APPENDIX VI-E

LEACHATE MANAGEMENT SYSTEM CALCULATIONS

APPENDIX VI-E.1

LEACHATE MANAGEMENT SYSTEM EVALUATION

Geosyntec consultants

COMPUTATION COVER SHEET

Client: DRPI **Project:** DRPI Landfill Expansion **Project #:** ME1571 **Task #:** 1

TITLE OF COMPUTATIONS LEACHATE MANAGEMENT SYSTEM EVALUATION

COMPUTATIONS BY:

Signature _____ 3/1/2018 DATE

Printed Name and Title: Chunling Li, Project Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY: (Peer Reviewer)

Signature _____ 3/2/2018 DATE

Printed Name and Title: Andrew Stallings, Senior Staff Engineer

COMPUTATIONS CHECKED BY:

Signature _____ 3/2/2018 DATE

Printed Name and Title: Andrew Stallings, Senior Staff Engineer

COMPUTATIONS BACKCHECKED BY: (Originator)

Signature _____ 3/3/2018 DATE

Printed Name and Title: Chunling Li, Project Engineer

APPROVED BY: (PM or Designate)

Signature _____ 3/4/2018 DATE

Printed Name and Title: David Espinoza, Senior Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

LEACHATE MANAGEMENT SYSTEM EVALUATION

PURPOSE

The purpose of this calculation package is to evaluate the effectiveness of the leachate management system design as part of the proposed vertical expansion of the Delaware Recyclable Products Inc. (DRPI) Landfill. The proposed vertical expansion increases the maximum final landfill elevation from the currently permitted elevation of 130 ft-msl to 190 ft-msl. This calculation package provides an estimate of the average and peak leachate generation rates, as well as the average and peak leachate head on the liner system under the proposed conditions. Figure 1 shows the proposed leachate management system layout.

SUMMARY OF PREVIOUS ANALYSES

The leachate management system design for Phase VI and Phases I and II overlay area was previously presented by Geosyntec [2005]. The leachate management system was sized based on leachate generation analysis for the active cell condition and intermediate cover condition, which assumes:

For operational cover condition:

- 6-inch operational cover;
- 10-ft waste;
- 24-inch protective cover;
- Geocomposite drainage layer;
- 60-mil HDPE geomembrane; and
- GCL barrier layer.

For intermediate cover condition:

- 12-inch intermediate cover;
- 30-ft waste;
- 24-inch protective cover;
- Geocomposite drainage layer;
- 60-mil HDPE geomembrane; and
- GCL barrier layer.

Using the leachate generation rates calculated, leachate collection pipes, leachate sumps, and the leachate transmission system were sized.

METHOD

For this analysis, Geosyntec evaluated how the proposed vertical expansion will affect the leachate generation rate at the site and whether the leachate management system can handle the expected leachate flow by considering increased waste thickness. The computer program HELP, Version 3 [USEPA, 1994a and 1994b] is used to aid the analysis.

Analysis of expected leachate generation at DRPI is done by considering typical operational practices at the site. Consistent with previous analysis, a 10 to 15-acre area of the site is assumed to be open at any one time. The remainder of the site will be covered with tarps or other low permeability intermediate cover materials to prevent infiltration of precipitation into the waste. Two conditions are analyzed to determine the overall site leachate generation rate: active cell condition and intermediate cover condition with varying waste thickness. The HELP model is used to calculate a per acre rate of leachate collected from the leachate collection system (LCS). Because the amount of leachate collected in the LCS is directly proportional to area, the per acre value calculated by the HELP model is multiplied by the site area to estimate leachate generation for the entire site. As runoff is allowed to occur on 100 percent of the site, total leachate generation will be calculated as leachate collected in the collection layer plus runoff for the active cell condition. For the intermediate cell condition, runoff is not included as part of the total leachate generated.

INPUT DATA

Introduction

The input data in the HELP model is classified into site/design specific data such as the layering configuration and material properties, and location specific data such as climatic data. For both types of input data properties, HELP offers the option of using default values or user defined values. For this analysis, only default values are used. Each set of input data is described in the following sections.

Weather Data

The HELP model requires the following weather-related input data: (i) evapotranspiration, (ii) precipitation, (iii) temperature, and (iv) solar radiation data. The HELP model provides default values and synthetically generated weather data for specific cities in the United States. Wilmington, Delaware was selected for use for all weather data.

The evaporative zone depth is calculated from default values and is the average of the minimum (8 in.) and maximum (36 in.) evaporative zone depths for the site location. The maximum leaf area index (LAI) is also based on default values, resulting in an LAI of 4.2.

Soil Data

The system consists of six layers, from top to bottom: (1) Cover (Intermediate or Daily), (2) Waste, (3) Soil Protection Layer, (4) Leachate Collection System, (5) Geomembrane Liner, and (6) Geosynthetic Clay Liner. A description of each of these layers is presented below.

Layer 1 – Cover (Intermediate or Operational)

The cover layer represents the soils or other materials that are placed over the waste between periods of waste placement. In the case of the active cell condition, this is operational cover placed weekly or at the end of each day and removed at the beginning of the next day. For the intermediate condition, this may be the same material as the operational cover or may be tarps or other low permeability materials used to reduce infiltration into the waste. At any point in time, the majority of the site is in the intermediate cover condition. For modeling purposes, it is conservatively assumed that the same material will be used for intermediate cover as is used for operational cover. The operational cover layer is assumed to be approximately 6 inches in thickness, while the intermediate cover is assumed to be 12 inches thick. The default soil texture number chosen for both operational cover and intermediate cover is 24, which is similar to the soils that are anticipated to be used for the cover soil at DRPI.

Layer 2 - Waste

Soil texture number 18 (Municipal Waste) was chosen for the waste layer. Although DRPI is construction and demolition (C&D) debris landfill, not a Municipal Solid Waste (MSW), the properties of the two types of waste are similar in nature, and therefore the soil texture number for MSW can be used for C&D waste.

For the active cell condition, the waste layer was modeled with a 10-ft thickness in the original analysis. The intermediate cell condition is likely to occur when there is more waste in place than the active cell condition. The waste layer for the intermediate cell condition was modeled as having a 30-ft thickness in the original analyses [Geosyntec, 2004].

For this analysis, two waste thicknesses (80 ft and 180 ft) were analyzed additionally to assess the effect of vertical expansion on leachate generation rates.

Layer 3 – Soil Protection Layer

This 2-ft layer is designed to protect the leachate collection system, as required by the Delaware Regulations Governing Solid Waste §6.D.2.b(1). It is modeled as a lateral drainage layer in order to be able to account for any liquid that may enter the leachate collection pipes from this layer. However, as this layer is not actually designed as a leachate collection layer (it is underlain by a geocomposite that will be designed as the leachate collection layer), it is not required to have a prescriptive hydraulic conductivity, and therefore is modeled using material texture number 10.

Layer 4 – Leachate Collection System

The chosen leachate collection system for DRPI is a geocomposite. The base grading for the landfill is designed to have a post-settlement slope of 1 percent. The maximum drainage length is estimated to be 1,150 ft.

Layer 5 – Geomembrane Liner

The geomembrane used for the liner will be a 60-mil high density polyethylene (HDPE). The geosynthetic material number chosen for the HELP simulations is 35, which is that for HDPE, at a thickness of 0.06 in. The geomembrane liner will be modeled conservatively as having a pinhole density of one per acre, and installation defect quantity of one per acre, and poor placement quality.

Layer 6 – Geosynthetic Clay Liner

The final layer is a geosynthetic clay liner (GCL). HELP does not have a specific default number for GCL; however, the soil texture number for bentonite (17) is used as bentonite is the main barrier component of a GCL.

<u>Surface Data</u>

HELP models the surface runoff using the Soil Conservation Service (SCS) curve number method. HELP uses the surface slopes, lengths, soil type, and vegetative cover to determine a runoff curve number, which is used for runoff calculations. The final cover slope on the majority of the landfill is approximately 4 percent with a maximum drainage length of 2,000 ft. Given that the sideslopes are steeper than 4 percent, modeling the entire cover area as having slopes of 4 percent will yield a conservative design. The soil texture number used here (24) is the same as that used in Layer 1 above. The surface is modeled as having bare ground, as this condition is

likely to prevail at most times over the majority of the site. The resulting runoff curve number using these parameters is 96.6.

LEACHATE GENERATION RESULTS

The HELP simulation results for the two cell conditions are included as Appendix A and are summarized in the table below. The values to be used for the collection system design are average annual totals.

Cell Condition	Waste Thickness (ft)	Lateral Drainage (ft^3/ac/yr)	Runoff (ft^3/ac/yr)	Leachate Generation (ft^3/ac/yr)	Leachate Generation (gal/ac/day)
Active	10	9,409	57,132	66,541	1,364
	80	9,409	57,132	66,541	1,364
	180	9,409	57,132	66,541	1,364
Intermediate	30	7,558	61,010	7,558	155
	80	7,558	61,010	7,558	155
	180	7,558	61,010	7,558	155

HEAD ON LINER RESULTS

The head on the liner is required to remain below 1 ft at all times. For this analysis, the peak daily results from the HELP analysis are used. The results, as shown in Appendix A and summarized below for each cell condition, show that the head on the liner remains below 1 ft at all times.

Cell Condition	Waste Thickness (ft)	Head on Liner (in.)
Active	10	7.06
	80	5.90
	180	5.85
Intermediate	30	5.97
	80	5.86
	180	5.84

CAPACITY OF LEACHATE COLLECTION SYSTEM

As shown in the results above, the calculated leachate generation rates are essentially the same as those used by Geosyntec [2005] in the lateral expansion permit application. The original leachate collection system design calculation [Geosyntec, 2005] is included as Attachment B. The increased waste thickness due to vertical expansion shows no effect for the average annual leachate generation rates that were used by Geosyntec [2005] for leachate collection and management system sizing. Thus, the existing or currently designed leachate collection management system is adequate to handle the leachate flow for the proposed vertical expansion condition.

SUMMARY

The existing or currently designed leachate collection management system is adequate to handle the leachate flow for the proposed vertical expansion condition. The maximum peak daily heads on the liner, as shown in the head on liner results, remains below 1 ft at all times.

REFERENCE:

Geosyntec Consultants, *"Permit Application Part VI- Engineering Report"*, Cell 6 Expansion, DRPI Industrial Landfill, New Castle, Delaware, prepared for Delaware Recyclable Products, Inc. Revised February 2005.

FIGURE

FIGURE 1 - LEACHATE MANAGEMENT SYSTEM LAYOUT

PERMIT DRAWING

NORTH

LEGEND

- PROPERTY BOUNDARY
- EXISTING GRADE CONTOUR (FEET–MSL)
- LEACHATE MANAGEMENT SYSTEM CONTOUR (FEET–MSL)
- EXISTING TREELINE
- EXISTING ROAD
- EXISTING BUILDING
- EXISTING DEEP GROUNDWATER MONITORING WELL, LOCATED 9/2001
- EXISTING AND PROPOSED LEACHATE COLLECTION PIPE (SEE NOTE 6)
- EXISTING LEACHATE FORCEMAIN
- EXISTING LEACHATE SUMP
- EXISTING LEACHATE JUNCTION MANHOLE
- EXISTING RISER
- H.P. HIGH POINT
- 1 LEACHATE CORRIDOR POINT (SEE SCHEDULE AND NOTE 7)

CELL 6 LEACHATE CORRIDOR SCHEDULE
(SEE NOTE 7)

POINTS	TYPE
1–2	B
2–4–5	C
2–3–4	D

NOTES:

1. SEE DRAWING 2 FOR GENERAL NOTES.
2. AN OVERLAY LINER SHALL BE CONSTRUCTED OVER THE REMAINDER OF CELLS 1, 2, AND 3 AS SHOWN ON DRAWING 6. EXISTING CELLS 4, 5, 6–1, AND 6–2A ARE LINED.
3. CELL 4 LINER SYSTEM FEATURES ARE FROM "DESIGN PLANS APPLICATION TO CONSTRUCT A SOLID WASTE FACILITY (INDUSTRIAL LANDFILL) CELL 4 – DELAWARE RECYCLABLE PRODUCTS, INC. NEW CASTLE COUNTY, DELAWARE" PREPARED BY GZA GEOENVIRONMENTAL, INC. DATED 5 MAY 1997.
4. CELL 5 LINER SYSTEM FEATURES ARE FROM "DESIGN PLANS APPLICATION TO CONSTRUCT A SOLID WASTE FACILITY (INDUSTRIAL LANDFILL) CELL 5 – DELAWARE DELAWARE RECYCLABLE PRODUCTS, INC. NEW CASTLE COUNTY, DELAWARE" PREPARED BY GZA GEOENVIRONMENTAL, INC. DATED 19 FEBRUARY 1998.
5. CELL 6 FEATURES FROM "DESIGN MODIFICATION APPLICATION – CELL 6 EXPANSION" BY GEOSYNTEC CONSULTANTS, INC. DATED JANUARY 2009.
6. LEACHATE COLLECTION PIPES IN CELL 6–2B AND CELLS 1–3 OVERLAY ARE PROPOSED; REMAINING LEACHATE COLLECTION PIPES ARE EXISTING.
7. CELL 6 LEACHATE CORRIDORS ARE EXISTING. LEACHATE CORRIDOR POINTS SHOWN AND IDENTIFIED IN THE LEACHATE CORRIDOR SCHEDULE ARE PRESENTED IN PROFILES ON DRAWING 9. LEACHATE CORRIDOR TYPES ARE PRESENTED ON DRAWING 10.
8. EXISTING LEACHATE TRANSMISSION FORCEMAIN LOCATION IS APPROXIMATE.

200 100 0 200 400
SCALE: 1" = 200'

REV	DATE	DESCRIPTION	DRN	APP
2	MAR 2019	UPDATED LEACHATE AND UNDERDRAIN SYSTEM	BGF	CHP
1	JAN 2019	UPDATED OVERLAY LINER AREA TO DECEMBER 2018 AS–BUILT SURVEY	BGF	CHP

Geosyntec consultants
10221 WINCOPIN CIRCLE, 4TH FLOOR
COLUMBIA, MARYLAND 21044 USA
PHONE: 410.381.4333

WASTE MANAGEMENT
DELAWARE RECYCLABLE PRODUCTS, INC.
246 MARSH LANE
NEW CASTLE, DELAWARE 19720
PHONE: 302.655.1360

TITLE: LEACHATE MANAGEMENT AND GROUNDWATER CONTROL SYSTEM PLAN

PROJECT: VERTICAL EXPANSION DESIGN MODIFICATION APPLICATION

SITE: DRPI INDUSTRIAL WASTE LANDFILL NEW CASTLE, DELAWARE

THIS DRAWING MAY NOT BE ISSUED FOR PROJECT TENDER OR CONSTRUCTION, UNLESS SEALED.

SIGNATURE

7/19/2018
DATE

DESIGN BY:	KSS	DATE:	JULY 2018
DRAWN BY:	MF/TJ/BF	PROJECT NO.:	ME1571
CHECKED BY:	KSS	FILE:	1571-008
REVIEWED BY:	CHP	DRAWING NO.:	8 OF 28
APPROVED BY:	CHP		

ATTACHMENT A

HELP MODEL OUTPUT

```
                                        RUN11
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN11.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run11.OUT


TIME:  12:25     DATE:   3/20/2018


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

     TITLE:  DRPI - 10 FT WASTE, GEOCOMPOSITE, DAILY COVER

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


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


                                    LAYER  1
                                    --------

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2832 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                                        RUN11

                       TYPE 1 - VERTICAL PERCOLATION LAYER
                           MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =    120.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.3024 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                    LAYER  3
                                    --------

                       TYPE 2 - LATERAL DRAINAGE 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 =      0.2568 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                    LAYER  4
                                    --------

                       TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
            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 =      0.0160 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                    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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN11
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.622  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     12.926  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.444  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     44.384  INCHES
TOTAL INITIAL WATER                 =     44.384  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                  RUN11
     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       3.11        2.99        3.87        3.39        3.23        3.51
       3.90        4.03        3.59        2.89        3.33        3.54


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WILMINGTON          DELAWARE

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
      31.20       33.20       41.80       52.40       62.20       71.20
      76.00       74.80       67.80       56.30       45.60       35.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WILMINGTON          DELAWARE
                     AND STATION LATITUDE  =  39.80 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                  3.22     2.34     3.98     3.24     3.36     3.74
                            4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS         1.79     0.97     1.40     1.29     1.55     1.72
                            1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                  1.340    1.140    1.721    0.853    0.961    1.344
                            1.684    1.811    1.858    1.054    1.001    0.970

    STD. DEVIATIONS         1.169    0.693    1.118    0.604    0.834    0.926
                            1.255    1.542    1.559    1.003    0.828    1.135

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                  0.678    0.675    1.971    2.903    3.991    3.278
                            2.314    2.452    1.653    1.082    0.849    0.592

    STD. DEVIATIONS         0.211    0.332    0.455    0.595    0.570    1.068
                            0.763    1.026    0.757    0.234    0.135    0.131

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                  0.1885   0.4190   0.4908   0.9176   0.4318   0.1269
                            0.0022   0.0001   0.0001   0.0001   0.0021   0.0130
```

STD. DEVIATIONS	0.3401	0.5568	0.5835	0.4941	0.2240	0.0883
	0.0060	0.0002	0.0001	0.0005	0.0111	0.0295

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	0.0846	0.2166	0.2250	0.3199	0.0419	0.0086
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0009
STD. DEVIATIONS	0.3184	0.6152	0.7592	0.4397	0.0736	0.0060
	0.0004	0.0000	0.0000	0.0000	0.0008	0.0019

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	15.739	(3.7765)	57132.17	38.658
EVAPOTRANSPIRATION	22.438	(2.2795)	81450.65	55.113
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.59214	(1.42809)	9409.479	6.36682
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00002	(0.00004)	0.083	0.00006
AVERAGE HEAD ON TOP OF LAYER 5	0.075	(0.138)		
CHANGE IN WATER STORAGE	-0.056	(1.5607)	-202.97	-0.137

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.624	16783.7441
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.37436
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000007	0.02375
AVERAGE HEAD ON TOP OF LAYER 5	7.062	
MAXIMUM HEAD ON TOP OF LAYER 5	11.759	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	192.4 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3605

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1111

*** 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	1.6311	0.2718
2	34.5227	0.2877
3	6.3204	0.2634
4	0.0077	0.0390
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN11

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN11a.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run11a.OUT


TIME:  12:26     DATE:   3/20/2018


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

     TITLE:  DRPI - 80 FT WASTE, GEOCOMPOSITE, DAILY COVER

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2832 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =    960.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2933 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                   LAYER  3
                                   --------

                     TYPE 2 - LATERAL DRAINAGE 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 =      0.2563 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                   LAYER  4
                                   --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
            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 =      0.0135 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                   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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN11A
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.622  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     12.926  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.444  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    289.665  INCHES
TOTAL INITIAL WATER                 =    289.665  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                RUN11A
   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     3.11        2.99        3.87        3.39        3.23        3.51
     3.90        4.03        3.59        2.89        3.33        3.54


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    31.20       33.20       41.80       52.40       62.20       71.20
    76.00       74.80       67.80       56.30       45.60       35.50


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE
                   AND STATION LATITUDE  =  39.80 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                 3.22     2.34     3.98     3.24     3.36     3.74
                           4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS        1.79     0.97     1.40     1.29     1.55     1.72
                           1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                 1.340    1.140    1.721    0.853    0.961    1.344
                           1.684    1.811    1.858    1.054    1.001    0.970

    STD. DEVIATIONS        1.169    0.693    1.118    0.604    0.834    0.926
                           1.255    1.542    1.559    1.003    0.828    1.135

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.678    0.675    1.971    2.903    3.991    3.278
                           2.314    2.452    1.653    1.082    0.849    0.592

    STD. DEVIATIONS        0.211    0.332    0.455    0.595    0.570    1.068
                           0.763    1.026    0.757    0.234    0.135    0.131

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                 0.1418   0.4086   0.4693   0.8949   0.5123   0.1458
                           0.0043   0.0001   0.0001   0.0001   0.0021   0.0129
```

STD. DEVIATIONS	0.2594	0.5954	0.5187	0.4486	0.3815	0.1025
	0.0109	0.0002	0.0001	0.0005	0.0111	0.0290

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	0.0425	0.1314	0.1138	0.2396	0.0951	0.0099
	0.0003	0.0000	0.0000	0.0000	0.0001	0.0008
STD. DEVIATIONS	0.1963	0.3877	0.2605	0.3436	0.2803	0.0069
	0.0007	0.0000	0.0000	0.0000	0.0008	0.0019

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	15.739	(3.7765)	57132.17	38.658
EVAPOTRANSPIRATION	22.438	(2.2795)	81450.65	55.113
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.59218	(1.42893)	9409.630	6.36692
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00002	(0.00002)	0.057	0.00004
AVERAGE HEAD ON TOP OF LAYER 5	0.053	(0.078)		
CHANGE IN WATER STORAGE	-0.056	(1.5610)	-203.09	-0.137

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.624	16783.7441
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.34949
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01848
AVERAGE HEAD ON TOP OF LAYER 5	5.904	
MAXIMUM HEAD ON TOP OF LAYER 5	10.022	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	173.9 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3605

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1111

*** 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	1.6311	0.2718
2	279.8027	0.2915
3	6.3211	0.2634
4	0.0071	0.0361
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN11A

```
♀
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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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN11B.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run11b.OUT


TIME:  12:27     DATE:   3/20/2018


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

     TITLE:  DRPI - 180 FT WASTE, GEOCOMPOSITE, DAILY COVER

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =      6.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2832 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =   2160.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2926 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                   LAYER  3
                                   --------

                     TYPE 2 - LATERAL DRAINAGE 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 =      0.2562 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                   LAYER  4
                                   --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
            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 =      0.0134 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                   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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN11B
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.622  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     12.926  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.444  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    640.065  INCHES
TOTAL INITIAL WATER                 =    640.065  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                RUN11B
   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     3.11        2.99        3.87        3.39        3.23        3.51
     3.90        4.03        3.59        2.89        3.33        3.54


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    31.20       33.20       41.80       52.40       62.20       71.20
    76.00       74.80       67.80       56.30       45.60       35.50


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE
                   AND STATION LATITUDE  =  39.80 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                3.22     2.34     3.98     3.24     3.36     3.74
                          4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS       1.79     0.97     1.40     1.29     1.55     1.72
                          1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                1.340    1.140    1.721    0.853    0.961    1.344
                          1.684    1.811    1.858    1.054    1.001    0.970

    STD. DEVIATIONS       1.169    0.693    1.118    0.604    0.834    0.926
                          1.255    1.542    1.559    1.003    0.828    1.135

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                0.678    0.675    1.971    2.903    3.991    3.278
                          2.314    2.452    1.653    1.082    0.849    0.592

    STD. DEVIATIONS       0.211    0.332    0.455    0.595    0.570    1.068
                          0.763    1.026    0.757    0.234    0.135    0.131

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                0.1399   0.4074   0.4664   0.8892   0.5215   0.1477
                          0.0048   0.0001   0.0001   0.0001   0.0021   0.0129
```

STD. DEVIATIONS	0.2548	0.5934	0.5092	0.4402	0.4030	0.1049
	0.0130	0.0002	0.0001	0.0005	0.0111	0.0290

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	0.0421	0.1049	0.0916	0.2412	0.0878	0.0100
	0.0003	0.0000	0.0000	0.0000	0.0001	0.0008
STD. DEVIATIONS	0.1943	0.2951	0.2180	0.3420	0.2389	0.0071
	0.0009	0.0000	0.0000	0.0000	0.0008	0.0019

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	15.739	(3.7765)	57132.17	38.658
EVAPOTRANSPIRATION	22.438	(2.2795)	81450.65	55.113
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.59219	(1.42891)	9409.643	6.36693
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00002)	0.053	0.00004
AVERAGE HEAD ON TOP OF LAYER 5	0.048	(0.064)		
CHANGE IN WATER STORAGE	-0.056	(1.5610)	-203.09	-0.137

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.624	16783.7441
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.34842
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01827
AVERAGE HEAD ON TOP OF LAYER 5	5.854	
MAXIMUM HEAD ON TOP OF LAYER 5	9.946	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	173.1 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3605

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1111

*** 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	1.6311	0.2718
2	630.2027	0.2918
3	6.3211	0.2634
4	0.0071	0.0359
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN11B

```
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN14.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run14.OUT


TIME:  13:31     DATE:   3/20/2018


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

     TITLE:  DRPI - 30 FT WASTE, GEOCOMPOSITE, INTERMEDIATE COVER

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =     12.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.3020 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =    360.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2948 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                   LAYER  3
                                   --------

                     TYPE 2 - LATERAL DRAINAGE 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 =      0.2572 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                   LAYER  4
                                   --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
            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 =      0.0252 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                   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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN14
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.708  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     11.090  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.194  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    116.171  INCHES
TOTAL INITIAL WATER                 =    116.171  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                  RUN14
     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
       3.11        2.99        3.87        3.39        3.23        3.51
       3.90        4.03        3.59        2.89        3.33        3.54


          NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WILMINGTON          DELAWARE

              NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

     JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
     -------     -------     -------     -------     -------     -------
      31.20       33.20       41.80       52.40       62.20       71.20
      76.00       74.80       67.80       56.30       45.60       35.50


          NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                   COEFFICIENTS FOR    WILMINGTON          DELAWARE
                     AND STATION LATITUDE  =  39.80 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                  3.22     2.34     3.98     3.24     3.36     3.74
                            4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS         1.79     0.97     1.40     1.29     1.55     1.72
                            1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                  1.559    1.325    1.927    0.918    0.995    1.352
                            1.693    1.820    1.880    1.096    1.123    1.120

    STD. DEVIATIONS         1.324    0.775    1.241    0.647    0.866    0.932
                            1.260    1.547    1.586    1.030    0.896    1.222

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                  0.690    0.681    1.978    2.671    3.845    2.968
                            2.312    2.436    1.660    1.120    0.890    0.620

    STD. DEVIATIONS         0.221    0.343    0.438    0.654    0.523    1.037
                            0.761    1.012    0.769    0.251    0.141    0.137

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                  0.1456   0.3970   0.3977   0.6822   0.3651   0.0794
                            0.0019   0.0001   0.0001   0.0002   0.0018   0.0110
```

STD. DEVIATIONS	0.2501	0.5044	0.4373	0.3545	0.1593	0.0741
	0.0093	0.0003	0.0004	0.0011	0.0092	0.0239

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	0.0388	0.1106	0.0706	0.0950	0.0239	0.0054
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0007
STD. DEVIATIONS	0.1658	0.3079	0.2662	0.1651	0.0104	0.0050
	0.0006	0.0000	0.0000	0.0001	0.0006	0.0016

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	16.807	(3.9745)	61009.87	41.282
EVAPOTRANSPIRATION	21.871	(2.1995)	79390.70	53.719
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.08224	(1.15405)	7558.524	5.11439
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00001)	0.032	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.029	(0.051)		
CHANGE IN WATER STORAGE	-0.047	(1.3175)	-169.74	-0.115

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.623	16781.4297
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.35089
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01877
AVERAGE HEAD ON TOP OF LAYER 5	5.971	
MAXIMUM HEAD ON TOP OF LAYER 5	10.123	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	175.0 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3436

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1452

*** 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	3.4383	0.2865
2	104.7258	0.2909
3	6.3755	0.2656
4	0.0032	0.0163
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN14

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN14a.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run14a.OUT


TIME:  13:31     DATE:   3/20/2018


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

     TITLE:  DRPI - 80 FT WASTE, GEOCOMPOSITE, INTERMEDIATE COVER

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =     12.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.3020 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =    960.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2931 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                   LAYER  3
                                   --------

                     TYPE 2 - LATERAL DRAINAGE 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 =      0.2570 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                   LAYER  4
                                   --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                         MATERIAL TEXTURE NUMBER  20
            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 =      0.0252 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                   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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN14A
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.708  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     11.090  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.194  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    291.371  INCHES
TOTAL INITIAL WATER                 =    291.371  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                RUN14A
   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     3.11        2.99        3.87        3.39        3.23        3.51
     3.90        4.03        3.59        2.89        3.33        3.54


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    31.20       33.20       41.80       52.40       62.20       71.20
    76.00       74.80       67.80       56.30       45.60       35.50


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE
                   AND STATION LATITUDE  =  39.80 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                3.22     2.34     3.98     3.24     3.36     3.74
                          4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS       1.79     0.97     1.40     1.29     1.55     1.72
                          1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                1.559    1.325    1.927    0.918    0.995    1.352
                          1.693    1.820    1.880    1.096    1.123    1.120

    STD. DEVIATIONS       1.324    0.775    1.241    0.647    0.866    0.932
                          1.260    1.547    1.586    1.030    0.896    1.222

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                0.690    0.681    1.978    2.671    3.845    2.968
                          2.312    2.436    1.660    1.120    0.890    0.620

    STD. DEVIATIONS       0.221    0.343    0.438    0.654    0.523    1.037
                          0.761    1.012    0.769    0.251    0.141    0.137

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                0.1408   0.3969   0.3940   0.6851   0.3694   0.0809
                          0.0019   0.0001   0.0001   0.0002   0.0018   0.0110
```

STD. DEVIATIONS	0.2421	0.5065	0.4204	0.3582	0.1663	0.0748
	0.0093	0.0003	0.0004	0.0011	0.0093	0.0240

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	0.0352	0.1041	0.0577	0.0935	0.0242	0.0055
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0007
STD. DEVIATIONS	0.1551	0.2864	0.1954	0.1617	0.0109	0.0051
	0.0006	0.0000	0.0000	0.0001	0.0006	0.0016

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	16.807	(3.9745)	61009.87	41.282
EVAPOTRANSPIRATION	21.871	(2.1995)	79390.70	53.719
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.08225	(1.15403)	7558.562	5.11441
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00001)	0.030	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.027	(0.045)		
CHANGE IN WATER STORAGE	-0.047	(1.3175)	-169.78	-0.115

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.623	16781.4297
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.34854
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01830
AVERAGE HEAD ON TOP OF LAYER 5	5.861	
MAXIMUM HEAD ON TOP OF LAYER 5	9.956	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	173.2 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3436

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1452

*** 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	3.4383	0.2865
2	279.9258	0.2916
3	6.3755	0.2656
4	0.0032	0.0162
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN14A

```
♀
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:\HELP3\drpi2\DATA4.D4
TEMPERATURE DATA FILE:      C:\HELP3\drpi2\DATA7.D7
SOLAR RADIATION DATA FILE:  C:\HELP3\drpi2\DATA13.D13
EVAPOTRANSPIRATION DATA:    C:\HELP3\drpi2\DATA11.D11
SOIL AND DESIGN DATA FILE:  C:\HELP3\drpi2\RUN14b.D10
OUTPUT DATA FILE:           C:\HELP3\drpi2\run14b.OUT


TIME:  13:31     DATE:   3/20/2018


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

     TITLE:  DRPI - 180 FT WASTE, GEOCOMPOSITE, INTERMEDIATE COVER

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


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


                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
            THICKNESS                  =     12.00   INCHES
            POROSITY                   =      0.3650 VOL/VOL
            FIELD CAPACITY             =      0.3050 VOL/VOL
            WILTING POINT              =      0.2020 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.3020 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
          NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                   FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.


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



```
                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  18
            THICKNESS                  =   2160.00   INCHES
            POROSITY                   =      0.6710 VOL/VOL
            FIELD CAPACITY             =      0.2920 VOL/VOL
            WILTING POINT              =      0.0770 VOL/VOL
            INITIAL SOIL WATER CONTENT =      0.2925 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC


                                   LAYER  3
                                   --------

                     TYPE 2 - LATERAL DRAINAGE 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 =      0.2570 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =  0.119999997000E-03 CM/SEC


                                   LAYER  4
                                   --------

                     TYPE 2 - LATERAL DRAINAGE LAYER
                       MATERIAL TEXTURE NUMBER  20
            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 =      0.0251 VOL/VOL
            EFFECTIVE SAT. HYD. COND.  =   10.0000000000     CM/SEC
            SLOPE                      =      1.00   PERCENT
            DRAINAGE LENGTH            =   1150.0    FEET


                                   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        =      1.00   HOLES/ACRE
            FML INSTALLATION DEFECTS   =      1.00   HOLES/ACRE
            FML PLACEMENT QUALITY      =  4 - POOR
```

```
                              RUN14B
                            LAYER  6
                            --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER  17
   THICKNESS                    =      0.30   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.    =  0.300000003000E-08 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  4.% AND
          A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER             =     96.60
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      1.000  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      6.708  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =     11.090  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      3.194  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =    641.771  INCHES
TOTAL INITIAL WATER                 =    641.771  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR


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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          WILMINGTON            DELAWARE

     STATION LATITUDE                        =  39.80 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   4.20
     START OF GROWING SEASON (JULIAN DATE)   =    107
     END OF GROWING SEASON (JULIAN DATE)     =    298
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   9.20 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  67.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  72.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  71.00 %


 NOTE:  PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
          COEFFICIENTS FOR    WILMINGTON          DELAWARE

          NORMAL MEAN MONTHLY PRECIPITATION (INCHES)
```



```
                                RUN14B
   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
     3.11        2.99        3.87        3.39        3.23        3.51
     3.90        4.03        3.59        2.89        3.33        3.54


        NOTE:  TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE

            NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

   JAN/JUL     FEB/AUG     MAR/SEP     APR/OCT     MAY/NOV     JUN/DEC
   -------     -------     -------     -------     -------     -------
    31.20       33.20       41.80       52.40       62.20       71.20
    76.00       74.80       67.80       56.30       45.60       35.50


        NOTE:  SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
                 COEFFICIENTS FOR    WILMINGTON          DELAWARE
                   AND STATION LATITUDE  =  39.80 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                 3.22     2.34     3.98     3.24     3.36     3.74
                           4.05     4.24     3.82     2.66     3.04     3.03

    STD. DEVIATIONS        1.79     0.97     1.40     1.29     1.55     1.72
                           1.83     2.28     2.24     1.38     1.45     1.97

  RUNOFF
  ------
    TOTALS                 1.559    1.325    1.927    0.918    0.995    1.352
                           1.693    1.820    1.880    1.096    1.123    1.120

    STD. DEVIATIONS        1.324    0.775    1.241    0.647    0.866    0.932
                           1.260    1.547    1.586    1.030    0.896    1.222

  EVAPOTRANSPIRATION
  ------------------
    TOTALS                 0.690    0.681    1.978    2.671    3.845    2.968
                           2.312    2.436    1.660    1.120    0.890    0.620

    STD. DEVIATIONS        0.221    0.343    0.438    0.654    0.523    1.037
                           0.761    1.012    0.769    0.251    0.141    0.137

  LATERAL DRAINAGE COLLECTED FROM LAYER  4
  -----------------------------------------
    TOTALS                 0.1397   0.3965   0.3926   0.6860   0.3708   0.0815
                           0.0019   0.0001   0.0001   0.0002   0.0018   0.0110
```

STD. DEVIATIONS	0.2396	0.5059	0.4141	0.3600	0.1685	0.0751
	0.0094	0.0003	0.0004	0.0011	0.0093	0.0240

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	0.0371	0.0996	0.0512	0.0959	0.0243	0.0055
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0007
STD. DEVIATIONS	0.1660	0.2690	0.1602	0.1704	0.0110	0.0051
	0.0006	0.0000	0.0000	0.0001	0.0006	0.0016

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	16.807	(3.9745)	61009.87	41.282
EVAPOTRANSPIRATION	21.871	(2.1995)	79390.70	53.719
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.08225	(1.15403)	7558.572	5.11442
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00001	(0.00001)	0.029	0.00002
AVERAGE HEAD ON TOP OF LAYER 5	0.026	(0.044)		
CHANGE IN WATER STORAGE	-0.047	(1.3175)	-169.79	-0.115

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)

PRECIPITATION	5.26	19093.801
RUNOFF	4.623	16781.4297
DRAINAGE COLLECTED FROM LAYER 4	0.09707	352.34805
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000005	0.01820
AVERAGE HEAD ON TOP OF LAYER 5	5.838	
MAXIMUM HEAD ON TOP OF LAYER 5	9.921	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	172.8 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3436
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1452

*** 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	3.4383	0.2865
2	630.3258	0.2918
3	6.3753	0.2656
4	0.0032	0.0162
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

RUN14B

ATTACHMENT B

LEACHATE MANAGEMENT EVALUATION
(Geosyntec, 2005)

GEOSYNTEC CONSULTANTS

COMPUTATION COVER SHEET

Client: DRPI **Project:** DRPI Landfill **Project/Proposal #:** ME0319 **Task:** 04

TITLE OF COMPUTATIONS: LEACHATE MANAGEMENT SYSTEM

COMPUTATATATIONS BY:

Signature Carrie H. Pendleton — 03/25/2004 DATE

Printed Name and Title: Carrie H. Pendleton, Senior Staff Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)

Signature Douglas T. Mandeville — 3/25/2004 DATE

Printed Name and Title: Douglas T. Mandeville, Engineer

COMPUTATATATIONS CHECKED BY:

Signature Douglas T. Mandeville — 3/25/2004 DATE

Printed Name and Title: Douglas T. Mandeville, Engineer

COMPUTATIONS BACKCHECKED BY:
(Originator)

Signature Carrie H. Pendleton — 03/25/2004 DATE

Printed Name and Title: Carrie H. Pendleton, Senior Staff Engineer

APPROVED BY:
(PM or Designate)

Signature — 3/25/04 DATE

Printed Name and Title: R. David Espinoza, Senior Engineer

APPROVAL NOTES:

REVISIONS: (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

LEACHATE MANAGEMENT SYSTEM

1.0 OBJECTIVE

The objective of this calculation package is to evaluate the future leachate generation rates for the proposed Cell 6 expansion at the Delaware Recyclable Products Inc. (DRPI) landfill and use this to evaluate appropriate pipe sizing, sump size, and pump size for the leachate collection and transmission systems. In addition, the expected head on the liner is evaluated for future conditions. The HELP, Version 3 [USEPA, 1994a and 1994b] computer program is used to aid the analysis

2.0 METHOD

Analysis of expected leachate generation at DRPI is done by considering typical operational practices at the site. For the analysis, a 10-15 acre area of the site is assumed to be open at any one time. The remainder of the site will be covered with tarps or other low permeability intermediate cover materials to prevent infiltration of precipitation into the waste. Two conditions are analyzed to determine the overall site leachate generation rate: active cell condition and intermediate cover condition. The HELP model is used to calculate a per acre rate of leachate collected from the leachate collection system (LCS). Because the amount of leachate collected in the LCS is directly proportional to area, the per acre value calculated by the HELP model is multiplied by the area to estimate leachate generation for the entire site. As runoff is allowed to occur on 100 percent of the site, total leachate generation will be calculated as leachate collected in the collection layer plus runoff for the active cell condition. For the intermediate cell condition, runoff is not included as part of the total leachate generated.

3.0 INPUT DATA

3.1 Introduction

The input data in the HELP model is classified into site/design specific data such as the layering configuration and material properties, and location specific data such as climatic data. For both types of input data properties, HELP offers the option of using default values or user defined values. For this analysis, only default values are used. Each set of input data is described in the following sections.

3.2 Weather Data

The HELP model requires the following weather-related input data: (i) evapotranspiration, (ii) precipitation, (iii) temperature, and (iv) solar radiation data. The HELP model provides default values and synthetically generated weather data for specific cities in the United States. Wilmington, Delaware was selected for use for all weather data.

The evaporative zone depth is calculated from default values and is the average of the minimum (8 in.) and maximum (36 in.) evaporative zone depths for the site location. The maximum leaf area index (LAI) is also based on default values, resulting in an LAI of 4.2.

3.3 Soil Data

A Typical cross section as used in the analysis is shown in Figure 1. As shown in the figure, the system consists of six layers, from top to bottom: (1) Cover (Intermediate or Operational), (2) Waste, (3) Soil Protection Layer, (4) Leachate Collection System, (5) Geomembrane Liner, and (6) Geosynthetic Clay Liner. A description of each of these layers is presented below.

Layer 1 - Cover (Intermediate or Operational)

The cover layer represents the soils or other materials that are placed over the waste between periods of waste placement. In the case of active cell condition, this is operational cover placed bi-weekly. For the intermediate condition, this may be the same material as the operational cover or may be tarps or other low permeability materials used to reduce infiltration into the waste. At any point in the time, the majority of the site is in the intermediate cover condition. For modeling purposes, it is conservatively assumed that the same material will be used for intermediate cover as is used for operational cover. The operational and intermediate cover layer are assumed to be approximately 6 inches in thickness, The default soil texture number chosen for both operational cover and intermediate cover is 24, which is similar to the soils that are anticipated to be used for the cover soil at DRPI.

Layer 2 - Waste

Soil texture number 18 (Municipal Waste) was chose for the waste layer. Although DRPI is construction and demolition (C&D) debris landfill, not a Municipal Solid Waste

(MSW), the properties of the two types of waste are similar in nature, and therefore the soil texture number for MSW can be used for C&D waste.

For the active cell condition, the waste layer is modeled with a 10-ft. thickness. The intermediate cell condition is likely to occur when there is more waste in place than the active cell condition, therefore the waste layer for the intermediate cell condition is modeled as having a 30-ft. thickness.

Layer 3 – Soil Protection Layer

This 2-ft. layer is designed to protect the leachate collection system, as required by the Delaware Regulations Governing Solid Waste §6.D.2.b(1). It is modeled as a lateral drainage layer in order to be able to account for any liquid that may enter the leachate collection pipes from this layer. However, as this layer is not actually designed as a leachate collection layer (it is underlain by a geocomposite that will be designed as the leachate collection layer), it is not required to have a prescriptive hydraulic conductivity, and therefore is modeled using material texture number 10.

Layer 4 – Leachate Collection System

The chosen leachate collection system for DRPI is a geocomposite. The base grading for the landfill is designed to have a post-settlement slope of 2 percent. The maximum drainage length for the expansion is 1,150 ft.

Layer 5 – Geomembrane Liner

The geomembrane used for the liner will be a 60-mil high density polyethylene (HDPE). The geosynthetic material number chosen for the HELP simulations is 35, which is that for HDPE, at a thickness of 0.06 in. The geomembrane liner will be modeled conservatively as having a pinhole density of one per acre, and installation defect quantity of one per acre, and poor placement quality.

Layer 6 – Geosynthetic Clay Liner

The final layer is a geosynthetic clay liner (GCL). HELP does not have a specific default number for GCL; however, the soil texture number for bentonite (17) is used as bentonite is the main barrier component of a GCL.

3.4 Surface Data

HELP models the surface runoff using the Soil Conservation Service (SCS) curve number method. HELP uses the surface slopes, lengths, soil type, and vegetative cover to determine a runoff curve number, which is used for runoff calculations. The final cover slope on the majority of the landfill is approximately 4 percent with a maximum drainage length of 2,000 ft. Given that the sideslopes are steeper than 4 percent, modeling the entire cover area as having slopes of 4 percent will yield a conservative design. The soil texture number used here (24) is the same as that used in Layer 1 above. The surface is modeled as having bare ground, as this condition is likely to prevail at most times over the majority of the site. The resulting runoff curve number using these parameters is 96.6.

4.0 HELP MODEL RESULTS

The HELP simulation results for the two cell conditions are included as Attachment A and are summarized in the table below. The values to be used for the collection system design are average annual totals.

Cell Condition	Lateral Drainage (ft^3/ac/yr)	Runoff (ft^3/ac/yr)	Total (ft^3/ac/yr)	Total (gpad)
Active	9,410	57,132	66,542	1,364
Intermediate	7,558	61,010	7,558	155

5.0 HEAD ON LINER

The head on the liner is required to remain below 1 ft. at all times. For this analysis, the peak daily results from the HELP analysis are used. The results, as shown in Attachment A and summarized below for each cell condition, show that the head on the liner remains below 1 ft. at all times.

Cell Condition	Head on Liner (in.)
Active	0.330
Intermediate	0.304

6.0 LEACHATE COLLECTION SYSTEM DESIGN

6.1 Corridor Sizing

Figure 2 shows a breakdown of the full expansion area into eight sub-areas. Each of these areas drains into its own leachate collection corridor. The following table summarizes the drainage areas:

Drainage Area Label	Area (acres)
A_1	11.2
A_2	15.7
A_3	13.7
A_4	4.79
A_5	17.0
A_6	3.75
A_7	17.9
A_8	1.42

The flow into each of the drainage corridors from the contributing drainage areas is as follows:

Leachate Corridor	Corridor Type	Contributing Drainage Areas/Corridors	Average Annual Flow (ft^3)
C_1	Pipe	A_1	745,272
C_2	Pipe	A_2	1,044,708
C_3	Pipe	$A_3 + C_4 + C_1$	1,975,633
C_4	Pipe	A_4	318,736
C_5	Pipe	$A_5+C_2+C_3+C_6+C_7$	5,781,170
C_6	Pipe	A_6	249,533
C_7	Pipe	A_7+C_8	1,285,592
C_8	Pipe	A_8	94,490

Leachate corridors will convey leachate through a pipe as designed in Section 6.2.1. As an alternative, leachate corridors C_1, C_2, C_4, and C_8 may convey leachate through layers of geonet, as described and designed in Section 6.3.

6.2 Pipe Design

6.2.1 Pipe Sizing

Based on the results summarized above, the maximum leachate flow that any pipe would need to carry is 5,781,170 ft^3/yr or 0.1833 ft^3/sec. The proposed pipe design is an 8 in. nominal outer diameter (OD) (7.611-in. inner diameter) SDR-17 HDPE pipe. The pipe capacity is calculated using Manning's equation:

$$Q_{pipe} = \frac{1.49}{n} A R_h^{2/3} S^{1/2}$$

where:

Q_{pipe} = maximum flow rate through the pipe (cfs)
R_h = hydraulic radius (ft) = wetted area/wetted perimeter
S = hydraulic gradient (ft/ft)
A = cross-sectional flow area (ft^2)
n = Manning's roughness coefficient

The Manning's coefficient, n, for an HDPE pipe is 0.009. The hydraulic gradient used in calculating the full flow pipe capacity is the minimum expected post-settlement slope, which is ½ percent. So, the full flowing pipe capacity for an 8 in. OD HDPE pipe is:

$$Q_{pipe} = \frac{1.49}{0.009}\left(0.3159\,ft^2\right)\left(\frac{0.3159\,ft^2}{1.993\,ft}\right)^{2/3}(0.005)^{1/2} = 1.08\,ft^3/\mathbf{sec}$$

The factor of safety against pipe overflow is:

$$FS = \frac{Q_{pipe}}{Q_{\max}} = \frac{1.08\,ft^3/\mathbf{sec}}{0.1833\,ft^3/\mathbf{sec}} = 5.9$$

6.2.2 Pipe Perforation Sizing

The maximum allowable diameter of perforations in the collector pipe will be specified to ensure the retention of the LCS gravel particles (AASHTO No. 57 stone). The maximum allowable diameter of the perforations in the collector pipes to provide particle retention of gravel particles may be determined as follows:

$$d_{h-\max} = \frac{d_{85}}{F}$$

where:

$d_{h\text{-max}}$ = maximum perforation diameter to provide particle retention (in.)
d_{85} = particle size of the pipe bedding material for which 85 percent by weight of the particles are finer
F = factor varying between 1.2 to 2

For calculations of the maximum perforation diameter in leachate collection pipes surrounded by AASHTO No. 57 stone, a particle gradation curve is shown as Figure 3. The range of d_{85} taken from the figure varies from 23 mm (0.905 in.) to 30 mm (1.18 in.). For a conservative design, the minimum d_{85} will be used with an F factor of 1.8, therefore the maximum pipe perforation size allowable for pipes surrounded by AASHTO No. 57 stone is ½ in.

The ability of the pipe perforation to convey leachate collected is evaluated using the equation of flow (Q) through an orifice:

$$Q = aC_B\sqrt{2gh}$$

where:

a = area of the orifice (ft.)
C_B = orifice coefficient (usually 0.6)
g = acceleration of gravity (ft/sec^2)
h = liquid depth above the hole (ft.)

Thus for a pipe perforation equal to 0.5 in. and assuming the pipe is fully submerged, so leachate head equal to 8 in., the calculated flow is:

$$Q = \pi(0.25/12)^2(0.6)\sqrt{2(32.2\,ft/\sec^2)(8/12)} = 0.0054\,cfs/hole$$

For an average leachate collection pipe length of 500 ft., the maximum flow per linear foot is equal to 0.1833 cfs/500 ft. = 0.000367 cfs/lf. Thus, 0.5-in. perforations spaced every 6 in. will have more than enough capacity to handle the maximum flow.

6.3 Geonet Trench Sizing

6.3.1 Introduction

An alternative design for the LCS drainage corridors 1, 2, 4, and 8 consists of a rectangular-shaped trenches with layers of geonet at the bottom, as shown in Figure 4. The purpose of this calculation is to evaluate the minimum required cross-sectional area for the trenches based on the required flow capacity and the hydraulic conductivity of the geonet within the trench.

6.3.2 Calculations

Required Flow Capacity

The required flow capacity for each geonet drainage corridor is shown in the Table in Section 6.1 above.

Required Area of Geonet Zone

The required flow area for the gravel zone is calculated using Darcy's Law, as follows:

$$q = k\,i\,A \tag{1}$$

where:

q = flow rate (L^3/T);
k = hydraulic conductivity (L/T);
i = hydraulic gradient (L/L); and
A = cross-sectional area of flow (L^2).

In the equation above, q represents the average daily rate of leachate collected from the lateral drainage layer. This parameter is calculated as the average daily rate of leachate for the two operational conditions examined (i.e., 182 ft^3/acre/day) multiplied by the area draining to that corridor. Drainage areas for the corridors range from 2.7 to 15.7 acres in size. The parameter k represents the hydraulic conductivity of a geonet within the trench. For a geonet, k is likely to vary between 1 cm/s and 10 cm/s. For this calculation, the hydraulic conductivity of the gravel/geonet zone was assumed to be 10 cm/sec. The hydraulic gradient, i, represents the slope along the LCS drainage corridor expressed in dimensionless form. The slope of the LCS

drainage corridor is either 0.5% or 2%. "*A*" represents the cross-sectional area of the gravel zone. Given values for *q*, *k*, and *i*, the equation was rearranged to solve for *A*. The required cross-sectional area for the geonet was calculated for each trench for $k = 4$ cm/s and $k = 10$ cm/s. These calculations are presented in Table 1.

6.3.3 Results

As shown in Table 1, the minimum required cross-sectional area for the geonet for $k_{geonet} = 4$ cm/s is 12.6 ft^2. The proposed geonet (Figure 4), will have a 6.3-ft depth and a width of 2.0 ft. For $k_{geonet} = 10$ cm/s, the minimum required cross-sectional area for the leachate collection trench is 5.04 ft^2. Based on the material properties of the geonet used to construct the trenches, the LCS drainage corridors will be designed with adequate capacity to convey the expected volume of leachate.

6.4 Sump and Pump Sizing

The leachate collection sump and pump will be sized assuming a condition of 15 acres in the open cell condition and the remaining 70 acres in the intermediate cell condition. The expected overall leachate impingement rate given this condition is calculated as follows:

$$Q_{max} = (66{,}542 ft^3 / ac / yr)(15ac)\left(\frac{1yr}{365days}\right) + (7{,}558 ft^3 / ac / yr)(70ac)\left(\frac{1yr}{365days}\right)$$

$$Q_{max} = 4{,}184 ft^3 / day$$

This value is used to determine adequate sump size and to choose an appropriate pump. The designed sump grades and corresponding volumes are shown in Figure 5. A pump off level of 6 in. (0.5 ft.) will be used to ensure adequate liquid level above the pump hose. The pump on level will be 2.0 ft. to prevent backup of leachate into the waste mass. For these pump on/off levels, the permanent leachate pool and maximum leachate pool, as shown in Figure 5, are 3,473 gal and 13,572 gal, respectively. The net leachate storage volume within the sump, considering the gravel porosity (*n*) equal to 0.23, is calculated as follows:

$$V = 0.23 \times (13{,}572 gal - 3{,}473 gal) = 2{,}323 gal$$

The minimum pumping rate is calculated as follows to provide a velocity greater than 2 ft/sec in a 2-in. diameter pipe (I.D. = 1.94 in., Area = 0.0205 ft^2).

$$q_{p,\min} = VA = (2ft/\sec)(0.0205ft^2)(60\sec/\min)(7.48gal/ft^3) = 18gpm$$

A pumping rate of at least 18 gpm is required. Since the leachate production rate is 21.7 gpm, a 40 gpm pump will be used. The pump time off (t_{off}) is calculated as follows:

$$t_{off} = \frac{2{,}323gal}{21.7gpm} = 107\,\mathbf{min}$$

The pump time on (t_{on}) is:

$$t_{on} = \frac{2{,}323gal}{(40gpm - 21.7gpm)} = 127\,\mathbf{min}$$

Calculate the pump on/off ratio (r) as:

$$r = \frac{127}{107} = 1.2$$

A spreadsheet has been prepared to perform these calculations and is included as Table 2. A 40-gpm pump will be used in the sump for the leachate collection system. The calculated operating cycle for the 40-gpm pump is 1440/(107+127) = 6.2 cycles/day.

7.0 LEACHATE TRANSMISSION SYSTEM DESIGN

7.1 Methods of Analyses

Selection of Required Head for Pump

The LCS pump will be designed to supply the required head to overcome the elevation difference between the sump and the existing leachate storage tank, as well as the frictional losses along the leachate force main. Frictional losses increase as flow velocity increases. The worst-case scenario (pump with greatest required head) is used as the minimum pump size for the expansion area.

The head required to transfer leachate between two points is calculated using the conservation of energy equation as follows:

$$Z_1 + \frac{P_1}{\gamma} + \frac{V_1^2}{2g} + H_p = Z_2 + \frac{P_2}{\gamma} + \frac{V_2^2}{2g} + \sum h_{L1-2}$$

where:

$Z_{1,2}$ = elevations at points 1 and 2;
$P_{1,2}$ = pressures at points 1 and 2;
γ = unit weight of leachate;
$V_{1,2}$ = velocities at points 1 and 2;
g = acceleration due to gravity;
H_p = required head supplied by pump at point 1; and
$\sum h_{L1-2}$ = summation of frictional head losses between points 1 and 2.

The velocity and pressure head terms ($V^2/2g$, P/γ) can be neglected because: (i) the pipe cross section is constant and, therefore, the velocity head terms cancel; and (ii) both ends of the trnamission system pipe (the sump and leachate storage tank) are at atmospheric pressure and therefore the pressure head terms cancel. Thus, the equation can be reduced and rearranged as follows:

$$H_p = (Z_2 - Z_1) + \sum h_{L1-2}$$

Therefore, the required head to be delivered by a pump is equal to the elevation difference between the pump and the leachate storage tank, and the frictional head losses along the force main.

Frictional losses occur due to the fittings and pipe that the leachate travels through. Frictional losses due to the fittings are calculated using the following equation:

$$h_{LF} = K\left(\frac{V^2}{2g}\right)$$

where:
h_{LF} = frictional head loss due to fitting;
K = loss coefficient for fitting (dimensionless); and
V = average flow velocity through fitting (flow rate/flow area).

Frictional losses due to the pipe wall are calculated using the Darcy-Weisbach equation:

$$h_{LP} = f\left(\frac{L}{D}\right)\left(\frac{V^2}{2g}\right)$$

where:
h_{LF} = frictional head loss due to fitting;
f = friction factor (see below);
L = length of pipe;
D = inside diameter of pipe; and

V = average flow velocity through pipe (flow rate/flow area).

The friction factor, f, is a function of Reynold's number (R_e) and the relative roughness of the pipe wall. The equation for Reynold's number is:

$$R_e = \frac{VD}{\upsilon}$$

where:

ν = kinematic viscosity of leachate.

7.2 Selection of Required LTS Pipe Size and Thickness

LTS pipe sizes (i.e., diameters) are chosen in conjunction with evaluating the pump requirements. Sizes are chosen that result in acceptable pump head requirements (since frictional head losses increase with flow velocity, a smaller pipe will necessitate a larger head to be supplied by a pump). In addition, the pressure rating of the LTS pipe must exceed the maximum expected operating pressure (i.e., the maximum head required by any pump).

7.3 Selection of Design Flow Rate for Pumps

The design flow rate for the LCS pump is taken from Section 6.4 above.

7.4 Selection of Required Head for Pumps

Elevation Head

The elevation head which must be overcome for each pump is the difference in elevation between the sump invert and the top of the leachate storage tank. The proposed elevation of the sump is 25.5 ft-msl and the elevation of the top of the existing leachate storage tank is 55 ft-msl (from "*Construction Permit Application Proposed Cell 5*" prepared by GZA Environmental, Inc). Therefore, a total elevation head difference of 29.5 feet must be overcome by the pump.

Frictional Losses

The layout of the pipe network between the sump and the existing leachate storage tank is shown in Figure 6. Pipes and fittings within the riser house are proposed to be 2-in. Schedule (SCH) 80 PVC. LTS force main pipes are proposed to be 4-in. standard dimension ratio (SDR) 17 HDPE pipe and fittings. The fittings, and associated loss coefficients between the sump and the LTS force main are listed in the following table:

Fitting Description	Head Loss Coefficient (K)
Flange (3-in. flexible hose to 2-in. PVC pipe)	1.0
90° 'L', 2-in.	0.95
90° 'L', 2-in.	0.95
Check valve, 2-in.	2.0
Branch 'T', 2-in..	0.85
Flow meter, 2-in.	2.0
90° 'L', 2-in.	0.95
In-line 'T', 2-in.	0.2
Ball valve, 2-in.	8.5
90° 'L', 2-in.	0.95
In-line 'T', 2-in.	0.2
90° 'L', 2-in.	0.65
90° 'L', 2-in.	0.65
Flange, 2-in. to 4-in.	1.0

NOTES:

(1) Assumes coupling from Figure 7.

(2) Assumes flanged globe valve from Figure 8.

(3) Assumes flanged check valve from Figure 8.

(4) The equation for sudden enlargement is $(V_1 - V_2)^2/2g$. Conservatively assuming $V_2=0$ is equivalent to using K=1 in the equation.

(5) The equation for sudden constriction is $K(V_2^2/2g)$. Conservatively assume K=1.

Frictional losses due to fittings along the 4-in. LTS force main are shown in the table below. The three fittings listed are used in the LTS manhole and/or riser house at each subcell.

Fitting Description	Head Loss Coefficient (K)
Check valve, 4in.	2.0
Ball valve, 4-in.	6.25
In-line 'T', 4-in.	0.15
Sum of the Coefficients	8.40

NOTES:

(1) Assumes flanged check valve from Figure 8.
(2) Assumes flanged globe valve from Figure 8.

Frictional losses along the pipe walls are based on the pipe length, pipe diameter, and liquid viscosity. The length of the LTS force main, including distances between the riser houses, is taken from "*Construction Permit Application Proposed Cell 5*" prepared by GZA Environmental, Inc and the "*Final Draft Permit Amendment Issue Landfill Expansion Drawings DRPI Industrial Waste Landfill*". The following distances are used in the calculations:

Start Point	End Point	Distance (ft)
Cell 6	Subcell 5E	340
Subcell 5E	Subcell 5D	340
Subcell 5D	Subcell 5C	370
Subcell 5C	Subcell 5B	370
Subcell 5B	Subcell 5A	330
Subcell 5A	Cell 4 Force Main	1,310
Cell 4 Force Main	Storage Tank	70

The inner diameters of the flexible hose and pipes are as follows:

Flexible hose	ID = 1.5 in.
2" SCH 80 PVC pipe	ID = 1.94 in. [Eslon Thermoplastics, 1995]
4" SDR 17 HDPE pipe	ID = 3.97 in. [Phillips 66, 1991]

The kinematic viscosity of leachate, ν, used in the calculation of the Reynolds number, is assumed to be equal to that of water at 50°F (i.e., 1.41×10^{-5} ft^2/sec) [Daugherty, 1985]. The friction factor, f, used in calculating the frictional losses along the pipe wall is taken from the Moody diagram (Figure 9). In the range of Reynold's numbers above 4,000, the Moody diagram for smooth walled pipe is modeled by the equation:

$$F = 0.195 \times (R_e)^{-0.206}$$

A graph of this equation and the part of the Moody diagram which it represents are shown together in Figure 10. For Reynolds numbers less than 4,000, the friction factor is calculated using the following equation:

$$f = \frac{64}{R_e}$$

7.5 Calculations and Results

Required Head for Pumps

The required head for the pump consists of the following components: (i) elevation head; (ii) friction head due to losses along the force main; and (iii) friction head due to losses in the riser house. The frictional losses in the riser houses and along the force main are both dependent on the velocity of flow through the pipes. The frictional losses in the riser house fittings and pipes for the pump design are shown in Tables 3 and 4. The pump must produce a minimum of 61.82 feet (29.5' elevation + 32.32' friction loss) of head at a design flowrate of 40 gpm.

LTS Pipe Pressure Requirements

Two inch SCH 80 PVC pipe placed in the riser house and 4-in SDR 17 HDPE pipe used in the LTS force main are rated for internal pressures of 400 psi and 100 psi, respectively. The maximum internal pressure expected by the 40 gpm pump operating at 47.14 feet of head is:

$$61.82\,ft \times 62.4\frac{lb}{ft^3} \times \frac{ft^2}{144in^2} = 26.8\,psi$$

The maximum operating pressure of the system is below the allowable pressure. Flexible hose used in the sump requires a pressure rating greater than 26.8 psi.

7.6 Evaluation of LTS Pipe Structural Stability

The stability of LTS force main transmission pipe against wall crushing, wall buckling, and ring deflection are evaluated in Attachment B to this calculation.

TABLE 1: EVALUATION OF REQUIRED DRAINAGE AREA FOR LCS DRAINAGE CORRIDORS
DRPI LANDFILL

Hydraulic Conductivity of Geonet = 10 cm/s

Volume of Leachate in Lateral Drainage Layer (see Note 1): 182 ft^3/day/acre
Hydraulic Conductivity of Geonet in LCS Drainage Corridor: 10 cm/s

LCS Drainage Corridor	Drainage Area (ac)	Slope of Leachate Collection Trench	Flow Rate (ft^3/day)	Flow Rate (cfs)	Required Area (ft^2)	Minimum Depth of Trench (ft)	Minimum Width of Trench (ft)
1	11.2	2.0%	2,038	0.02	3.60	0.9	4.0
2	15.7	2.0%	2,857	0.03	5.04	1.3	4.0
4	2.87	0.5%	522	0.01	3.69	0.9	4.0
8	2.70	0.5%	491	0.01	3.47	0.9	4.0

Notes:
1. For leachate generation calculations, see section 4.0 of this calculation package.

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TABLE 2

LEACHATE COLLECTION SUMP AND PUMP DESIGN

Delaware Recyclable Products, Inc.
New Castle, Delaware

Leachate Rate =	21.7	gpm
Sump Volumes		
Permanent Pool Volume =	3,473	gals
Maximum Pool Volume =	13,572	gals
Porosity =	0.23	
Net Volume =	2,323	gals
Selected Pumping Rate =	40.0	gpm
	Pump Cycle	
	127	min on
	107	min off
Cycles/day =	6.2	

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TABLE 3

FRICTIONAL LOSS BETWEEN LCS SUMP AND LTS FORCE MAIN

Delaware Recylable Products, Inc.
New Castle, Delaware

PLCS DESIGN FLOW RATE = 40 gpm

FRICTIONAL LOSS IN FITTINGS

Fitting	Quantity	Diameter (in.) Nominal	Diameter (in.) Inner	Head Loss Coeff., K	Flow Velocity (ft/s)	Frictional Loss, h_{LF} (ft)
Flange	1	2	1.94	1	4.34	0.29
90° 'L', 2-in.	1	2	1.94	0.95	4.34	0.28
90° 'L', 2-in.	1	2	1.94	0.95	4.34	0.28
Check valve, 2-in.	1	2	1.94	2	4.34	0.59
Branch 'T', 2-in.	1	2	1.94	0.85	4.34	0.25
Flow meter, 2-in.	1	2	1.94	2	4.34	0.59
90° 'L', 2-in.	1	2	1.94	0.95	4.34	0.28
In-line 'T', 2-in.	1	2	1.94	0.2	4.34	0.06
Ball valve, 2-in.	1	2	1.94	8.5	4.34	2.49
90° 'L', 2-in.	1	2	1.94	0.95	4.34	0.28
In-line 'T', 2-in.	1	2	1.94	0.2	4.34	0.06
90° 'L', 2-in.	1	2	1.94	0.65	4.34	0.19
Flange, 2-in. to 4-in.	1	2	1.94	1	4.34	0.29
90° 'L', 4-in.	1	4	3.97	0.65	1.04	0.01
					Sum of fitting frictional losses	**5.35**

FRICTIONAL LOSS IN HOSE

Pipe	Length, L (ft)	Inner Diameter, D_{ID} (in.)	Flow Velocity (ft/s)	Reynold's Number, Re	Friction Factor, f	Frictional Loss, h_{LP} (ft)
2" PVC Pipe (1)	5	1.94	4.34	5.0E+04	0.0210	0.19
Flexible hose (2)	33	1.5	7.26	6.4E+04	0.0200	4.31
					Sum of frictional losses in hose	**4.50**
					Total head loss (ft)	**9.86**

Notes:
(1) 5 feet of 2 inch PVC pipe assumed.
(2) Flexible hose length based on 2:1 side slope with 14.5 feet of vertical rise.

TABLE 4

FRICTIONAL LOSS IN LTS FORCE MAIN

Delaware Recylable Products, Inc.
New Castle, Delaware

Section Information			Flow From	Total	Pipe	Flow	Reynold's	Friction		Frictional Loss, $h_{LP} + h_{LF}$	
Start Cell[1]	End Cell[1]	Length (ft)	Start Cell (gpm)	Flow (gpm)	I.D. (in.)	Velocity (ft/s)	Number, R_e	Factor, f	K_{FM}[2]	In Pipe Section, h_{LP} (ft)	Force Main Fittings h_{LF} (ft)
C-6	C-5E	340	40	40	3.97	1.04	2.43E+4	0.0244	8.40	0.42	0.14
C-5E	C-5D	340	12	52	3.97	1.35	3.16E+4	0.0231	8.40	0.67	0.24
C-5D	C-5C	370	12	64	3.97	1.66	3.89E+4	0.0221	8.40	1.06	0.36
C-5C	C-5B	370	12	76	3.97	1.97	4.62E+4	0.0214	8.40	1.44	0.51
C-5B	C-5A	330	12	88	3.97	2.28	5.35E+4	0.0207	8.40	1.67	0.68
C-5A	C-4 FM	1310	12	100	3.97	2.59	6.08E+4	0.0202	8.40	8.34	0.88
C-4 FM	Tank	70	120	220	3.97	5.70	1.34E+5	0.0172	8.40	1.83	4.24
										15.43	7.04

NOTES:
1 - "C" = Cell.
2 - K_{FM} = sum of the loss coefficients for the LTS force-main fittings.
3 - Calculation assumes all of Cells 4 and 5 are in intermediate cover condition.

TOTAL - THIS TABLE	**22.46**
TOTAL - TABLE 2	**9.86**
TOTAL FRICTIONAL LOSS	**32.32**

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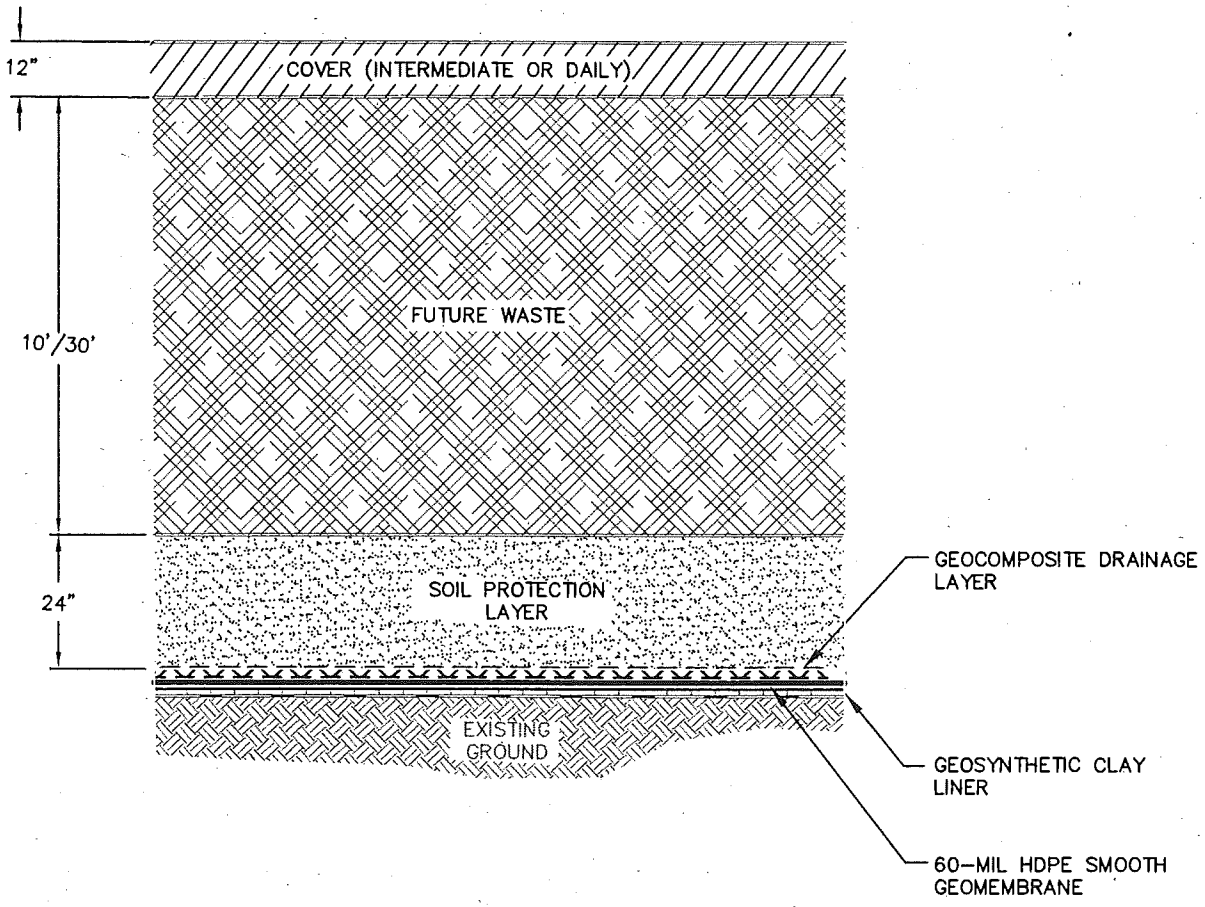


GEOSYNTEC CONSULTANTS
COLUMBIA, MARYLAND

FIGURE NO.	1
PROJECT NO.	ME0319
DOCUMENT NO.	
FILE NO.	0319F0003

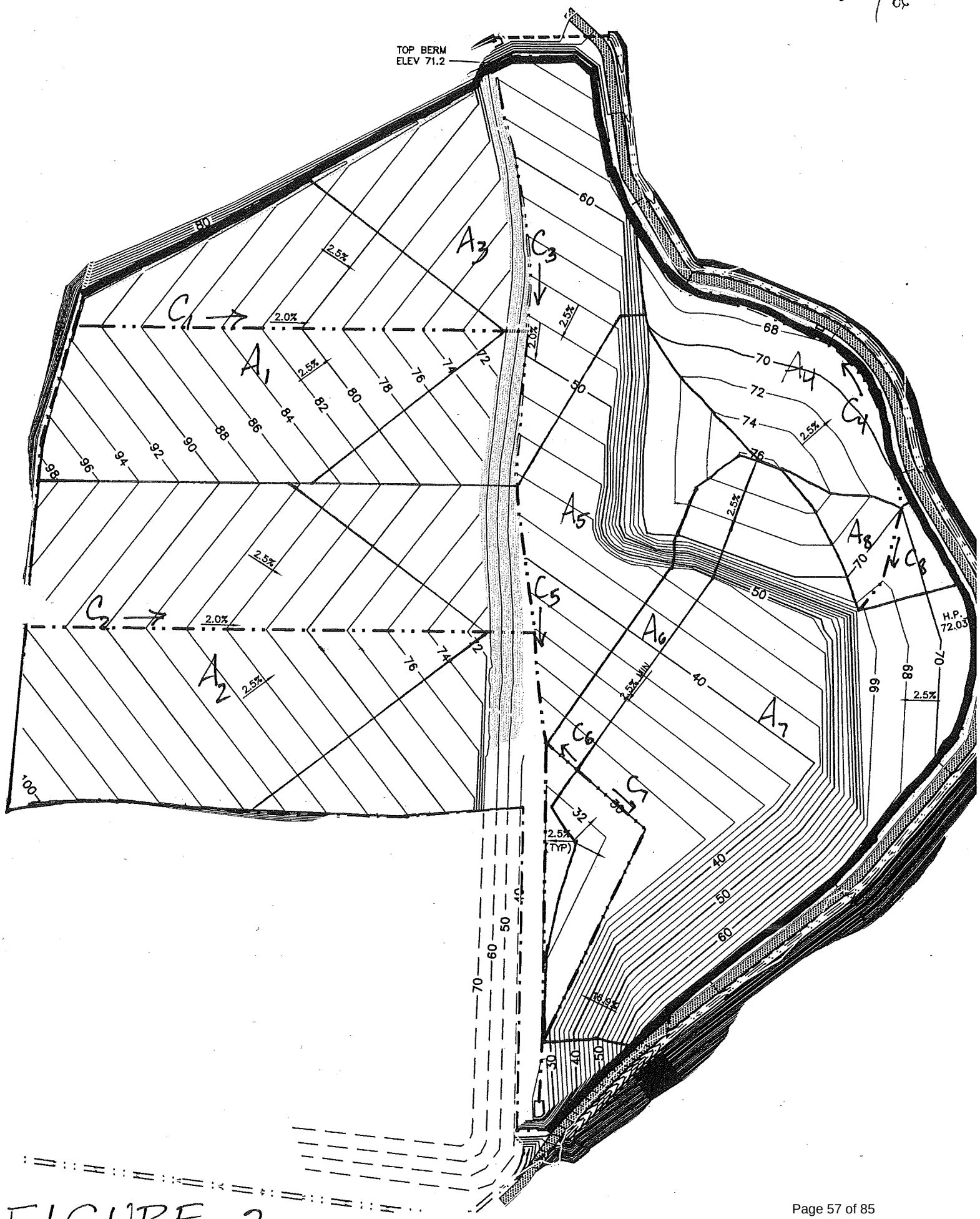
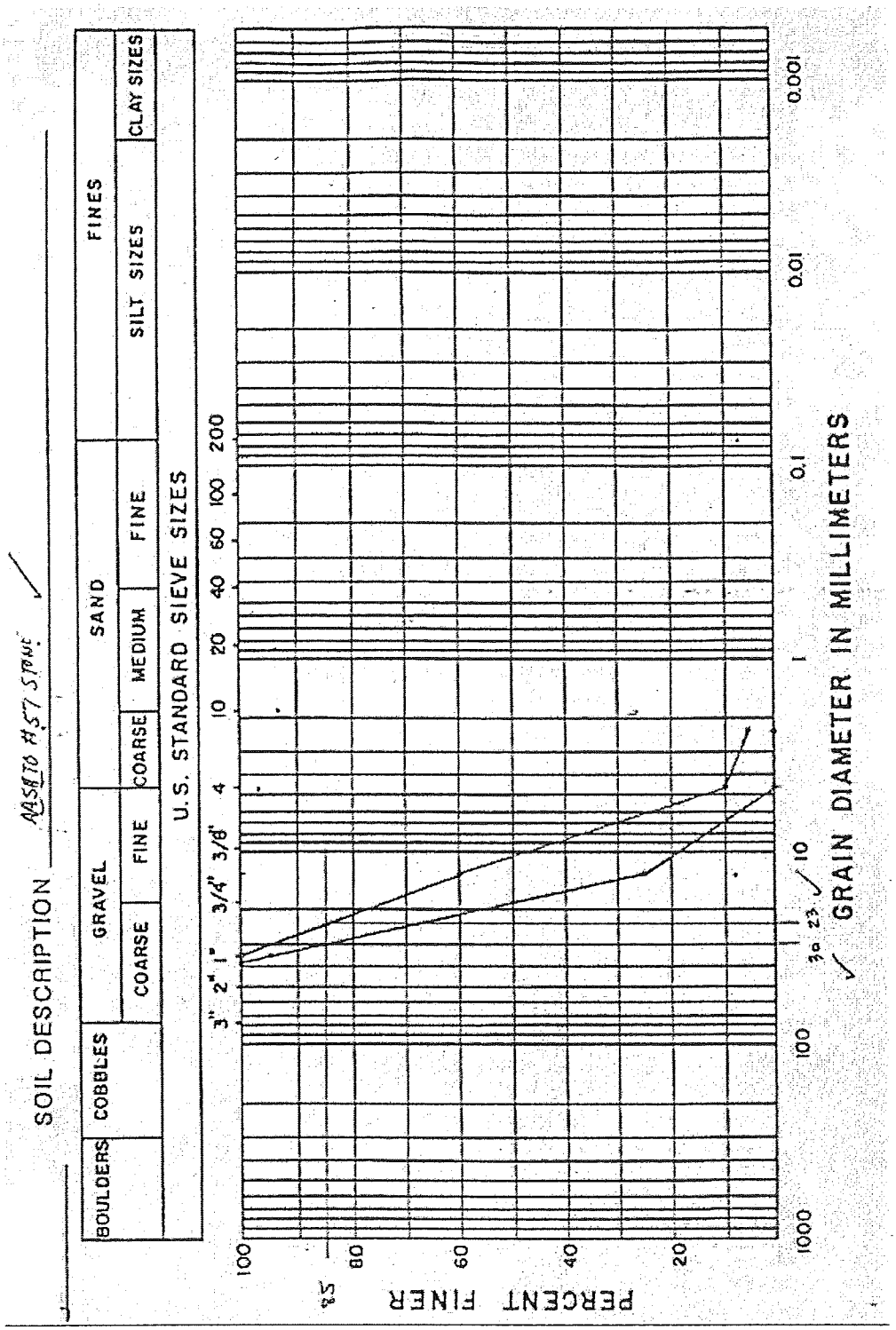

TOP BERM
ELEV 71.2
A1
A2
A3
A4
A5
A6
A7
A8
C1
C2
C3
C4
C5
C6
C7
C8
2.0%
2.5%
2.5% MIN
2.5% (TYP)
H.P. 72.03

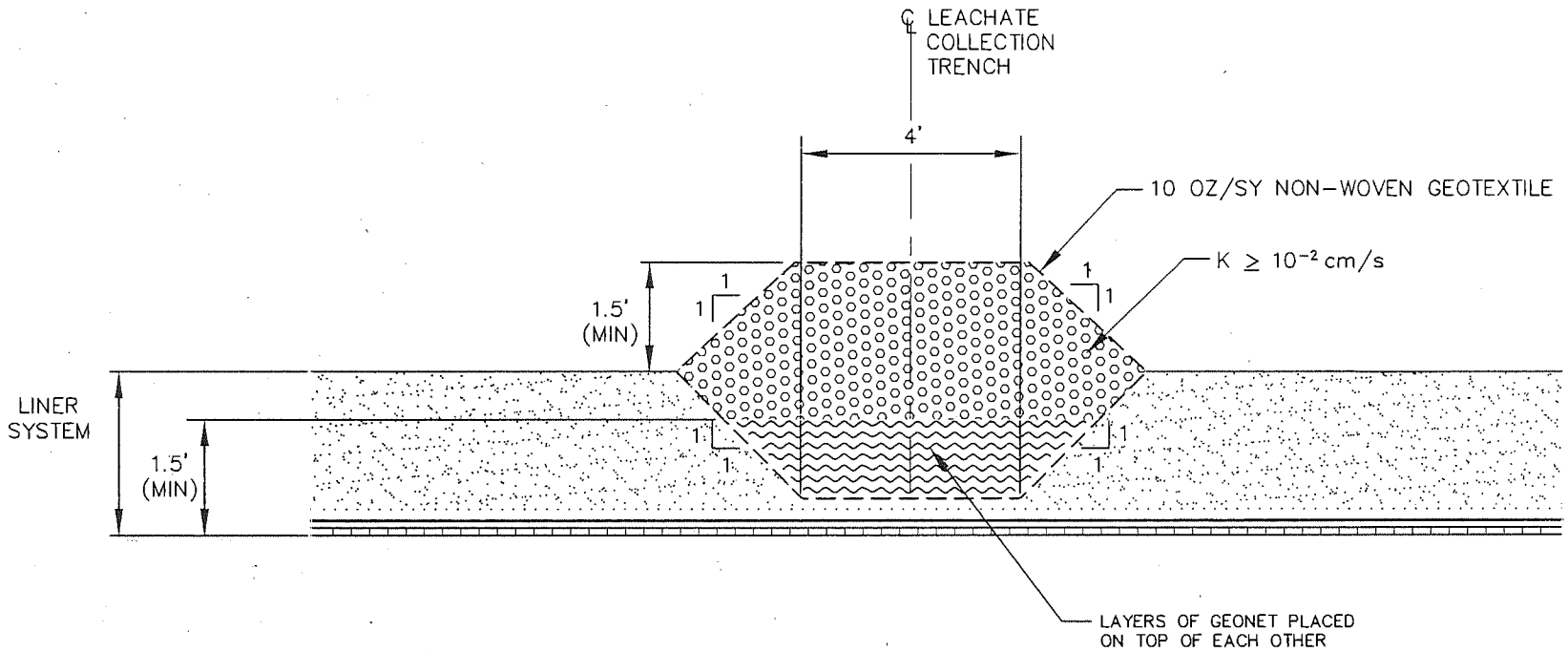
FIGURE 2

Written by: C. Pendleton Date: 03/05/2004 Reviewed by: Date:

Client: DRPI Project: DRPI Landfill Proj./Proposal No.: ME0319 Task No. 04

FIGURE 3





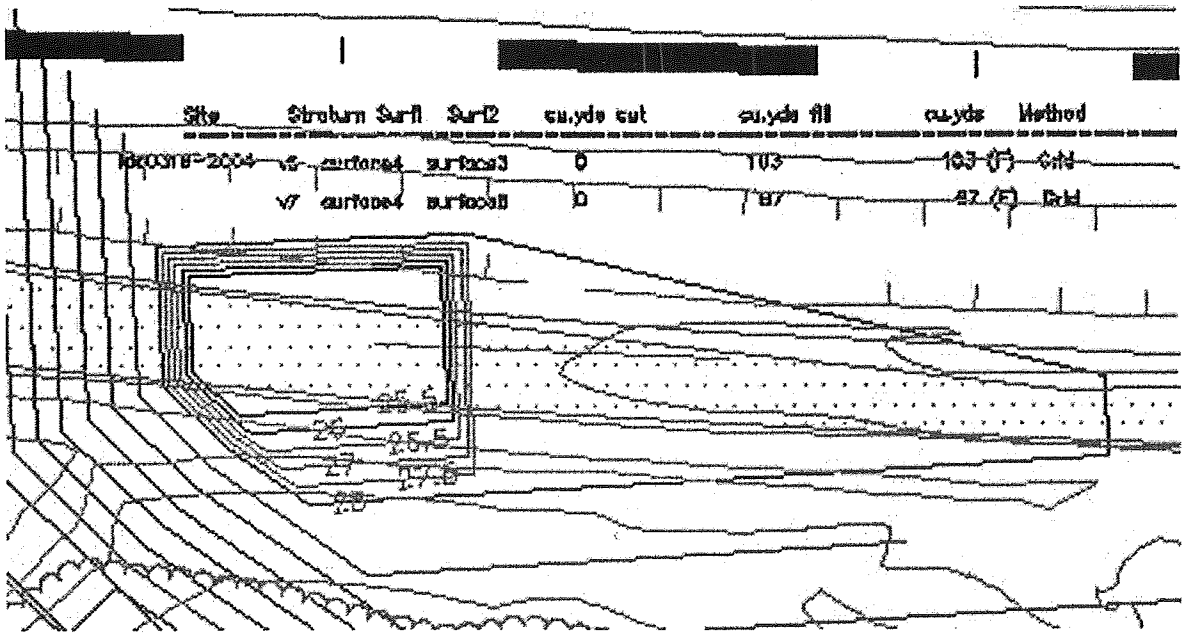
not to scale

Figure 4

Trench Cross Section

FIGURE 5

DRPI (ME0319)
Sump areas from ACAD
4 mar 04, joc



(not to scale – base of sump is roughly 20' x 40')

elev 25.5 Area = 834.85, Perimeter = 118.62

elev 26.0 Area = 1022.29, Perimeter = 128.96 VOLUME = 464.285 FT^3

elev 26.5 Area = 1217.87, Perimeter = 139.16 = 1,024.325 FT^3

elev 27.0 Area = 1421.26, Perimeter = 149.37 = 1,684.1075 FT^3

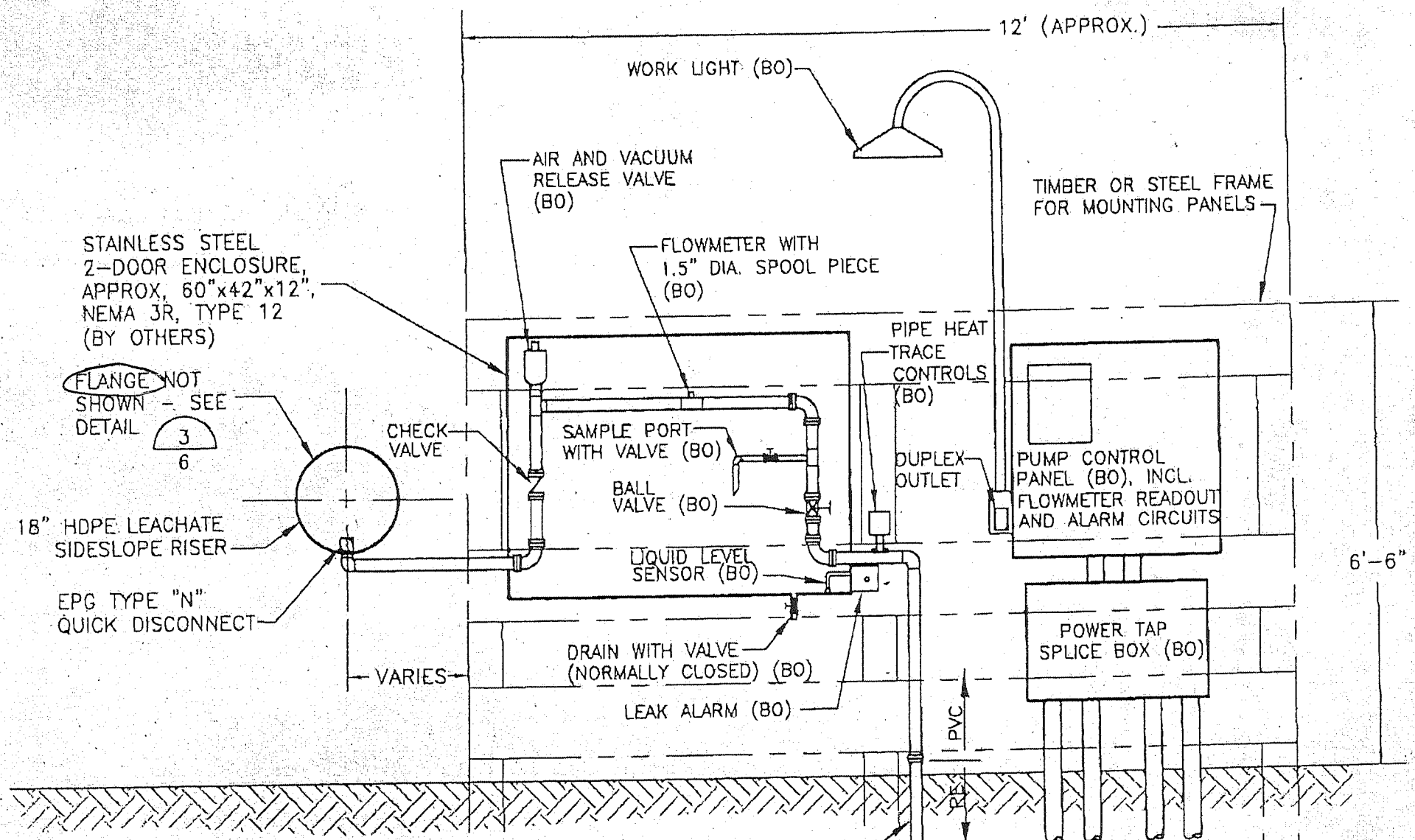
elev 27.5 Area = 1632.46, Perimeter = 159.57

elev 28.0 Area = 4471.67, Perimeter = 342.71

$$\text{VOLUME} = \left(\frac{A_1 + A_2}{2}\right) \times h$$

volume to elev 27.5 = 67 c.y. = 13,572 gal

volume to elev 28.0 = 103 c.y. = 20,803 gal



NOTES:

1. (BO) = BY OTHERS
2. HEAT TRACE ALL ABOVE GRADE PIPING.
3. HEADWORKS PIPING IS 2" SCH. 80 PVC EXCEPT SPOOL PIECE FOR FLOW METER 1.5" DIA.) AND SAMPLE PORT (0.5" OR 0.75" DIA)

FIGURE 6 (1 OF 4)

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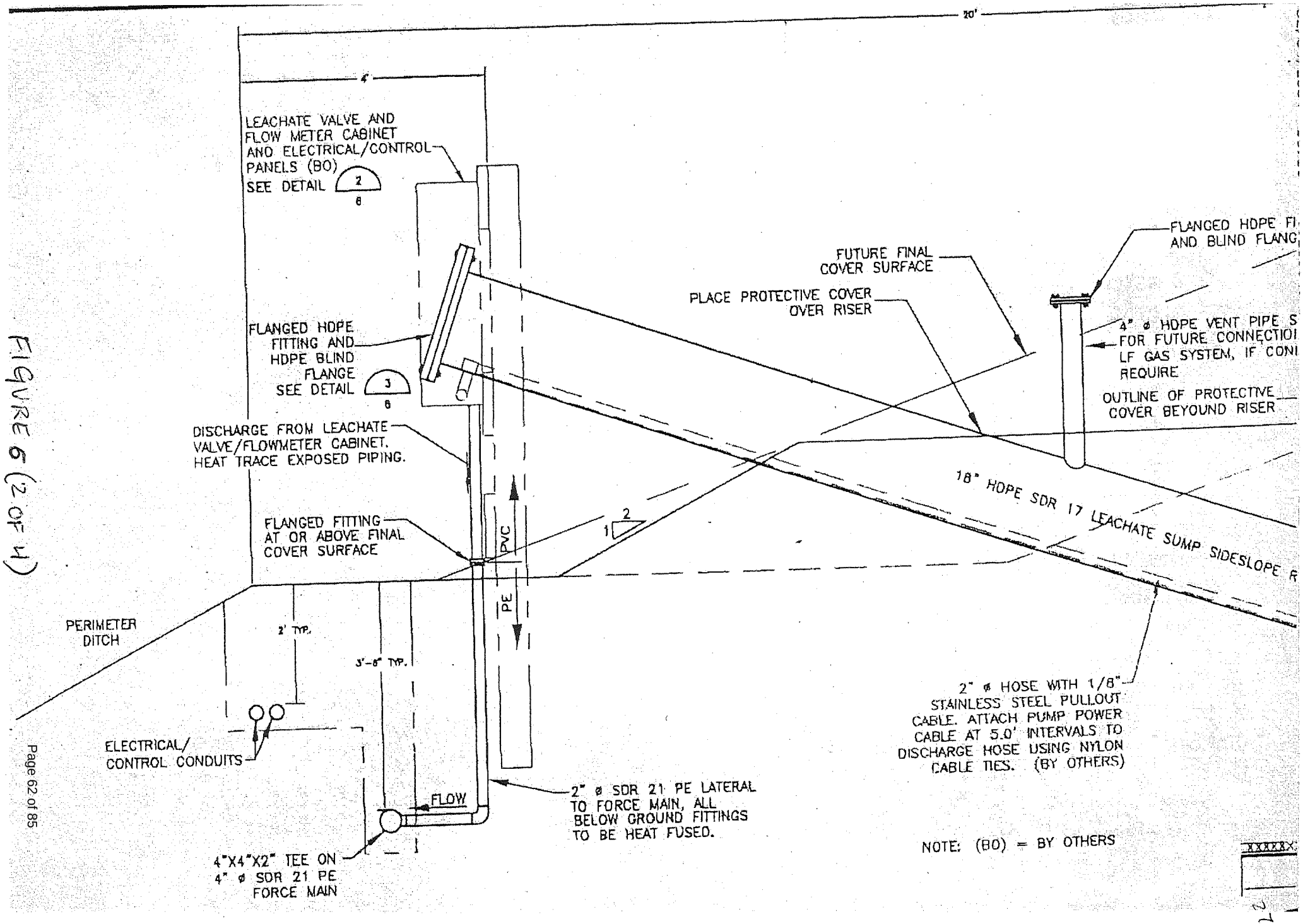
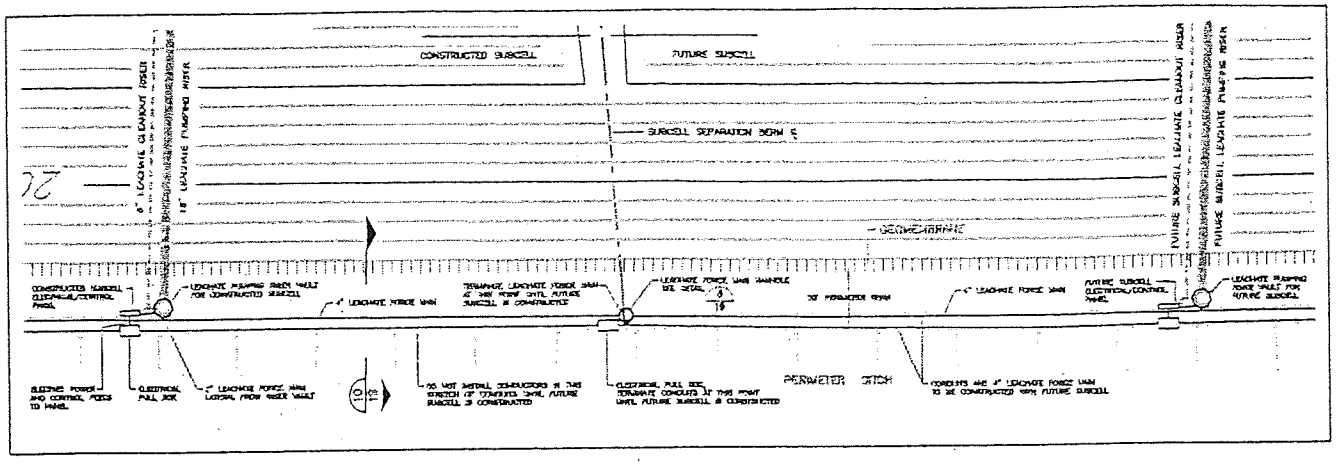


FIGURE 6 (2 OF 4)



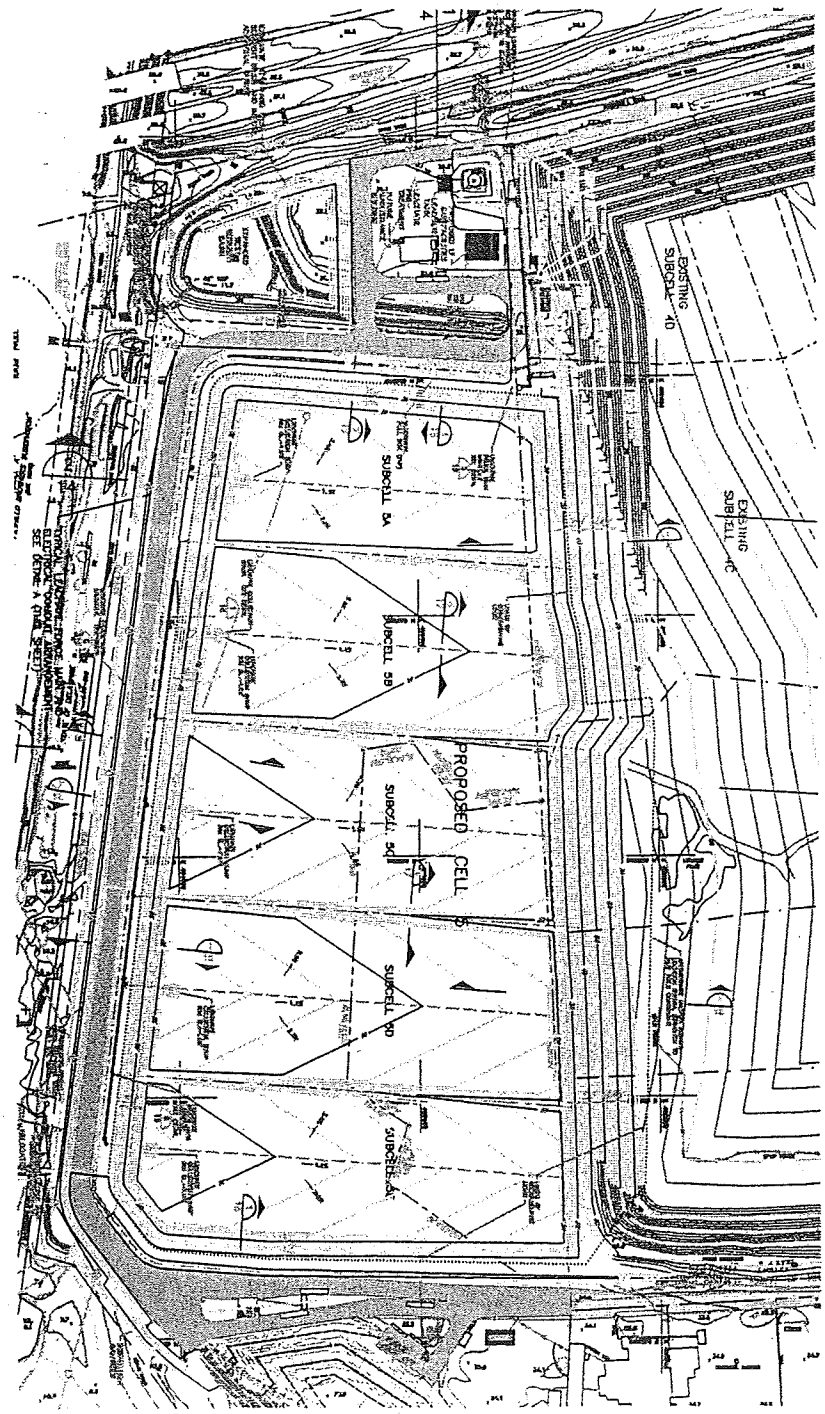
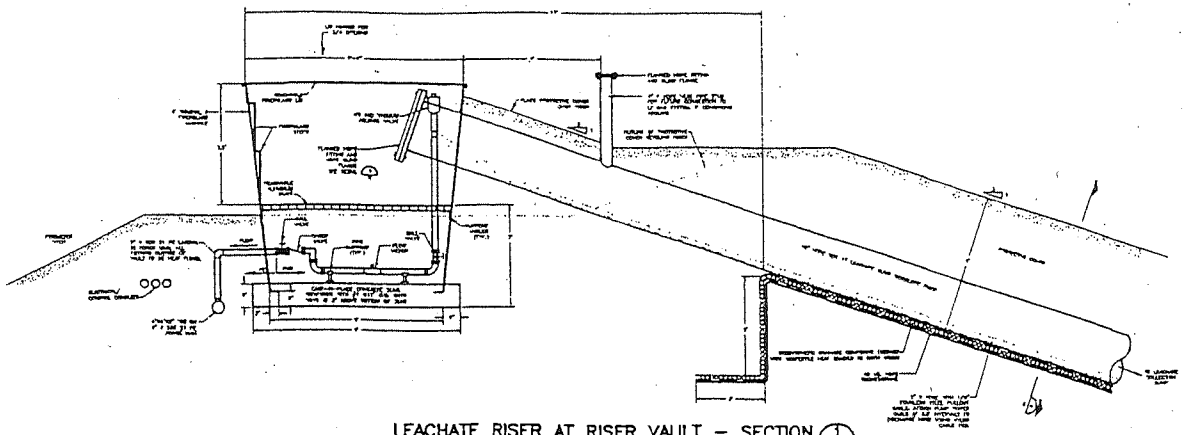
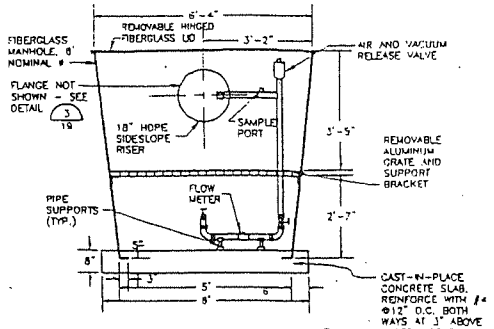


FIGURE 6 (3 OF 4)



LEACHATE RISER AT RISER VAULT – SECTION 1/18
SCALE: 1"=2'

NOTE: FIBERGLASS MANHOLES TO BE 8-FOOT NOMINAL DIAMETER BY 8' HIGH POLYGONAL FIBERGLASS MANHOLES AS MANUFACTURED BY FIBERGLASS UNLIMITED (LANDFILL DESIGN PRODUCTS), VICTORIA, TEXAS (512-575-6651) OR CROWCO DRILLING, NATALIA, TEXAS (210-599-3210).



LEACHATE RISER VAULT 2/18
SCALE: 1"=2'

RISER VAULT AND LEACH

1. Leachate Force Mai density polyethylene pipe and tested in accordanc pipe shall be installed i accordance with the pro

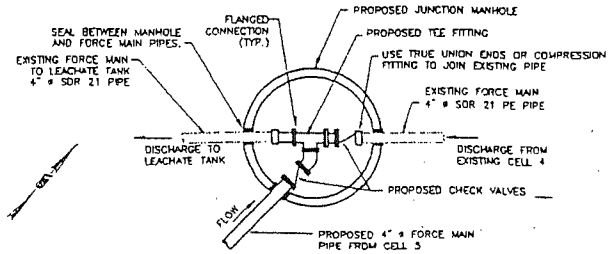
2. Piping within riser v except where 1 1/2" pi

3. Ball Valves shall be Sloan or approved equi

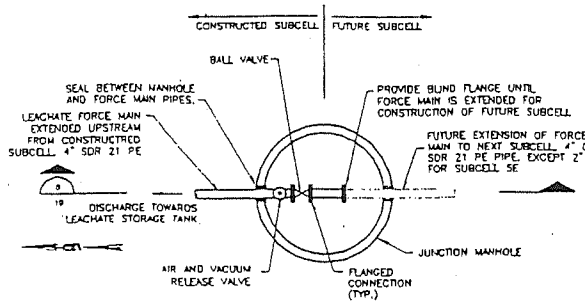
4. Check Valves shall Model No. 5104-PVC-P

5. Air and Vacuum Rel or Val-Matic Combinatio

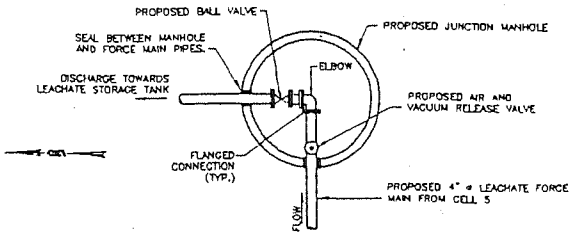
6. Flow meters shall b 52 EP 150 flow sensors at least 20" upstream



LEACHATE MANHOLE PLAN – TIE-IN TO EXISTING CELL 4 FORCE MAIN 4/4,5
NOT TO SCALE



TYPICAL LEACHATE FORCE MAIN JUNCTION MANHOLE – PLAN 6/4,5,6,7,8
NOT TO SCALE



LEACHATE MANHOLE AT NE CORNER OF CELL 5 – PLAN 5/4,5
NOT TO SCALE

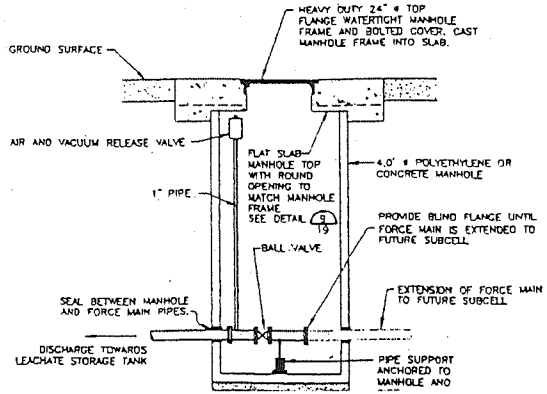


FIGURE 6 (4 OF 4)

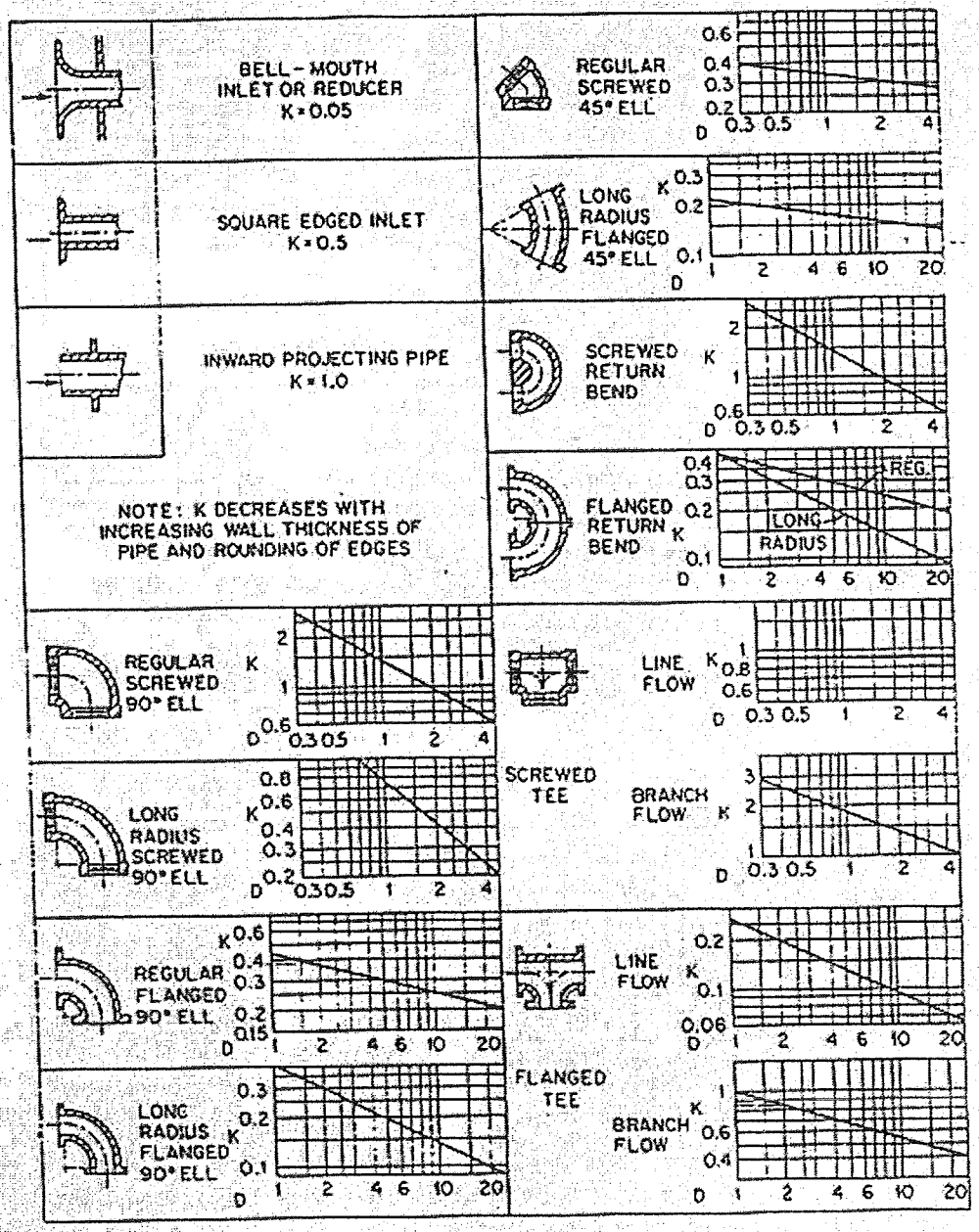
20/66

Written by: C. Pendleton Date: 03/25/04 Reviewed by: D. Mandeville Date: 03/25/04

Client: DRPI Project: DRPI Landfill Proj./Proposal No.: ME0319 Task No. 04

FIGURE 7

Resistance Coefficients K for Valves and Fittings



$h = K\frac{v^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm).

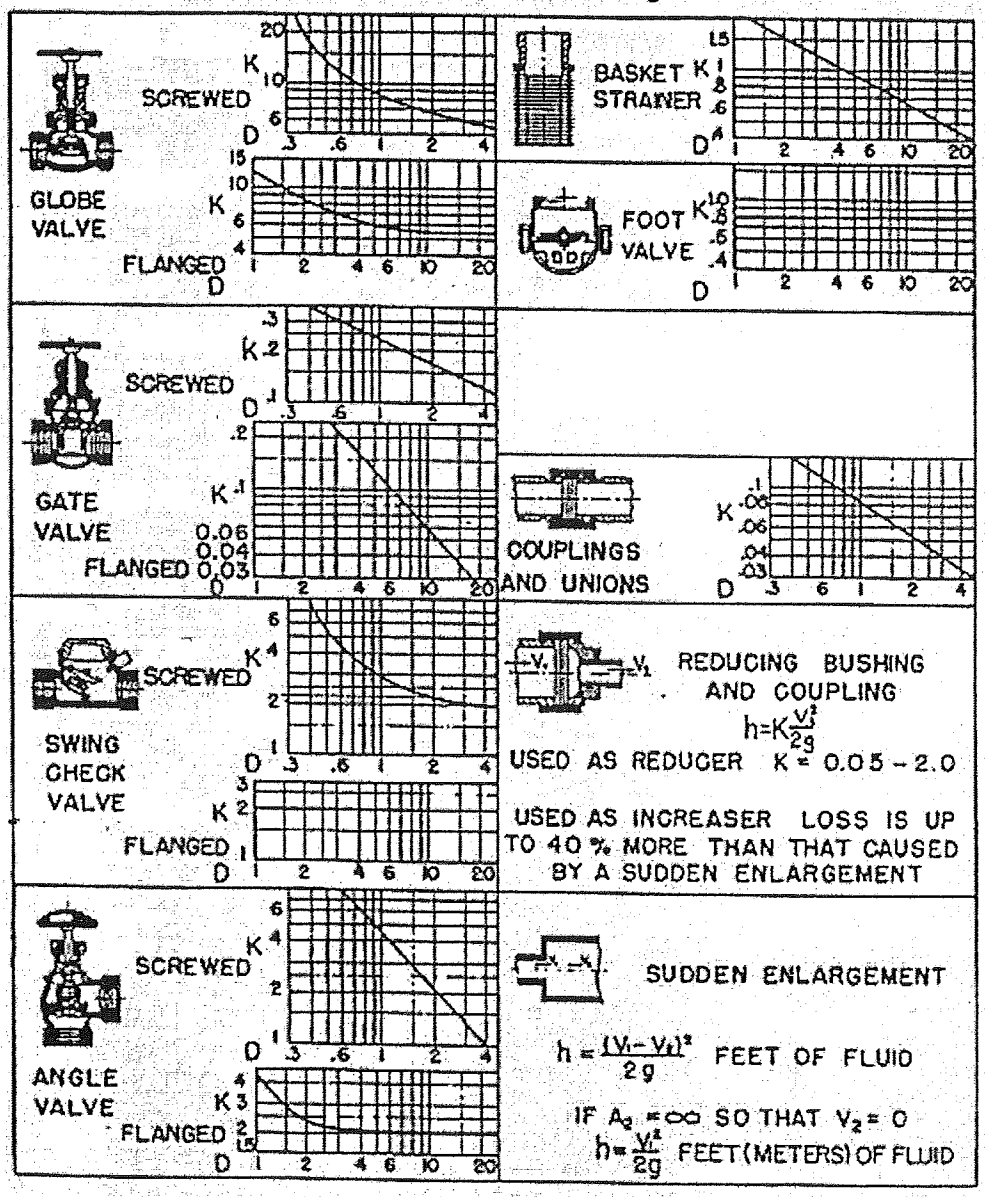
Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

Written by: C. Pendleton Date: 03/25/04 Reviewed by: D. Mandeville Date: 03/25/04

Client: DRPI Project: DRPI Landfill Proj./Proposal No.: ME0319 Task No. 04

FIGURE 8

Resistance Coefficients K for Valves and Fittings



$h=K\frac{V^2}{2g}$ FEET (METERS) OF FLUID

NOTE: D = nominal iron pipe size in inches (in × 25.4 = mm). For velocities below 15 ft/s (4.6 m/s), check valves and foot valves will be only partially open and will exhibit higher values of K than shown.

Source: *Pipe Friction Manual*, 3d ed., Hydraulic Institute, Cleveland, 1961.

Written by: C. Pendleton Date: 03/25/04 Reviewed by: D. Mandeville Date: 03/25/04

Client: DRPI Project: DRPI Landfill Proj./Proposal No.: ME0319 Task No. 04

FIGURE 9

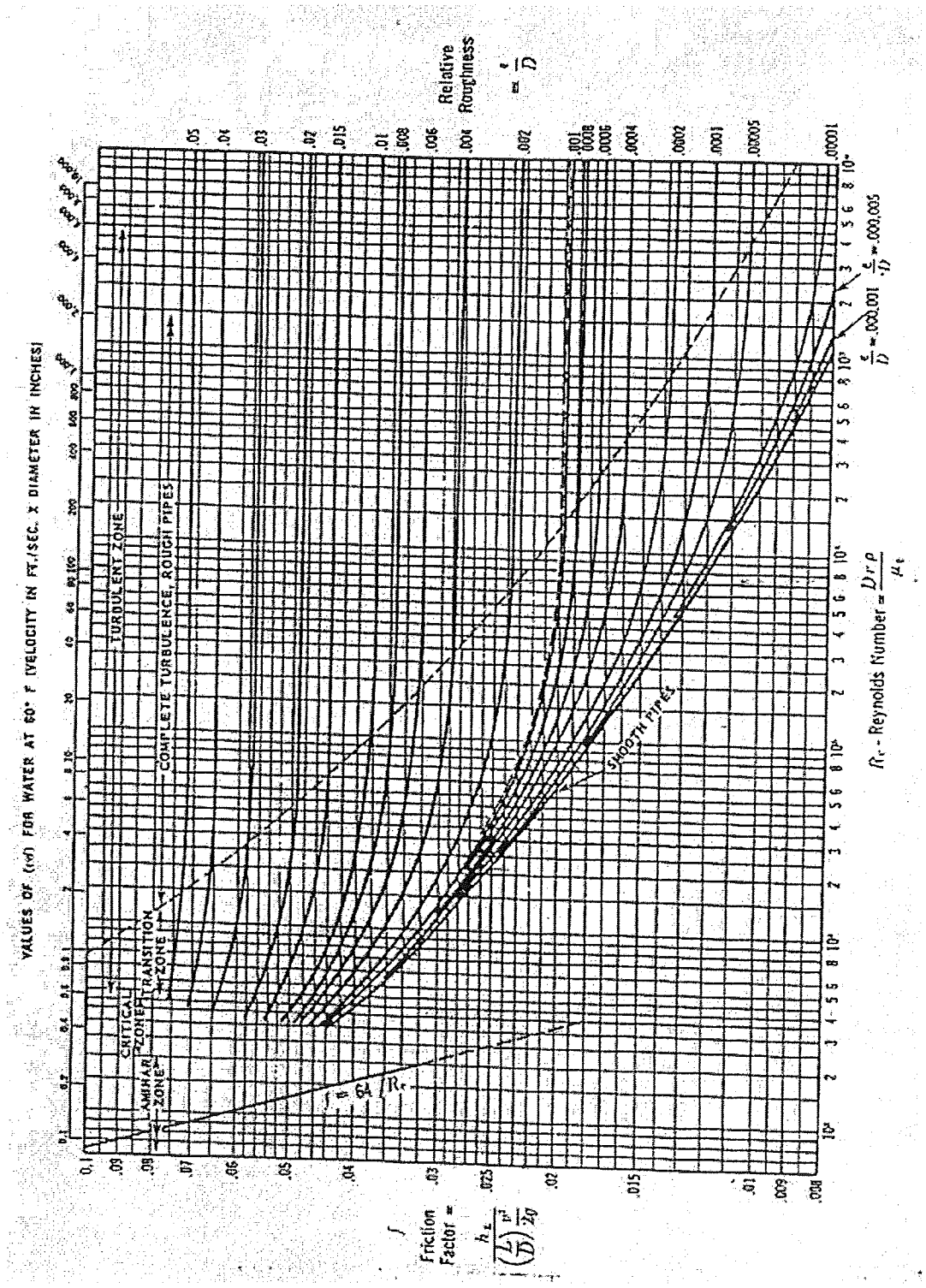
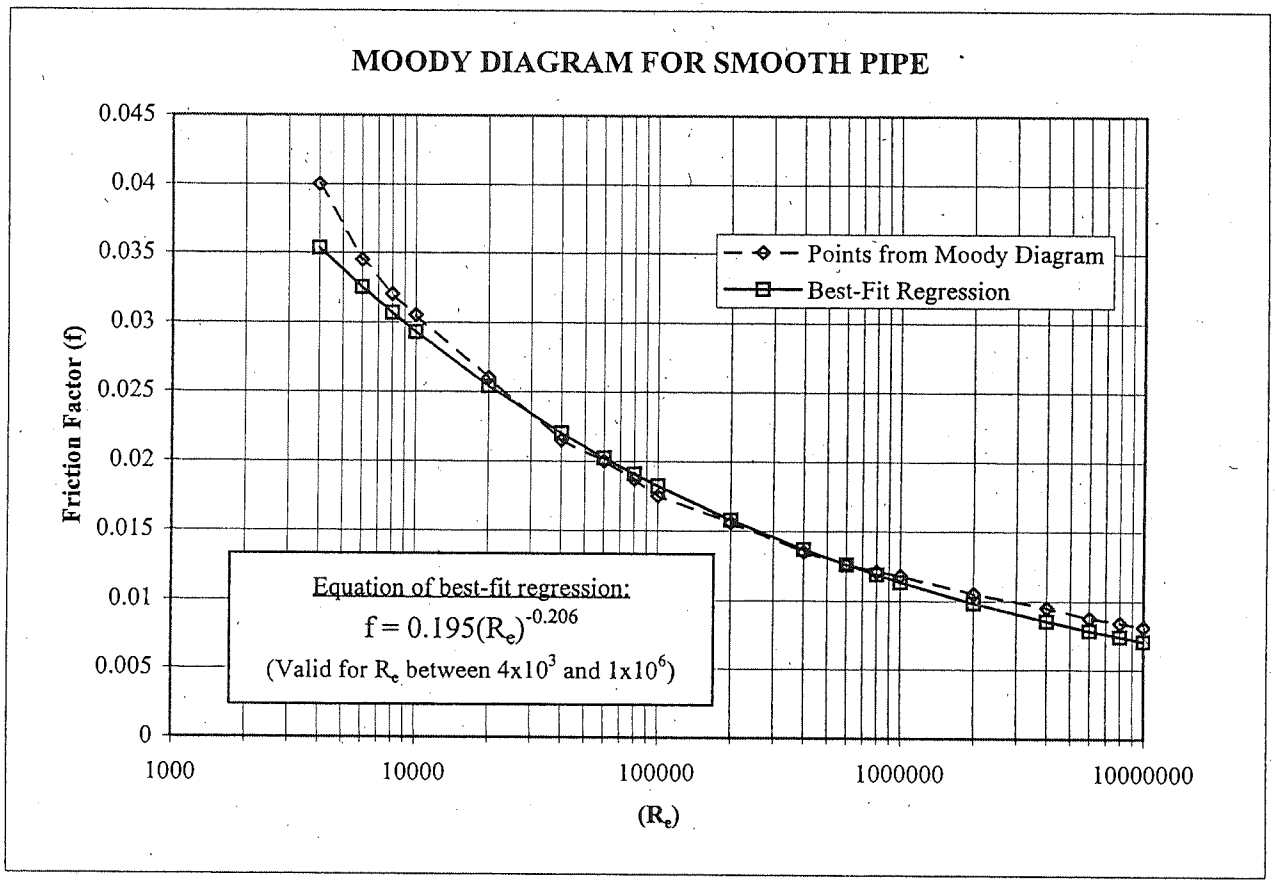


FIGURE 10

REGRESSION OF CURVE FOR SMOOTH PIPE FROM MOODY DIAGRAM

Reynold's Number, R_e	Friction Factor (f) for Smooth Pipe	
	From Moody Diagram	From Regression
4.0E+03	0.0400	0.0354
6.0E+03	0.0345	0.0325
8.0E+03	0.0320	0.0307
1.0E+04	0.0305	0.0293
2.0E+04	0.0260	0.0254
4.0E+04	0.0215	0.0220
6.0E+04	0.0200	0.0202
8.0E+04	0.0187	0.0191
1.0E+05	0.0175	0.0182
2.0E+05	0.0156	0.0158
4.0E+05	0.0135	0.0137
6.0E+05	0.0126	0.0126
8.0E+05	0.0121	0.0119
1.0E+06	0.0118	0.0113
2.0E+06	0.0105	0.0098
4.0E+06	0.0095	0.0085
6.0E+06	0.0088	0.0078
8.0E+06	0.0084	0.0074
1.0E+07	0.0081	0.0071



ATTACHMENT A

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              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:      P:\PRJ1\MDENG\HELP3\ME0319\DATA4.D4
TEMPERATURE DATA FILE:        P:\PRJ1\MDENG\HELP3\ME0319\DATA7.D7
SOLAR RADIATION DATA FILE:    P:\PRJ1\MDENG\HELP3\ME0319\DATA13.D13
EVAPOTRANSPIRATION DATA:      P:\PRJ1\MDENG\HELP3\ME0319\DATA11.D11
SOIL AND DESIGN DATA FILE:    P:\PRJ1\MDENG\HELP3\ME0319\RUN11.D10
OUTPUT DATA FILE:             P:\PRJ1\MDENG\HELP3\ME0319\RUN11.OUT


TIME:   9:27     DATE:   3/18/2004


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

     TITLE:  DRPI - 10 FT WASTE, GEOCOMPOSITE, DAILY COVER

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


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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3650 VOL/VOL
          FIELD CAPACITY             =      0.3050 VOL/VOL
          WILTING POINT              =      0.2020 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2832 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
        NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	120.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3024	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE 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	=	0.2568	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

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	=	0.0111	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	1150.0	FEET

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	=	1.00	HOLES/ACRE
FML INSTALLATION DEFECTS	=	1.00	HOLES/ACRE
FML PLACEMENT QUALITY	=	4 - POOR	

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

THICKNESS	=	0.30	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.	=	0.300000003000E-08	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND A SLOPE LENGTH OF 2000. FEET.

SCS RUNOFF CURVE NUMBER	=	96.60	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	22.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	6.622	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	12.926	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	2.444	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	44.383	INCHES
TOTAL INITIAL WATER	=	44.383	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WILMINGTON DELAWARE

STATION LATITUDE	=	39.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	4.20
START OF GROWING SEASON (JULIAN DATE)	=	107
END OF GROWING SEASON (JULIAN DATE)	=	298
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	9.20 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	71.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.11	2.99	3.87	3.39	3.23	3.51
3.90	4.03	3.59	2.89	3.33	3.54

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.20	33.20	41.80	52.40	62.20	71.20
76.00	74.80	67.80	56.30	45.60	35.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE
AND STATION LATITUDE = 39.80 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	3.22	2.34	3.98	3.24	3.36	3.74
	4.05	4.24	3.82	2.66	3.04	3.03

STD. DEVIATIONS	1.79	0.97	1.40	1.29	1.55	1.72
	1.83	2.28	2.24	1.38	1.45	1.97

RUNOFF

TOTALS	1.340	1.140	1.721	0.853	0.961	1.344
	1.684	1.811	1.858	1.054	1.001	0.970
STD. DEVIATIONS	1.169	0.693	1.118	0.604	0.834	0.926
	1.255	1.542	1.559	1.003	0.828	1.135

EVAPOTRANSPIRATION

TOTALS	0.678	0.675	1.971	2.903	3.991	3.278
	2.314	2.452	1.653	1.082	0.849	0.592
STD. DEVIATIONS	0.211	0.332	0.455	0.595	0.570	1.068
	0.763	1.026	0.757	0.234	0.135	0.131

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.2044	0.4209	0.4906	0.9303	0.4089	0.1196
	0.0015	0.0001	0.0001	0.0001	0.0021	0.0137
STD. DEVIATIONS	0.3683	0.5490	0.5741	0.5096	0.1818	0.0863
	0.0044	0.0002	0.0001	0.0005	0.0112	0.0302

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	0.0067	0.0151	0.0161	0.0315	0.0134	0.0040
	0.0000	0.0000	0.0000	0.0000	0.0001	0.0004
STD. DEVIATIONS	0.0121	0.0196	0.0188	0.0172	0.0059	0.0029
	0.0001	0.0000	0.0000	0.0000	0.0004	0.0010

****

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	15.739	(3.7765)	57132.17	38.658
EVAPOTRANSPIRATION	22.438	(2.2795)	81450.65	55.113
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.59223	(1.42705)	9409.798	6.36703
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.010	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.007	(0.004)		
CHANGE IN WATER STORAGE	-0.056	(1.5597)	-203.21	-0.138

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.26	19093.801
RUNOFF	4.624	16783.7441
DRAINAGE COLLECTED FROM LAYER 4	0.16370	594.22504
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00035
AVERAGE HEAD ON TOP OF LAYER 5	0.166	
MAXIMUM HEAD ON TOP OF LAYER 5	0.330	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	8.7 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3605
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1111

*** 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	1.6311	0.2718
2	34.5227	0.2877
3	6.3204	0.2634
4	0.0047	0.0239
5	0.0000	0.0000
6	0.2250	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              **
**                                                                          **
**                                                                          **
******************************************************************************
******************************************************************************


PRECIPITATION DATA FILE:      P:\PRJ1\MDENG\HELP3\ME0319\DATA4.D4
TEMPERATURE DATA FILE:        P:\PRJ1\MDENG\HELP3\ME0319\DATA7.D7
SOLAR RADIATION DATA FILE:    P:\PRJ1\MDENG\HELP3\ME0319\DATA13.D13
EVAPOTRANSPIRATION DATA:      P:\PRJ1\MDENG\HELP3\ME0319\DATA11.D11
SOIL AND DESIGN DATA FILE:    P:\PRJ1\MDENG\HELP3\ME0319\RUN14.D10
OUTPUT DATA FILE:             P:\PRJ1\MDENG\HELP3\ME0319\RUN14.OUT


TIME:  11: 2     DATE:   3/23/2004


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

     TITLE:  DRPI - 30 FT WASTE, GEOCOMPOSITE, INTERMEDIATE COVER

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


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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER  24
          THICKNESS                  =     12.00   INCHES
          POROSITY                   =      0.3650 VOL/VOL
          FIELD CAPACITY             =      0.3050 VOL/VOL
          WILTING POINT              =      0.2020 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.3020 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.270000010000E-05 CM/SEC
       NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  4.96
                FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS	=	360.00	INCHES
POROSITY	=	0.6710	VOL/VOL
FIELD CAPACITY	=	0.2920	VOL/VOL
WILTING POINT	=	0.0770	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2948	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE 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	=	0.2572	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.119999997000E-03	CM/SEC

LAYER 4

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 20

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	=	0.0139	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	10.0000000000	CM/SEC
SLOPE	=	2.00	PERCENT
DRAINAGE LENGTH	=	1150.0	FEET

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           =      1.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =      1.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  4 - POOR
```

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 17

```
THICKNESS                     =      0.30   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.     =  0.300000003000E-08 CM/SEC
```

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #24 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 4.% AND A SLOPE LENGTH OF 2000. FEET.

```
SCS RUNOFF CURVE NUMBER              =     96.60
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      6.708  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =     11.090  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      3.194  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =    116.168  INCHES
TOTAL INITIAL WATER                  =    116.168  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
WILMINGTON DELAWARE

STATION LATITUDE	=	39.80 DEGREES
MAXIMUM LEAF AREA INDEX	=	4.20
START OF GROWING SEASON (JULIAN DATE)	=	107
END OF GROWING SEASON (JULIAN DATE)	=	298
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	9.20 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	71.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
3.11	2.99	3.87	3.39	3.23	3.51
3.90	4.03	3.59	2.89	3.33	3.54

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
31.20	33.20	41.80	52.40	62.20	71.20
76.00	74.80	67.80	56.30	45.60	35.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR WILMINGTON DELAWARE
AND STATION LATITUDE = 39.80 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	3.22	2.34	3.98	3.24	3.36	3.74
	4.05	4.24	3.82	2.66	3.04	3.03

STD. DEVIATIONS	1.79	0.97	1.40	1.29	1.55	1.72
	1.83	2.28	2.24	1.38	1.45	1.97

RUNOFF

TOTALS	1.559	1.325	1.927	0.918	0.995	1.352
	1.693	1.820	1.880	1.096	1.123	1.120
STD. DEVIATIONS	1.324	0.775	1.241	0.647	0.866	0.932
	1.260	1.547	1.586	1.030	0.896	1.222

EVAPOTRANSPIRATION

TOTALS	0.690	0.681	1.978	2.671	3.845	2.968
	2.312	2.436	1.660	1.120	0.890	0.620
STD. DEVIATIONS	0.221	0.343	0.438	0.654	0.523	1.037
	0.761	1.012	0.769	0.251	0.141	0.137

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	0.1557	0.3962	0.4002	0.6868	0.3543	0.0733
	0.0017	0.0001	0.0002	0.0003	0.0019	0.0114
STD. DEVIATIONS	0.2649	0.5013	0.4509	0.3599	0.1469	0.0720
	0.0081	0.0003	0.0004	0.0013	0.0098	0.0242

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	0.0051	0.0142	0.0131	0.0232	0.0116	0.0025
	0.0001	0.0000	0.0000	0.0000	0.0001	0.0004
STD. DEVIATIONS	0.0087	0.0180	0.0148	0.0122	0.0048	0.0024
	0.0003	0.0000	0.0000	0.0000	0.0003	0.0008

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.71	(5.898)	147789.4	100.00
RUNOFF	16.807	(3.9745)	61009.87	41.282
EVAPOTRANSPIRATION	21.871	(2.1995)	79390.70	53.719
LATERAL DRAINAGE COLLECTED FROM LAYER 4	2.08220	(1.15323)	7558.402	5.11431
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.00000	(0.00000)	0.009	0.00001
AVERAGE HEAD ON TOP OF LAYER 5	0.006	(0.003)		
CHANGE IN WATER STORAGE	-0.047	(1.3167)	-169.60	-0.115

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 30

	(INCHES)	(CU. FT.)
PRECIPITATION	5.26	19093.801
RUNOFF	4.623	16781.4297
DRAINAGE COLLECTED FROM LAYER 4	0.15033	545.68927
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000000	0.00033
AVERAGE HEAD ON TOP OF LAYER 5	0.153	
MAXIMUM HEAD ON TOP OF LAYER 5	0.304	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	3.3 FEET	
SNOW WATER	4.03	14622.6279

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3436
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1452

*** 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	3.4383	0.2865
2	104.7258	0.2909
3	6.3755	0.2656
4	0.0022	0.0111
5	0.0000	0.0000
6	0.2250	0.7500
SNOW WATER	0.000	

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APPENDIX VI-E.2

PIPE STRUCTURAL STABILITY CALCULATIONS

Geosyntec consultants

COMPUTATION COVER SHEET

Client: DRPI **Project:** DRPI Landfill Expansion **Project #:** ME1571 **Task #:** 1

TITLE OF COMPUTATIONS PIPE STRUCTURAL STABILITY CALCULATIONS

COMPUTATIONS BY:
Signature
3/1/2018
DATE
Printed Name and Title: Chunling Li, Project Engineer

ASSUMPTIONS AND PROCEDURES CHECKED BY:
(Peer Reviewer)
Signature
3/2/2018
DATE
Printed Name and Title: Andrew Stallings, Senior Staff Engineer

COMPUTATIONS CHECKED BY:
Signature
3/2/2018
DATE
Printed Name and Title: Andrew Stallings, Senior Staff Engineer

COMPUTATIONS BACKCHECKED BY: (Originator)
Signature
3/3/2018
DATE
Printed Name and Title: Chunling Li, Project Engineer

APPROVED BY:
(PM or Designate)
Signature
3/4/2018
DATE
Printed Name and Title: David Espinoza, Senior Principal

APPROVAL NOTES:

REVISIONS (Number and initial all revisions)

NO.	SHEET	DATE	BY	CHECKED BY	APPROVAL

PIPE STRUCTURAL STABILITY CALCULATIONS

PURPOSE

The purpose of this calculation is to evaluate the structural adequacy of the leachate collection pipes for the proposed vertical expansion of the DRPI Landfill located in New Castle, Delaware. These pipes are evaluated for structural stability in terms of wall crushing, buckling, and ring deflection. A factor of safety is calculated for wall crushing and buckling.

BACKGROUND

Regulations stipulate that landfills must have a leachate collection network in place that can effectively convey the leachate collected in the drainage layer located above the geomembrane liner. In order to effectively convey the leachate, the pipes must be structurally able to withstand expected loads.

The existing leachate collection pipe in Cell 6 is high-density polyethylene (HDPE), perforated, has a diameter of 8-in. along the leachate collection system (LCS) network, and a standard dimension ratio (SDR) of 17. The proposed LCS pipes in the Cells 1-3 overlay area are the same as Cell 6 LCS pipes. Existing leachate collection lateral and header pipes in Cells 4 and 5 are also HDPE with SDR of 15.5. Three different leachate pipe sizes were used for Cells 4 and 5, which are nominal 4, 6 and 8 inches.

SDR is the ratio of outer diameter of the pipe to wall thickness. Parameters used for the design of the HDPE pipe are taken from *Plastics Pipe Institute® Handbook of Polyethylene Pipe* and are provided in Attachment A (Supporting Information) at the end of this calculation package.

CASES ANALYZED

Evaluation of the stability of the leachate collection pipes will be done based on engineering procedures described in *Plastics Pipe Institute® Handbook of Polyethylene Pipe*. Previously, Geosyntec evaluated three loading conditions as a part of the previous permit application [Geosyntec, 2005], which are listed below:

CASE 1: The maximum pressure on the pipe induced by construction equipment during construction of the landfill liner and leachate collection pipes.

CASE 2: The stress induced by a 90 cubic yard capacity waste truck placing waste on top of the soil protective cover layer. The minimum thickness of the first lift will be 10 ft.

CASE 3: The maximum pressure exerted on the pipe due to the overburden of the landfill after the final grades have been achieved.

CALCULATION METHOD

Induced Pipe Stresses

All LCS pipes have been constructed except one pipe in the Cells 1-3 overlay area. Thus, for Cases 1 and 2, only the 8-inch SDR-17 pipes are considered. For Case 3, all types of LCS pipes are considered.

Case 1 (Construction Equipment)

The initial conditions for the leachate collection system assume that the collector pipe is buried under 24 inches of granular material before construction equipment will cross the pipe. The typical cross section for a leachate collection pipe along a cell base is shown in the permit drawings. The stress due to traffic above the pipe is assumed to come from a HS-20 standard truck load which applies an axle load of 32,000 lbs (i.e., 16,000 per tire). For the calculations, a concentrated load of 20,000 lbs is assumed to be applied above the crown of the pipe. The stress on the pipe will be calculated as described in *Plastics Pipe Institute® Handbook of Polyethylene Pipe*.

$$\sigma_{max} = C_H \frac{I\ W_l}{L\ D}$$

Where:

σ_{max} = Maximum stress applied (lbs/ft^2)
I = Impact factor
L = Pipe length (ft)
C_H = Load coefficient
D = Pipe outer diameter (ft)
W_l = Wheel load (pounds)

The Chevron manual suggests an impact factor of 1.5 be used for calculations and a pipe length of 3 feet for pipes which are 3 feet or longer. The load coefficient (C_H) is a function of the pipe burial depth (H), length (L) and outer diameter (D).

$$C_H = f\left(\frac{L}{2H}, \frac{D}{2H}\right)$$

For Case 1, H_{min} = 1 ft., L = 3 ft., and D = 8in. Therefore, $L/2H$ = 1.5 and $D/2H$ = 0.33. From this, C_H can be determined from Reference A-7 in Attachment A by interpolating between D/2H of 0.3 and 0.4, and is 0.38. The induced pipe stress for Case 1, therefore, is:

$$\sigma_{max} = \left(0.38\frac{1.5(20{,}000\text{lbs})}{(3\text{ft})(8\text{in}/12)}\right)\times\left(\frac{\text{ft}^2}{144\text{in}^2}\right) = \mathbf{39.58}\ \text{lbs/in}^2$$

Case 2 (Select Waste Placement on Top of Leachate Collection Zone)

This case considers a 90 cubic yard waste truck (operating weight of 100,000 lbs when full) driving on a 10-ft layer of select waste within the newly lined area. The unit weight of the waste is assumed to be 65 lbs/ft^3 for this 10-ft layer of select waste. This case considers the stresses induced on the pipe by the weight of the truck and the overburden stress resulting from the 10 feet of select waste. The maximum stress acting on the pipe is calculated in the same manner as Case 1. For Case 2, an impact factor of 1.5 and a pipe length of 3 was used in accordance with the Chevron manual. The load coefficient from Reference A-7, therefore, is C_H = 0.026. The induced pipe stress for Case 2 is:

$$\sigma_{max} = \left(0.026\frac{1.5(100{,}000\text{lbs})}{(3\text{ft})(8\text{in}/12)}\right)\times\left(\frac{\text{ft}^2}{144\text{in}^2}\right) + 65 lbs/ft^3 \times 10 ft \times \left(\frac{\text{ft}^2}{144\text{in}^2}\right) = \mathbf{18.05}\ \text{lbs/in}^2$$

Case 3 (Post-Closure)

During post closure conditions, the pipe will be subjected to overburden stresses due to the materials above the pipe (i.e., waste and protective cover soils). The vertical stresses can be calculated as follows:

$$\sigma_{max} = I_z\ (\gamma_{waste})\ (H) \qquad (1)$$

where:

σ_{max} = Maximum vertical applied stress (lbs/ft^2)

γ_{waste}	=	Unit weight of waste (lbs/ft^3)
H	=	Maximum depth of waste in the landfill (ft)
I_z	=	Influence factor for vertical stress

The maximum thickness of waste is approximately 180 ft (190 ft-msl – 10 ft-msl). The influence factor is estimated to be approximately 1.0 for the pipe buried under the maximum height of the landfill using the embankment stress calculation design chart shown in Figure 1.

Using the above equation, the stresses acting on the pipes are calculated as follows:

For leachate collection pipes:

$$\sigma_{max} = 1.0 \times 70 \text{ pcf} \times 180 \text{ ft} = 12{,}600 \text{ psf} = \mathbf{87.5} \text{ psi}$$

<u>Pipe Structural Capacity Calculations</u>

CASES 1 and 2: For pipes installed with overburden soil less than 50 ft

For pipes installed within trench or underneath an embankment with overburden soil thickness less than 50 ft, the following calculation procedure can be used:

Wall Crushing

Wall crushing can occur when the stresses in the pipe wall due to external vertical pressure exceed the compressive strength of the pipe material. The pipe wall compressive stress can be calculated as:

$$\sigma_{compressive} = \frac{\sigma_{max}(SDR)}{288} \tag{6}$$

where:

σ_y	=	Compressive design strength of the pipe (Reference I-2) (psi)
SDR	=	Standard dimension ratio of the pipe (i.e., outer diameter/wall thickness)
σ_{max}	=	Maximum stress applied to the pipe (psf)

The calculated pipe wall compressive stress should be less than the allowable compressive stress shown in Attachment 1(Reference I-2).

Wall Buckling

Wall buckling, a longitudinal wrinkling in the pipe wall, can occur when the external vertical pressure exceeds the critical buckling pressure of the pipe/bedding aggregate system. The factor of safety against pipe wall buckling can be calculated using the following equation adapted from the *Plastic Pipe Institute® Handbook of Polyethylene Pipe.*

$$FS_{wb} = \frac{5.65}{\sigma_{\max}}\left[\frac{RB'E'E}{12(SDR-1)^3}\right]^{1/2} \tag{7}$$

where:

FS_{wb} = Factor of safety against pipe wall buckling

σ_{max} = Maximum stress applied to the pipe (psi)

E' = Modulus of soil reaction for pipe bedding (Reference I-6)(psi)

E = Modulus of elasticity of the pipe material (Reference I-3)(psi)

SDR = Standard dimension ratio of the pipe

H = Height of overburden

B' = Support Factor

$$B' = \left[1 + 4e^{(-0.065H)}\right]^{-1}$$

R = Buoyancy reduction factor

$$R = 1 - 0.33H_{GW} / H$$

H_{GW} = Height of ground water above pipe

Ring Deflection

Ring deflection is the change in vertical diameter of the pipe as the pipe/bedding aggregate system deforms under the external vertical pressure. The pipe ring deflection may be estimated by the following equation, according to the *Plastic Pipe Institute® Handbook of Polyethylene Pipe*:

$$\frac{\Delta X}{D_M} = \frac{1}{144}\left(\frac{KL_{DL}P_E + KP_L}{2\frac{E}{3}\left(\frac{1}{SDR-1}\right)^3 + 0.061F_sE'}\right) \tag{8}$$

where:

ΔX = horizontal deflection, in.
D_M = mean diameter, in. (=*Do-t*)
P_E = Pressure induced by earth, psf
P_L = Pressure induced by live load
Fs = Soil support factor (Reference I-7)
K = bedding factor, typically 0.1
L_{DL} = reflection lag factor, typically between 1.0-1.5, (1.25 is used)
E' = Modulus of soil reaction for pipe bedding (Reference I-6) (psi)
E = Modulus of elasticity of the pipe material (Reference I-3) (psi)

According to *Plastic Pipe Institute® Handbook of Polyethylene Pipe*, the safe deflection limit $\Delta X/ D_M$, is 7.5%, which contains a factor of safety greater than 3.

CASE 3: for Pipes Installed with Overburden Thickness Greater than 50 ft

Earth Pressure Due to Arching Effect

For pipes installed with overburden soil thickness greater than 50 ft, a significant arching effect will occur and the following calculation procedures are recommended by the *Plastics Pipe Institute® Handbook of Polyethylene Pipe*.

A vertical arching factor defined as follows can be used to account for the arching effect.

$$VAF = 0.88 - 0.71\frac{S_A - 1}{S_A + 2.5} \quad (2)$$

where: S_A = Hoop thrust stiffness ratio, which can be calculated as follows:

$$S_A = \frac{1.43 M_s r_{cent}}{EA} \quad (3)$$

where: r_{cent} = radius to centroidal axis of the pipe;
M_s = one-dimensional modulus of soil (reference A-5);
E = elastic modulus of pipe material;
A = wall thickness of solid-wall pipes in inches.

The radial-directed pressure induced on the pipe can then be calculated as:

$$p_{rd} = VAF \cdot \sigma_{\max} \quad (4)$$

Where: $\sigma_{\max}$ is the overburden calculated without consideration of arching effect

Wall Crushing

$$\sigma = \frac{p_{rd}(SDR)}{288} \quad (5)$$

where: p_{rd} = radial directed earth pressure in psf.

The calculated pipe wall compressive stress should be less than the allowable compressive stress shown in Reference A-2.

Ring Deflection

The ring deflection of pipe buried under deep fill can be calculated using the Watkins-Gaube Graph. To use the Watkins-Gaube Graph, the designer first determines the relative stiffness between pipe and soil, which is given by the Rigidity Factor, defined as follows:

$$R_F = \frac{12\,E_s\,(SDR - 1)^3}{E} \tag{6}$$

$$E_s = \frac{M_s(1+\mu)(1-2\mu)}{(1-\mu)} \tag{7}$$

Where: E_s = secant modulus of the soil;
μ = Poisson's ratio.

With the calculated rigidity factor, a deformation factor (D_F) can be determined from the Watkins-Gaube Graph (reference A-6). The deflection ratio can be calculated as follows:

$$\frac{\Delta X}{D_M} = \frac{\sigma_{\max}}{E_s} D_F \tag{8}$$

Wall Buckling

The Moore-Selig equation can be used to estimate the critical earth pressure (P_{cr}) at which wall buckling may occur:

$$P_{cr} = \frac{2.4\varphi R_H}{D_M}(EI)^{1/3}\left(\frac{E_s}{1-\mu}\right)^{2/3} \tag{9}$$

Where: φ = calibration factor (= 0.55 for granular soil);
R_H = geometry factor (= 1 for deep uniform fill)
I = pipe wall moment of inertia (= t^3 /12 for solid wall pipe, t = wall thickness)

The factor of safety against wall buckling can be calculated as:

$$FS_{wb} = \frac{P_{CR}}{\sigma_{\max}} \tag{10}$$

CALCULATIONS

For this analysis, the short-term modulus (2 hr duration) of 71,000 psi is used during construction stage (Case 1) and a long-term modulus (100 years duration) of 27,000 psi is conservatively used for Cases 2 and 3. The structural capacity of the pipe is evaluated using Excel spreadsheets

shown as Tables 1 through 6. The value of M_s is selected to be 3,000 psi (Reference A-5). The modulus of elasticity of the pipe varies based on the load duration.

The calculation results are summarized below:

Results of Structural Stability Evaluation

Cases 1 and 2:

Design Parameters	Cell 1-3 Overlay 8-in. Pipe Case 1	Cell 1-3 Overlay 8-in. Pipe Case 2	Comments
Pipe Wall Compressive Stress (psi)	336	153	<allowable stress (1000 psi)
F.S. Wall Buckling	2.49	4.17	FS > 2.0
Ring Deflection Ratio (%)	6.29	3.16	< allowable ratio (7.5%)

Case 3:

Design Parameters	Cell 4,5 4-in. Pipe	Cell 4, 5 6-in. Pipe	Cell 4,5 8-in. Pipe	Cell 6, 1-3 Overlay 8-in. Pipe	Comments
Pipe Wall Compressive Stress (psi)	575	575	575	612	<allowable stress (1000 psi)
F.S. Wall Buckling	3.09	3.09	3.09	2.80	FS > 2.0
Ring Deflection Ratio (%)	5.02	5.02	5.02	5.35	< allowable ratio (7.5%)

CONCLUSIONS

The pipe wall stress and ring deflection ratio computed for this calculation are all less than the allowable value recommended by the manufacturer, and the calculated factor of safety against wall buckling is greater than 2.0. The leachate pipes at DRPI landfill will withstand the anticipated loads for the vertically expanded landfill.

REFERENCES

Geosyntec Consultants (2005), *"Permit Application Part VI- Engineering Report"*, Cell 6 Expansion, DRPI Industrial Landfill, New Castle, Delaware., prepared for Delaware Recyclable Products, Inc. Revised February 2005.

Plastics Pipe Institute, *"Handbook of Polyethylene Pipe*", 2nd Edition, http://plasticpipe.org/publications/pe_handbook.html.

USEPA, "*Lining of Waste Impoundment and Disposal Facilities*", SW-870, U.S. Environmental Protection Agency, Washington, DC, March 1983, Revised Edition.

TABLES

Table 1 Cells 1-3 Overlay Area Pipe Structural Stability Calculation (6-inch Pipe)
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 1)

General Input Parameters

σ_{max}=	39.58	psi	SDR =	17					
Di =	7.611	in.	*Do* =	8.625	in.	*t* =	0.507	in.	

Wall Crushing

σ_y=	1000	psi	σ=	336	psi	σ<	σ_y

Wall Buckling

E' =	1000	psi	*E* =	71,000	psi	*B'* =	0.211	**FS_{wb}=**	**2.49**
H=	1	ft	H_{GW} =	0	ft	*R*=	1		

Deflection

K=	0.1		L_{DL} =	1.25				**$\Delta X/D_M$ =**	**6.29%**
E_N =	1500	psi	E_N/E'=	1.5		*Fs*=	1.1	(reference A-7)	

Table 2 Cells 1-3 Overlay Area Pipe Structural Stability Calculation (6-inch Pipe)
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 2)

General Input Parameters

σ_{max}=	18.05	psi	SDR =	17					
Di =	7.611	in.	*Do* =	8.625	in.	*t* =	0.507	in.	

Wall Crushing

σ_y=	1000	psi	σ=	153	psi	$\sigma <$	σ_y

Wall Buckling

E' =	1000	psi	*E* =	27,000	psi	*B'* =	0.324	FS_{wb}=	**4.17**
H=	10	ft	H_{GW} =	0	ft	*R*=	1		

Deflection

K=	0.1		L_{DL} =	1.25				$\Delta X/D_M$ =	**3.16%**
E_N =	1500	psi	E_N/E'=	1.5		*Fs*=	1.1	(reference A-7)	

Table 3 Phase IV and V Pipe Structural Stability Calculation (4-inch Pipe)
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 3)

General Input Parameters

σ_{max}=	87.5	psi	SDR =	15.5			
Di =	3.885	in.	*Do* =	4.5	in.	*t* =	0.29 in.

Wall Crushing

σ_y=	1000	psi	M_s =	3000	psi	r_{cent}=	2.11 in.
E =	27,000	psi	S_A=	1.153		VAF =	0.84548
p_{rd} =	73.979	psi	σ=	**573.3**	psi		

σ< σ_y

Ring Deflection

μ =	0.2		E_s =	2700	psi	R_F =	3658.35
D_F =	1.55	(from Reference A-6)					

$\Delta X/D_M$ = 5.02%

Wall Buckling

Pcr= **268.08** psi

FS_{wb}= 3.06

Table 4. Phase IV and V Pipe Structural Stability Calculation (8-inch Pipe)
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 3)

General Input Parameters

σ_{max}=	87.5	psi	SDR =	15.5			
Di =	7.549	in.	*Do* =	8.625	in.	*t* =	0.556 in.

Wall Crushing

σ_y=	1000	psi	M_s =	3000	psi	r_{cent}=	4.03 in.
E =	27,000	psi	S_A=	1.153		VAF =	0.84556
p_{rd} =	73.986	psi	σ=	573.4	psi		

$\sigma < \sigma_y$

Ring Deflection

μ =	0.2		E_s =	2700	psi	R_F =	3658.35
D_F =	1.55	(from Reference A-6)					

$\Delta X/D_M$ = 5.02%

Wall Buckling

Pcr= **268.17** psi

FS_{wb}= 3.06

Table 5. Phase IV and V Pipe Structural Stability Calculation (6-inch Pipe)
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 3)

General Input Parameters

σ_{max}=	87.5	psi	SDR =	15.5			
Di =	5.719	in.	*Do* =	6.625	in.	*t* =	0.427 in.

Wall Crushing

σ_y=	1000	psi	M_s =	3000	psi	r_{cent}=	3.10	in.
E =	27,000	psi	S_A=	1.153		VAF =	0.84551	
p_{rd} =	73.982	psi	σ=	**573.4**	psi			

σ< σ_y

Ring Deflection

μ =	0.2		E_s =	2700	psi	R_F =	3658.35
D_F =	1.55	(from Reference A-6)					

$\Delta X/D_M$ = 5.02%

Wall Buckling

Pcr= **268.12** psi

FS_{wb}= 3.06

Table 6. Phase 6 Pipe Structural Stability Calculation
DRPI Landfill Vertical Expansion, New Castle, Delaware

(Case 3)

General Input Parameters

σ_{max}=	87.5	psi	SDR =	17			
Di =	7.611	in.	*Do* =	8.625	in.	*t* =	0.507 in.

Wall Crushing

σ_y=	1000	psi	M_s =	3000	psi	r_{cent}=	4.06 in.
E =	27,000	psi	S_A=	1.272		VAF =	0.82097
p_{rd} =	71.835	psi	σ=	**610.6**	psi		

$\sigma < \sigma_y$

Ring Deflection

μ =	0.2		E_s =	2700	psi	R_F =	4915.2
D_F =	1.65	(from Reference A-6)					

$\Delta X/D_M$ = 5.35%

Wall Buckling

Pcr= **243.06** psi

FS_{wb}= 2.78

FIGURE

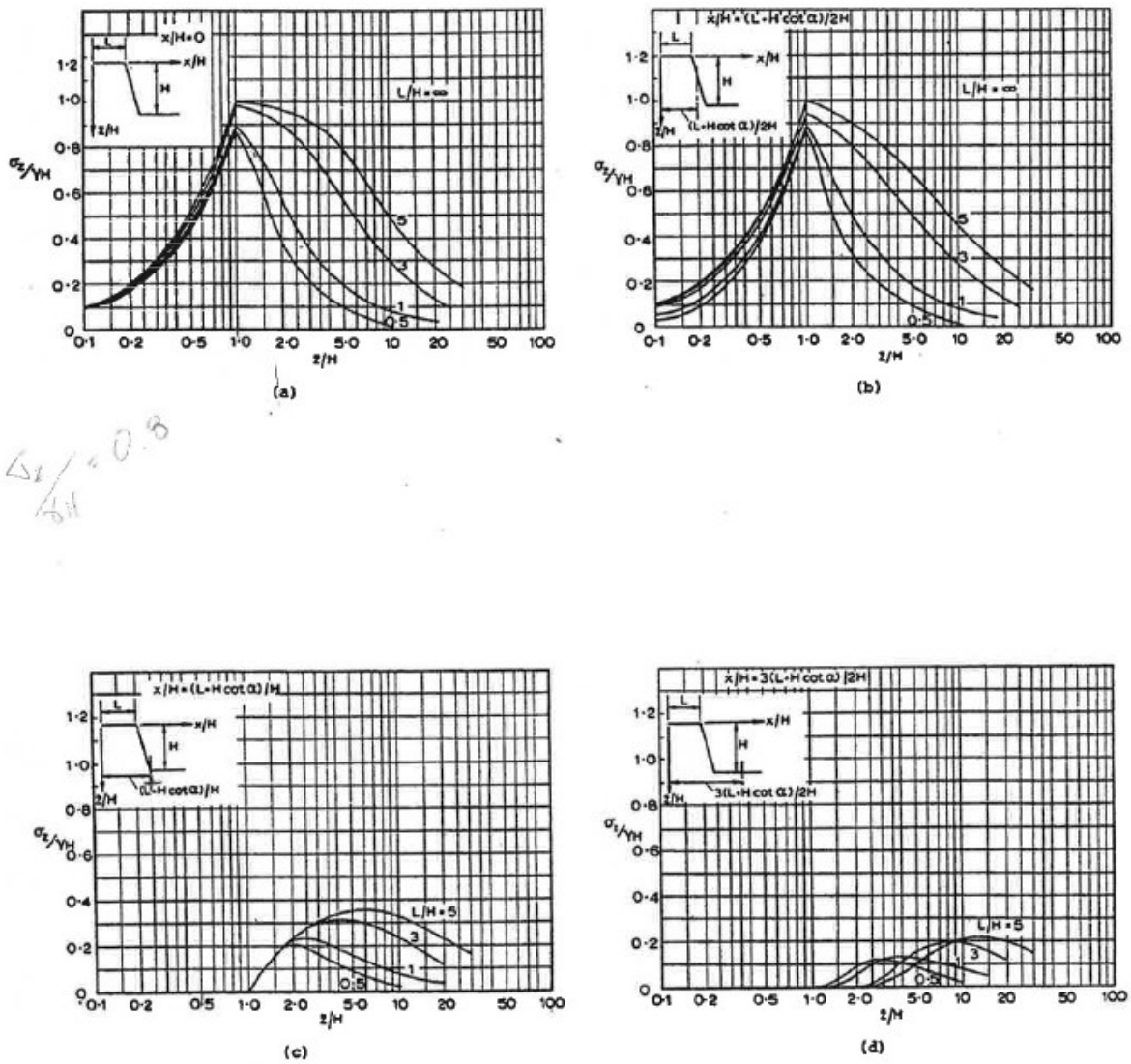


FIG.10.30 Vertical stress along selected vertical sections.
α=75°, ν=0.3 (Perloff et al, 1967).

Figure 1. Vertical Stress Distribution Underneath an Embankment

ATTACHMENT A

Performance Pipe Literature

REFERENCE A-1

HDPE Pipe

- Items highlighted in Blue indicates standard stocking items that are more readily available.
- Pressures are based on using water at 23°C (73°F).
- Average inside diameter calculated using nominal OD and minimum wall plus 6% for use in estimating fluid flows. Actual ID will vary.
- Other piping sizes or DR's may be available upon request.
- Standard Lengths: 40' for 2"-24" 50' for 26" and larger Coils available for 3/4"-6"(8" by special order)

PE 3608/3408 IPS HDPE Pipe Sizes

Pressure Rating	Nominal Size	3/4"	1"	1 1/4"	1 1/2"	2"	3"	4"	5"	5"	6"	7"	8"	10"	12"	14"	16"
	Actual O.D.	1.05"	1.315"	1.66"	1.90"	2.375"	3.50"	4.50"	5.375"	5.563"	6.625"	7.125"	8.625"	10.75"	12.75"	14.00"	16.00"
DR 7 (267psi)	Min. wall	0.150"	0.188"	0.237"	0.271"	0.339"	0.500"	0.643"	0.768"	0.795"	0.946"	1.018"	1.232"	1.536"	1.821"	2.000"	2.286"
	Average I.D.	0.732"	0.917"	1.157"	1.325"	1.656"	2.440"	3.137"	3.747"	3.878"	4.619"	4.967"	6.013"	7.494"	8.889"	9.760"	11.42"
	Weight lb/ft	0.190	0.290	0.460	0.603	0.950	2.060	3.400	4.850	5.200	7.360	8.490	12.480	19.400	27.280	32.900	42.970
DR 7.3 (254psi)	Min. wall	0.144"	0.180"	0.227"	0.260"	0.325"	0.479"	0.616"	0.736"	0.762"	0.908"	0.976"	1.182"	1.473"	1.747"	1.918"	2.192"
	Average I.D.	0.745"	0.933"	1.176"	1.348"	1.685"	2.484"	3.193"	3.814"	3.947"	4.701"	5.056"	6.120"	7.628"	9.047"	9.934"	11.353"
	Weight lb/ft	0.180	0.280	0.445	0.583	0.911	1.980	3.280	4.680	5.020	7.120	8.230	12.060	18.740	26.360	31.780	41.510
DR 9 (200psi)	Min. wall	0.117"	0.146"	0.184"	0.211"	0.264"	0.389"	0.500"	0.597"	0.618"	0.736"	0.792"	0.958"	1.194"	1.417"	1.556"	1.778"
	Average I.D.	0.803"	1.005"	1.269"	1.452"	1.816"	2.676"	3.440"	4.109"	4.253"	5.064"	5.447"	6.593"	8.218"	9.747"	10.702"	12.231"
	Weight lb/ft	0.150	0.234	0.372	0.490	0.770	1.660	2.750	3.920	4.200	5.932	6.890	10.054	15.680	22.070	26.610	34.750
DR 11 (160psi)	Min. wall	0.095"	0.120"	0.151"	0.173"	0.216"	0.318"	0.409"	0.489"	0.506"	0.602"	0.648"	0.784"	0.977"	1.159"	1.273"	1.455"
	Average I.D.	0.848"	1.062"	1.340"	1.534"	1.917"	2.825"	3.633"	4.339"	4.491"	5.348"	5.752"	6.963"	8.678"	10.293"	11.302"	12.916"
	Weight lb/ft	0.130	0.200	0.312	0.410	0.640	1.387	2.300	3.290	3.520	4.990	5.780	8.460	13.140	18.490	22.300	29.120
DR 13.5 (128psi)	Min. wall	---	---	---	---	0.176"	0.259"	0.333"	0.398"	0.412"	0.491"	0.528"	0.639"	0.796"	0.944"	1.037"	1.185"
	Average I.D.	---	---	---	---	2.002"	2.950"	3.793"	4.531"	4.689"	5.585"	6.006"	7.271"	9.062"	10.748"	11.801"	13.487"
	Weight lb/ft	---	---	---	---	0.531	1.160	1.910	2.730	2.920	4.150	4.800	7.030	10.920	15.360	18.520	24.190
DR 15.5 (110psi)	Min. wall	---	---	---	---	0.153"	0.226"	0.290"	0.347"	0.359"	0.427"	0.460"	0.556"	0.694"	0.823"	0.903"	1.032"
	Average I.D.	---	---	---	---	2.050"	3.021"	3.885"	4.640"	4.802"	5.719"	6.150"	7.445"	9.280"	11.006"	12.085"	13.812"
	Weight lb/ft	---	---	---	---	0.470	1.020	1.680	2.400	2.570	3.637	4.210	6.164	9.580	13.480	16.242	21.214
DR 17 (100psi)	Min. wall	---	---	---	---	0.140"	0.206"	0.265"	0.316"	0.327"	0.390"	0.419"	0.507"	0.632"	0.750"	0.824"	0.941"
	Average I.D.	---	---	---	---	2.079"	3.064"	3.939"	4.705"	4.869"	5.799"	6.236"	7.549"	9.409"	11.160"	12.254"	14.005"
	Weight lb/ft	---	---	---	---	0.430	0.932	1.540	2.200	2.353	3.340	3.860	5.660	8.880	12.362	14.910	19.470
DR 19 (89psi)	Min. wall	---	---	---	---	---	---	0.237"	0.283"	0.293"	0.349"	0.375"	0.454"	0.566"	0.671"	0.737"	0.842"
	Average I.D.	---	---	---	---	---	---	3.998"	4.775"	4.942"	5.886"	6.330"	7.663"	9.551"	11.327"	12.438"	14.215"
	Weight lb/ft	---	---	---	---	---	---	1.390	1.980	2.120	3.010	3.480	5.100	7.920	11.140	13.430	17.540
DR 21 (80psi)	Min. wall	---	---	---	---	---	---	0.214"	0.256"	0.265"	0.315"	0.339"	0.411"	0.512"	0.607"	0.667"	0.762"
	Average I.D.	---	---	---	---	---	---	4.046"	4.832"	5.001"	5.956"	6.406"	7.754"	9.665"	11.463"	12.587"	14.385"
	Weight lb/ft	---	---	---	---	---	---	1.262	1.801	1.930	2.740	3.170	4.640	7.21	10.134	12.220	15.960

REFERENCE A-2

Appendix C

Allowable Compressive Stress

Table C.1 lists allowable compressive stress values for 73°F (23°C). Values for allowable compressive stress for other temperatures may be determined by application of the same multipliers that are used for pipe pressure rating (See Table A.2).

TABLE C.1

Allowable Compressive Stress for 73°F (23°C)

	Pe Pipe Material Designation Code[1]					
	PE 2406		PE3408		PE 4710	
	PE 2708		PE 3608			
			PE 3708			
			PE 3710			
			PE 4708			
	psi	MPa	psi	MPa	psi	MPa
Allowable Compressive Stress	800	5.52	1000	6.90	1150	7.93

(1) See Chapter 5 for an explanation of the PE Pipe Material Designation Code.

REFERENCE A-3

Appendix B
Apparent Elastic Modulus

B.1 – Apparent Elastic Modulus for the Condition of Either a Sustained Constant Load or a Sustained Constant Deformation

B.1.1 – Design Values for the Base Temperature of 73°F (23°C)

TABLE B.1.1
Apparent Elastic Modulus for 73°F (23°C)

Duration of Sustained Loading	Design Values For 73°F (23°C) (1,2,3)					
	PE 2XXX		PE3XXX		PE4XXX	
	psi	MPa	psi	MPa	psi	MPa
0.5hr	62,000	428	78,000	538	82,000	565
1hr	59,000	407	74,000	510	78,000	538
2hr	57,000	393	71,000	490	74,000	510
10hr	50,000	345	62,000	428	65,000	448
12hr	48,000	331	60,000	414	63,000	434
24hr	46,000	317	57,000	393	60,000	414
100hr	42,000	290	52,000	359	55,000	379
1,000hr	35,000	241	44,000	303	46,000	317
1 year	30,000	207	38,000	262	40,000	276
10 years	26,000	179	32,000	221	34,000	234
50 years	22,000	152	28,000	193	29,000	200
100 years	21,000	145	27,000	186	28,000	193

(1) Although there are various factors that determine the exact apparent modulus response of a PE, a major factor is its ratio of crystalline to amorphous content – a parameter that is reflected by a PE's density. Hence, the major headings PE2XXX, PE3XXX and, PE4XXX, which are based on PE's Standard Designation Code. The first numeral of this code denotes the PE's density category in accordance with ASTM D3350 (An explanation of this code is presented in Chapter 5).

(2) The values in this table are applicable to both the condition of sustained and constant loading (under which the resultant strain increases with increased duration of loading) and that of constant strain (under which an initially generated stress gradually relaxes with increased time).

(3) The design values in this table are based on results obtained under uni-axial loading, such as occurs in a test bar that is being subjected to a pulling load. When a PE is subjected to multi-axial stressing its strain response is inhibited, which results in a somewhat higher apparent modulus. For example, the apparent modulus of a PE pipe that is subjected to internal hydrostatic pressure – a condition that induces bi-axial stressing – is about 25% greater than that reported by this table. Thus, the Uni-axial condition represents a conservative estimate of the value that is achieved in most applications.

It should also be kept in mind that these values are for the condition of continually sustained loading. If there is an interruption or a decrease in the loading this, effectively, results in a somewhat larger modulus.

In addition, the values in this table apply to a stress intensity ranging up to about 400psi, a value that is seldom exceeded under normal service conditions.

REFERENCE A-4

crown may completely reverse its curvature inward and collapse. See Figure 3-1A. A deflection limit of 7.5% provides at least a 3 to 1 safety factor against reverse curvature.

Bending strain occurs in the pipe wall as a result of ring deflection—outer-fiber tensile strain at the pipe springline and outer-fiber compressive strain at the crown and invert. While strain limits of 5% have been proposed, Jansen [12] reported that, on tests of PE pipe manufactured from pressure-rated resins and subjected to soil pressure only, "no upper limit from a practical design point of view seems to exist for the bending strain." In other words, as deflection increases, the pipe's performance limit will not be overstraining but reverse curvature collapse.

Thus, for non-pressure applications, a 7.5 percent deflection limit provides a large safety factor against instability and strain and is considered a safe design deflection. Some engineers will design profile wall pipe and other non-pressure pipe applications to a 5% deflection limit, but allow spot deflections up to 7.5% during field inspection.

The deflection limits for pressurized pipe are generally lower than for non-pressurized pipe. This is primarily due to strain considerations. Hoop strain from pressurization adds to the outer-fiber tensile strain. But the internal pressure acts to reround the pipe and, therefore, Eq. 3-10 overpredicts the actual long-term deflection for pressurized pipe. Safe allowable deflections for pressurized pipe are given in Table 3-11. Spangler and Handy [13] give equations for correcting deflection to account for rerounding.

TABLE 3-11
Safe Deflection Limits for Pressurized Pipe

DR or SDR	Safe Deflection as % of Diameter
32.5	7.5
26	7.5
21	7.5
17	6.0
13.5	6.0
11	5.0
9	4.0
7.3	3.0

*Based on Long-Term Design Deflection of Buried Pressurized Pipe given in ASTM F1962.

REFERENCE A-5

TABLE 3-12
Typical Values of M_S, One-Dimensional Modulus of Soil

Vertical Soil Stress[1] (psi)	Gravelly Sand/Gravels 95% Std. Proctor (psi)	Gravelly Sand/Gravels 90% Std. Proctor (psi)	Gravelly Sand/Gravels 85% Std. Proctor (psi)
10	3000	1600	550
20	3500	1800	650
40	4200	2100	800
60	5000	2500	1000
80	6000	2900	1300
100	6500	3200	1450

* Adapted and extended from values given by McGrath[20]. For depths not shown in McGrath[20], the MS values were approximated using the hyperbolic soil model with appropriate values for K and n where n=0.4 and K=200, K=100, and K=45 for 95% Proctor, 90% Proctor, and 85% Proctor, respectively.

[1] Vertical Soil Stress (psi) = [soil depth (ft) x soil density (pcf)]/144

REFERENCE A-6

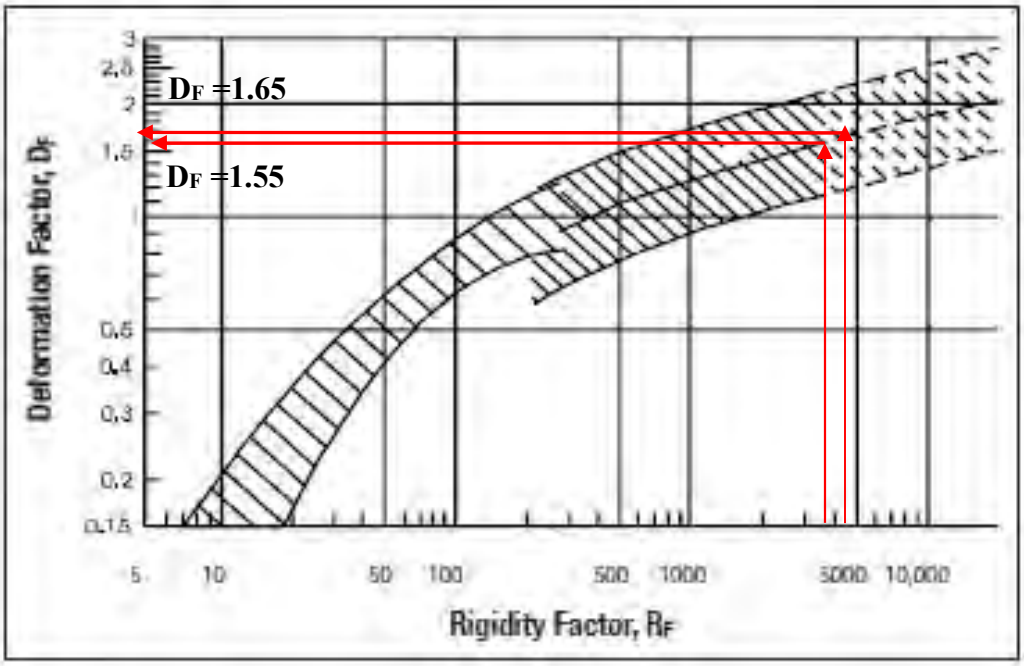
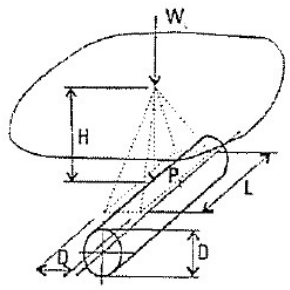


Figure 3-6 Watkins-Gaube Graph

REFERENCE A-7

Table 7-4 Load Coefficient, C_H, for Holl's Integration of Boussinesq's Equation



D/2H	L/2H													
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.2	1.5	2.0	20.0
0.1	0.019	0.037	0.053	0.067	0.079	0.089	0.097	0.103	0.108	0.112	0.117	0.121	0.124	0.127
0.2	0.037	0.072	0.103	0.131	0.155	0.174	0.189	0.202	0.211	0.219	0.229	0.238	0.244	0.248
0.3	0.053	0.103	0.149	0.190	0.224	0.252	0.274	0.292	0.306	0.318	0.333	0.346	0.355	0.361
0.4	0.067	0.131	0.190	0.241	0.284	0.320	0.349	0.373	0.391	0.405	0.425	0.442	0.454	0.462
0.5	0.079	0.155	0.224	0.284	0.336	0.379	0.414	0.441	0.463	0.481	0.505	0.525	0.540	0.550
0.6	0.089	0.174	0.252	0.320	0.379	0.428	0.467	0.499	0.524	0.544	0.572	0.596	0.613	0.625
0.7	0.097	0.189	0.274	0.349	0.414	0.467	0.511	0.546	0.574	0.597	0.628	0.655	0.674	0.688
0.8	0.103	0.202	0.292	0.373	0.441	0.499	0.546	0.584	0.615	0.639	0.674	0.703	0.725	0.740
0.9	0.108	0.211	0.306	0.391	0.463	0.524	0.574	0.615	0.647	0.673	0.711	0.743	0.766	0.783
1.0	0.112	0.219	0.318	0.405	0.481	0.544	0.597	0.639	0.673	0.701	0.740	0.775	0.800	0.818
1.2	0.117	0.229	0.333	0.425	0.505	0.572	0.628	0.674	0.711	0.740	0.783	0.821	0.849	0.871
1.5	0.121	0.238	0.346	0.422	0.525	0.596	0.655	0.703	0.743	0.775	0.821	0.863	0.895	0.920
2.0	0.124	0.244	0.355	0.454	0.540	0.613	0.674	0.725	0.766	0.800	0.849	0.895	0.930	0.960
20.0	0.127	0.248	0.361	0.462	0.550	0.625	0.688	0.740	0.783	0.818	0.871	0.920	0.960	1.000