of 1.2.

F.S.=	1.2	
West forcemain $\Sigma\Delta P$ * F.S.=	0.0139	psi
East forcemain $\Sigma\Delta P$ * F.S.=	0.0092	psi

Calculate total head at the pump:

$$P_{tot} = \Delta h + \Sigma\Delta P$$

where:

P_{tot} = Total head at pump, psi
Δh = Geometric head (from Step B)
$\Sigma\Delta P$= Total head loss, psi

P_{tot} = 0.15 psi + 12.57 psi

West forcemain P=	8.68	psi
East forcemain P=	17.34	psi

D. Evaluate the flow velocity in the forcemain pipe.

$$V = 0.408 * (Q/D^2)$$ (Ref. 1)

where:

Q = Rate of flow, gpm
D = Pipe internal diameter, inches

West forcemain Q =	1	gpm (from Step A)
East forcemain Q =	2	gpm (from Step A)
D =	1.943	inches
West forcemain V=	0.07	fps
East forcemain V=	0.27	fps

E. Conclusion.

The pipe capacity (106 gpm west forcemain and 45 gpm east forcemain) is not exceeded by the maximum expected flow of 2 gpm.

The forcemain can withstand 160 psi, and the maximum pressure calculated as 17.34 psi; therefore, the pipe strength is acceptable.

The calculated velocity of the 2-inch forcemain for 2 gpm of flow is well within acceptable flow velocity range.

Throughout the life of the site, the flow rate in the forcemain will range from 0 to 2 gpm. Excessive sediment accumulation in the forcemain will be prevented by the system operation. For example, the pump will operate on a periodic basis. When the pump activates, flow in the forcemain will surge and the velocity will increase periodically which will transport sediment to the discharge point. This variation in Q will functionally minimize the sediment build-up potential in the pipe.

3/4" (1.050 OD)

SDR 11	160 psi	0.12 lbs./ft.	0.860 ID	.095 wall

1" (1.315 OD)

SDR 11	160 psi	0.19 lbs./ft.	1.075 ID	.120 wall

1-1/4" (1.660 OD)

SDR 11	160 psi	0.31 lbs./ft.	1.358 ID	.151 wall

1-1/2" (1.900 OD)

SDR 11	160 psi	0.41 lbs./ft.	1.554 ID	.173 wall

2" (2.375 OD)

SDR 7	267 psi	0.94 lbs/ft	1.697 ID	.339 wall
SDR 9	200 psi	0.76	1.847	.264
SDR 11 ●	**160 psi**	**0.64**	**1.943**	**.216**
SDR 13.5	128 psi	0.53	2.023	.176
SDR 15.5	110 psi	0.47	2.069	.153
SDR 17	100 psi	0.43	2.095	.140

3" (3.500 OD)

SDR 7	267 psi	2.05 lbs./ft.	2.500 ID	.500 wall
SDR 9	200 psi	1.66	2.722	.389
SDR 11 ●	**160 psi**	**1.39**	**2.864**	**.318**
SDR 13.5	128 psi	1.15	2.982	.259
SDR 15.5	110 psi	1.02	3.048	.226
SDR 17 ●	**100 psi**	**0.93**	**3.088**	**.206**
SDR 19	89 psi	0.84	3.132	.184
SDR 21	80 psi	0.77	3.166	.167
SDR 26	64 psi	0.62	3.230	.135
SDR 32.5	51 psi	0.50	3.284	.108

4" (4.500 OD)

SDR 7	267 psi	3.39 lbs/ft.	3.214 ID	.643 wall
SDR 9	200 psi	2.74	3.500	.500
SDR 11 ●	**160 psi**	**2.29**	**3.682**	**.409**
SDR 13.3	128 psi	1.90	3.834	.333
SDR 15.5 ●	**110 psi**	**1.68**	**3.020**	**.290**
SDR 17 ●	**100 psi**	**1.54**	**3.970**	**.265**
SDR 19	89 psi	1.39	4.026	.237
SDR 21	80 psi	1.26	4.072	.214
SDR 26 ●	**64 psi**	**1.03**	**4.154**	**.173**
SDR 32.5	51 psi	0.83	4.224	.138

5-3/8" (5.375 OD)

SDR 17	100 psi	2.20 lbs./ft.	4.743 ID	.316 wall
SDR 21	80 psi	1.80	4.863	.256
SDR 26	64 psi	1.47	4.961	.207
SDR 32.5	51 psi	1.18	5.045	.165

5" (5.563 OD)

SDR 7	267 psi	5.17 lbs./ft.	3.973 ID	.795 wall
SDR 9	200 psi	4.18	4.327	.618
SDR 11	160 psi	3.51	4.551	.506
SDR 13.5	128 psi	2.91	4.739	.412
SDR 15.5	110 psi	2.57	4.845	.359
SDR 17	100 psi	2.35	4.909	.327
SDR 19	89 psi	2.12	4.977	.293
SDR 21	80 psi	1.93	5.033	.265
SDR 26	64 psi	1.57	5.135	.214
SDR 32.5	51 psi	1.27	5.221	.171

6" (6.625 OD)

SDR 7	267 psi	7.33 lbs./ft.	4.733 ID	.946 wall
SDR 9	200 psi	5.93	5.153	.736
SDR 11 ●	**160 psi**	**4.97**	**5.421**	**.602**
SDR 13.5	128 psi	4.13	5.643	.491
SDR 15.5	110 psi	3.63	5.771	.427
SDR 17 ●	**100 psi**	**3.34**	**5.845**	**.390**
SDR 19	89 psi	3.01	5.927	.349
SDR 21 ●	**80 psi**	**2.73**	**5.995**	**.315**
SDR 26 ●	**64 psi**	**2.23**	**6.115**	**.255**
SDR 32.5 ●	**51 psi**	**1.80**	**6.217**	**.204**

7" (7.125 OD)

SDR 7	267 psi	8.49 lbs./ft.	5.089 ID	1.018 wall
SDR 9	200 psi	6.86	5.541	.792
SDR 11	160 psi	5.75	5.829	.648
SDR 13.5	128 psi	4.78	6.069	.528
SDR 15.5	110 psi	4.21	6.205	.460
SDR 17	100 psi	3.86	6.287	.419
SDR 19	89 psi	3.48	6.375	.375
SDR 21	80 psi	3.16	6.445	.340
SDR 26 ●	**64 psi**	**2.58**	**6.577**	**.274**
SDR 32.5	51 psi	2.08	6.685	.220

8" (8.625 OD)

SDR 7	267 psi	12.43 lbs.ft.	6.161 ID	1.232 wall
SDR 9	200 psi	10.05	6.709	.958
SDR 11 ●	**160 psi**	**8.42**	**7.057**	**.784**
SDR 13.5	128 psi	7.00	7.347	.639
SDR 15.5	110 psi	6.16	7.513	.556
SDR 17 ●	**100 psi**	**5.65**	**7.611**	**.507**
SDR 19	89 psi	5.10	7.717	.454
SDR 21 ●	**80 psi**	**4.64**	**7.803**	**.411**
SDR 26 ●	**64 psi**	**3.79**	**7.961**	**.332**
SDR 32.5 ●	**51 psi**	**3.05**	**8.095**	**.265**

● denotes standard sizes

Effective: 3-1-94

Chart 4

Table of "C" Values for "Hazen and Williams Formula"

Constant	Type of Pipe
155	Driscopipe
140	New steel pipe or tubing Glass tubing Asbestos cement
130	Copper tubing Ordinary brass pipe Cast iron – new Cast iron – tar coated but new Cast iron – fully cement lined
125	Steel pipe – old
120	Wood stave pipe Concrete pipe New wrought iron pipe Four to six years old cast iron pipe
110	Ten to twelve years old cast iron pipe Vitrified pipe Spiral riveted steel, flow with lap Galvanized steel
100	Spiral riveted steel, flow against lap Thirteen to twenty years old cast iron pipe Galvanized steel – over 5 years old Cast iron – tar coated over 10 years old
90	Twenty-six to thirty-year old cast iron pipe
60	Corrugated steel pipe

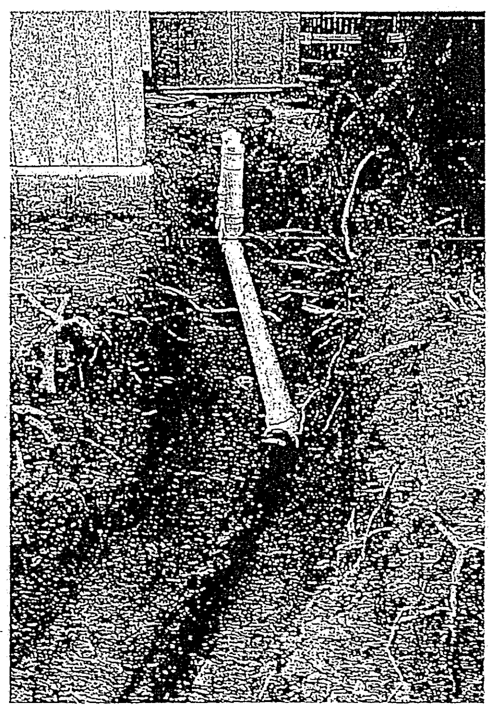
Fitting Pressure Drop: Listed below in Chart 5 are various common piping system components and the associated pressure loss through the fitting expressed as an equivalent length of straight pipe in terms of diameters. The inside diameter (in feet) multiplied by the equivalent length diameters gives the equivalent length (in feet) of pipe. This equivalent length of pipe is added to the total footage of the piping system when calculating the total system pressure drop.

These equivalent lengths should be considered an approximation suitable for most installations.

Chart 5

Fabricated Fitting	Equiv. Length
Running Tee	20 D
Branch Tee	50 D
90° Fab, Ell	30 D
60° Fab, Ell	25 D
45° Fab, Ell	18 D
45° Fab, Wye	60 D
Conventional Globe Valve (Full Open)	350 D
Conventional Angle Valve (Full Open)	180 D
Conventional Wedge Gate Valve (Full Open)	15 D
Butterfly Valve (Full Open)	40 D
Conventional Swing Check Valve	100D

(See Appendix for further data on resistance of valves and fittings to flow).



CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS
TCEQ PERMIT NO. MSW-2293C

MAJOR PERMIT AMENDMENT APPLICATION

PART III – SITE DEVELOPMENT PLAN
APPENDIX IIID
LINER QUALITY CONTROL PLAN

Prepared for

Meadow Landfill, LLC

August 2024

STATE OF TEXAS
KYLE D. GOULD
106018
LICENSED
PROFESSIONAL ENGINEER

08/05/2024

Prepared by

Weaver Consultants Group, LLC
TBPE Registration No. F-3727
6420 Southwest Boulevard, Suite 206
Fort Worth, TX 76109
817-735-9770

WCG Project No. 0120-809-11-05

This document intended for permitting purposes only.

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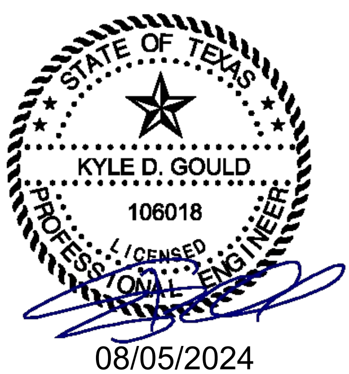

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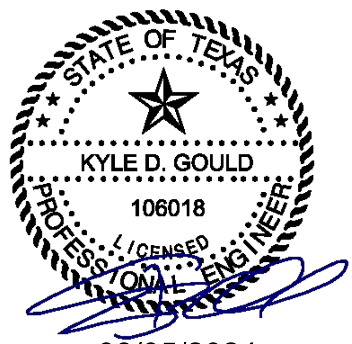

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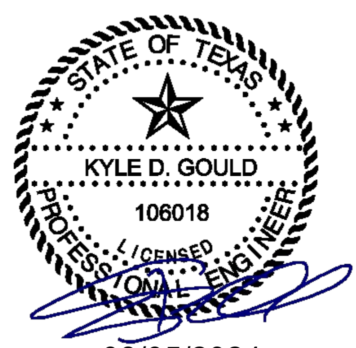
TABLES



08/05/2024

1 INTRODUCTION

1.1 Purpose

This appendix addresses §330.63(d)(4)(G), §330.337, §330.339, and §330.341.

This Liner Quality Control Plan (LQCP) has been prepared to provide the Operator, Design Engineer, Construction Quality Assurance Professional of Record, and the Contractor the means to govern the construction quality and to satisfy the environmental protection requirements under current Texas Commission on Environmental Quality (TCEQ) Municipal Solid Waste Rules (MSWR). More specifically, the LQCP addresses the soil and geosynthetic components of the liner system. The provisions of this LQCP were developed based on the latest technical guidelines of the TCEQ, including quality control of construction, testing frequencies and procedures, and quality assurance of sampling and testing procedures.

This LQCP is divided into the following parts:

- Section 1 – Introduction
- Section 2 – Construction Quality Assurance for Earthwork and Drainage Aggregates
- Section 3 – Construction Quality Assurance for Geosynthetics
- Section 4 – Construction Quality Assurance for Geosynthetic Clay Liner
- Section 5 – Construction Quality Assurance for Piping
- Section 6 – Geotechnical Strength Testing Requirements
- Section 7 – Documentation

1.2 Definitions

Whenever the terms listed below are used, the intent and meaning will be interpreted as indicated.

ASTM

The American Society for Testing and Materials

Construction Quality Assurance (CQA)

A planned system of activities that provides the Operator and permitting agency assurance that the facility was constructed as specified in the design. Construction quality assurance includes observations and evaluations of materials, and workmanship necessary to determine and document the quality of the constructed facility. Construction quality assurance (CQA) refers to measures taken by the CQA organization to assess if the installer or contractor is in compliance with the plans and specifications for a project.

Construction Quality Assurance Professional of Record (POR)

The POR is an authorized representative of the Operator and has overall responsibility for construction quality assurance that confirms that the facility was constructed in accordance with plans and specifications approved by the permitting agency. The POR must be registered as a Professional Engineer in Texas and experienced in geotechnical testing and its interpretations. Experience and education must include geotechnical engineering, engineering geology, soil mechanics, geotechnical laboratory testing, construction quality assurance and quality control testing, and hydrogeology. The POR must show competency and experience in certifying like installations, and be approved by the permitting agency, and be presently employed by or practicing as a geotechnical engineer in a recognized geotechnical/environmental engineering organization. POR or his designated representative will be on-site during all liner system construction. Reference within this appendix to the field inspection or monitoring obligations of the POR implies "the POR or designated representative under the supervision of the POR".

The POR may also be known in applicable regulations and guidelines as the CQA Engineer, Resident Project Representative, or the Geotechnical Professional (GP).

Construction Quality Assurance (CQA) Monitors

These are representatives of the POR who work under direct supervision of the POR. The CQA monitor is responsible for quality assurance monitoring and performing on-site tests and observations. The CQA monitor performing QA/QC observation and testing will be a qualified professional meeting one of the following qualifications: NICET-certified in geotechnical engineering technology at level II or higher for soils testing; a minimum of four years of directly related experience; a minimum of six months of directly related experience and has completed the Geosynthetic Institutes (GSI) Construction Quality Assurance Inspectors Certification Program (CQA-ICP); or a graduate engineer or geologist. Field observations, testing, or other activities associated with CQA may be performed by the CQA monitor(s) on behalf of the POR.

Additional CQA monitors may be used if they work under the direct supervision of a qualified CQA monitor who is on-site.

Contract Documents

These are the official set of documents issued by the Operator. The documents include bidding requirements, contract forms, contract conditions, specifications, contract drawings, addenda, and contract modifications.

Contract Specifications

These are the qualitative requirements for products, materials, and workmanship upon which the contract is based.

Contractor

This is the person or persons, firm, partnership, corporation, or any combination, private or public, who, as an independent contractor, has entered into a contract with the Operator, and who is referred to throughout the contract documents by singular number and masculine gender.

Design Engineer

These individuals or firms are responsible for the design and preparation of the project construction drawings and specifications. Also referred to as "designer" or "engineer."

Earthwork

This is a construction activity involving the use of soil materials as defined in the construction specifications and Section 2 of this plan.

Film Tear Bond (FTB)

A failure in the geomembrane sheet material on either side of the seam and not within the seam itself.

Geomembrane Liner (GM)

This is a synthetic lining material, also referred to as geomembrane, membrane liner, or sheet. The term Flexible Membrane Liner (FML) is also used for GM.

Geomembrane Liner Evaluation Report (GLER)

Certification report for the geomembrane liner, prepared and sealed by the POR that is submitted to the TCEQ for approval. Also referred to as flexible membrane liner evaluation report (FMLER).

Geosynthetic Clay Liner (GCL)

This is a synthetic lining material, which in the most basic form consists of bentonite sandwiched between two geotextiles. Also referred to as prefabricated bentonite blankets, mats or panels, or clay blankets, mats, or panels.

Geosynthetic Clay Liner Evaluation Report (GCLER)

Certification report for the geosynthetic clay liner, prepared and sealed by POR, which is submitted to TCEQ for approval.

Geosynthetics Contractor

This individual is also referred to as the "contractor" or "installer," and is the person or firm responsible for geosynthetic construction. This definition applies to any person installing FML or geotextile, even if not his primary function.

Independent Testing Laboratory

A laboratory that is independent of ownership or control by the permittee or any party to the construction of the liner system or the manufacturer of the liner system products used.

Manufacturing Quality Assurance (MQA)

A planned system of activities that provides assurance that the raw materials were constructed (manufactured) as specified.

Manufacturing Quality Control (MQC)

A planned system of inspection that is used to directly monitor and control the manufacture of a material.

Nonconformance

This is a deficiency in characteristic, documentation, or procedure that renders the quality of an item or activity unacceptable or indeterminate. Examples of non-conformances include, but are not limited to, physical defects, test failures, and inadequate documentation.

Operator

The organization that will operate the disposal unit.

Organics

Organic matter is material that may be capable of decay (e.g., plant material), the product of decay, or both.

Permittee's Representative

This is the person that is an official representative of the permittee responsible for planning, organizing, and controlling the design and construction activities.

Panel

This is a unit area of the FML, which will be seamed in the field.

Quality Assurance

This is a planned and systematic pattern of procedures and documentation to ensure that items of work or services meet the requirements of the contract documents. Quality assurance includes quality control. Quality assurance will be performed by the POR and CQA monitor.

Quality Control

These actions provide a means to measure and regulate the characteristics of an item or service to comply with the requirements of the contract documents. Quality control will be performed by the contractor.

Soil Liner Evaluation Report (SLER)

Construction report for the soil liner prepared and sealed by the POR and submitted to the TCEQ.

2 CONSTRUCTION QUALITY ASSURANCE FOR EARTHWORK AND DRAINAGE AGGREGATES

2.1 Introduction

This section of the LQCP addresses the construction of the soil and drainage components of the liner system and outlines the LQCP program to be implemented with regard to materials selection and evaluation, laboratory test requirements, field test requirements, and treatment of problems.

The scope of earthwork and related construction quality assurance includes the following elements:

- Subgrade preparation
- Soil liner stockpile
- Soil liner placement
- General fill
- Drainage aggregates
- Anchor trench backfill

2.2 Composite Liner

The landfill is designed to include a Subtitle D composite liner for the undeveloped liner area. The liner system for the undeveloped area will consist of a 2-foot-thick compacted clay liner and a 60-mil-thick high-density polyethylene (HDPE) Flexible Membrane Liner (FML). A GCL may be used in lieu of the 2-foot-thick compacted clay liner.

The liner systems are detailed in Appendix IIIA – Landfill Unit Design Information. A structural stability analysis for the liner system, including calculations for anchor trench runout lengths, stress on the liner components, and an interface slope stability analysis, is included in Appendix IIIE – Geotechnical Report.

2.3 Earthwork Construction

The following paragraphs describe general construction procedures to be used for various earthwork components within the landfill. The earthwork construction specifications will be developed based on the material and construction procedures outlined in this section of the LQCP for each specific liner construction. The earthwork construction specifications will include details for compaction of soils and cross sections showing typical slopes, widths, and thicknesses for compacted lifts.

2.3.1 Subgrade

Subgrade refers to a surface which is exposed after stripping topsoil or excavating to establish the grade directly beneath the composite liner. The prepared subgrade must conform to the Excavation Plan included in Appendix IIIA – Landfill Unit Design Information.

Prior to beginning liner construction, the subgrade area will be stripped to a depth sufficient to remove all loose surface soils or soft zones within the exposed excavation. The liner subgrade area will be proof rolled with heavy, rubber-tired construction equipment to detect unstable areas. Unstable areas will be undercut to firm material and refilled with suitable compacted general fill. Soil used for backfill will meet the same material requirements as the soil liner and will be installed in accordance with the soil liner installation procedures. The fill will be free of organic matter, foreign objects, and other deleterious matter, and compacted sufficiently to provide a firm base for composite liner placement. The subgrade will also be scarified a minimum of 2 inches prior to placement of the first lift of soil liner. The subgrade preparation specifications for each liner construction event will be developed in accordance with this section. Construction project specifications and construction plans will be developed for each cell construction event in accordance with this LQCP and consistent with the Excavation Plan (included in Appendix IIIA) and the sector design as contained in the approved Site Development Plan.

Subgrade voids and cracks are expected to be minor. However, the subgrade will be re-worked as necessary to provide a foundation suitable for composite liner placement. Visual examination of the subgrade preparation by the CQA monitor will generally be sufficient to evaluate its suitability as a foundation for the composite liner. The CQA monitor may find that physical testing is necessary to evaluate the prepared subgrade or fill placed in large voids.

The POR will approve the prepared subgrade prior to the placement of composite liner or structural fill. Approval will be based on a review of test information, if applicable, and CQA monitoring of the subgrade preparation. Additionally, during the subgrade acceptance, the POR will verify that the underlying material is consistent with the geotechnical design assumptions included in Appendix IIIE.

Surveying will be performed to verify that the finished subgrade is to the lines and grades specified in design with a vertical tolerance of -0.2 feet to +0.0 feet to ensure that the soil liner will achieve a 2-foot minimum thickness. The surface slope of the top layer of composite liner will conform to the slope requirements of the leachate collection layer.

2.3.2 Soil Liner

The soil liner will consist of a minimum 2-foot-thick compacted clay liner (measured perpendicular to the subgrade surface) that will extend along the floor and side slopes of the landfill. The soil liner will be constructed in continuous, single, compacted lifts (6 inches thick) parallel to the floor and sideslope subgrades. A GCL may be used in lieu of the 2-foot-thick compacted clay liner. Details depicting the liner system are included in Appendix IIIA – Landfill Unit Design Information.

2.3.2.1 Soil Borrow Material

Adequate soil liner material will be available from proposed landfill excavations and/or on-site or off-site borrow sources. The liner soil will be free of debris, rock greater than 1 inch in diameter, vegetative matter, frozen materials, foreign objects, and organics. Laboratory tests will verify that materials are adequate to meet the compacted clay liner requirements listed in §330.339(c)(5) prior to liner construction.

Soils used in soil liners will have the following minimum values verified by testing in a soil laboratory prior to liner construction.

Table 2-1
Required Borrow Soil Properties

Test[1]	Specification
Coefficient of Permeability (Remolded Sample)[2]	$1.0x10^{-7}$ cm/s or less
Plasticity Index	15 minimum
Liquid Limit	30 minimum
Percent Passing No. 200 Mesh Sieve	30 minimum
Percent Passing 1-inch Sieve	100

[1] Testing will be performed in accordance with the test methods included in Section 2.4.
[2] The coefficient of permeability for remolded sample is run at a minimum of 95% of the maximum dry density at or above the optimum moisture content.

Representative preliminary sampling and testing will be performed on on-site soils to be used as liner material or on off-site borrow source material. The CQA monitor, Earthwork Contractor, and/or Operator will identify the clay material in on-site stockpiles or during excavation, and the clay material will be stockpiled separately, if stockpiling is required. Prior to construction of each new cell, conformance tests that include liquid limit, plasticity index, percent passing the No. 200 and 1-inch sieves, Standard Proctor (ASTM D 698) compaction test, and coefficient of permeability test will be performed for each material proposed for each individual liner construction. The coefficient of permeability test specimens will be prepared by laboratory compaction to a dry density of approximately 95 percent of the Standard Proctor maximum dry density at or above the optimum moisture content. One Proctor moisture-density relationship and remolded coefficient of permeability test will be required for each different material. Additional conformance tests will be conducted if there are visual changes (color, texture, etc.) in borrow material or as determined necessary by the POR. The soil is considered as a separate soil borrow source if the liquid limit or plasticity index is determined to vary by more than 10 points. The liquid limit and plasticity index testing will be performed on the separate borrow source as an initial determination. If the liquid limit or plasticity index varies by more than 10 points then all other testing listed in Table 2-1 will be performed on the separate borrow source.

The physical characteristics of the liner materials will be evaluated through visual observation before and during construction. To adjust moisture of the material properly, any clod sizes will first be crushed into manageable sizes of 4 inches in diameter or less. Rocks within the compacted liner must be less than 1 inch in diameter. Soil clod size will be reduced to the smallest size necessary to achieve the coefficient of permeability reported by the testing laboratory. Additionally, the rock content of the soil liner will not be more than 10 percent by weight. Water used for the soil liner moisture adjustment must be clean and not contaminated by waste or any objectionable material. Stormwater collected on-site may be used if it has not come into contact with waste.

2.3.2.2 Liner Construction

The soil liner material will be placed in maximum 8-inch-thick loose lifts to produce compacted lift thicknesses of approximately 6 inches. The soil liner will have elevations, slopes, thickness, and widths as depicted on the Excavation Plan and Liner System Details in Appendix IIIA – Landfill Unit Design Information.

The soil liner material will be compacted to a minimum of 95 percent of the maximum dry density at or above the optimum moisture content as determined by Standard Proctor (ASTM D 698). The soil liner must be compacted with a pad/tamping-foot (preferable) or prong-foot (sheepsfoot) roller. The lift thickness will be controlled so that there is total penetration through the loose lift under compaction into the top of the previously compacted lift; therefore, the lift thickness must not be greater than the pad or prong length. Use of pad/tamping-foot or prong-foot rollers will provide sufficient roughening of liner lifts surface for bonding between lifts. These procedures are necessary to achieve adequate bonding between lifts and reduce seepage pathways. Adequate cleaning devices must be in place and maintained on the compaction roller so that the prongs or pad feet do not become clogged with clay soils to the point that they cannot achieve full penetration during initial compaction. The footed roller is necessary to achieve this bonding and to reduce the individual clods and achieve a blending of the soil matrix through its kneading action.

In addition to the kneading action, weight of the compaction equipment is important. The minimum weight of the compactor should be 40,000 pounds (in no case should ground pressure be less than 1,500 lbs per linear foot for each drum or wheel length), and a minimum of four passes are recommended for the compaction process. A pass is defined as one pass (1 direction) of the compactor, not just an axle, over a given area. The recommended minimum of four passes is for a vehicle with front and rear drums. The Caterpillar 815B and 825C are examples of equipment typically used to achieve satisfactory results. The soil liner will not be compacted with a bulldozer or any track-mobilized equipment unless it is used to pull a pad-footed drum which is at a minimum 1,500 lbs per linear foot of drum length.

During the construction of continuous liners, the new liner segment will not be constructed by "butting" the entire thickness of the new liner directly against the edge of the old liner. The tie-in will be constructed by a sloped transition (typical 5 horizontal to 1 vertical) as shown in Appendix IIIA – Landfill Unit Design Information. The length of the tie-in must be at least 5 feet per foot of liner thickness. The tie-in will be scarified prior to placement of the next lift.

CQA testing of the soil liner will be performed as the liner is being constructed. Testing of the soil liner is addressed in Section 2.4. Soil liner construction and testing will be conducted in a systematic and timely fashion on each lift. Delays will be avoided in liner construction. Construction and testing of the soil liner will generally not exceed 60 working days from beginning of liner installation to completion. The TCEQ will be notified during construction if delays in excess of 60 days are anticipated. Reasons for liner construction taking more than 60 days to complete will be fully explained in the SLER submittal.

The finished surface of the final lift of soil liner must be rolled with a smooth, steel-wheeled roller to obtain a hard, uniform, and smooth surface. The surface of the final lift of soil liner will then be inspected by the CQA monitor. All undesired materials will be removed from the liner surface, and any voids created by removing undesired materials will be backfilled with liner material to the density specifications outlined for liner construction and tested at the discretion of the CQA monitor. Surveying will be performed to verify that the finished top of liner grade is to the lines and grades specified in construction plans for a particular cell. Top of soil liner surveying will be performed within a tolerance of 0.0 feet to +0.2 feet. The surface slope of the top layer will conform to the slope requirements of the leachate collection layer. Survey frequency is included in Table 2-2.

The POR will submit to the TCEQ a SLER for approval of each soil liner area. This LQCP has been developed in accordance with the TCEQ regulations. The requirements for testing and evaluation of the soil liner during construction are included in this LQCP. The construction methods and test procedures documented in the SLER will be consistent with this LQCP and TCEQ regulations.

The soil liner will be prevented from losing moisture during the SLER approval process. Preserving the moisture content of the installed soil liner will be dependent on the earthwork contractors means and methods and is subject to POR approval.

Upon completion of liner construction, SLER markers will be installed to clearly indicate the limits of constructed and approved liner areas in accordance with Section 4.7 – Landfill Markers and Benchmark of the approved Site Operating Plan. SLER markers will be located so that they are not destroyed during operations. The POR will document in the GLER that SLER markers are installed prior to approval of the GLER.

2.3.3 General Fill

General fill material will be uncontaminated earthen fill. General fill includes soils placed for earthen berm or embankment construction, channel swales, roadways, or other earthen features at the landfill. General fill material will be placed in uniform loose lifts which do not exceed 12 inches in loose thickness. General fill will be compacted to at least 90 percent of Standard Proctor maximum dry density (ASTM D 698) at a moisture content range of plus or minus 3 percent of the optimum moisture content.

Proctor and index property (i.e., gradation, Atterberg limits) tests will be performed for each of the general fill borrow sources used for construction. Field density and moisture testing will be limited to embankment construction at a frequency of 1 test per 20,000 square feet of soil placement per 12-inch loose lift. Field testing of non-landfill related fill areas (e.g., roadways, stormwater impoundment features, drainage features) will not be required.

2.3.4 Drainage Aggregate Around Pipes

The coarse aggregate selected for placement around the leachate collection pipes used in the leachate collection system (LCS) for the composite liner and for the temporary hydrostatic pressure relief system discussed in Section 6 will consist of normal (e.g., unit weight of 90 to 110 pcf) or lightweight (e.g., unit weight less than 70 pcf) materials that comply with the following criteria. The LCS aggregate will have a calcium carbonate content less than 15 percent. Either the J&L Testing method or the ASTM D 3042 method, modified to use a solution of hydrochloric acid having a pH of 5, can be used to determine calcium carbonate content. The drainage aggregate will meet the following gradation for ASTM D 448, size number 467.

Sieve Size Square Opening	Percent Passing
2 inches	100
1½ inches	95 - 100
¾ inch	35 - 70
3/8 inch	10 - 30
No. 4 (3/16 inch)	0 - 5

However, if approved by the POR, coarse aggregates not complying with the size number 467 gradation may also be used if demonstrated to have a hydraulic conductivity of at least 1.0 cm/s and meet the filter gradation requirements given below (in no case will the maximum rock size be more than 2 inches) for the specific leachate collection pipe perforation design:

For circular holes in the leachate collection pipe:

$$\frac{\text{85 Percent Size of Filter Material}}{\text{Hole Diameter}} > 1.7$$

For slots in the leachate collection pipe:

$$\frac{\text{85 Percent Size of Filter Material}}{\text{Slot Width}} > 2.0$$

The coarse aggregate will be tested for gradation (ASTM D 448) at the supply source or from the on-site stockpile prior to acceptance. Gradation testing will be conducted at a minimum frequency of 1 test per 3,000 cubic yards of coarse aggregate or per liner construction event if less than 3,000 cubic yards of coarse aggregate is required for the specific construction. The aggregate will be free of organics, angular rocks, foreign objects, or other deleterious materials. The physical characteristics of the aggregate will be evaluated through visual observation and laboratory classification testing before construction and visual observation during construction. The coarse aggregate may be tested during construction at the discretion of the CQA monitor. The test results for the coarse aggregate will be included in the GLER.

2.3.5 Protective Cover

Protective cover will be placed over the drainage layer in accordance with this section and project plans and specifications. The geosynthetics of the composite liner system will be covered with a minimum of 2 feet of protective cover for the Subtitle D composite liner. The protective cover will consist of soil materials that have not previously come in contact with solid waste or other deleterious materials, and do not contain materials detrimental to the underlying geosynthetics. The protective cover will be free of organic matter, foreign objects, or other deleterious materials. The physical characteristics of the protective cover will be evaluated through visual observation (and laboratory testing if the POR deems it necessary) before construction and visual observation during construction. Additional testing during construction will be at the discretion of the CQA monitor and POR. The protective cover will have passageways (i.e., chimney drains) to allow moisture to drain to the leachate collection system.

The protective cover layer will be placed using any low ground pressure equipment as outlined in Section 3.6. The protective cover will be placed by spreading in front of the spreading equipment with a minimum of 12 inches of soil between the spreading equipment and the installed geosynthetics. Under no circumstances will the construction equipment come in direct contact with the installed geosynthetics.

The thickness of the protective cover layer placed over the composite liner and will be verified with surveying procedures at a minimum of 1 survey point per 5,000 square feet of constructed area by a qualified surveyor or professional engineer with a minimum 2 reference points. Thickness may be verified with settlement plates. The survey results and method of surveying for the protective cover will be included in the GLER.

During construction the CQA monitor will:

- Verify that grade control is performed prior to work.
- Verify that underlying geosynthetic installations are not damaged during placement operations or by survey grade controls. Mark damaged geosynthetics and verify that damage is repaired.
- Verify that the cover soil for sideslopes is pushed from the toe up the slope.
- Monitor haul road thickness over geosynthetic installations and verify that equipment hauling and materials placement meet equipment specifications (see Section 3.6).
- The POR will coordinate with the project surveyor to perform a thickness verification survey of the protective cover materials upon completion of placement operations. Verify corrective action measures as determined by the verification survey.

2.3.6 Anchor Trench Backfill

The anchor trench backfill material for geosynthetic anchoring will be uncontaminated earthen material and will be placed and compacted. In-place moisture/density tests may be performed at the discretion of the CQA monitor to evaluate the quality of the backfill. The test results will not be required as part of the GLER or GCLER.

2.3.7 Surface Water Removal

The excavation may encounter water from storm events or groundwater. Soil liner will not be placed in standing water. The excavation area will therefore have a temporary sump area to collect water entering the excavation and be graded to allow drainage at planned areas. Portable pumps will be on site to dewater the sumps. Temporary earthen berms will be constructed to divert surface flow away from the excavation. Surface water that accumulates on the constructed soil liner or geosynthetics surface will be removed promptly after the end of a rainfall event. POR will inspect and approve the constructed area that received rainfall prior to placement of the overlying liner system component. The criteria for approval of the finished surface of the soil liner for geomembrane placement will follow the requirements of Section 3.3.3 and for geocomposite placement on top of geomembrane will follow the requirements of Section 3.5.3. Surface water from the site will be discharged per the site's TPDES permit requirement.

2.3.8 Liner Tie-In Construction

Newly constructed liners will be tied-in with any adjoining existing liners. Additionally, terminations will be constructed for future tie-ins along edges where the liner will be extended in the future. The tie-ins with existing clay liners will be constructed utilizing a sloped transition a minimum of 10 feet wide for the 2-foot-thick clay liner. Terminations for future tie-ins will be constructed by extending the clay liner approximately 10 feet past the limits for the cell under construction. The liner tie-in details are shown in Appendix IIIA – Landfill Unit Design Information. Waste and intermediate cover will not be deposited closer than 10 feet to the edge of any cell or 20 feet from the leading edge of a constructed clay liner (whichever is greater) where a future tie-in will be constructed. Red-colored markers (i.e., SLER markers) will be placed along the limits of the cells with constructed clay liners and tied to the site grid system in accordance with Title 30 TAC §330.143(b)(1).

2.4 Construction Testing

2.4.1 Standard Operating Procedures

Qualified CQA monitors will perform field and laboratory tests in accordance with applicable standards specified in this LQCP. All quality control testing and evaluation of soil liners will be performed during construction of the liner and must be complete before placement of the leachate collection system, except for the testing required for the final constructed lift, verification of liner thickness, or cover material thickness. Standard operating and test procedures will be utilized per the POR's direction. Sampling from the constructed soil liner lifts will be performed in accordance with ASTM D 1587. The sampling holes (e.g., samples for coefficient of permeability test) will be backfilled with bentonite or bentonite/liner soil material mixture. Prior written approval from the TCEQ via a permit modification will be obtained if any changes will be made to material requirements or procedures set forth on this LQCP.

The following test standards apply as called out in this LQCP and in the technical specifications provided in this LQCP.

Standard Test Method	Test Description
ASTM D 698	Moisture-density relations of soils and soil-aggregate mixtures, using 5½-lb hammer and 12-inch drop
ASTM D 422	Particle size analysis of soils
ASTM D 6938	Standard test method for in-place density and water content of soil and soil aggregate by nuclear methods (shallow depth)
ASTM D 1587	Thin-walled tube sampling of soils for geotechnical purposes
ASTM D 2167	Density and unit weight of a soil in place by the rubber balloon method
ASTM D 6938	In-place density and water content of soil and soil-aggregate by nuclear methods (shallow depth)
ASTM D 2216	Laboratory determination of water (moisture) content of soil, rock, and soil-aggregate mixtures
ASTM D 2434	Method of test for permeability of porous granular material
ASTM D 5084	Method of test for permeability of fine-grained soils
ASTM D 4318	Atterberg limits
ASTM D 1140	Amount of material in soils finer than the No. 200 sieve
ASTM D 2487	Classification of soils for engineering purposes
ASTM D 2488	Description and identification of soils (visual-manual procedure)
EM 1110-2-1906, Appendix VII	U.S. Army Corps of Engineers permeability test
ASTM D 448	Standard classification for sizes of aggregate for road and bridge construction
ASTM D 3042	Test method for insoluble residue in carbonate aggregates

2.4.2 Test Frequencies

This LQCP establishes the minimum test frequencies for the soil liner construction quality assurance. The test frequencies for soil liner are listed in Table 2-2. Additional testing must be conducted whenever work or materials are suspect, marginal, or of poor quality. Additional testing may also be performed to provide additional data for engineering evaluation. The minimum number of tests is interpreted to mean minimum number of passing tests, and any tests that do not meet the requirements will not contribute to the total number of tests performed to satisfy the minimum test frequency.

Table 2-2
Required Tests and Observations on Soil Liner

Parameter	Frequency	Test Method	Passing Criteria
Field Density and Moisture	1 each per 8,000 SF per 6-inch parallel lift	ASTM D 6938 and ASTM D 2216[1]	95% Maximum Standard Proctor Dry Density. Standard Proctor optimum moisture content or greater determined during preconstruction testing.
Sieve Analysis (passing no. 200 and 1-inch)	1 test per 100,000 square feet per 6-inch parallel lift, with a minimum of 1 test per 6-inch lift	ASTM D 1140	30 percent minimum (#200) 100 percent minimum (1-inch)
Atterberg Limits	1 test per 100,000 square feet per 6-inch parallel lift, with a minimum of 1 test per 6-inch lift	ASTM D 4318	PI = 15 percent minimum LL = 30 percent minimum
Coefficient Permeability (Hydraulic Conductivity)[2]	1 test per 100,000 square feet per 6-inch parallel lift, with a minimum of 1 test per 6-inch lift	ASTM D 5084 (Falling head, flex wall) Corps of Engineers EM 1110-2-1906, Appendix VII (Falling head permeameter)	$1.0x10^{-7}$ cm/s or less
Thickness Verification	1 each 5,000 square feet with a minimum of 2 reference points by a qualified surveyor	Survey subgrade and top of soil liner and protective cover layer	2 feet minimum compacted soil liner thickness and 2 feet minimum protective cover thickness

[1] This method is not applicable if the field nuclear gauge reads both density and moisture.
[2] Field permeability testing performed in accordance with Title 30 TAC §330.339(c)(7), may be performed to augment this testing program if a permit modification is submitted and approved by the TCEQ.

2.4.3 Soil Liner Testing

CQA testing of the soil liner will be performed as the liner is being constructed. Sections of compacted soil liner which do not pass both the density and moisture requirements will be reworked with additional passes of the compactor until the section in question passes. All field density and moisture test results will be incorporated into the SLER.

Soil liner field density and moisture testing will be completed on each 6-inch compacted lift at a frequency of one test per 8,000 square feet of soil liner installed. Passing tests will be achieved with a minimum of 95 percent compaction of the Standard Proctor maximum dry density at a moisture content at or above optimum moisture content. Areas that do not receive satisfactory field density and moisture testing will be moisture conditioned and recompacted to achieve satisfactory results.

Hydraulic conductivity samples will be obtained by pushing a sampler through each lift of the constructed clay liner prior to construction of the next lift. The sample from each test location will be sealed and transported to the laboratory. Two samples may be collected at each sample location and labeled the "A" and "B" sample. The sampling holes (e.g., samples for hydraulic conductivity) will be backfilled with bentonite or a bentonite/clay liner soil material mixture consisting of at least 20 percent bentonite and compacted by hand tamping.

If the integrity of the "A" sample appears to have been compromised during the transportation of the sample prior to testing, the "B" sample may be tested. In addition, if an "A" sample hydraulic conductivity test does not comply with the minimum allowable value, the "B" sample collected at the same location may be tested to determine compliance with the hydraulic conductivity requirements if during testing of the "A" sample the ASTM D 5084 or EM 1110-2-1906 procedure was not followed or the permeameter malfunctioned. The POR will provide a detailed justification of the use of the "B" sample, if applicable, in the SLER.

If the "B" sample passes, the area will be considered in compliance. If the "B" sample fails (or Sample "A" fails in such a way that there is not an option to use the "B" sample), the test interval will be considered unsatisfactory for the area bounded by passing test locations (but not extending past a satisfactory test location). Additional tests may be taken to further define the unsatisfactory area. The area defined unsatisfactory will be reworked and retested in accordance with this section.

Furthermore, if it is determined that the "B" sample may not be used to replace the "A" sample result, then the test interval will be considered unsatisfactory for the area bounded by passing test locations (but not extending past a satisfactory test location).

Once the exact area is determined, the constructed liner lifts will be removed to the bottom of the lift that did not pass the hydraulic conductivity test and reconstructed until all the samples obtained from the failed area meet the hydraulic conductivity requirements. At a minimum, one hydraulic conductivity test will be performed for each lift, given that the reconstructed liner area is not larger than 100,000 square feet (i.e., 4 hydraulic conductivity tests per 100,000 square feet of reconstructed liner area). The reconstructed liner area will be tied into the currently constructed liner with a 5H:1V transition slope according to the tie-in detail included in

Appendix IIIA – Landfill Unit Design Information. Reconstructed liner area is also subject to field density and moisture content testing per Table 2-2 (at least one field density and one moisture content test is required for each lift regardless of the size of the area that is reconstructed).

Each lift of the reconstructed liner area will be tested for hydraulic conductivity. Reconstruction activities, including additional testing and surveying, will be incorporated into the SLER.

2.4.4 Material Strength Requirements

The geotechnical analysis is included in Appendix IIIE – Geotechnical Report and includes slope stability, foundation heave, and settlement analyses. Soil parameters used in the geotechnical analysis were obtained from subsurface investigations and geotechnical reports, as well as from geotechnical testing performed on soil samples recovered at the site. The POR will verify that the proposed liner material meets the minimum soil properties used in the geotechnical analysis included in Appendix IIIE prior to liner construction, as applicable. These soil properties include unit weight, moisture content, cohesion, friction angle, and consolidation strength parameters used in the slope stability and settlement analyses. The POR will verify that the underlying material below the composite liner is consistent with design assumptions. If the POR determines that the underlying material or borrow material is not consistent with design assumptions, the appropriate geotechnical analysis (e.g., slope stability) will be updated consistent with the procedures in Appendix IIIE. The updated analysis will be incorporated into the SLER/GLER.

2.5 Reporting

The POR will submit to the TCEQ a SLER for approval of each Subtitle D soil liner area. Section 7 describes the documentation requirements.

3 CONSTRUCTION QUALITY ASSURANCE FOR GEOSYNTHETICS

3.1 Introduction

Section 3 describes CQA procedures for the installation of geosynthetic components, except GCL for which procedures are provided in Section 4.

The scope of geosynthetic related construction quality assurance includes the following elements:

- Bottom Liner Geomembrane
  - Floor Grades: 60-mil HDPE – smooth or textured on both sides
  - Sideslopes: 60-mil HDPE – textured on both sides
- Geotextile
- Drainage Layer
  - Single-sided drainage geocomposite (on bottom liner floor grades)
  - Double-sided drainage geocomposite (bottom liner side slopes)

The overall goal of the geosynthetics quality assurance program is to assure that proper construction techniques and procedures are used, the geosynthetic contractor implements his quality control plan in accordance with this LQCP, and that the project is built in accordance with the project construction drawings and technical specifications that will be developed in accordance with this LQCP for each liner construction. The quality assurance program is intended to identify and define problems that may occur during construction and to observe that these problems are avoided and/or corrected before construction is complete. A GLER, prepared after project completion, will document that the constructed facility meets design intent and specifications outlined in this LQCP.

3.2 Geosynthetics Quality Assurance

3.2.1 General

The composite liner system provides the primary means for preventing leachate infiltration into groundwater. A geomembrane is a component of the bottom liner. Proper geomembrane installation is a crucial work element, which greatly affects the performance of the liner systems. Construction quality control for the geomembrane installation will be performed by the geomembrane installation contractor. Construction quality assurance for the geomembrane installation will be performed by the POR to assure the geomembrane is constructed as specified in the design. Construction must be conducted in accordance with the procedures outlined in this LQCP. To monitor compliance, a quality assurance program will include the following:

- A review of the manufacturer's quality control testing
- Material conformance testing by an independent third-party laboratory
- Field and construction testing
- Construction monitoring

The manufacturer's quality control testing will include resin and geomembrane testing. The required tests for material properties are included in Section 3.3.

Conformance testing refers to material testing performed by an independent third-party laboratory that takes place prior to material installation. Field and construction testing includes testing that occurs during geosynthetics installation.

Quality assurance testing will be conducted in accordance with this LQCP. Field testing will be observed by the CQA monitor. Documentation must meet the requirements of this LQCP.

3.3 Bottom Liner Geomembrane

The bottom liner geomembrane will consist of a 60-mil HDPE geomembrane. The geomembrane will be smooth or textured on both sides on the floor and textured on both sides on the sideslopes. Required manufacturer's quality control tests for the bottom liner geomembrane are included in Table 3-1 and required material properties for the bottom liner geomembrane are included in Table 3-2.

3.3.1 Delivery

Upon delivery of FML, the CQA monitor will observe that:

- The geomembrane is delivered in rolls and is not folded. Folded geomembrane is not acceptable because the highly crystalline structure of the geomembrane will be damaged if it is folded. Any evidence of folding (other than from the manufacturing process) or other shipping damage is cause for rejection of the material.
- Equipment used to unload and store the rolls does not damage the geomembrane.
- The geomembrane is stored in an acceptable location in accordance with the manufacturer's specifications and stacked not more than 5 rolls high. The geomembrane is protected from puncture, dirt, grease, water, moisture, mud, mechanical abrasions, excessive heat, or other damage.
- All manufacturing documentation required by the specifications outlined in this LQCP has been received and reviewed for compliance. This documentation will be included in the GLER.
- A geosynthetics receipt log form has been completed for all materials received.

Damaged geomembrane will be rejected and removed from the site or stored at a location separate from accepted geomembrane. Geomembrane that does not have proper manufacturer's documentation must be stored at a separate location until all documentation has been received, reviewed, and accepted.

3.3.2 Conformance Testing

Tests. One geomembrane sample will be obtained for every resin lot of material supplied and for each 100,000 square feet of geomembrane installed. The material will be sampled at the manufacturing plant by the third-party testing laboratory or the site by the CQA monitor. The samples will be forwarded to the independent third-party laboratory for the following conformance tests:

- Specific gravity/Density (ASTM D 1505 or alternate ASTM D 792, Method A if approved by the POR)
- Carbon black content (ASTM D 4218)
- Carbon black dispersion (ASTM D 5596)
- Thickness (ASTM D 5199 for smooth FML and for textured FML use ASTM D 5994
- Tensile properties (ASTM D 638/Type IV, ASTM D 6693 may be used upon approval by POR)

Table 3-1
Required Testing for 60-mil-thick Smooth and Textured (Both Sides) HDPE Geomembranes[1]

Test	Type of Test	Standard Test Method	Frequency of Testing (Minimum)
Resin	Specific Gravity/Density	ASTM D 792, Method A or ASTM D 1505	Per 200,000 SF and every resin lot
	Melt Flow Index	ASTM D 1238	Per 100,000 SF and every resin lot
Manufacturer's Quality Control	Thickness	ASTM D 5199 (smooth) or ASTM D 5994[2] (textured)	Per Roll of Geomembrane
	Specific Gravity/Density	ASTM D 1505/D 792	Per 200,000 pounds
	Carbon Black Content	ASTM D 4218	Per 20,000 pounds
	Carbon Black Dispersion	ASTM D 5596	Per 45,000 pounds
	Tensile Properties	ASTM D 638 / Type IV (ASTM D 6693 may be used as an alternative upon POR's approval)	Per 20,000 pounds
	Tear	ASTM D 1004	Per 45,000 pounds
	Puncture	ASTM D 4833	Per 45,000 pounds
	Stress Crack Resistance	ASTM D 5397	Per GRI-GM 10
	Oxidative Induction Time	ASTM D 3895 or ASTM D 5885	Per 200,000 pounds
	Oven Aging @ 85°C Standard OIT (min. avg.) or High pressure OIT - % retained after 90 days for both	ASTM D 5721 ASTM D 3895 ASTM D 5885	Per each formulation
	UV Resistance[3] High Pressure OIT (min. avg.) - % retained after 1,600 hours	ASTM D 7238 ASTM D 5885	Per each formulation
	Asperity Height	ASTM D 7466	Every 2nd roll[4]

[1] All tests will conform to the minimum requirements set forth by GRI testing standard GM13. Required values for the parameters are listed in Table 3-2.
[2] ASTM D 1593 may also be used for thickness of textured geomembrane.
[3] 20 hours of UV cycle at 75°C followed by 4 hours condensation at 60°C.
[4] Measurement side will be alternated for double-sided textured sheet. This testing is specified for textured geomembrane only.

Table 3-2
Minimum Required Properties of 60-mil-thick Smooth and Textured (Both Sides) HDPE Geomembranes

Property	Test Method	Minimum Required Property[8]	
		Smooth	Textured
Thickness, mils Minimum average Lowest individual reading Lowest individual of 8 of 10 readings	ASTM D 5199 (smooth) ASTM D 5994 (textured)	60 54 NA	57 51 54
Density, g/cc	ASTM D 1505/D 792	0.94	0.94
Asperity Height, mils	GRI GM12	N/A	16
Tensile Properties[1] 1. Yield Strength, lb/in 2. Break Strength, lb/in 3. Yield Elongation, % 4. Break Elongation, %	ASTM D 638 (Type IV Specimen @ 2 in/min) (ASTM D 6693 may be used as an alternative upon approval by POR)	126 228 12 700	126 90 12 100
Tear Resistance, lb	ASTM D 1004	42	42
Puncture Resistance, lb	ASTM D 4833	108	90
Stress Crack Resistance[2], hrs	ASTM D 5397	500	500
Carbon Black Content[3], %	ASTM D 1603	2.0 – 3.0	2.0 – 3.0
Carbon Black Dispersion[4], Category	ASTM D 5596	see note 4	see note 4
Oxidative Induction Time (OIT)[5] (Minimum Average) Standard OIT, minutes High Pressure OIT, minutes	ASTM D 3895 ASTM D 5885	100 400	100 400
Oven Aging at 85ºC Standard OIT – % retained after 90 days High Pressure OIT – % retained after 90 days	ASTM D 5721 ASTM D 3895 ASTM D 5885	55 80	55 80
UV Resistance[6] High Pressure OIT[7] – % retained after 1600 hrs	ASTM D 7238 ASTM D 5885	50	50
Seam Properties (5 out of 5 specimens, per GRI-GM19) 1. Shear Strength, lb/in 2. Peel Strength, lb/in	ASTM D 6392	120 91 & FTB (78, Extrusion Weld)	120 91 & FTB (78, Extrusion Weld)

[1] Machine direction (MD) and cross machine direction (XMD) average values will be on the basis of 5 test specimens each direction. Yield elongation is calculated using a gauge length of 1.3 inches; break elongation is calculated using a gauge length of 2.0 inches.
[2] The yield stress used to calculate the applied load for the Single Point Notched Constant Tensile Load (SP-NCTL) test will be the mean value via MQC testing.
[3] Other methods such as ASTM D 4218 or microwave methods are acceptable if an appropriate correlation can be established.
[4] Carbon black dispersion for 10 different views: 9 in Categories 1 and 2 and 1 (max) in Category 3.
[5] The manufacturer has the option to select either one of the OIT methods listed to evaluate the antioxidant content in the geomembrane.
[6] The condition of the test will be 20 hr UV cycle at 75ºC followed by 4 hr. condensation at 60ºC.
[7] UV resistance is based on percent retained value regardless of the original HP-OIT value.
[8] Minimum required properties are based on GRI-GM13, except for the seam properties which are based on GRI-GM19. At the time of each liner construction event, an updated GRI-GM13 and GRI-GM19 will be used if available.

The density of the geomembrane must be greater than 0.94 g/cc; the carbon black content must be between 2 percent and 3 percent; and recycled or reclaimed material must not be used in the manufacturing process.

The design engineer may require additional test procedures and will inform the third-party laboratory in writing. The POR must review all test results and report any nonconformance to the design engineer prior to product installation. In addition to the conformance thickness tests shown above, field thickness measurements must be taken at maximum 5-foot intervals along the leading edge of each geomembrane panel. No single measurement will be less than 10 percent (15 percent for textured) below the required nominal thickness for the panel to be accepted, and the average must be at least 60 mils (57 mils for textured). Refer to Table 3-2 for a complete listing of the material requirements for both smooth and textured geomembranes that will be used for the composite Subtitle D bottom liner.

Sampling Procedure. Samples will be taken across the entire roll width. Unless otherwise specified, samples will be approximately 15 inches long by the roll width. The third-party testing laboratory or CQA monitor must mark the machine direction and the manufacturer's roll identification number on the sample. The third-party testing laboratory or CQA monitor must also assign a conformance test number to the sample and mark the sample with that number.

3.3.3 Geomembrane Installation

Surface Preparation. Prior to any geomembrane installation, the installed soil liner or GCL surface will be inspected by the CQA and geosynthetics contractor. The POR or CQA monitor must observe the following:

- All lines and grades for the soil liner or GCL have been verified by the surveyor and accepted by the contractor for geosynthetic installation. The POR or his representative, the owner, and geomembrane installer will certify and accept in writing the finished final lift of the soil liner or GCL surface.
- The soil liner has been prepared in accordance with the earthwork construction plans and specifications as outlined in Section 2.
- The GCL has been prepared in accordance with the construction plans and specifications as outlined in Section 4.
- The soil liner is free of surface irregularities and protrusions. The soil liner will be rolled and compacted to ensure a clean surface.
- The soil liner or GCL surface does not contain stones or other objects that could damage the geomembrane or underlying soil liner or GCL. The surface of the soil liner or GCL will be smooth and free of foreign and organic material, sharp objects, exposed soil or aggregate particles greater than 3/4 inch (or less if recommended by the geosynthetic manufacturer), or other deleterious material.

- The anchor trench dimensions have been checked, and the trenches are free of sharp objects and stones.
- There are no excessively soft areas in the soil liner that could result in geomembrane damage.
- The geomembrane will not be placed over soil liner or GCL during inclement weather such as rain or high winds.
- The soil liner is not saturated, and no standing water is present above the soil liner or GCL.
- The soil liner has not desiccated (e.g., areas with desiccation cracks).
- All construction stakes and hubs have been removed and the resultant holes have been backfilled. There are no rocks, debris, or any other objects on the soil liner surface.
- The geosynthetics contractor has certified in writing that the soil liner or GCL surface on which the geomembrane will be installed is acceptable.

Panel Placement. Prior to the installation of the geomembrane, the contractor must submit drawings showing the panel layout, indicating panel identification number, both fabricated (if applicable) and field seams, as well as details not conforming to the drawings.

The CQA monitor must maintain an up-to-date panel layout drawing showing panel numbers that are keyed to roll numbers on the placement log. The panel layout drawing will also include seam numbers and repair and destructive test locations.

During panel placement, the POR or CQA monitor must:

- Observe that geomembrane is placed in direct and uniform contact with the underlying soil liner or GCL.
- Record roll numbers, panel numbers, and dimensions on the panel or seam logs. Measure and record thickness of leading edge of each panel at 5-foot maximum intervals. No single thickness measurement can be less than 10 percent (15 percent for textured) below the required nominal thickness.
- Observe the sheet surface as it is deployed and record all panel defects and repair of the defects (panel rejected, patch installed, extrudate placed over the defect, etc.) on the repair sheet. All repairs must be made in accordance with the specifications as outlined in Section 3.3.5 and located on a repair drawing.
- Observe that support equipment is not allowed on the geomembrane during handling (see Section 3.6 also).
- Observe that the surface beneath the geomembrane has not deteriorated since previous acceptance.

- Observe that there are no stones, construction debris, or other items beneath the geomembrane that could cause damage to the geomembrane.
- Observe that the geomembrane is not dragged across a surface that could damage the material. If the geomembrane is dragged across an unprotected surface, the geomembrane must be inspected for scratches and repaired or rejected, as necessary.
- Record weather conditions including temperature, wind, and humidity. The geomembrane must not be deployed in the presence of excess moisture (fog, dew, mist, or wind, etc.). In addition, geomembrane will not be placed when the air temperature is less than 41°F or greater than 104°F, or when standing water or frost is on the ground, unless this requirement is waived by the design engineer or TCEQ. Excessive wind is that which can lift and move the geomembrane panels.
- Observe that people working on the geomembrane do not smoke, wear shoes that could damage the liner, or engage in activities that could damage the liner.
- Observe that the method used to deploy the sheet minimizes wrinkles but does not cause bridging and that the sheets are anchored to prevent movement by the wind (the contractor is responsible for any damage to or from windblown geomembrane). Excessive wrinkles will be walked-out or removed at the discretion of the CQA monitor.
- Observe that no more panels are deployed than can be seamed on the same day.
- Observe that there are no horizontal seams on side slopes, and the textured material extends a minimum of approximately 5 feet out past the toe of the slope where textured geomembrane is used. This requirement may be waived if textured material is utilized on the floor.

The CQA monitor must inform both the contractor and the POR of the above conditions.

Field Seaming. The contractor must provide the POR with a seam and panel layout drawing and update this drawing daily as the job proceeds. No panels will be seamed until the panel layout drawing has been accepted by the POR. A seam numbering system must provide a unique number for each seam and be agreed to by the POR and contractor prior to the start of seaming operations. One procedure is to identify the seam by adjacent panels. For example, the seam located between Panels 306 and 401 would be Seam No. 306/401.

Prior to geomembrane welding, each welder and welding apparatus (both wedge and extrusion welders), must be tested, at a minimum, at daily start-up and at midday break, or any break that the seaming machine is stopped more than 30 minutes to determine if the equipment is functioning properly. The GLER will include the names for each seamer and the time and the temperatures for each seaming apparatus used each day. The trial weld sample must be 3 feet long and 12 inches wide, with the seam centered lengthwise. The minimum number of specimens per trial weld test must be two coupons for shear and two coupons for peel. Both the inner and outer welds of dual track fusion welds must be tested for each peel test coupon (or additional coupons will be required). Trial weld samples must comply with “Passing Criteria for Welds” included in Section 3.3.4 – Construction Testing. The CQA monitor must observe all welding operations, quantitative testing of each trial weld for peel and shear and recording of the results on the trial weld form. The trial weld will be completed under conditions similar to those under which the panels will be welded. Regarding the locus-of-break patterns of the different seaming methods in shear and peel, the following are unacceptable break codes per their description in ASTM D 6392 and GRI-GM19:

Hot Wedge: AD and AD-Brk>25%

Extrusion Fillet: AD1, AD2, AD-WLD (unless strength is achieved)

Additionally, there will be no apparent weld separation. The strength tests must meet the manufacturer’s specifications for the sample sheets, or the percentage of the manufacturer’s parent sheet strength as determined by the manufacturer. For dual-track fusion welds, both sides (the inner and outer weld) must meet the minimum requirements for a satisfactory peel test. Reference to 25% peel or separation during testing means 25% of the width of a single weld (i.e., full width of an extrusion weld, or a single track of a dual track fusion weld). If, at any time, the CQA monitor believes that an owner or welding apparatus is not functioning properly, a weld test must be performed. If there are wide changes in temperature (±30° Fahrenheit), humidity, or wind speed, the test weld will be repeated. The test weld must be allowed to cool to ambient temperature before testing. If a weld test fails the shear or peel test, the length of the non-passing weld will be identified at a 10-foot interval and the failed area will be patched. Patching will performed by placing additional geomembrane over the failed area or removing the failed area geomembrane weld and patching it with additional geomembrane per POR’s direction. Welding for patches must comply with the welding passing criteria requirements outlined in this section.

Construction quality assurance documentation of trial seam procedures will include, at a minimum, the following:

- Documentation that trial seams are performed by each welder and welding apparatus prior to commencement of welding and prior to commencement of the second half of the workday.
- The welder, the welding apparatus number, time, date, ambient air temperature, and welding machine temperatures.

During geomembrane welding operations, the CQA monitor must observe the following:

- The contractor has the number of welding apparatuses and spare parts necessary to perform the work.
- Equipment used for welding will not damage the geomembrane.
- The extrusion welder is purged prior to beginning a weld until all the heat-degraded extrudate is removed (extrusion welding only).
- Seam grinding has been completed less than one hour before seam welding, and the upper sheet is beveled (extrusion welding only).
- The ambient temperature, measured 6 inches above the geomembrane surface, is between 41° and 104° Fahrenheit unless more stringent limits are required by the manufacturer.
- The end of old welds, more than five minutes old, are ground to expose new material before restarting a weld (extrusion welding only).
- The contact surfaces of the sheets are clean, free of dust, grease, dirt, debris, and moisture prior to welding.
- The weld is free of dust, rocks, and other debris.
- The seams are overlapped a minimum of 3 inches for extrusion and hot-wedge welding, or in accordance with manufacturer's recommendations, whichever is more stringent. Panels will be overlapped (shingled) in the downgrade direction.
- No solvents or adhesives are present in the seam area.
- The procedure used to temporarily hold the panels together does not damage the panels and does not preclude CQA testing.
- The panels are being welded in accordance with the plans and specifications that will be developed in accordance with this section for each liner construction. Seams will be oriented parallel to the line of maximum slope with no horizontal seams on side slopes. In corners and odd-shaped geometric locations, the number of field seams will be minimized.
- There is no free moisture in the weld area.
- Measure surface sheet temperature every two hours.
- Observe that at the end of each day or installation segment, all unseamed edges are anchored with sandbags or other approved device. Penetration anchors will not be used to secure the geomembrane.

3.3.4 Construction Testing

Nondestructive Seam Testing. The purpose of nondestructive testing is to detect discontinuities or holes in the seam. It also indicates whether a seam is continuous and non-leaking. Nondestructive tests for geomembrane include vacuum testing for extrusion welds and air pressure testing for dual track fusion welds. Nondestructive testing must be performed over the entire length of the seam.

Nondestructive testing is performed entirely by the contractor. The CQA monitor's responsibility is to document the date, time and location of seaming and testing, and to observe and document that testing was performed in compliance with this section and document any seam defects and their repairs.

Nondestructive testing procedures are described below.

- For welds tested by vacuum method, the weld is placed under suction utilizing a vacuum box made of rigid housing with a transparent viewing window, a soft neoprene rubber gasket attached to the open bottom perimeter, a vacuum gauge on the inside, and a valve assembly attached to the vacuum hose connection. The box is placed over a seam section, which has been thoroughly saturated with a soapy water solution (1 oz. soap to 1 gallon water). The rubber gasket on the bottom perimeter of the box must fit snugly against the soaped seam section of the liner, to ensure a leak-tight seal. The vacuum pump is energized, and the vacuum box pressure is reduced to approximately 3 to 5 psi gauge. Any pinholes, porosity or non-bonded areas are detected by the appearance of soap bubbles in the vicinity of the defect. Dwell time must not be less than ten seconds.
- Air pressure testing is used to test double seams with an enclosed air space (i.e., dual-track fusion welds). Both ends of the air channel will be sealed. The pressure feed device, usually a needle equipped with a pressure gauge, is inserted into the channel. Air is then pumped into the channel to a minimum pressure of 30 psi or ½ psi per mil of geomembrane thickness, whichever is greater. The air chamber must sustain the pressure for five minutes without losing more than 4 psi. Following a passed pressure test, the opposite end of the tested seam must be punctured to release the air. The pressure gauge must return to zero; if not, a blockage is most likely present in the seam channel. Locate the blockage and test the seam on both sides of the blockage. The penetration holes must be sealed after testing.

During nondestructive testing, the CQA monitor must perform the following work:

- Review technical specifications regarding test procedures.
- Observe that equipment operators are fully trained and qualified to perform their work.
- Observe that test equipment meets project specifications that will be developed in accordance with this LQCP for each liner construction.
- Observe that the entire length of each seam is tested in accordance with the specifications outlined in this section.

- Observe all continuity testing and record results on the appropriate log.
- Observe that all testing is completed in accordance with the specifications outlined in this section.
- Identify the failed areas by marking the area with a waterproof marker compatible with the geomembrane and inform the contractor of any required repairs, then record the repair area on the repair log.
- Observe that all repairs are completed and tested in accordance with the project specifications outlined in this section and Section 3.3.5.
- Record all completed and tested repairs on the repair log and the repair drawing.

Destructive Seam Testing. Destructive seam tests for geomembrane seams will be performed at intervals of at least one test per 500 linear feet of seam length. At a minimum, a destructive test will be completed for each welding machine used for seaming. A destructive test will also be performed for individual repairs (or additional seaming for the failed seams) at intervals of at least one test per 500 linear feet. Only individual repairs (or additional seaming for failed seams) requiring more than 10 feet of seaming shall count toward the testing interval. The CQA monitor must perform additional tests if he suspects a seam does not meet specification requirements outlined in this section. Reasons for performing additional tests may include, but are not limited to the following:

- Wrinkling in seam area
- Non-uniform weld
- Excess crystallinity
- Suspect seaming equipment or techniques
- Weld contamination
- Insufficient overlap
- Adverse weather conditions
- Possibility of moisture, dust, dirt, debris, and other foreign material in the seam
- Failing tests

There are two types of destructive testing required for the geomembrane installation: peel adhesion (peel) and bonded seam strength (shear) in accordance with ASTM D 6392. The purpose of peel and shear tests is to evaluate seam strength and to evaluate long-term performance. Shear strength measures the continuity of tensile strength through the seam and into the parent material. Peel strength determines weld quality. Test welds must be allowed to cool naturally to ambient temperature prior to testing.

The CQA monitor selects locations where seam samples will be cut for laboratory testing. Select these locations as follows:

- A minimum of one random test within each 500 feet of seam length. This is an average frequency for the entire installation; individual samples may be taken at greater or lesser intervals.
- Sample locations will not be disclosed to the contractor prior to completion of the seam.
- A maximum frequency must be agreed to by the contractor, POR, and the Operator at the preconstruction meeting. However, if the number of failed samples exceeds 5 percent of the tested samples, this frequency may be increased at the discretion of the POR. Samples taken as the result of failed tests do not count toward the total number of required tests.

Sampling Procedures. The contractor will remove samples at locations identified by the CQA monitor. The CQA monitor must:

- Observe sample cutting.
- Mark each sample with an identifying number, which contains the seam number and destructive test number.
- Record sample location on the panel layout drawing and destructive seam log.
- Record the sample location, weather conditions, and reason sample was taken (e.g., random sample, visual appearance, result of a previous failure, etc.).

For each destructive test obtain one sample approximately 45 inches long by 12 inches wide, with the weld centered along the length. Cut two 1-inch-wide coupons from each end of the sample. The contractor must test two of these coupons in shear and two in peel (one shear and one peel from each end) using a tensiometer capable of quantitatively measuring the seam strengths. For double wedge welding, both sides of the air channel will be tested in peel. The CQA monitor must observe the tests and record the results on the destructive seam test log. A geomembrane seam sample passes the field testing when the break is Film Tear Bond (FTB) and the seam strength meets the required strength values for peel and shear given previously for trial seams under field seaming and below for third-party laboratory testing. As previously discussed, both welds have to pass for dual-track welds. Also, it is recommended that additional samples be obtained as discussed in the following paragraph if there is apparent separation of the weld during peel testing.

If one or both of the 1-inch specimens fail in either peel or shear, the contractor can, at his discretion: (1) reconstruct the entire seam between passed test locations, or (2) take two additional test samples 10 feet or more in either direction from the point of the failed test and repeat this procedure. For tracking purposes, the additional samples will be identified by assigning an identifying letter to the initial destructive test sample number (e.g., DS-6A and B). Only satisfactory tests count toward the required minimum number, and additional tests (i.e., A and B) count as one test, if passing. If the second set of tests passes, the contractor can reconstruct or cap-strip the seam between the two passed test locations. If subsequent tests fail, the sampling and testing procedure is repeated until the length of the poor quality seam is established. Repeated failures indicate that either the seaming equipment or operator is not performing properly, and appropriate corrective action must be taken immediately.

If the field test coupons are satisfactory, divide the remaining sample into three parts: one 12-inch by 12-inch section for the contractor, one 12-inch by 16-inch section for the third-party laboratory for testing, and one 12-inch by 12-inch section for the operator to archive. The laboratory sample will be shipped to the third-party laboratory for overnight delivery and next day testing.

If the laboratory test fails in either peel or shear, the contractor must either reconstruct the entire seam between passing test locations or recover additional samples at least 10 feet on either side of the failed sample for retesting. Sample size and disposition must be as described in the preceding paragraph. This process is repeated until passed tests bracket the failed seam section. All seams must be bounded by locations from which passing laboratory tests have been taken. Laboratory testing governs seam acceptance. In no case can field testing of repaired seams be used for final acceptance.

Third-party Laboratory Testing. Destructive samples must be shipped to the third-party laboratory for seam testing. Testing for each sample will include 5 bonded seam shear strength tests and 5 peel adhesion tests (10 for dual-track welds). For dual-track welds each peel test specimen (coupon) will be tested on both sides of the air channel (i.e., the inner and outer welds). All five specimens tested in peel and shear shall meet the minimum strength requirements. The minimum peel strength and the minimum shear strength values must meet the passing criteria listed below. Additionally, all 5 of the peel test coupons must have no greater than 25 percent seam separation. For dual-track welds if either weld exhibits greater than 25 percent separation or does not meet the required strength, that coupon is considered out of compliance and causes the weld to fail. The third-party laboratory must provide test results within 24 hours, in writing or via telephone, to the CQA monitor. Certified test results are to be provided within 5 days. The CQA monitor must immediately notify the POR in the event of a calibration discrepancy or failed test results.

Passing Criteria for Welds. Passing criteria are established by GRI GM19 for geomembranes. A passing extrusion or fusion welded seam will be achieved when the following values are tested. The following values listed for shear and peel strengths are for all 5 test specimens. Elongation measurements will be omitted for field testing.

- Shear strength (lb/in) 120 (90 for Textured)
- Shear elongation at break (%) 50
- Peel strength (lb/in) 91 (78 Extrusion Weld) & FTB
- Peel separation (%) 25

A passing extrusion or fusion welded seam will be achieved in peel when:

- Yield strength for all 5 specimens (10 tests for dual-track welds) is not less than the above minimum peel strength value and the average of all 5 specimens is not less than the minimum value.
- No greater than 25 percent of the seam width peels (separates) at any point for all 5 specimens (both inner and outer welds for dual-track welds).

A passing extrusion or fusion weld will be achieved in shear when:

- Yield strength for all 5 specimens is not less than the above minimum shear strength value and the average for all 5 specimens is not less than the minimum value.
- Break strain for all 5 specimens is at least 50 percent.

3.3.5 Repairs

Any portion of the geomembrane with a detected flaw, or which fails a nondestructive or destructive test, or where destructive tests were cut, or where nondestructive tests left cuts or holes, must be repaired in accordance with the specific liner construction specifications and consistent with all the applicable parts (e.g., material requirement, installation, testing, etc.) of this section. The CQA monitor must locate and record all repairs on the repair sheet and panel layout drawing. Repair techniques include the following:

- Patching – used to repair large holes, tears, large panel defects, undispersed raw materials, contamination by foreign matter, and destructive sample locations.
- Extrusion – used to repair small defects in the panels and seams. In general, this procedure will be used for defects less than ⅜-inch in the largest dimension.
- Capping – used to repair failed welds or to cover seams where welds or bonded sections cannot be nondestructively tested.
- Removal – used to replace areas with large defects where the preceding methods are not appropriate. Also used to remove excess material (wrinkles, fishmouths, intersections, etc.) from the installed geomembrane. Areas of removal will be patched or capped.

Repair procedures include the following:

- Abrade geomembrane surfaces to be repaired (extrusion welds only) no more than one hour prior to the repair.
- Clean and dry all surfaces at the time of repair.
- Extend patches or caps at least 6 inches beyond the edge of the defect, and round all corners of material to be patched and the patches to a radius of at least 3 inches. Bevel the top edges of patches prior to extrusion welding.
- Testing of repaired seams consistent with Section 3.3.4 – Construction Testing.

3.3.6 Wrinkles

During placement of cover materials over the geomembrane, temperature changes or creep can cause wrinkles to develop in the geomembrane. Any wrinkles which can fold over must be repaired either by cutting out excess material or, if possible, by allowing the liner to contract by temperature reduction. In no case can material be placed over the geomembrane, which could result in the geomembrane folding. The CQA monitor must monitor geomembrane for wrinkles and notify the contractor if wrinkles are being covered by soil. The CQA monitor is then responsible for documenting corrective action to remove the wrinkles.

3.3.7 Folded Material

All folded geomembrane must be removed. Remnant folds evident after deployment of the roll, which are due to manufacturing process, are acceptable.

3.3.8 Geomembrane Anchor Trench

The geomembrane anchor trench will be left open until seaming is completed. Expansion and contraction of the geomembrane will be accounted for in the liner placement. Prior to backfilling, the depth of penetration of the geomembrane into the anchor trench must be verified by the CQA monitor at a minimum of 100-foot spacings along the anchor trench. The anchor trench will be filled in the morning when temperatures are coolest to reduce bridging of the geomembrane. The material used will meet the criteria outlined in Section 2.3.7.

3.3.9 Geomembrane Acceptance

The contractor retains all ownership and responsibility for the geomembrane until acceptance by the Operator. In the event the contractor is responsible for placing cover over the geomembrane, the contractor retains all ownership and responsibility for the geomembrane until all required documentation is complete, and the cover material is placed. After panels are placed, seamed, tested successfully, and any repairs are made, the completed installation will be walked by the Operator's and contractor's representatives. Any damage or defect found during this inspection will be repaired properly by the installer. The installation will not be accepted until it meets the requirements of both representatives. In addition, the geomembrane will be accepted by the POR only when the following has been completed:

- The installation is finished.
- All seams have been inspected and verified to be acceptable.
- All required laboratory and field tests have been completed and reviewed.
- All required contractor-supplied documentation has been received and reviewed.
- All as-built record drawings have been completed and verified by the POR. The as-built drawings show the true panel dimensions, the location of all seams, trenches, pipes, appurtenances, and repairs.
- Acceptance of the GLER by TCEQ.

3.3.10 Bridging

Bridging must be removed.

3.4 Geotextiles

Geotextiles will be used to prevent clogging of drainage materials. The main usage of geotextiles will be enveloping drainage stone used for chimney drains in the leachate collection system (LCS). Geotextiles for the LCS will meet the design requirements set forth in Appendix IIIC – Leachate and Contaminated Water Management Plan. Manufacturer's testing for geotextile is listed in Table 3-5.

3.4.1 Delivery

During delivery the CQA monitor must observe the following:

- Equipment used to unload the rolls will not damage the geotextile.
- Rolls are wrapped in impermeable and opaque protection covers.
- Care is used when unloading the rolls.
- All documentation required by this LQCP and the specifications has been received and reviewed for compliance with this LQCP.
- Each roll is marked or tagged with the manufacturer's name, project identification, lot number, roll number, and roll dimensions.

- Materials are stored in a location that will protect the rolls from precipitation, mud, dirt, dust, puncture, cutting, or any other damaging or deleterious conditions.

Any damaged rolls must be rejected and removed from the site or stored at a location separate from accepted rolls, designated by the Operator. All rolls which do not have proper manufacturer's documentation must also be stored at a separate location until all documentation has been received and approved.

3.4.2 Testing

The geotextile manufacturer will conduct manufacturer quality control (MQC) testing and certify that the materials delivered to the site comply with project specifications outlined in this LQCP. The material certification will be reviewed by the POR and approved for the project prior to acceptance of any of the material. The MQC testing will include the following tests with at least one test for each 100,000 square feet of geotextile delivered.

- Grab tensile strength/elongation (ASTM D 4632)
- Mass per unit area (ASTM D 5261)
- Thickness (ASTM D 5199)
- Puncture resistance (ASTM D 4833)
- Trapezoidal tear strength (ASTM D 4533)
- Hydraulic tests (ASTM D 4491)
- Apparent opening size (ASTM D 4751)

Where optional procedures are noted in the test method, the specification requirements of this LQCP prevail. The POR will review all test results and report any nonconformance.

3.4.3 Geotextile Installation

Surface Preparation. Prior to geotextile installation, the CQA monitor must observe the following:

- All lines and grades have been verified by the surveyor.
- The supporting surface does not contain stones that could damage the geotextile or the underlying geomembrane.
- There are no excessively soft areas that could result in damage to the geotextile, or other components of the liner system.
- Construction stakes and hubs have been removed.

Geotextile Placement. During geotextile placement, the CQA monitor must:

- Observe the geotextile as it is deployed and record all defects and disposition of the defects (panel rejected, patch installed, etc.). Repairs are to be made in accordance with the specifications outlined in Section 3.5.4.
- Observe that equipment used does not damage the geotextile by handling, equipment transit, leakage of hydrocarbons, or other means.
- Observe that people working on the geotextile do not smoke, wear shoes that could damage the geotextile, or engage in activities that could damage the geotextile.
- Observe that the geotextile is securely anchored or thermal bonded.
- Observe that the geotextiles are anchored to prevent movement by the wind.
- Observe that the panels are overlapped a minimum of six inches.
- Examine the geotextile after installation to ensure that no potentially harmful foreign objects are present.
- Observe that seams (where required) are continuously sewn or thermal bonded in accordance with the manufacturer's recommendations and the project specifications outlined in this LQCP.

The CQA monitor must inform both the contractor and POR if the above conditions are not met.

3.4.4 Repairs

Repair procedures include:

- Patching – used to repair large holes, tears, and large defects.
- Removal – used to replace areas with large defects where the preceding method is not appropriate.

Holes, tears, and defects must be repaired in the following manner. Soil or other material which may have penetrated the defect must be removed completely prior to repair. If located on a slope, the defect must be patched using the same type of geotextile and continuously seamed into place. Should any tear, hole, or defect exceed 30 percent of the width of the roll, the roll will be cut off and the defect removed or the roll removed and replaced. If the defect is not located on a slope, the patch must be made using the same type of material seamed into place with a minimum of 24 inches overlap in all directions. Seams will be either thermal bonded or sewn in accordance with the manufacturer's recommendations.

3.5 Drainage Geocomposite – Geonet and Geotextile

A drainage geocomposite will be used for the liner LCS. The drainage geocomposite will meet the requirements set forth in Appendix IIIC – Leachate and Contaminated Water Management Plan of the Site Development Plan along with this LQCP. Manufacturer's testing for geotextile and drainage geocomposite for the composite liner are listed in Table 3-3. Third-party laboratory transmissivity conformance testing for the geocomposite liner is listed in Table 3-4. The drainage geocomposite for the composite liner will meet the required properties listed in Table 3-3 and Table 3-4.

Reference to "geocomposite thickness" within this LQCP and in supporting calculations (Appendix IIIC) refers to the thickness of the geonet, not the overall thickness of the geocomposite. The transmissivity values used for the calculations supporting this LQCP may or may not be representative of actual transmissivity values for every geocomposite manufacturer and may require a prospective material supplier to provide a geocomposite that varies in thickness from the geocomposite presented in this LQCP to meet the minimum transmissivity criteria set forth in this LQCP.

3.5.1 Delivery

Upon delivery the CQA monitor must observe the following:

- The drainage geocomposite is wrapped in rolls with protective covering.
- The rolls are not damaged during unloading.
- Protect the drainage geocomposite from mud, soil, dirt, dust, debris, cutting, or impact forces.
- Each roll must be marked or tagged with proper identification.

Any damaged rolls will be rejected and removed from the site or stored at a location, separate from accepted rolls, designated by the Operator. All rolls which do not have proper manufacturer's documentation will also be stored at a separate location until all documentation has been received and approved.

3.5.2 Testing

The drainage geocomposite manufacturer (or supplier) will conduct quality control testing and certify that all materials delivered to the site comply with the specifications listed in Table 3-3 and Table 3-4. The minimum testing frequency will be one test sample per 100,000 square feet of geocomposite (or geonet/geotextile). See footnotes 2 and 3 of Table 3-4 for testing frequency for transmissivity. The material certifications will be reviewed by the POR to verify that the geocomposite meets the values given in Table 3-3 and Table 3-4.

Geonet will be tested by the manufacturer for thickness, tensile strength, and carbon black content. Geotextile will be tested for mass per unit area, grab tensile strength, and AOS. The finished geocomposite will be tested for peel adhesion and transmissivity (note that the geocomposite transmissivity tests need to be conducted by a third-party laboratory only under the specific conditions listed in Table 3-4). The manufacturer's testing for drainage material is also summarized in Table 3-3.

Where optional procedures are noted in the test method, the specification requirements of this LQCP prevail. The CQA monitor will review all test results and will report any nonconformance to the POR and to the contractor.

3.5.3 Installation

Surface Preparation. Prior to drainage geocomposite installation, the CQA monitor will observe the following:

- All lines and grades have been verified by the surveyor (where required).
- The subgrade has been prepared in accordance with the earthwork specifications outlined in Section 2.
- When placed over a geomembrane, the geomembrane installation, including all required documentation, has been completed.
- The supporting surface does not contain stones that could damage the geocomposite or the geomembrane.

Drainage Geocomposite Placement. During placement, the CQA monitor will:

- Observe that the geocomposite is placed where the geonet drainage direction is oriented parallel with the sideslope and in the direction of flow on the floor.
- Observe the drainage geocomposite as it is deployed and record defects and disposition of the defects (panel rejected, patch installed, etc.). Repairs are to be made in accordance with the specifications outlined in Section 3.5.4.
- Verify that equipment used does not damage the drainage geocomposite or underlying geomembrane by handling, trafficking, leakage of hydrocarbons, or by other means.
- Verify that people working on the drainage geocomposite do not smoke, wear shoes that could damage the drainage geocomposite, or engage in activities that could damage the drainage geocomposite or underlying geomembrane.
- Verify that the drainage geocomposite is anchored to prevent movement by the wind (the contractor is responsible for any damage resulting to or from windblown drainage geocomposite).

- Verify that the drainage geocomposite remains free of contaminants such as soil, grease, fuel, etc.
- Observe that the drainage geocomposite is laid smooth and free of tension, stress, folds, wrinkles, or creases.
- Observe that equipment or geocomposite complies with Section 3.6.
- Observe that on slopes the drainage geocomposite is secured in the liner anchor trench and then rolled down the side slope.
- Observe that adjacent rolls of drainage geocomposite are overlapped a minimum of six inches, tied, and seamed in accordance with the manufacturer's recommendations.
- Observe that tying is with plastic fasteners in accordance with the manufacturer's recommendations. In the absence of other specifications, the drainage geocomposite panels will be tied approximately every 5 feet along the roll length (edges) and every 1 foot along the roll width (ends).
- Observe that the geotextile component is overlapped and either heat bonded or sewn together.

Table 3-3
Manufacturer Certification Tests and Properties for the Leachate Collection System Drainage Geocomposite

Material	Test	Standard	Required Property[2]	Test Frequency
Geotextile (Before Lamination)	Mass/Unit Area[4]	ASTM D 5261	6 oz/sy	See Note 1
	Apparent Opening Size	ASTM D 4751	0.25 mm	
	Grab Strength	ASTM D 4632	157 lbs	
	Tear Strength	ASTM D 4533	55 lbs	
	Puncture Strength	ASTM D 6241	310 lbs	
	Permittivity	ASTM D 4491	0.2 sec^{-1}	
HDPE Geonet (Before Lamination)	Specific Gravity	ASTM D 1505	0.95 g/cm^3	Per 50,000 lb.
	Thickness	ASTM D 5199	0.25 inch (bottom liner)	Per 50,000 lb.
	Carbon Black	ASTM D 1603	2%	Per 100,000 lb.
	Tensile Strength	ASTM D 5035	45 lb/in	Per 50,000 lb.
Drainage Geocomposite	Transmissivity	ASTM D 4716	See Table 3-4	Per 200,000 lb.
	Ply Adhesion	ASTM D 7005	1.0 lb/in	Per 100,000 lb.

1 Minimum Average Roll Valve (MARV) except Apparent Opening Site (AOS) is Maximum Average Roll Valve (MaxARV).

2 Minimum required property values for the geotextile and HDPE geonet are based on calculations provided in Appendix IIIC-B. The geonet properties are based on values specified in GRI standard GM-13. In addition, each material will be tested prior to construction to verify that it meets the minimum required properties. Actual geonet thickness, if greater than the minimum, will be determined by manufacturer quality control testing and recommendations.

3 Reference to "geocomposite thickness" within the LQCP and in supporting calculations (Appendix IIIC) refers to the thickness of the geonet, not the overall thickness of the geocomposite. The transmissivity values used for the calculations supporting this LQCP may or may not be representative of actual transmissivity values for every geocomposite manufacturer and may require a prospective material supplier to provide a geocomposite that varies in thickness from the geocomposite presented in this LQCP in order to meet the minimum transmissivity criteria set forth in this LQCP.

4 Higher mass/unit area geotextile may be used; however, it will be required to pass all strength requirements and geocomposite transmissivity requirements under varying loading conditions.

Table 3-4
Third-Party Laboratory Transmissivity Conformance Test for the Leachate Collection System Drainage Geocomposite

Material[1]	Standard	Gradient	Test Point	Normal Pressure (PSF)	Leachate Collection System Design Demonstration Values		Required Property[2,3,4]
					Thickness[4] (In)	Hydraulic Conductivity (cm/s)	Minimum Transmissivity (m^2/s)
Single-Sided Drainage Geocomposite (Floor Grades)	ASTM D 4716	0.025	1	726	.199	0.90	1.00E-04
			2	2,874	.190	0.53	8.00E-05
			3	6,024	.179	0.33	6.00E-05
			4	8,254	.171	0.19	4.14E-05
			5	8,524	.170	0.19	4.71E-05
Double-Sided Drainage Geocomposite (Side-Slope Grades)	ASTM D 4716	0.33	1	726	0.199	0.14	1.57E-05
			2	2,874	0.190	0.07	1.12E-05
			3	6,024	0.179	0.04	7.27E-06
			4	8,254	0.172	0.03	5.89E-06
			5	8,524	0.171	0.02	5.74E-06

1 The minimum testing frequency will be one test sample per 100,000 SF. The drainage geocomposite will be single-sided for the floor grades of the bottom liner. The drainage geocomposite will be double-sided for the sideslopes of the bottom liner.

2 As noted in Appendix IIIC, Appendices IIIC-A and IIIC-A.2, the transmissivity of the single-sided and double-sided geocomposite for the undeveloped areas will be aligned with the geonet drainage direction oriented in the direction of flow and will be measured at the gradient specified above, normal pressures at each test point, boundary conditions consisting of soil/geocomposite/geomembrane with minimum seating time of 100 hours and will be performed for the first 200,000 lb. of liner construction. For each additional 200,000 lb. of geocomposite placement area, one additional transmissivity test will be performed under the maximum normal stress (i.e., 14,833 psf) or higher with all the same assumptions. The transmissivity shall be greater than specified above.

3 Minimum required property values for the drainage geocomposite transmissivity are based on calculations provided in Appendix IIIC-A. In addition, each material will be tested prior to construction to verify that it meets the minimum required properties. Actual geonet thickness, if greater than the minimum, will be determined by manufacturer quality control testing and recommendations.

4 Reference to "geocomposite thickness" within this LQCP and in supporting calculations (Appendix IIIC) refers to the thickness of the geonet, not the overall thickness of the geocomposite. The transmissivity values used for the calculations supporting this LQCP may or may not be representative of actual transmissivity values for every geocomposite manufacturer and may require a prospective material supplier to provide a geocomposite that varies in thickness from the geocomposite presented in this LQCP in order to meet the minimum transmissivity criteria set forth in this LQCP.

Table 3-5
Manufacturer Certification Tests and Properties for the Leachate Collection System Chimney Drain Geotextile

Material	Test	Standard	Required Property[2]	Test Frequency
Geotextile	Mass/Unit Area[3]	ASTM D 5261	6 oz/sy	See Note 1
	Apparent Opening Size	ASTM D 4751	0.25 mm	
	Grab Strength	ASTM D 4632	157 lbs	
	Tear Strength	ASTM D 4533	55 lbs	
	Puncture Strength	ASTM D 6241	310 lbs	
	Permittivity	ASTM D 4491	0.2 sec^{-1}	

1 Minimum Average Roll Valve (MARV) except Apparent Opening Site (AOS) is Maximum Average Roll Valve (MaxARV).

2 Minimum required property values for the geotextile are based on calculations provided in Appendix IIIC-B. The geotextile properties are based on values specified in GRI standard GM-13.

3 Higher mass/unit area geotextile may be used; however, it will be required to pass all strength requirements and geocomposite transmissivity requirements under varying loading conditions.

3.5.4 Repairs

Repair procedures include:

- Holes or tears in the drainage geocomposite will be repaired by placing a patch extending 2 feet beyond the edges of the hole or tear.
- Secure patch to the originally installed drainage geocomposite by tying every 6 inches.
- Where the hole or tear width across the roll is more than 50 percent of the roll width the damaged area will be cut out across the entire roll and the two portions of the drainage geocomposite will be jointed.

3.6 Equipment on Geosynthetic Materials

Construction equipment on the bottom liner systems will be minimized to reduce the potential for liner puncture. The CQA monitor will verify that small equipment such as generators are placed on scrap liner material (rub sheets) above geosynthetic materials in the liner system. Aggregate drainage layers and/or protective cover will be placed using low ground pressure equipment. The CQA monitor will verify that the geosynthetics are not displaced while the soil layers are being placed.

Unless otherwise specified by the POR, all lifts of protective soil material placed over geosynthetics will conform with the following guidelines.

Equipment Ground Pressure (psi)	Minimum Lift Thickness (in)
<5.0	12
5.1 – 8.0	18
8.1 – 16.0	24
>16.0	36

No equipment will be left running and unattended over the lined area.

3.7 Reporting

The POR will submit to the TCEQ a GLER for approval of the flexible membrane liner, leachate collection system and protective cover. Section 7 describes the documentation requirements.

4 CONSTRUCTION QUALITY ASSURANCE FOR GEOSYNTHETIC CLAY LINER

4.1 Introduction

GCL may be used in lieu of soil liner in the composite liner system. The GCL will be covered with geomembrane, drainage geocomposite, and a minimum 24-inch-thick protective cover. A geotechnical analysis of the liner system with a GCL is included in Appendix IIIE – Geotechnical Report. Material properties based on Geosynthetic Research Institute recommendations as described in GRI-GCL3 have been included in Table 4-1 – Required Testing for GCL Materials. The GCL will meet or exceed the required properties.

4.2 Material Requirements

1. A reinforced GCL which consists of bentonite encapsulated between two geotextiles, one nonwoven and one woven, which are needle punched together will be used. The GCL materials and its components will be tested in accordance with Table 4-1 by the supplier/GCL manufacturer and a third-party independent laboratory and will have the required values listed in Table 4-2. A certificate of analysis for each GCL panel will be submitted as part of the quality control documentation. The GCL permeability will be certified by the manufacturer and will be tested by an independent laboratory at frequencies included in Table 4-1. The manufacturer will provide recommended seaming procedures and supporting test data (flow box or other suitable device). The manufacturer will provide documentation showing the GCL seams are no more permeable than the GCL itself at a confining pressure anticipated in the field. The nonwoven side of the GCL will be in contact with the geomembrane. Table 4-2 includes further details for the GCL material.
2. The GCL will be shipped in rolls, which are wrapped individually in relatively impermeable and opaque protective covers. GCL rolls will be offloaded with equipment that will not damage the GCL rolls. The roll may be stacked only as allowed by manufacturer's recommendations. The GCL rolls must be stored above ground (i.e., wooden pallets) and covered with a waterproof tarpaulin.

3. GCL testing will be performed by the manufacturer and a third-party independent laboratory. The POR will review the manufacturer's certification (quality control certificate) and verify that the GCL meets the values given in the plan or specifications for those tests listed in Table 4-1. Required quality control documentation will be submitted to the POR a minimum of 7 days prior to deployment of any GCL. Requirements for GCL materials are listed in Table 4-2.
4. The POR will perform verification testing as required by additional detailed construction specifications or as required by the POR.

4.3 GCL Installation

Installation of GCL will have continuous on-site monitoring during construction by the POR or his designated representative. The installer will provide a panel layout plan, which will be reviewed by the POR prior to any material deployment. The POR must review field conditions and approve a revised panel layout plan if the field conditions vary from the original plan layout.

4.3.1 Subgrade Preparation

The surface of subgrade for the GCL installation will be stable. It will be smooth and free of foreign and organic material, sharp objects, exposed soil or aggregate particles greater than 3/4 inch (or less if recommended by the manufacturer), or other deleterious materials. Standing water or excessive water on the subgrade will not be allowed. If standing water is encountered it will be removed and soils with excessive moisture will be excavated and replaced with suitable borrowed soils to provide a firm, smooth-surfaced base for GCL placement. The POR will verify that the subgrade does not contain excessive moisture, and that soft soil is removed from the area. A firm, smooth-surfaced base grade will be established before GCL placement. The POR may require additional compaction and grading that will result in a smooth surface (e.g., proof rolling), as necessary.

Prior to GCL installation, the POR will verify the following:

- The grades below the GCL have been verified and accepted by the GCL contractor.
- Required documentation for subgrade preparation below the GCL have been completed and are acceptable.
- The supporting surface has been rolled to provide a smooth surface and does not contain materials, which could damage the GCL or adjacent layer. The subgrade will be rolled with a smooth-drum compactor. Protrusions extending more than 3/4 inches (or less if recommended by the manufacturer) from the base grade surface will be either removed or pushed into the surface with a smooth-drum compactor.

4.3.2 Deployment

Equipment used to deploy GCL over soil must not cause excessive rutting of the GCL subgrade. Deployed GCL panels should contain no folds or excessive slack. Generators, gasoline or solvent cans, tools, or supplies must not be stored directly on GCL. Installation personnel must not smoke or wear damaging shoes when working on GCL.

GCL seams will be constructed overlapping their adjacent edges a minimum of 12 inches. GCL seams will be constructed per manufacturer's directions. The CQA monitor will verify that steps are taken to minimize the presence of loose soil or other debris within the overlap zone.

GCL on sideslopes must not be unrolled in a direction perpendicular to the direction of the slope. GCL should be anchored temporarily (e.g., sandbags) at the top of the slope and then unrolled working from the top of the slope so as to keep the material free of wrinkles and folds, and GCL should be anchored at the bottom of the slope.

Horizontal seams will only be allowed on the slopes under one of the following conditions:

- 2 feet of overlap with horizontal seams being staggered.
- 1 foot of overlap with the underlying panel having a 1-foot runout anchored with 6 inches of subgrade.

Manufacturer hydraulic conductivity testing of GCL seams must be performed by using a flow box or other suitable device per adjoining material and type. Hydraulic conductivity value must be equal to or less than the specified hydraulic conductivity value for the GCL ($5x10^{-9}$ cm/s).

The POR or his designated representative will observe the GCL as it is deployed for even bentonite distribution, thin spots, or other panel defects. Defects and the disposition of the defects (panel rejected, patch installed, etc.) will be recorded. Repairs are to be made in accordance with the specifications at the discretion of the POR. The POR will verify that only panels that can be covered on the same day with an FML are deployed and that the GCL panels are not placed during wet, rainy weather. In accordance with the construction specifications, the POR will also verify the following:

- Proper GCL deployment techniques.
- Proper overlap during deployment.
- Seams between GCL panels are constructed per manufacturer's recommendations.
- The bentonite does not exceed the specified amount of hydration prior to covering.

- Defects are patched and overlapped properly.
- On sideslopes, the GCL is anchored at the top and then unrolled.
- Observe that no debris is trapped beneath or within the GCL.
- Observe that broken needle pieces do not exist within needle-punched GCL.
- Observe that wind speed is less than 40 miles per hour unless a lower wind speed is recommended by the manufacturer. At a minimum, a hand-held anemometer will be used, and readings will be taken at least once a day during GCL deployment to verify that the wind speed is less than 40 miles per hour.

The POR will observe the GCL for premature hydration visually and by walking over the GCL to locate soft spots. GCL that has prematurely hydrated according to the specifications will be removed and replaced with new GCL. These observations will be documented in the GCLER.

4.3.3 GCL Anchor Trench

The GCL anchor trench will be left open to allow installation of FML. Temporary anchoring will be provided until the placement of FML by using sandbags as discussed in Section 4.3.2. Slightly rounded corners will be provided in anchor trenches where the GCL enters the trench to avoid sharp bends in the GCL. No loose soil (e.g., excessive water content) will be allowed to underlie the anchored components of the liner system. Backfilling of soil will be in accordance with Section 2.3.7.

4.3.4 Patching

Torn or otherwise damaged GCL (with no loss of bentonite from the GCL) must be patched with the same type of GCL. The GCL patch must extend at least 12 inches beyond the damaged area and must be bonded to the main GCL to avoid shifting during backfilling. If the GCL damage includes loss of bentonite, the patch must consist of full GCL extending at least 12 inches beyond the damaged area. Lapping procedures must be the same as specified for original laps of GCL panels.

4.4 GCL Protection

Protection of GCL will be verified from production to deployment using the procedures discussed in this section. The manufacturer will provide inspection reports demonstrating that needle-punched nonwoven geotextile was inspected using metal detectors for the presence of broken needles and were found to be needle free. GCL must be rolled by the manufacturer in a fashion to prevent collapse during transit. Rolls will be labeled and bagged in a packaging that is resistant to water.

Visual inspection of each GCL roll will be made during unloading to identify any packaging that has been damaged. Rolls with damaged packaging will be marked and set aside for further inspection. The packaging will be repaired, for acceptable GCL rolls, prior to being placed in storage. If necessary, the party responsible for unloading the GCL will contact the manufacturer prior to shipment to ascertain the suitability of the proposed unloading methods and equipment.

The GCL-installing contractor will be responsible for the storage of GCL material. A dedicated storage area will be selected at the job site or at an alternate off-site area per owner's direction. The selected area will be level, dry, and well drained. Rolls will be stored in a manner that prevents sliding or rolling from the stacks. Rolls should be stacked no higher than three rolls to protect the integrity of roll cores and ensure safe material handling. Stored GCL materials will be covered with a plastic sheet or tarpaulin until it is installed. The integrity and legibility of the labels will be preserved during storage.

Construction equipment (other than low contact pressure rubber-tired vehicles such as ATVs or golf carts) on the GCL will not be allowed. The CQA monitor will verify that small equipment such as generators is placed on scrap FML material (rub sheets). The protective cover will be placed (using low ground pressure equipment as discussed under Section 2.3.6) as soon as possible after installation of FML and drainage layer. Refer to Section 3.6 for equipment operating requirements over geosynthetic materials.

The CQA monitor will verify that GCL (or overlying geosynthetics) are not displaced or damaged while overlying materials are being placed.

4.5 Reporting

The POR will submit to the TCEQ a GCLER for approval of the GCL. Section 7 describes the documentation requirements.

Table 4-1
Required Testing for GCL Materials

Responsible Party	Test	Type of Test	Standard Test Method	Frequency of Testing
Supplier or GCL Manufacturer	Bentonite[1]	Free Swell	ASTM D 5890	per 50 tons (minimum of 1 test for each construction event)
		Fluid Loss	ASTM D 5891	
	Geotextile	Mass/Unit Area	ASTM D 5261	per 25,000 sy
		Grab Tensile Strength	ASTM D 4632	
GCL Manufacturer	GCL Product	Clay Mass/Unit Area	ASTM D 5993	per 5,000 sy
		Bentonite Moisture Content	ASTM D 5993	
		Tensile Strength	ASTM D 6768	per 25,000 sy
		Peel Strength	ASTM D 6496	per 5,000 sy
		Permeability [2]	ASTM D 5887	per 30,000 sy
		Lap Joint Permeability	Flow box or other suitable device	per GCL adjoining material and lap type[3]
Independent Laboratory (Conformance Testing)	GCL Product	Clay Mass/Unit Area	ASTM D 5993	per 100,000 sf
		Permeability	ASTM D 5887	
		Direct Shear [4]	ASTM D 6243	One per GCL/adjoining material type

[1] Tests to be performed on bentonite before incorporation into GCL.
[2] Report last 20 permeability values, ending on production date of supplied GCL.
[3] May also be performed by an independent laboratory as part of conformance testing.
[4] Testing must be on material in hydrated states and must use strain rates, confining pressures, and other parameters, which simulate field conditions. Only reinforced GCL (bentonite encapsulated between two geotextiles, one nonwoven and one woven, which are needle punched together) will be used. The nonwoven side of the GCL will be in contact with the geomembrane. Refer to Appendix IIIE – Geotechnical Report for the stability analysis.

Table 4-2
Required Properties for Reinforced GCL Materials

Property	Required Values[1]
Free Swell (milliliters)	24 (minimum)
Fluid Loss (milliliters)	18 (maximum)
Bentonite Mass per Unit Area[2] (lb/sf)	0.75 (minimum)
Tensile Strength[3] (lb/in)	23 (minimum)
Peel Strength (lb/in)	2.1 (minimum)
GCL Permeability[4] (cm/s)	$5x10^{-9}$ (maximum)
Lab Joint Permeability[5, 6] (cm/s)	$5x10^{-9}$ (maximum)

1 Manufacturer will demonstrate that the above listed values will be met prior to shipment in accordance with Table 4-1.
2 Bentonite mass per unit area of GCL must be reported at zero percent moisture content for the finished product.
3 Value is required for GCL and geotextile.
4 Permeability is listed for the finished product at a gradient of 1.0.
5 Minimum overlap is 12 inches. The values listed are minimum dry bentonite amount for 12 inches of overlap. Manufacturer-specified value will be used if it is higher.
6 Manufacturer will provide certification that seams are no more permeable than the GCL material under similar normal stress conditions.

5 QUALITY ASSURANCE FOR PIPING

5.1 Introduction

This section describes CQA procedures for the installation of HDPE pipe for the leachate collection system used for the composite liner. This plan stresses careful documentation during the quality assurance process, from the selection of materials through installation.

The goal of the pipe quality assurance program is to assure that proper construction techniques and procedures are used, and that the project is built in accordance with the project construction drawings and specifications that will be developed in accordance with this LQCP for each liner construction. The following specifications apply to the leachate collection system piping:

- Minimum internal diameter = 5.845 inches for leachate collection pipe and nominal diameter of 18 inches for riser pipe
- Standard dimension ratio = 17
- Perforation hole diameter = 0.5 inches (if slotted pipe is used, standard slot width = 0.125 inches)
- Young's modulus for pipe material = 33,000 psi
- For LCS design/requirements regarding chemical resistance, refer to Appendix IIIC.

The quality assurance program is intended to identify and define problems that may occur during construction and to observe that these problems are corrected before construction is complete. A construction report, prepared after project completion, will document that the constructed facility meets design standards and specifications.

5.2 Pipe and Fittings

5.2.1 General

Construction must be conducted in accordance with the project construction drawings and specifications for each liner constructed. Piping design and specifications are provided in Appendix IIIC – Leachate and Contaminated Water Management Plan. To monitor compliance, a quality assurance program will be implemented that includes: (1) a review of the manufacturer's quality control testing, (2) material conformance testing, and (3) construction monitoring. Conformance testing refers to testing by an independent third-party laboratory that will take place prior to material installation on materials delivered to the site.

5.2.2 Delivery

The CQA monitor will observe:

- That upon delivery, the pipe and pipe fittings are in compliance with the requirements of the construction specifications that will be developed in accordance with this LQCP for each liner construction.
- That a storage location is selected in which the pipe and pipe fittings are protected from excessive heat, cold, construction traffic, hazardous chemicals, and solvents. If the pipe and pipe fittings are stored at a location where other construction materials are present, the CQA monitor will assure that stacking or insertion of the other construction materials onto or into the pipe and pipe fitting is prohibited. The CQA monitor will periodically examine the storage area to observe that the pipe fittings are undamaged and have been protected.
- That upon transporting pipe and fittings from the storage location to the construction site the contractor will use pliable straps, slings, or rope to lift the pipe. Steel cables or chains will not be allowed to transport or lift the pipe.
- That the contractor will provide that a pipe greater than 20 feet in length will be lifted with at least two support points. The contractor will not drop, impact, or bump into the pipe, particularly at the pipe ends. Pipe and fitting ends must be cleaned of all dirt, debris, oil, or any other contaminant which may prohibit making a sound joint.

The CQA monitor will document all activities associated with the handling and storage of this material to maintain compliance with this portion of the CQA plan.

5.2.3 Conformance Testing

Prior to the installation of pipe, the pipe manufacturer will provide the Operator and the POR a quality control certificate for each lot or batch of pipe provided. The quality control certificate will be signed by a responsible party employed by the pipe manufacturer, such as the quality control manager. The quality control certificate and documentation will include:

- A description of the pipe delivered to the project, including but not limited to the strength classification, diameter, perforations, and production lot.
- Properties sheet including, at a minimum, all specified properties, measured using test methods indicated in the specifications that will be developed in accordance with this LQCP for each liner construction, or equivalent.
- A certification that property values given in the properties sheet are minimum values and are guaranteed by the pipe manufacturer.
- A list of quantities and descriptions of materials other than the base resin which comprise the pipe.
- The sampling procedure and results of testing for actual samples manufactured in the same lot as the pipe delivered to the project.

The CQA monitor will observe that:

- The property values certified by the pipe manufacturer meet all of the specifications that will be developed in accordance with this LQCP for each liner construction.
- The measurements of properties by the pipe manufacturer are properly documented and the test methods used are acceptable.
- Verification that the quality control certificates have been provided at the specified frequency for all lots or batches of pipe, and that each certificate identifies the pipe lot/batch related to it.
- The certified properties meet the specifications that will be developed in accordance with this LQCP for each liner construction.

5.2.4 Pipe and Fitting Installation

Surface Preparation. Prior to pipe installation, the CQA monitor must observe the following:

- All lines and grades have been verified by the contractor and project surveyor.
- The pipe trenches are swept clean of any deleterious material which may damage the pipe or geomembrane or may clog the pipe.

- Pipe perforations for leachate collection system are drilled in the pipe outside of the drainage trench where the pipe is to be laid. The drill cuttings must be completely removed from the pipe prior to being placed in the drainage trench.
- Pipe perforations are to the correct size and spacing according to the project specifications that will be developed in accordance with this LQCP for each liner construction. Perforations can be either factory installed slots or factory predrilled holes or field drilled holes.

Pipe and Fitting Placement. During pipe and fitting installation, the CQA monitor will:

- Observe all pipe, pipe fittings, and joints as the pipe is being laid. The CQA monitor will observe that pipes and fittings are not broken, cracked, or otherwise damaged or unsatisfactory. Prior to fusing (if fusion welding is utilized), the pipe installer will provide a fusion surface area which is clean and free of moisture, dust, dirt, debris of any kind, and foreign material.
- If fusion welding is utilized, verify welder credentials and that the procedure is consistent with the pipe manufacturer's recommendations.
- Observe that the pipe and fittings are being constructed in accordance with specifications that will be developed in accordance with this LQCP for each liner construction and accepted practices.
- Observe that the people and equipment utilized to install the pipe do not damage the pipe or any other component of the liner system.

6 GEOTECHNICAL STRENGTH TESTING REQUIREMENTS

This section of the LQCP addresses the geotechnical strength requirements for the Subtitle D bottom liner. Each component of the Subtitle D bottom liner system is subject to the material testing requirements outlined in Sections 2 through 5 of this LQCP, as applicable. Prior to each Subtitle D bottom liner construction event, the geotechnical testing outlined in Table 6-1 will be performed using actual materials to verify that the Subtitle D bottom liner meets the material strength requirements set forth in Appendix IIIE-A-5 during shear strength conformance testing. A geotechnical analysis of the landfill is presented in Appendix IIIE.

The testing outlined in Table 6-1 and Appendix IIIE-A-5 will be performed under the supervision of the POR by a third-party independent geotechnical laboratory. The POR will ensure that (1) the strength values set forth in Appendix IIIE-A-5 are met or (2) provide an updated geotechnical analysis in the GLER that will be submitted to TCEQ after each liner construction event. If the geotechnical analysis is updated, the resulting factor of safety values must meet the recommended minimum factor of safety values established in Appendix IIIE.

Table 6-1
Recommended Strength for Various Parameters for Subtitle D Bottom Liner Components[1,2]

Interface Description	Peak Strength		Residual Strength	
	Adhesion (psf)	Friction Angle (degree)	Adhesion (psf)	Friction Angle (degree)
Liner System Component Interface				
Protective Cover/Double-sided Geocomposite Interface	200	20	270	15
Geocomposite/Textured HDPE Geomembrane Interface	200	19	120	10
Textured HDPE Geomembrane/Clay Liner Interface	210	18	50	14
Clay Liner (Internal)	100	18	80	13
Clay Liner/Underdrain Geocomposite Interface	200	18	80	10
Underdrain Geocomposite/Subgrade Interface	200	20	270	15
Protective Cover/Single-sided Geocomposite-Geotextile Interface	200	20	270	15
Single-sided Geocomposite-Geonet/Textured HDPE Geomembrane Interface	0	13	0	10
Textured HDPE Geomembrane/Clay Liner Interface	210	18	50	14
Alternative Liner System Component Interface				
Textured LLDPE Geomembrane/Reinforced GCL Interface	850	25	400	10
Reinforced GCL (Internal)	800	18	380	11
Reinforced GCL/Subgrade Interface	100	18	--	--

[1] The adhesion and interface friction angle of liner components will be determined using ASTM D5321 by a third-party verified geotechnical laboratory to verify they meet the values used in the slope stability analysis included in Appendix IIIE-A. Refer to Appendix IIIE-A for detailed strength information and procedures for determining acceptable shear strength parameters during conformance testing.

[2] Interface and material peak and residual strength values in above table are recommendations only. Actual shear strength values may vary. The adequacy of the interface and material shear strength values will be evaluated in accordance with the Appendix IIIE-A-5 Interface Shear Strength Conformance Testing Requirements.

7 DOCUMENTATION

The quality assurance plan depends on thorough monitoring and documentation of all construction activities. Therefore, the POR and CQA monitor will document that all quality assurance requirements have been addressed and satisfied. Documentation will consist of daily recordkeeping, testing and installation reports, nonconformance reports (if necessary), progress reports, photographic records, and design and specification revisions. The appropriate documentation will be included in the SLER, GCLER, and GLER. Standard report forms will be provided by the POR prior to construction.

7.1 Preparation of SLER, GCLER, and GLER

The POR will submit to the TCEQ a SLER for review and acceptance for each soil liner portion of the composite liner. After construction of the geosynthetics portion of the liner, the POR will submit a GCLER and a GLER to the TCEQ for review and acceptance. The GCLER and the GLER may be submitted as a single document. All of these reports will be approved by TCEQ prior to placement of solid waste over the specified constructed area.

Testing, evaluation, and submission of the SLERs, GCLERs, and GLERs for the composite liner system will be in accordance with this LQCP. The construction methods and test procedures documented in the SLERs, GCLERs, and GLERs will be consistent with this LQCP, the TCEQ MSWR, and specifications outlined in this LQCP.

At a minimum, the SLER, GCLER, and GLER will contain:

- A summary of all construction activities.
- A summary of all laboratory and field test results.
- Sampling and testing location drawings.
- A description of significant construction problems and the resolution of these problems.
- As-built record drawings signed and sealed by a Texas registered surveyor or professional engineer.
- A statement of compliance with the permit LQCP and construction plans.

- The reports will be signed and stamped by a professional engineer(s) licensed to practice in the state of Texas.

The as-built record drawings will accurately identify the constructed location of all work items, including the piping and anchor trenches. The POR will review and verify that as-built drawings are correct. As-built drawings will be included in the SLER, GCLER, and GLER as appropriate.

7.2 Reporting Requirements

The SLER, GCLER, and GLER will be signed and sealed by the POR and signed by the Site Manager and submitted in triplicate (including all attachments) to the MSW Permits Section of the Waste Permits Division of the TCEQ for review and acceptance. If the Executive Director provides no response, either written or verbal, within 14 days of receipt, the owner or operator may continue facility construction or operation. Any notice of deficiency received from the TCEQ will be promptly addressed and incorporated into the SLER/GCLER/GLER report. No solid waste will be placed over the constructed liner areas until the final acceptance is obtained from the TCEQ. Additionally, upon approval of this application if a new liner area is developed, prior to accepting any solid waste to the newly developed liner area, a pre-opening inspection will be requested. The TCEQ staff will conduct a pre-opening inspection within 14 days of the request. If the TCEQ does not provide a written or verbal response 14 days after conducting the pre-opening inspection, the newly developed liner area will be considered acceptable for solid waste placement, given that the SLER, GCLER, and GLER for the area are also submitted to the TCEQ in accordance with this section.

If a layer of waste is not placed over the top of the protective cover in the dewatering system installation area within 6 months, then the POR will visually observe that the liner is not damaged (e.g., excessive erosion) due to prolonged exposure of the surface of the protective cover. Repairs will be done promptly, and the POR will report findings and measures taken to repair damage in a letter report to the executive director for review and acceptance.

APPENDIX IIID-A

HIGHEST MEASURED GROUNDWATER INFORMATION

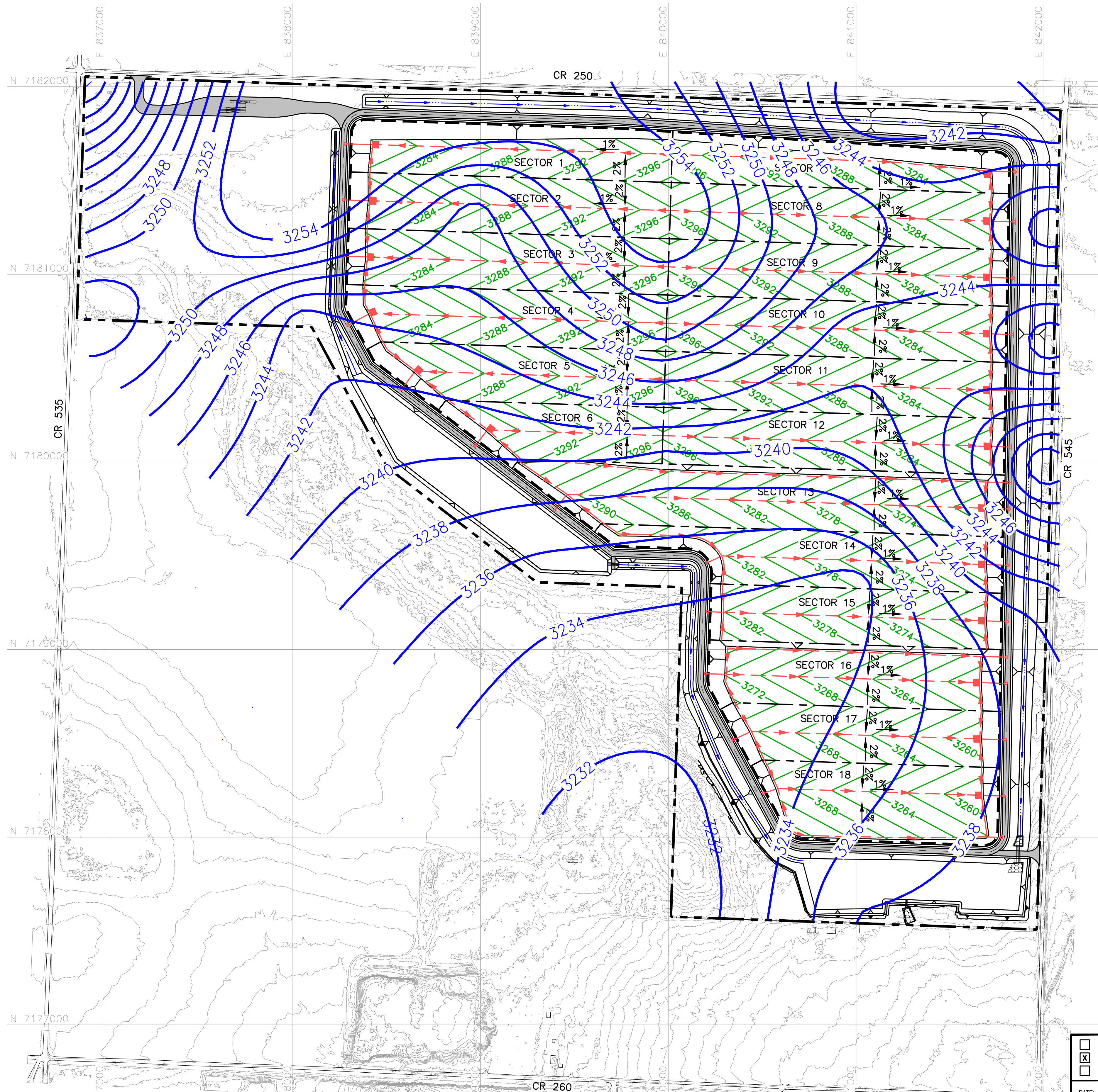
Includes Pages IIID-A-1 and IIID-A-2

STATE OF TEXAS
KYLE D. GOULD
106018
LICENSED
PROFESSIONAL ENGINEER

08/05/2024

HIGHEST MEASURED GROUNDWATER INFORMATION

The attached figure has been reproduced from Appendix IIIG-D – Site Hydrogeologic Data. Additional information regarding highest measured groundwater and top of uppermost aquifer can be found in Appendix G, Section 4 – Groundwater Investigation Report.



N

0 300 600
SCALE IN FEET

LEGEND

- PROPOSED PERMIT BOUNDARY
- PROPOSED LIMIT OF WASTE
- N 7180000 — STATE PLANE COORDINATE SYSTEM
- 3300 — EXISTING CONTOUR
- 560 — PROPOSED EXCAVATION CONTOUR
- SECTOR BOUNDARY
- CHANNEL CENTERLINE
- LEACHATE COLLECTION PIPE
- LEACHATE COLLECTION SUMP
- LEACHATE RISER PIPE
- 3250 — TOP OF UPPERMOST AQUIFER HYDROSTRATIGRAPHIC STRUCTURAL CONTOUR IN FT–MSL (SEE NOTES 3 AND 4)

NOTES:

1. EXISTING CONTOURS ARE CREATED FROM UNMANNED AERIAL SURVEY DATA COLLECTED BY WEAVER CONSULTANTS GROUP, LLC ON OCTOBER 20, 2022. THE GRID SYSTEM IS TIED TO THE TEXAS COORDINATE SYSTEM OF 1983, NORTH CENTRAL ZONE, NAD83 (2011) EPOCH 2010.00 AND HAS BEEN SCALED TO SURFACE COORDINATES BY DIVIDING BY THE COMBINED SCALE FACTOR OF 0.99972824 FROM AN ORIGIN OF 0,0.
2. PERMIT BOUNDARY WAS PREPARED BY WEAVER CONSULTANTS GROUP IN APRIL 2023.
3. TOP OF UPPERMOST AQUIFER HYDROSTRATIGRAPHIC STRUCTURAL CONTOUR REPRESENTS HIGHEST GROUNDWATER ELEVATION WITHIN THE UPPERMOST AQUIFER ZONE OF SATURATION AS OBSERVED AT TIME OF DRILLING AT EACH EXPANSION BOREHOLE LOCATION.
4. TOP OF UPPERMOST AQUIFER HYDROSTRATIGRAPHIC STRUCTURAL CONTOURS DO NOT REPRESENT GROUNDWATER POTENTIOMETRIC HEAD OR GROUNDWATER FLOW.

STATE OF TEXAS
KYLE D. GOULD
106018
LICENSED PROFESSIONAL ENGINEER
08/05/2024

- [ ] DRAFT
- [x] FOR PERMITTING PURPOSES ONLY
- [ ] ISSUED FOR CONSTRUCTION

DATE: 08/2024
FILE: 0120-809-11
CAD: IIID-A-2 GROUNDWATER.DWG

DRAWN BY: JDW
DESIGN BY: JPI
REVIEWED BY: KDG

Weaver Consultants Group
TBPE REGISTRATION NO. F-3727

PREPARED FOR
MEADOW LANDFILL, LLC

REVISIONS

NO.	DATE	DESCRIPTION

MAJOR PERMIT AMENDMENT
TOP OF UPPERMOST AQUIFER CONTOUR MAP

CITY OF MEADOW LANDFILL
TERRY COUNTY, TEXAS

WWW.WCGRP.COM

FIGURE IIID-A-2

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