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KEY WORDS:

Saltstone Disposal Facility

Performance Assessment

Closure Cap

SALTSTONE DISPOSAL FACILITY
CLOSURE CAP CONFIGURATION AND DEGRADATION
BASE CASE:
INSTITUTIONAL CONTROL TO PINE FOREST SCENARIO (U)

SEPTEMBER 22, 2003

PREPARED BY:

Mark A. Phifer[a]

Eric A. Nelson[a]

Westinghouse Savannah River Company LLC[a]

Westinghouse Savannah River Company LLC

Savannah River Site

Aiken, SC 29808

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LIST OF ACRONYMS AND ABBREVIATIONS

ACRONYMS

ATG	Atmospheric Technologies Group
CLSM	Controlled Low Strength Material
CN	Curve Number
FC	field capacity
FML	flexible membrane liner
GCL	geosynthetic clay liner
GSE	GSE Lining Technology, Inc.
HELP	Hydrologic Evaluation of Landfill Performance
MMES	Martin Marietta Energy Systems, Inc.
NCSU	North Carolina State University
PA	Performance Assessment
QA/QC	Quality Assurance / Quality Control
SCS	Soil Conservation Service
SDF	Saltstone Disposal Facility
SRP	Savannah River Plant
SRS	Savannah River Site
SRTC	Savannah River Technology Center
U.S.	United States
USCS	Unified Soil Classification System
USDA	United States Department of Agriculture
USEPA	United States Environmental Protection Agency
WP	wilting point
WSRC	Westinghouse Savannah River Company

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATIONS

A	Area
A	Universal Soil Loss Equation soil loss
b	width
C	Universal Soil Loss Equation vegetative cover factor
cm	centimeter
cm^2	square centimeter
cm^3	cubic centimeter
cu	cubic
d	thickness or depth
D	duration
d_{50}	median particle size
F	fraction
^oF	degree Fahrenheit
ft	feet
ft^2	square feet
ft^3	cubic feet
g	gram
hr	hour
in	inch
Instal.	installation
K	saturated hydraulic conductivity
K	Universal Soil Loss Equation soil erodibility factor
L	liter
lbs	pounds
LS	Universal Soil Loss Equation slope length and steepness factor
m	meter
m^2	square meter
m^3	cubic meter
mg	milligram
min	minute

LIST OF ACRONYMS AND ABBREVIATIONS

ABBREVIATIONS (continued)

n	porosity
n	Manning's equation coefficient of roughness
N	no
P	precipitation
P	Universal Soil Loss Equation erosion control practice factor
Q	flow
R	Manning's equation hydraulic radius
R	Universal Soil Loss Equation rainfall erosion index
Recirc.	Recirculation
s	second
S	Manning's equation slope
Sat. Hyd.	saturated hydraulic
sec	second
STD.	Standard
T	time
V	Manning's equation velocity
VEG.	vegetative
Vol	volume
Y	yes
yd	yard
yd^3	cubic yard
yr	year
ρ_b	bulk density
ρ_p	particle density
μm	micrometer
'	foot
"	inch
%	percent
#	number

1.0 EXECUTIVE SUMMARY

The Performance Assessment (PA) for the Saltstone Disposal Facility (SDF) is currently under revision. As part of the PA revision and as documented herein, the closure cap configuration has been reevaluated and closure cap degradation mechanisms and their impact upon infiltration through the closure cap have been evaluated for the institutional control to pine forest, land use scenario. This land use scenario is considered the base case land use scenario. This scenario assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. At the end of institutional control, it is assumed that a pine forest succeeds the cap's original bamboo cover. Infiltration through the upper hydraulic barrier layer of the closure cap as determined by this evaluation will be utilized as the infiltration input to subsequent PORFLOW vadose zone contaminant transport modeling, which will also be performed as part of the PA revision.

The reevaluation of the closure cap configuration has resulted in the following primary changes to the closure cap configuration:

- The previous kaolin hydraulic barriers have been replaced with geosynthetic clay liners (GCL).
- The drainage system configuration has been revised to decrease the drainage slope lengths.
- An erosion barrier separate from and above the upper drainage layer has been added.
- A backfill layer has been added between the erosion barrier and the upper drainage layer to help promote evapotranspiration.
- The previous grout layer directly above the vault has been replaced with soil.
- The thickness of the lower drainage layer has been increased, a vertical drainage layer has been added along the sides of the vaults, and a drainage layer has been added at the base of the vaults to minimize the hydraulic head on top of the vaults.

The impacts of pine forest succession, erosion, and colloidal clay migration as degradation mechanisms on the hydraulic properties of the closure cap layers over time have been estimated and the resulting infiltration through the closure cap has been evaluated. The primary changes caused by the degradation mechanisms that result in increased infiltration are the formation of holes in the upper GCL by pine forest succession and the reduction in the saturated hydraulic conductivity of the drainage layers due to colloidal clay migration into the layers. Erosion can also result in significant increases in infiltration if it causes the removal of soil layers, which provide water storage for the promotion of evapotranspiration. For this scenario, infiltration through the upper GCL was estimated at approximately 0.29 inches/year under initial intact conditions, it increased to approximately 11.6 inches/year at year 1000 in nearly a linear fashion, and it approached an asymptote of around 14.1 inches/year at year 1800 and thereafter. At year 1800, it was estimated that holes covered approximately 0.3 percent of the GCL due to root penetration, and that this resulted in an infiltration near that of typical background infiltration (i.e. as though the GCL were not there at all). This demonstrated that a very small area of holes essentially controlled the hydraulic performance of the GCL.

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2.0 INTRODUCTION

The current Saltstone Disposal Facility (SDF) operational and final closure concepts are outlined in detail within the following documents:

- Radiological Performance Assessment for the Z-Area Saltstone Disposal Facility (MMES 1992),
- Closure Plan for the Z-Area Saltstone Disposal Facility (Cook et al. 2000), and
- Special Analysis: Reevaluation of the Inadvertent Intruder, Groundwater, Air, and Radon Analyses for the Saltstone Disposal Facility (Cook et al. 2002a)

The SDF operational and final closure concepts outlined in the above documents involve mixing low-level radioactive salt solution with blast furnace slag, flyash, and cement to form a grout, which is pumped into above grade reinforced concrete vaults. Within the vaults the grout solidifies to form a dense, microporous, monolithic, low-level radioactive waste called saltstone. This concept anticipates that active saltstone disposal operations will last for approximately 30 years. During the operations period the roofed, saltstone-filled vaults remain above grade (interim closure). This concept assumes that the vaults consist of the following from top to bottom:

- 0.1 m (4 inches) thick concrete vault roof,
- 0.4 m (16 inches) thick clean grout layer,
- 7.3 m (288 inches) thick saltstone layer, and
- 0.76 m (30 inches) thick concrete vault floor.

Figure 2.0-1 provides the current projected SDF vault layout based upon this concept. Only vaults 1 and 4 have been constructed based upon this concept. Vault 1 is approximately 600 ft long by 100 ft wide, the apex of the vault roof runs lengthwise (i.e. 600 ft) down its center, and the roof is sloped at 2 percent from the apex to the vault side. This results in a slope length of 50 ft over the vault itself. Vault 4 is approximately 600 ft long by 200 ft wide, the apex of the vault roof runs lengthwise (i.e. 600 ft) down its center, and the roof is sloped at 2 percent from the apex to the vault side. This results in a slope length of 100 ft over the vault itself. Based upon this concept the remaining vaults will be constructed similarly to vault 4 with an approximate footprint of 600 ft by 200 ft and similar roof construction.

Final closure of all the filled vaults is not anticipated until near or at the end of the operational period. This concept assumes that the final closure cap will consist of the following major components from the ground surface to the top of the vault roof (i.e., top to bottom):

- Bamboo vegetative cover
- 0.15 m (6 inches) of vegetative soil (i.e., topsoil),
- 0.76 m (30 inches) of backfill (i.e., structural fill),
- 0.3 m (12 inches) of a gravel drainage layer
- 0.76 m (30 inches) of controlled compacted clay (kaolin),
- 0.3 m (12 inches) of backfill,
- 0.15 m (6 inches) of a gravel drainage layer
- 0.5 m (19.68 inches) of controlled compacted clay (kaolin), and
- 1.0 m (39.37 inches) of grout directly on top of the vault roof.

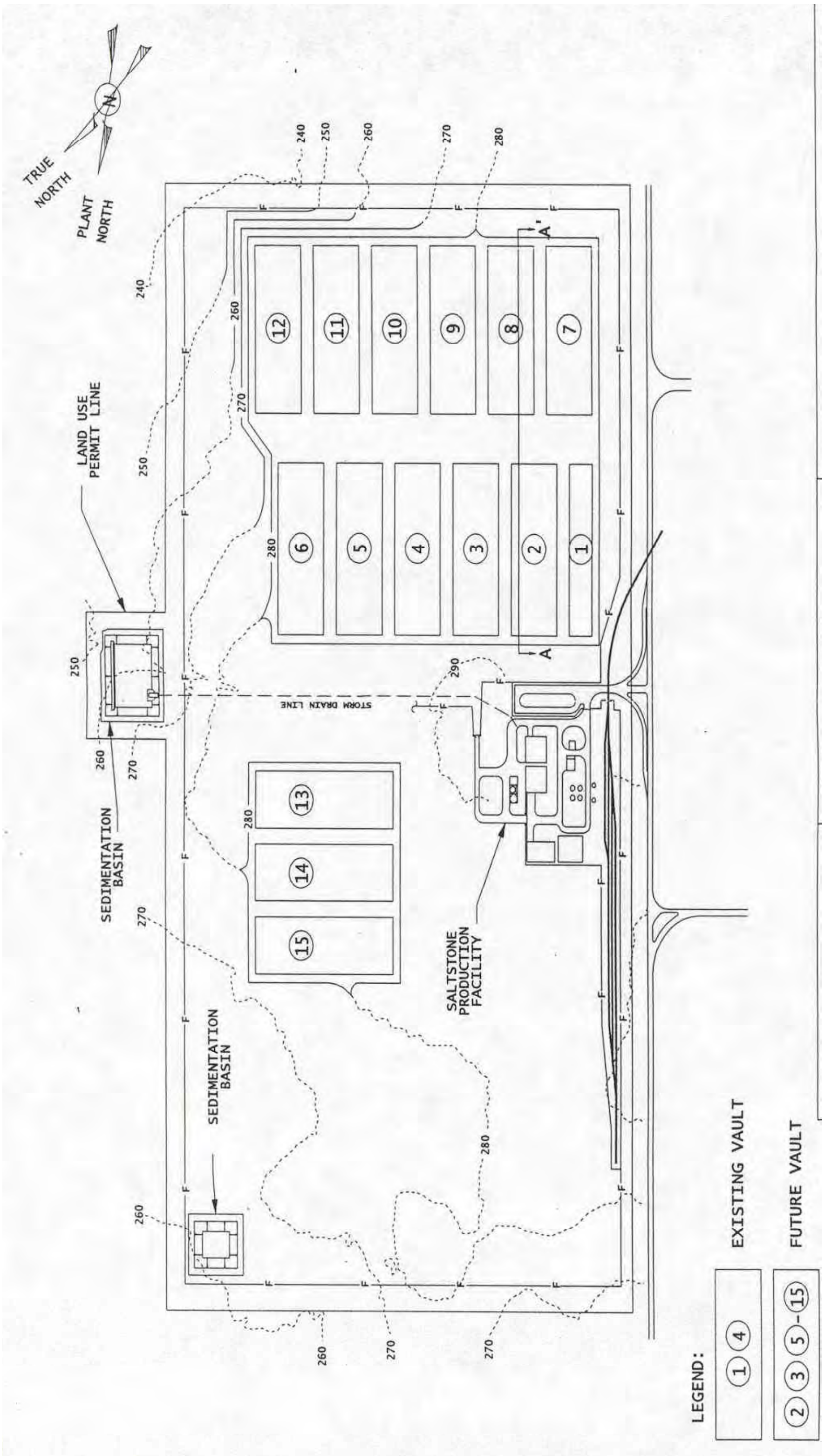

Figure 2.0-1. Current Saltstone Disposal Facility Vault Layout (reproduced from Cook et al. 2000)

The required thickness of the closure cap is driven by the resident scenario intruder analysis. This scenario assumes that the resident excavates 3 meters deep for construction of a basement. In order to maintain acceptable exposure results for this scenario the following closure cap assumptions have been made:

- The upper vegetative soil and backfill (0.91 m (36 inches)) erodes away by 1,000 years,
- The upper gravel drainage layer prevents further erosion, and
- A material thickness of 3 meters (119 inches) is maintained above the vault roof,

For this concept at closure, the vault roof slope and slope length will propagate upward from the vault roof to the first backfill layer overlaying the roof. This backfill layer will be used to change the direction of slope by 90 degrees, to increase the slope length to 600 ft, and to increase the slope to 3 percent over the vault itself. The slope and slope length of this backfill layer will propagate upward to the ground surface. Runoff and lateral drainage out of the upper gravel drainage layer will be directed to rip rap filled drainage ditches located along the perimeter of the final cover. Lateral drainage out of the lower gravel drainage layer will be directed to subsurface rip rap filled drainage ditches, located between vaults in each row, which discharge into the perimeter to rip rap filled drainage ditches. The perimeter riprap filled drainage ditches will transport the collected water to a surface discharge point downhill from the SDF and final cover.

The Performance Assessment (PA) for the SDF is currently under revision. As part of the PA revision and as documented herein, the closure cap configuration has been reevaluated and closure cap degradation mechanisms and their impact upon infiltration through the closure cap have been evaluated for the institutional control to pine forest, land use scenario. This land use scenario is considered the base case land use scenario. This scenario assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. At the end of institutional control, it is assumed that a pine forest succeeds the cap’s original bamboo cover. Infiltration through the upper hydraulic barrier layer of the closure cap as determined by this evaluation will be utilized as the infiltration input to subsequent PORFLOW vadose zone contaminant transport modeling, which will also be performed as part of the PA revision.

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3.0 HELP MODEL AND ASSOCIATED INPUT DATA

The Hydrologic Evaluation of Landfill Performance (HELP) model has been utilized to conduct the evaluations of the closure cap configuration and of the impact of closure cap degradation upon infiltration. The HELP model is a quasi-two-dimensional water balance model designed to conduct landfill water balance analyses. The model requires the input of weather, soil, and design data. It provides estimates of runoff, evapotranspiration, lateral drainage, vertical percolation (infiltration), hydraulic head, and water storage for the evaluation of various landfill designs. Personnel at the U.S. Army Engineer Waterways Experiment Station in Vicksburg, Mississippi developed the HELP model, under an interagency agreement with the U.S. Environmental Protection Agency (USEPA). HELP model version 3.07, issued on November 1, 1997, is the latest version of the model available from the Waterways Experiment Station (USEPA 1994a and USEPA 1994b). (WSRC 2002)

The HELP model requires the input of evapotranspiration, precipitation, temperature, and solar radiation data. There are several input options for each type of weather data required. In general the options available for weather data input include:

- Historical records from specific cities ("default"),
- Synthetically generated data based upon the statistical characteristics of historic data from specific cities,
- Synthetically generated data modified with average monthly precipitation and temperature data from the site in question, and
- Manual data entry (USEPA 1994a and USEPA 1994b).

The default weather databases included in the HELP model are very limited in terms of the period of time and cities covered in the database. A complete set of historic weather data is not available for the Savannah River Site (SRS) or Augusta, Georgia within the HELP model. The HELP model can generate synthetic weather data for up to a 100-year span and many more cities are included than in the default weather databases. In particular, synthetic weather data can be generated for Augusta, however it is not available for SRS. However average monthly data from SRS is available to modify the Augusta synthetically generated data. The manual input option requires data availability and placement of the data in a format acceptable to the HELP model, which is a very time consuming operation. Therefore for the purposes of this modeling, synthetic daily weather data for precipitation, temperature, and solar radiation over 100 years was generated based upon the HELP data for Augusta and modified with the SRS specific average monthly precipitation and temperature data.

To generate the evapotranspiration data, the default option for Augusta, Georgia was utilized, since it is available and is considered constant from year to year. Additionally, the user must specify two values, the evaporative zone depth and maximum leaf area index. An evaporative zone depth of 22 inches was selected based upon HELP model guidance, which lists this depth as a "fair" depth for Augusta, Georgia. A maximum leaf area index of 3.5 was selected based upon HELP model guidance, which lists this value for a "good" stand of grass.

The SRS specific average monthly precipitation and temperature data was obtained from the Savannah River Technology Center (SRTC) Atmospheric Technologies Group (ATG) web site located at http://shweather.srs.gov/servlet/idg.Weather.Weather (SRTC – ATG 2003). Table 3.0-1 provides the average monthly precipitation and temperature data. The average monthly precipitation data is from the 200-F Weather Station and covers the time period from 1968 to 2002. The average temperature data covers the time period from 1972 to 2002.

Table 3.0-1. Average Monthly Precipitation and Temperature Data

Month	Average Precipitation (inches)	Average Temperature (^{o}F)
January	4.38	46.3
February	3.95	50.0
March	4.68	57.2
April	2.91	64.3
May	3.56	72.1
June	4.99	78.4
July	5.43	81.6
August	5.41	80.3
September	3.93	75.2
October	3.12	65.1
November	2.96	56.7
December	3.45	48.8

The HELP model weather data input files, which were utilized for all HELP model runs, are provided in the following appendices:

- Appendix A, Augusta Synthetic Precipitation Modified with SRS Specific Average Monthly Precipitation Data over 100 Years (file name: Zprec.d4),
- Appendix B, Augusta Synthetic Temperature Modified with SRS Specific Average Monthly Temperature Data over 100 Years (file name: Ztemp.d7),
- Appendix C, Augusta Synthetic Solar Radiation Data over 100 Years (file name: Zsolar.d13), and
- Appendix D, Augusta Evapotranspiration Data (file name: Zevap.d11).

The HELP model also requires the input of soil property data. Table 3.0-2 provides the initial intact soil property data for the soil types utilized within the HELP modeling documented within this report.

Table 3.0-2. HELP Model Required Soil Property Data

Layer	Saturated Hydraulic Conductivity (cm/sec)	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)
Topsoil [1]	1.00E-03	0.4	0.11	0.058
Backfill [1]	1.00E-04	0.37	0.24	0.136
Gravel Drainage [1]	1.00E-01	0.38	0.08	0.013
Kaolin [1]	1.00E-07	0.56	0.55	0.5
GCL	5.00E-09 [2]	0.75 [3]	0.747 [3]	0.40 [3]
Clean grout [1]	1.00E-08	0.19	0.18	0.17
Concrete vault roof and floor [1]	1.00E-12	0.19	0.18	0.17
Saltstone [1]	5.00E-12	0.42	0.41	0.4

[1] WSRC (2002)

[2] GSE (2002)

[3] USEPA (1994a) and USEPA (1994b)

4.0 CLOSURE CAP CONFIGURATION

Sections 4.1 through 4.6 provide a progressive reevaluation of the closure cap configuration previously presented in Section 2.0. The changes made in a previous section are carried over into the evaluation of subsequent sections, until all changes have been discussed and made. The final revised closure cap configuration is summarized in Section 4.7, Figure 4.7-1 and Table 4.7-1.

4.1 Hydraulic Barrier

As outlined in section 2.0, the current SDF PA (MMES 1992) and closure plan (Cook et al. 2000) assume that controlled compacted kaolin is utilized as the closure cap hydraulic barrier layer. However the previously planned controlled compacted kaolin layer for the E-Area Low-Level Waste Facility closure cap was replaced with a geosynthetic clay liner (GCL) as the hydraulic barrier layer within revision 2 of the 'Closure Plan for the E-Area Low-Level Waste Facility' (Cook et al. 2002b). The applicability of also replacing the kaolin layers in the SDF closure cap with GCLs is investigated herein. The acceptability of this change in the hydraulic barrier layer for E-Area was documented within 'Unreviewed Disposal Question Evaluation: Closure Cap Design Change from Compacted Kaolin to Geosynthetic Clay Liner' (Jones and Phifer 2003). An overview of the reasoning for the E-Area change is presented below (Cook et al. 2002a; Cook et al. 2003; Jones and Phifer 2003).

A GCL consists of "bentonite sandwiched between two geotextiles" (USEPA 2001). Bentonite, the hydraulically functional portion of a GCL, is the general term given to a swelling-type montmorillonite clay which formed as the stable alteration product of volcanic ash (Worrall 1975; Jones and Phifer 2003). Therefore bentonite is expected to remain mineralogically and chemically stable. The following is the definition of a Geotextile GCL as defined by the Environmental Protection Agency (USEPA 2001):

> A Geotextile GCL "is a relatively thin layer of processed" bentonite … "fixed between two sheets of geotextile. … A geotextile is a woven or nonwoven sheet material … resistant to penetration." … "Adhesives, stitchbonding, needlepunching, or a combination of the three" are used to affix the bentonite to the geotextile. "Although stitchbonding and needlepunching create small holes in the geotextile, these holes are sealed when the installed GCL's clay layer hydrates."

The following are some of the typical advantages of a Geotextile GCL over compacted clay layers, which led to the replacement of the compacted kaolin with a GCL:

- A GCL has a lower hydraulic conductivity than compacted kaolin (i.e. $< 5.0\times10^{-9}$ cm/s for a GCL versus $< 1.0\times10^{-7}$ cm/s for a compacted kaolin layer) (Phifer 1991; USEPA 2001; GSE 2002)
- Infiltration through a GCL closure cap is generally lower than infiltration through a compacted kaolin closure cap (Cook et al. 2002a; Jones and Phifer 2003).
- A GCL is faster and easier to install than an equivalent compacted kaolin layer (USEPA 2001). Installation of a GCL essentially consists of unrolling the dry GCL like a carpet, overlapping adjacent GCL panels, and covering the GCL with at least a foot of soil. Whereas compacted kaolin must be installed wet of optimum to tight moisture and density controls in multiple lifts with heavy equipment. (Jones and Phifer 2003)
- The bulk of the required Quality Assurance / Quality Control (QA/QC) associated with a GCL is factory based whereas that of compacted kaolin is entirely field based. Factory based QA/QC generally provides a higher degree of QA/QC, and it is included in the cost of the material. (Phifer 1991; GSE 2002; Jones and Phifer 2003)
- Installation of a GCL hydraulic barrier generally costs less than installation of an equivalent compacted kaolin layer (USEPA 2001; Jones and Phifer 2003).

- Installation of a GCL is generally safer than installation of an equivalent compacted kaolin layer, since less heavy equipment use is required (Jones and Phifer 2003).
- A GCL has the ability to self-heal rips or holes, whereas compacted kaolin does not. Additionally a GCL can undergo repeated cycles of dehydration and hydrate without negative impacts to the GCL's saturated hydraulic conductivity, whereas compacted kaolin may irreversibly shrink, crack, and incur increases in its saturated hydraulic conductivity (Phifer 1991; Phifer et al. 1995; Rumer and Ryan 1995; USEPA 2001).
- A GCL incurs less negative impact "due to differential settlement, freezing-thawing cycles, and wetting-drying cycles" than a compacted kaolin layer (Rumer and Mitchell 1995).
- A GCL is not as thick as a compacted kaolin layer (USEPA 2001).
- Hydraulic barriers consisting of compacted clay are 1970's and 1980's technology whereas GCLs are 1990's technology (Jones and Phifer 2003).

The same reasoning for the E-Area change is applicable to the SDF. In order to confirm that replacement of the SDF closure cap compacted kaolin hydraulic barrier with a GCL is appropriate, HELP modeling has been performed. The modeling has been performed to demonstrate that a GCL closure cap is equivalent to or better than the current kaolin closure cap in terms of percolation through the cap and out the facility bottom. Table 4.1-1 provides a comparison of the two configurations from top to bottom. Both configurations consist of 119 inches of material from the top of the upper gravel drainage layer to the bottom of the clean grout on top of the concrete vault roof as required by the PA resident scenario intruder analysis.

Table 4.1-1. Closure Cap Configuration Comparison

Current Kaolin Closure Cap		Replacement GCL Closure Cap	
Layer	Thickness (inches)	Layer	Thickness (inches)
Topsoil	6	Topsoil	6
Backfill	30	Backfill	30
Gravel Drainage	12	Drainage Layer	12
Kaolin	30	GCL	0.2
Backfill	12	Backfill	61.28
Gravel Drainage	6	Drainage Layer	6
Kaolin	19.68	GCL	0.2
Clean Grout	39.37 (1 m)	Clean Grout	39.37 (1 m)
Concrete Vault Roof	4	Concrete Vault Roof	4
Clean Grout	16	Clean Grout	16
Saltstone	288	Saltstone	288
Concrete Vault Floor	30	Concrete Vault Floor	30

Several required HELP model input parameters are common to both configurations. Table 4.1-2 provides a listing of these generic input parameters (i.e., HELP model query) and the associated values selected. Use of selected fixed values for these HELP model queries provides compatibility between the different HELP model runs. The landfill area is based upon the length (600 feet) and width (200 feet) of vault 4, which results in a surface area of 120,000 feet squared or 2.75 acres. It has been assumed that the final covers are appropriately sloped so that 100 percent of the covers allow runoff to occur (i.e., there are no depressions). A yes response has been provided to the HELP model query, which asks, “Do you want to specify initial moisture storage? (Y/N).” The amount of water or snow on the surface of the covers was assumed to be zero as the initial model condition.

Table 4.1-2. Generic Input Parameter Values

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 in.

As stated the initial moisture storage has been specified for all soil layers. While the initial moisture storage is not a fixed value for all runs, a fixed method of selecting the initial moisture storage value has been utilized for consistency. The initial, soil moisture storage value has been selected as follows:

- The initial moisture storage of soil layers designated as either a vertical percolation layer or a lateral drainage layer was set at the field capacity of the soil.
- The initial moisture storage of soil layers designated as a barrier soil liner was set at the porosity of the soil.

The Soil Conservation Service (SCS) runoff curve number (CN) is another required HELP model input parameter that has been made consistent. The HELP model provides three options to specify the CN. The option that produces a HELP model computed curve number, based on surface slope and slope length, soil texture of the top layer, and vegetation, was utilized. Table 4.1-3 provides the input values of surface slope and slope length, soil texture of the top layer, and vegetation that were utilized to produce the HELP model computed curve number. The 3 percent slope is that specified for the top surface of the Saltstone final cover within the Saltstone closure plan (Cook et al. 2000). The 600-foot slope length is the length of an individual Saltstone vault (Cook et al. 2000). The soil texture selected as an input for calculation of the CN is a loamy fine sand per the United States Department of Agriculture (USDA) and a silty sand per Unified Soil Classification System (USCS), since it closely represents the typical vegetative soil layers utilized at SRS. The corresponding number in the HELP default soil texture list is 5. Based upon these input parameter values the HELP model computed a CN of 53.40.

Table 4.1-3. Input Parameters for HELP Model Computed Curve Number

CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3%
Slope length =	600 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 53.40	

Table 4.1-4 provides a comparison of the HELP model results for both configurations. The HELP model estimate for the average annual percolation through the upper kaolin hydraulic barrier layer was approximately 0.90 inches/year, while that through the upper GCL hydraulic barrier layer was approximately 0.47 inches/year, approximately half that through the kaolin. The HELP model estimate for the average annual percolation through the lower kaolin hydraulic barrier layer was approximately 0.84 inches/year, while that through the lower GCL hydraulic barrier layer was

approximately 0.055 inches/year, approximately fifteen times less than that through the kaolin. For both configurations the average annual percolation through the vault floor was estimated to be 0.00001 inches/year, however this percolation is controlled by the very low saturated hydraulic conductivity of the vault roof and floor (see Table 3.0-2) rather than by the closure cap hydraulic barrier layers. The results clearly show that replacement of the kaolin layers with GCLs produces a closure cap that is equivalent to or better than the current kaolin closure cap in terms of percolation. See the following appendices for the detailed HELP model input data and output files for both configurations:

- Appendix E, Current Kaolin Closure Cap: HELP Model Input Data and Output File (output file name: ZKAOout.OUT)
- Appendix F, Replacement GCL Closure Cap: HELP Model Input Data and Output File (output file name: ZGCLout.OUT)

Table 4.1-4. Comparison of Closure Cap Configurations HELP Model Results

HELP Model Output Parameter	Current Kaolin Closure Cap	Replacement GCL Closure Cap	Replacement GCL Closure Cap w/o Vault
Percolation through upper hydraulic barrier layer	0.90 inches/year	0.47 inches/year	0.47 inches/year
Percolation through lower hydraulic barrier layer	0.84 inches/year	0.055 inches/year	0.055 inches/year
Percolation out vault floor	0.00001 inches/year	0.00001 inches/year	Not applicable

A separate HELP model run was made for the GCL closure cap without inclusion of the vault layers (i.e. the last four layers in Table 4.1-1). This was done to determine whether or not inclusion of the vault layers was necessary to determine the percolation rate through the upper GCL hydraulic barrier. Percolation through the upper GCL hydraulic barrier is to be utilized as input to the subsequent PORFLOW vadose zone flow and contaminant transport modeling. The PORFLOW model will be utilized to model flow and contaminant transport through the vault. The vault is assumed to degrade over time, particularly through settlement- and earthquake-induced cracking. The HELP model can not take into account such cracking degradation directly. The cracking would have to be converted into an equivalent saturated hydraulic conductivity for use in the HELP model. Therefore, if inclusion of the vault layers is not necessary, the HELP modeling could be significantly simplified by their exclusion. As indicated by Table 4.1-4 elimination of the vault layer from the replacement GCL closure cap configuration HELP modeling did not affect the estimated percolation through the upper GCL, therefore these layer will be deleted from further HELP modeling associated with this evaluation. See the following appendix for the detailed HELP model input data and output file:

- Appendix G, Replacement GCL Closure Cap without Vault Layers: HELP Model Input Data and Output File (output file name: ZGCLAout.OUT)

4.2 Drainage System Configuration

Three conceptual SDF closure cap drainage system configurations have been evaluated versus percolation through the upper GCL, soil fill volume, ditch length, and relative long-term maintenance requirements. The relationship of each of these parameters to configuration preference is as follows:

- The configuration with the least amount of percolation through the upper GCL is preferable in order to minimize contaminant transport. The configuration determines the maximum slope length over a vault, which in turn impacts the quantity of percolation.
- The configuration that requires the least amount of soil fill volume is preferable in order to minimize construction costs.
- The configuration that requires the least ditch length is preferable in order to minimize construction costs and long-term maintenance. The ditches must be specialized ditches that not only accommodate surface runoff but also intersect and accommodate flow from the subsurface drainage layers. These ditches are expensive to construct and will require substantial long-term maintenance in order to maintain their functionality.

Vaults 1 through 12 are considered representative of all the vaults, therefore vaults 13 through 15 are not considered specifically here (see Figure 2.0-1). The 600-foot slope length configuration shown in Figure 4.2-1 is essentially the configuration presented in the current Performance Assessment (MMES 1992) and Closure Plan (Cook et al. 2000). The closure cap crest is between the two rows of vaults (i.e. between vaults 1 through 6 and vaults 7 through 12) and drainage is directed to the perimeter of the entire disposal area in this configuration. The 300-foot slope length configuration shown in Figure 4.2-2 has a crest down the centerline of each row of vaults and drainage is directed to the perimeter of the entire disposal area and between the two rows of vaults. The 100-foot slope length configuration shown in Figure 4.2-3 has a separate crest down the centerline of each individual vault and drainage is directed between vaults and then to the perimeter of the entire disposal facility.

Table 4.2-1 provides a comparison of the percolation, soil fill volume, ditch length, and relative long-term maintenance requirements relative to the three drainage system configurations. The percolation through the upper GCL associated with the Figure 4.2-1 drainage configuration is the same as that presented in Table 4.1-4 for the GCL closure cap without vault layers. See the following appendices for the detailed HELP model input data and output files associated with the Figures 4.2-2 and 4.2-3 drainage system configurations, respectively:

- Appendix H, Replacement GCL Closure Cap with 300-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLBout.OUT)
- Appendix I, Replacement GCL Closure Cap with 100-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLCout.OUT)

See Appendix J for the calculations associated with the fill volume and ditch lengths associated with each drainage system configuration.

Based upon this evaluation the 300-foot, slope length drainage system configuration (Figure 4.2-2) has been selected. It substantially reduces percolation through the upper GCL and required soil fill volume over the current PA (MMES 1992) and closure plan (Cook et al. 2000) configuration, while minimizing the increase in ditch lengths and resultant relative long-term maintenance over the 100-foot, slope length drainage system configuration.

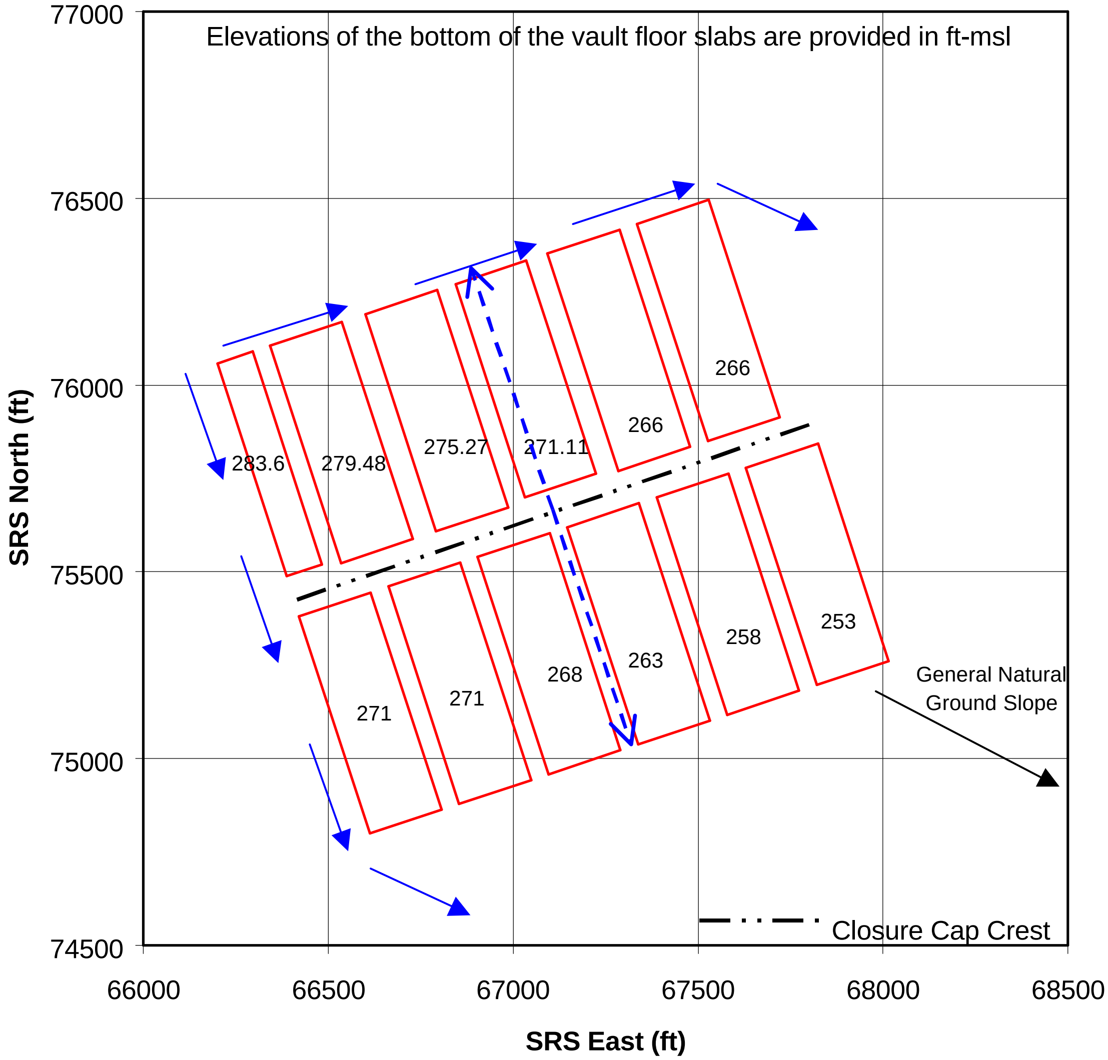

Figure 4.2-1. Current PA and Closure Plan 600-foot Slope Length Drainage System Configuration

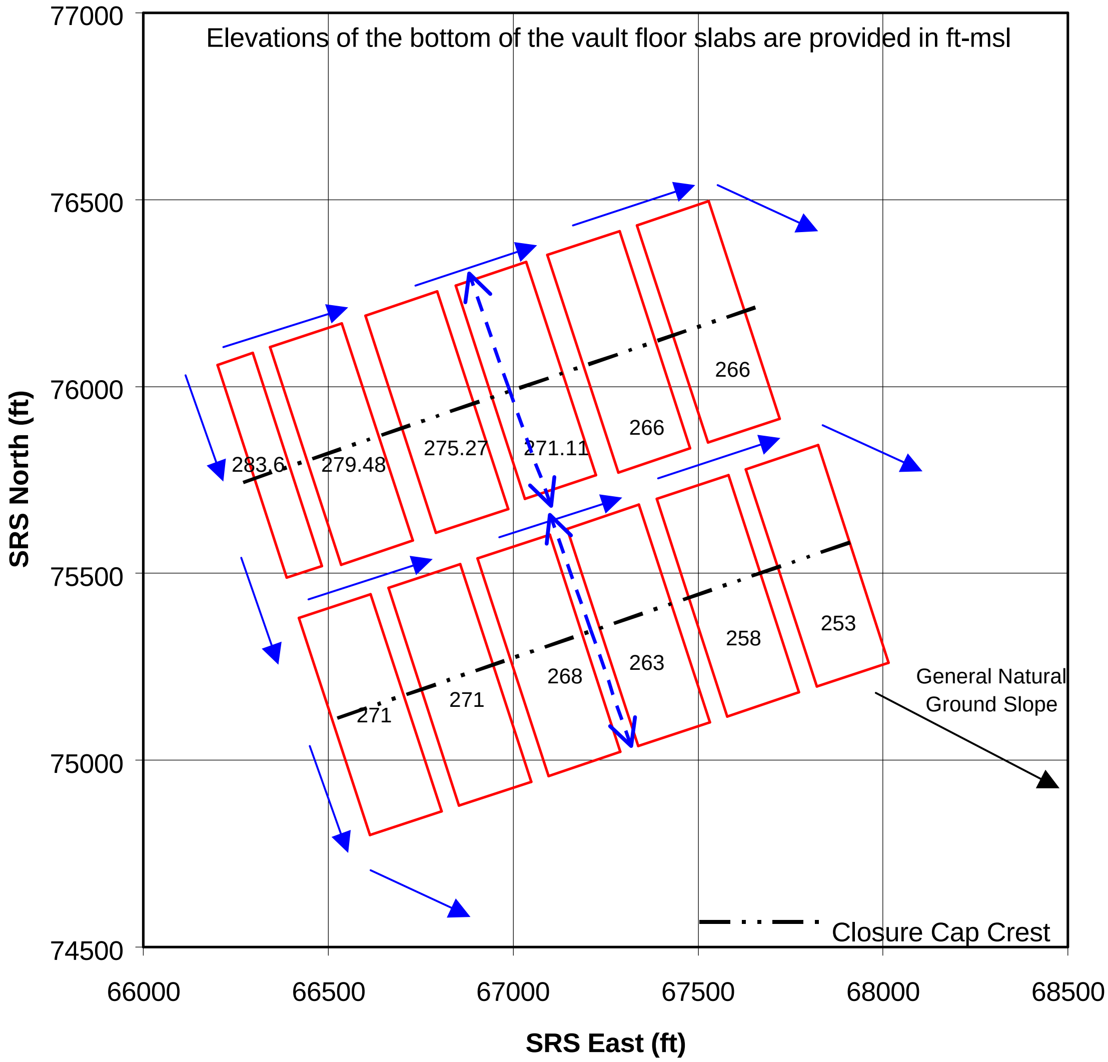

Figure 4.2-2. 300-Foot Slope Length Drainage System Configuration

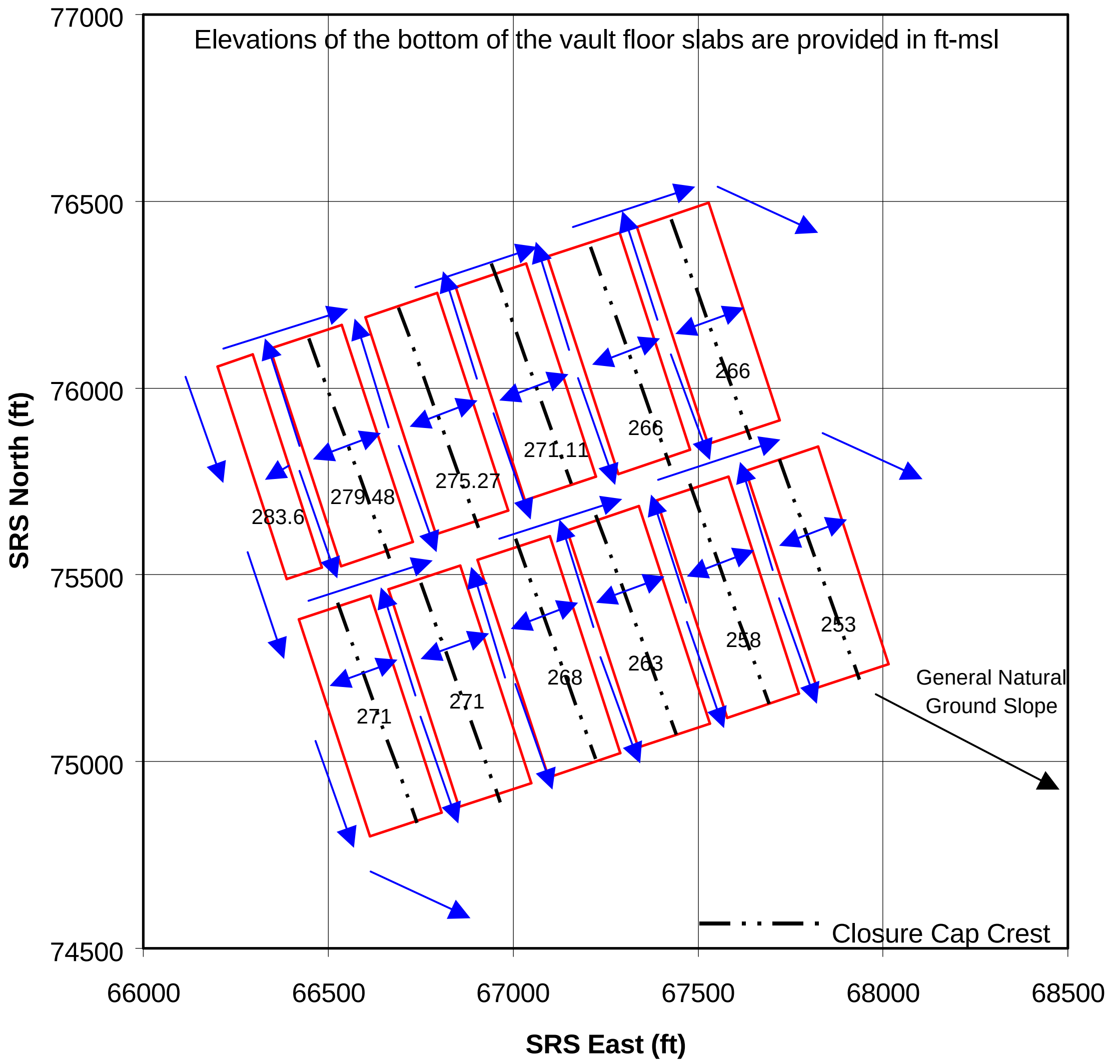

Figure 4.2-3. 100-Foot Slope Length Drainage System Configuration

Table 4.2-1. Drainage System Configuration Comparison

Parameter	Drainage System Configuration		
	Figure 4.2-1 [1]	Figure 4.2-2 [2]	Figure 4.2-3 [3]
Maximum Slope Length over a Vault, ft	600	300	100
Percent Slope Length Reduction		50%	83%
Percolation through Upper GCL, in/yr	0.467	0.254	0.110
Percent Percolation Reduction		46%	76%
Soil Fill Volume, cu yd	1,588,300	1,197,600	987,600
Percent Fill Reduction		25%	38%
Ditch Lengths, ft	4,200	5,650	13,450
Percent Ditch Increase		134%	320%
Relative Long-term Maintenance Requirements	Least	Slightly More	Significantly More

[1] Current PA (MMES 1992) and closure plan (Cook et al. 2000) 600-foot slope length drainage system configuration.

[2] 300-foot slope length drainage system configuration

[3] 100-foot slope length drainage system configuration

4.3 Erosion Barrier And Upper Drainage Layer

To produce acceptable exposure results associated with the resident scenario intruder analysis, the current PA and closure plan assume that the upper gravel drainage layer functions as both a drainage layer and an erosion barrier to maintain the required material thickness of 3 meters (119 inches) above the vault roof. To function as a drainage layer the grain size of the material needs to be balanced between the need for a fairly high saturated hydraulic conductivity and the need to minimize the infiltration of overlying fines. Such an infiltration of fines would negatively impact the saturated hydraulic conductivity. To function as an erosion barrier the grain size of the material needs to be large enough to prevent material transport by erosion. These two functions can not be readily reconciled therefore an erosion control barrier separate from and overlying the drainage layer will be utilized.

The erosion barrier has been sized based upon the maximum precipitation event for a 10,000-year return period. The maximum precipitation event for a 10,000-year return period is 3.3 inches over a 15-minute accumulation period (Table XIX from Weber et al. 1998). Based upon this precipitation event a one foot thick layer of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches has been selected for use as the erosion barrier (sizing based upon Logan 1977; Goldman et al. 1986; NCSU 1991). See Appendix K for the calculations associated with this selection.

In order to prevent the loss of overlying material into the erosion barrier and to reduce the saturated hydraulic conductivity of the erosion barrier layer, the granite stone will be filled with a Controlled Low Strength Material (CLSM) or Flowable Fill. This results in a combined material with the soil properties listed in Table 4.3-1. See Appendix K for the calculations associated with the soil properties for this combined material.

Table 4.3-1. Erosion Barrier Combined Material Soil Properties

Property	Property Value
Saturated hydraulic conductivity	3.97E-04 cm/s
Porosity	0.06
Field Capacity	0.056
Wilting Point	0.052

4.4 Erosion Impact upon Evapotranspiration Zone

Table 4.4-1 presents the revised GCL closure cap configuration based upon the changes outlined in Sections 4.1 through 4.3. HELP modeling of this configuration with and without the layers above the erosion barrier (i.e. topsoil and underlying backfill layers) has been performed to evaluate the potential impact of complete erosion of these layers on the hydraulic performance. See the following appendices for the detailed HELP model input data and output files associated with the configurations with and without the layers above the erosion barrier, respectively:

- Appendix L, Replacement GCL Closure Cap with Erosion Barrier: HELP Model Input Data and Output File (output file name: ZGCLDout.OUT)
- Appendix M, Replacement GCL Closure Cap with Erosion Barrier without Overlying Layers: HELP Model Input Data and Output File (output file name: ZGCLEout.OUT)

Table 4.4-1. Replacement GCL Closure Cap Configuration

Layer	Thickness (inches)
Topsoil	6
Upper Backfill	30
Erosion Barrier	12
Geotextile Filter Fabric [1]	-
Upper Drainage Layer	12
Upper GCL	0.2
Lower Backfill	49.28
Geotextile Filter Fabric [1]	-
Lower Drainage Layer	6
Lower GCL	0.2
Clean Grout	39.37 (1 m)

[1] It is assumed that a geotextile filter fabric will be placed above the drainage layers to minimize the infiltration of fines from the overlying layers into the drainage layer. However it is not necessary to include the filter fabric in the HELP models.

Table 4.4-2 presents a comparison of the pertinent HELP model results for this configuration with and without the layers above the erosion barrier. As seen in Table 4.4-2 elimination of the layer above the erosion barrier result in significantly less evapotranspiration and significantly more water flux into the upper drainage layer. This increased water flux to the upper drainage layer would require the drainage system to handle additional water volumes and would result in increased infiltration through the upper GCL particularly with any degradation of the GCL. The decrease in evapotranspiration is due the intersection of the evapotranspiration zone with the drainage layer. The evapotranspiration zone is assumed to extend 22 inches deep from the ground surface (USEPA 1994a; USEPA 1994b). It intersects the top 10 inches of the upper drainage layer with elimination of the layers above the erosion barrier. The drainage layer does not provide effective water storage for evapotranspiration but quickly removes water from the evapotranspiration zone, and therefore decreases the overall evapotranspiration. In order to increase evapotranspiration for the case where the soil layers above the erosion barrier have eroded away, a twelve-inch backfill layer will be placed between the erosion barrier and the upper drainage layer. HELP modeling of this configuration without the layers above the erosion barrier but with the backfill layer between the erosion barrier and upper drainage layer has been performed. See the following appendix for the detailed HELP model input data and output file associated with this configuration:

- Appendix N, Replacement GCL Closure Cap with Erosion Barrier without Overlying Layers Plus Middle Backfill Layer: HELP Model Input Data and Output File (output file name: ZGCLFout.OUT)

A comparison of the HELP model results for this configuration with the other two is also provided in Table 4.4-2. As seen the addition of this backfill layer between the erosion barrier and upper drainage layer, the evapotranspiration greatly improves.

Table 4.4-2. HELP Model Results for Replacement GCL Closure Cap Configurations with and without Upper Topsoil and Backfill Layers

HELP Model Output Parameter	Configuration with Upper Topsoil and Backfill Layers	Configuration without Upper Topsoil and Backfill Layers	Deviation	Configuration without Upper Topsoil and Backfill Layers Plus Middle Backfill Layer
Runoff, inches/year	0.16	0.19	Increase of 0.03	0.24
Evapotranspiration, inches/year	34.6	23.7	Decrease of 10.9	29.7
Lateral Drainage from Upper Drainage Layer, inches/year	13.8	24.5	Increase of 10.7	18.6
Percolation / Leakage through Upper GCL, inches/year	0.25	0.43	Increase of 0.18	0.33

4.5 Grout Layer over Vault Roof

The 2002 Saltstone Intruder Special Analysis (Cook et al. 2002a) assumed in the resident scenario intruder analysis that the resident excavates 3 meters deep for construction of a basement. This lead to the requirement for 3 meters of material between the vault top and the top of the erosion barrier in order to prevent the resident from excavating into the Saltstone waste itself. In the Special Analysis, a 1-meter-thick grout layer above the vault roof was added to achieve the requirement for 3 meters of material. According to the Special Analysis the only reason for adding the grout layer was to increase the material thickness between the vault top and the top of the erosion barrier. Typical soil materials would perform the required function as well as grout. Therefore the 1-meter-thick grout layer will be replaced with 1 meter of soil materials.

4.6 Lower Drainage Layer

Previous undocumented PORFLOW modeling has indicated that water could build up on top of the vault, due to the low permeability of the vault roof and the inadequate thickness of the overlying drainage layer particularly as the drainage layer silts-in over time (see Section 5.3). Such a build up increases the hydraulic head, which is the driving force for flow of water through the vault. To minimize build up of water on top of the vault the following changes to the closure cap configuration were made:

- The lower drainage layer thickness was increased from 6 inches to 2 feet,
- A 3-foot wide vertical drainage layer was added along the sides of the vaults, and
- A 5-foot-thick by 10-foot-long drainage layer was added at the base of the vaults.

All three of these layers are interconnected in order to route water off the vault top along the vault sides to the soil layer below the vaults.

4.7 Closure Cap Configuration Summary and Intact Infiltration

The following are the changes that have been made to the closure cap configuration from that described within the current PA, Closure Plan, and PA Intruder Special Analysis (MMES 1992; Cook et al. 2000; Cook et al. 2002a) as outlined in Section 2.0:

- The kaolin hydraulic barriers have been replaced with GCLs (see Section 4.1).
- The drainage system configuration has been revised from that depicted in Figure 4.2-1 to that of Figure 4.2-2. This decreases the slope lengths from a maximum of 600 feet to 300 feet over the vaults. The Figure 4.2-2 configuration has a crest down the centerline of each row of vaults and drainage is directed to the perimeter of the entire disposal area and between the two rows of vaults. (see Section 4.2)
- An erosion barrier separate from and above the upper drainage layer has been added. The erosion barrier is one-foot thick and consists of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches. (see Section 4.3)
- A twelve-inch-thick backfill layer has been added between the erosion barrier and the upper drainage layer.
- The 3-meter-thick grout layer has been replaced with 3 meters of soil materials.
- The lower drainage layer thickness has been increased from 6 inches to 2 feet, a 3-foot wide vertical drainage layer has been added along the sides of the vaults, and a 5-foot-thick by 10-foot-long drainage layer has been added at the base of the vaults.

Figure 4.7-1 and Table 4.7-1 present the resulting SDF GCL closure cap configuration. Table 4.7-1 also includes the associated HELP Model soil input data. Additional HELP model input change from the previous modeling include:

- The landfill area modeled has been modified to conform to the Figure 4.2-2 drainage layer configuration as shown in Figure 4.7-1. The area modeled has been changed 350-foot by 250-foot, which results in a surface area of 87,500 feet squared or 2.009 acres.
- The surface slope length has been changed to 350 feet as shown in Figure 4.7-1. This change results in a HELP model computed curve number of 55.20.
- The slope length of the upper drainage layer has been changed to 350 feet.
- The slope length of the lower drainage layer has been changed to 250 feet.

The initial moisture storage has been specified as done in Section 4.1.

HELP modeling of the Table 4.7-1 intact SDF GCL closure cap configuration has been performed as outlined above. Based upon this modeling the infiltration through the upper GCL has been estimated to be 0.29 inches per year for intact conditions. The following appendix provides the detailed HELP model, input data and output file for the intact condition:

- Appendix O, Intact SDF GCL Closure Cap (0 Years): HELP Model Input Data and Output File (output file name: ZGCLIout.OUT)

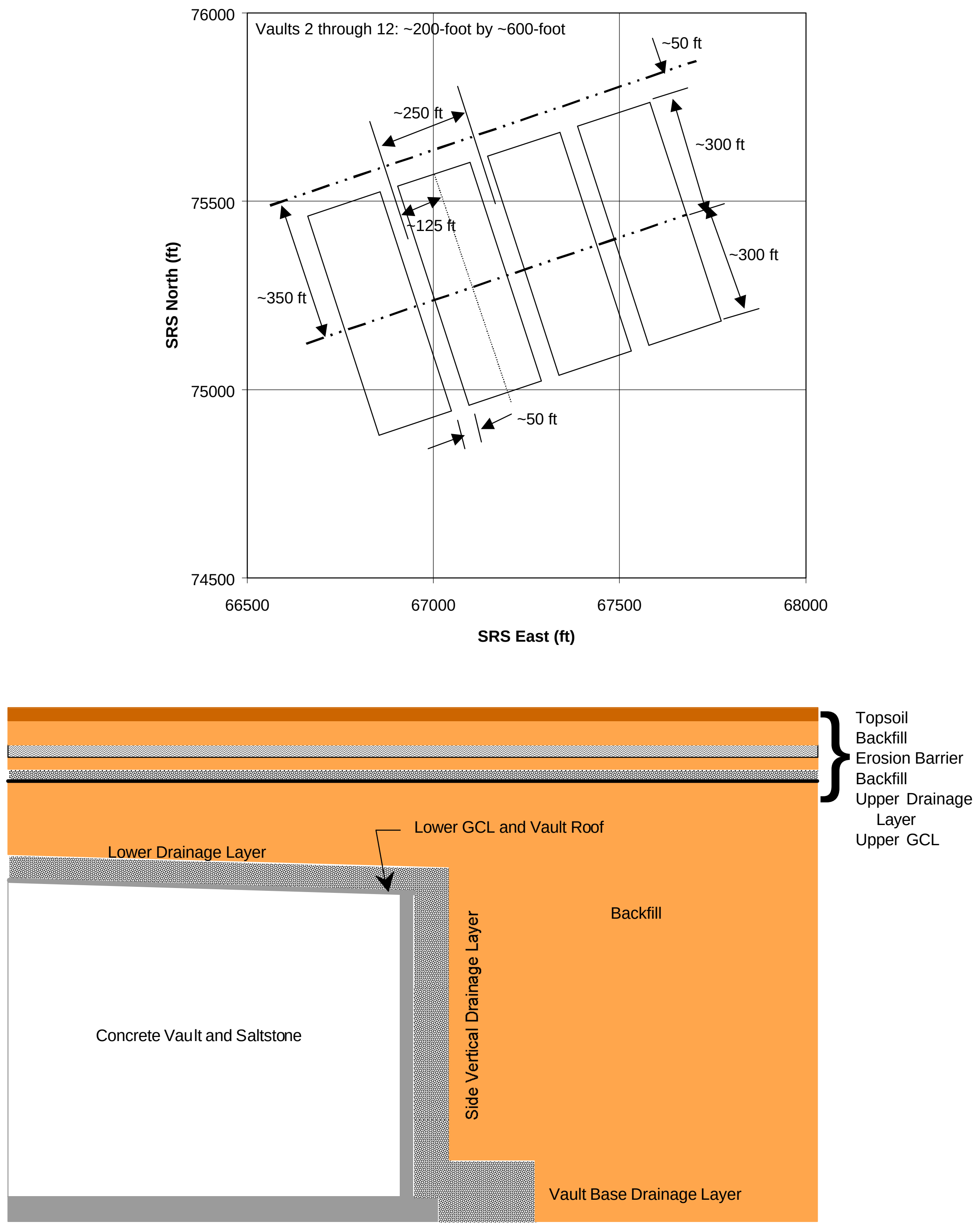

Figure 4.7-1. SDF GCL Closure Cap Configuration

Table 4.7-1. Intact SDF GCL Closure Cap Configuration and HELP Model Required Soil Property Data

Layer	Thickness (inches)	Saturated Hydraulic Conductivity (cm/sec)	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)
Topsoil [1]	6	1.00E-03	0.4	0.11	0.058
Upper Backfill [1]	30	1.00E-04	0.37	0.24	0.136
Erosion Barrier [2]	12	3.97E-04	0.06	0.056	0.052
Middle Backfill [1]	12 [6]	1.00E-04	0.37	0.24	0.136
Geotextile Filter Fabric [5]	-	-	-	-	-
Upper Drainage Layer [1]	12	1.00E-01	0.38	0.08	0.013
Upper GCL	0.2	5.00E-09 [3]	0.75 [4]	0.747 [4]	0.40 [4]
Lower Backfill [1]	58.65 [6]	1.00E-04	0.37	0.24	0.136
Geotextile Filter Fabric [5]	-	-	-	-	-
Lower Drainage Layer [1]	24 [6]	1.00E-01	0.38	0.08	0.013
Lower GCL	0.2	5.00E-09 [2]	0.75 [3]	0.747 [3]	0.40 [3]

[1] WSRC 2002

[2] See Section 4.3

[3] GSE 2002

[4] USEPA 1994a and USEPA 1994b

[5] It is assumed that a geotextile filter fabric will be placed above the drainage layers to minimize the infiltration of fines from the overlying layers into the drainage layer. However it is not necessary to include the filter fabric in the HELP models.

[6] The 39.37 inches (1 m) of clean grout immediately above the vault roof was replaced with 12 inches of Middle Backfill, 9.37 inches of Lower Backfill, and 18 inches of lower drainage layer.

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5.0 CLOSURE CAP DEGRADATION

The following three primary closure cap degradation mechanism have been assumed to significantly impact the infiltration through the closure cap over time:

- Pine forest succession
- Erosion
- Colloidal clay migration

Each of these degradation mechanisms is discussed in detail below.

5.1 Pine Forest Succession

According to the PA and Closure Plan the SDF closure cap will be vegetated with bamboo. Bamboo is a shallow-rooted species that quickly establishes a dense ground cover and evapotranspirates year-round in the SRS climate. Pine trees are the most deeply rooted naturally occurring plants at SRS. (MMES 1992; Cook et al. 2000). The institutional control to pine forest, land use scenario evaluated herein assumes a 100-year institutional control period following final SDF closure during which the closure cap is maintained. It is assumed that a pine forest begins to encroach upon the bamboo at the end of institutional control, when the approximately 43-acre closure cap (approximate area (~1300 foot by ~1450 foot) over vaults 1 through 12 in Figure 2.0-1) is no longer maintained.

The following discussion of the assumed successional transition from bamboo to pine trees is derived from the following references: Bohm (1979), Burns and Hondala (1990), Ludovici et al. (2002), Taylor (1974), Ulrich et al. (1981), Walkinshaw (1999), and Wilcox (1968).

After institutional control, it is assumed that it will take approximately 100 years for loblolly pine to be established around the closure cap perimeter and for some breakup of the bamboo to begin to occur. Within 10 years of pine tree establishment around the perimeter, the pines begin shading the bamboo located along the perimeter, which allows the establishment of pine tree seedlings 50 feet in from the perimeter of the closure cap. The process of pine tree growth and bamboo shading followed by further seedling encroachment in 50-foot increments toward the cap center continues to occur on a 10-year cycle until the entire closure cap is established with pine trees. 200 years after the end of institutional control it is assumed that the entire cap is covered with pine trees, with the oldest trees near the perimeter and the youngest in the center (i.e. an uneven age distribution).

Because of the age structure difference from edge to center, the second generation, and subsequent ones, will also probably be variable across the cap. Decline of loblolly will begin around 100 years of age. After the second establishment, the new seedlings will be established as “gaps” occur in the overstory, either through the decline or death of a dominant tree, or through abiotic occurrences (wind throw, lightning strikes, fire, insect outbreak, tornado, etc.). This will tend towards making the entire acreage an uneven age, constantly re-establishing forest. In this region, fire may be quite important in the long-term ecology of the cap. Fire will reduce the smaller understory individuals and seedlings, but will have minimal impact on the dominant individuals. It may affect the age structure over long periods of time and make the 43-acre cap closer in age distribution than the original establishment period would indicate.

It is anticipated that tree density will remain fairly constant. For a natural regeneration stand, the tree density is assumed to be approximately 550 dominant and co-dominant trees per acre with approximately 400 mature (i.e. 70 to 125 years old) trees per acre. Smaller trees will be suppressed and die.

It is assumed that mature pine will have 5 deep roots, mainly near the center of the tree spread (i.e., concentrated near main trunk). Of these 5 deep roots, four go to a depth of 6 feet and one to 12 feet.

Deep roots have a diameter of 3 inches in the top foot of soil and taper with depth to 0.25 inches at depth. These roots will be maintained over the life of the tree and exhibit little turnover prior to death. They will enlarge with yearly growth, similar to branches, although anatomically different and at a slower rate. Smaller trees, which are suppressed and die, will not establish deep roots in excess of 4 to 5 feet, and primarily only 1 or 2 such roots. Hard layers and water-saturated layers will slow root penetration. A continuous water surface will stop elongation. Hard layers will eventually be penetrated.

Decomposition of roots near the ground surface should occur fairly quickly due to better microclimate for microbial populations than at depth. Decomposition of roots at depth will be fairly slow, depending on the soil environment and aeration. It is assumed that it will take 25 years for the decomposition of intermediate depth roots and 30 years at depth due to the soil environment. Some shrinkage of the deep roots may occur at depth and provide a channel for water or sediment movement along the surface. Very rapid yearly turnover of fine roots and feeder roots occurs in the soil, although these are primarily in the top 18 inches of soil and will not go vertically with any intensity or longevity.

Based upon this discussion the following assumptions are made relative to the succession of bamboo by a pine forest for this evaluation:

- 200 years after the end of institutional control it is assumed that the entire cap is dominated by pine.
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

5.2 Erosion

The topsoil and upper backfill layers, which are located above the erosion barrier, are subject to erosion. For the institutional control to pine forest land use scenario, it is assumed that the closure cap will be vegetated with bamboo during the institutional control period, with a combination of bamboo and pine trees for 200 years immediately following the institutional control period, and with a pine forest thereafter. The projected erosion rate for both the topsoil and upper backfill layers has been determined utilizing the Universal Soil Loss Equation (Horton and Wilhite 1978; Goldman et al. 1986). The Universal Soil Loss Equation is expressed as:

$$A = R \times K \times LS \times C \times P \qquad \text{(Eq. 5.2-1)}$$

where

A = soil loss (tons/acre/year)

R = rainfall erosion index (100 ft·ton/acre per in/hr)

K = soil erodibility factor, tons/acre per unit of R

LS = slope length and steepness factor, dimensionless

C = vegetative cover factor, dimensionless

P = erosion control practice factor, dimensionless

The erosion rate for the SRP Burial Grounds (i.e. current SRS E-Area) was previously estimated and documented by Horton and Wilhite (1978) as provided in Table 5.2-1.

Table 5.2-1. Previous SRP Burial Grounds Estimated Erosion Rate (Horton and Wilhite 1978)

Parameter	Value Utilized	Comment
R	260	-
K	0.28	Dothan subsoil
LS	0.67	1000 foot long 2% slope
C	0.001	Natural successional forest
P	1	No supporting practices
A (soil loss)	0.05 tons/acre/year	-
A (soil loss)	0.0007 cm/year	Assuming dry bulk density of 1.6 g/cm^3

The following are estimated parameter values based upon Horton and Wilhite 1978 and Goldman et al. 1986:

- From Figure 5.2 of Goldman et al. (1986), R is slightly greater than 250 but significantly less than 300 100 ft·ton/acre per in/hr. Therefore will utilize the Horton and Wilhite 1978 R value of 260 100 ft·ton/acre per in/hr
- From Figure 5.6 of Goldman et al. (1986):
  - If topsoil is assumed to consist of 70% sand, 25% silt, and 5% clay, K equals 0.28 tons/acre per unit of R.
  - If backfill is assumed to consist of 70% sand, 20% silt, and 10% clay, K equals 0.20 tons/acre per unit of R.
- With a slope length of 350 feet (see Figure 4.2-2) and a slope of 3% the LS value equals 0.40 as determined from Table 5.5 of Goldman et al. (1986).
- Will assume that both bamboo and a pine forest, have C values of a natural successional forest, therefore the C value equals 0.001 as utilized by Horton and Wilhite (1978).
- No supporting practices are associated with the closure cap therefore P equals 1.

Based upon the Universal Soil Loss Equation and the parameter values listed above the following are the estimated soil losses:

- Topsoil with a natural successional forest has an estimated soil loss of 0.0291 tons/acre/year ($A = 260 \times 0.28 \times 0.40 \times 0.001 \times 1$). Based upon the dry bulk density the estimated soil loss can be converted to a loss in terms of depth of loss per year. From Jones and Phifer (2002), the dry bulk density of topsoil was taken as 90 lbs/ft^3. Topsoil with a natural successional forest has an estimated depth of soil loss of approximately 1.8E-04 inches/year ($Loss = \dfrac{0.0291\, tons/acre/year \times 2000\, lbs/ton \times 12\, inches/foot}{43560\ ft^2/acre \times 90\, lbs/ft^3}$).
- Backfill with a natural successional forest has an estimated soil loss of 0.0208 tons/acre/year ($A = 260 \times 0.20 \times 0.40 \times 0.001 \times 1$). Based upon the dry bulk density the estimated soil loss can be converted to a loss in terms of depth of loss per year. From Jones and Phifer (2002), the dry bulk density of backfill was taken as 104 lbs/ft^3. Backfill with a natural successional forest has an

estimated depth of soil loss of approximately 1.1E-04 inches/year ($Loss = \frac{0.0208\ tons/acre/year \times 2000\ lbs/ton \times 12\ inches/foot}{43560\ ft^2/acre \times 104\ lbs/ft^3}$).

The previous estimated erosion rate of 0.0007 cm/year (2.8E-04 inches/year) for the SRP Burial Grounds (Horton and Wilhite 1978) compares well with the current estimates for the SDF closure cap of 1.8E-04 and 1.1E-04 inches/year for topsoil and backfill, respectively. The primary difference in input between the two estimates is associated with the site-specific slopes and slope lengths.

5.3 Colloidal Clay Migration

It is assumed that colloidal clay migrates from overlying backfill layers and accumulates in the drainage layers reducing the saturated hydraulic conductivity of the drainage layers over time. The clay minerals (in order of predominance) at SRS are shown in Table 5.3-1 along with the percentage range of the clay mineral fraction and typical range in particle size for each. Colloids can be mineral grains such as clays, which have particle sizes between 0.01 and 10 μm (Looney and Falta 2000). Colloidal clay can exist in groundwater in concentrations up to 63 mg/L as measured by suspended solids (Puls and Powell 1991). Based upon this information and the previous assumption, it will be assumed that water flux driven colloidal clay migration at a concentration of 63 mg/L occurs from overlying backfill layers to the drainage layers. It will be further assumed that the colloidal clay accumulates in the drainage layer from the bottom up filling the void space of the drainage layer with clay at a density of 1.1 g/cm^3 (Hillel 1982). These assumptions are analogous to the formation of the B soil horizon as documented in the soil science literature. Clay translocation is a very slow process where discrete clay particles are washed out in slightly acidic conditions and deposited lower in the soil profile (McRae 1988). Evidence has been found that the B-horizon where the translocated clay is deposited may form at a rate of 10 inches per 5,000 years (Buol et al. 1973).

Table 5.3-1. SRS Clay Minerals

Clay Mineral	Percentage Range of the Clay Mineral Fraction [1] (%)	Typical Particle Size Range [2] (μm)
Kaolinite	62.6 to 98.8	0.1 to 4
Vermiculite	0.7 to 34.3	0.1 to 2
Illite	0 to 7.1	0.1 to 2

[1] Looney et al. (1990), Table 6.31

[2] Mitchell (1993)

5.4 Closure Cap Degradation Summary

Base upon the assumed closure cap degradation mechanisms, pine forest succession, erosion, and colloidal clay migration, an assumed degradation scenario has been assumed for each layer as outlined in Table 5.4-1. These degradation scenarios form the basis for modifying the thickness and hydraulic properties of each layer over time. This information will be utilized in section 6.0 to determine infiltration though the upper GCL over time.

Table 5.4-1. SDF GCL Closure Cap Layer Degradation Scenarios

Layer	Degradation Scenario
Vegetation	Bamboo is maintained during the 100-year institutional control period, pine trees begin to encroach upon the bamboo at the end of institutional control, and a pine forest covers the cap 200 years after the end of institutional control.
Topsoil	Topsoil erosion occurs at 1.8E-04 inches per year.
Upper Backfill	Backfill erosion occurs at 1.1E-04 inches per years, after the topsoil layer has been depleted.
Erosion Control Barrier	Maintenance during institutional control period prevents degradation of the erosion control barrier. However pine forest succession and associated root penetration results in holes through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes left after the roots decompose.
Middle Backfill	Colloidal clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the saturated hydraulic conductivity to increase over time.
Geotextile Filter Fabric	For purposes of colloidal clay migration into the underlying drainage layer the geotextile filter fabric is assumed to be ineffective over the time period under consideration.
Upper Drainage Layer	Colloidal clay migration from the overlying 1-foot-thick backfill into the 1-foot-thick upper drainage layer causes the saturated hydraulic conductivity to decrease over time.
Upper GCL	Maintenance during institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the GCL. This allows the overlying drainage layer to fill the holes after the roots decompose.
Lower Backfill	None. While it is assumed that colloidal clay migration from this layer to the underlying lower drainage layer occurs, it is also assumed that the thickness of the lower backfill layer (almost 5-foot) relative to the lower drainage layer (2-foot) prevents the quantity of clay loss necessary to change the hydraulic properties of the lower backfill.
Geotextile Filter Fabric	For purposes of colloidal clay migration into the underlying drainage layer the geotextile filter fabric is assumed to be ineffective over the time period under consideration.
Lower Drainage Layer	Colloidal clay migration from the overlying ~5-foot-thick lower backfill into the 1-foot-thick lower drainage layer reduces its saturated hydraulic conductivity over time.
Lower GCL	None. Pine tree roots do not penetration to a sufficient enough depth to impact this layer. Additionally the underlying concrete vault roof along with the GCL produces a hard layer and continuous water saturation within and above these layers so that root elongation is stopped.
Side Vertical Drainage Layer [1]	None, until the vault base drainage layer has been filled with colloidal clay.
Vault Base Drainage Layer [1]	Colloidal clay migrates from the overlying ~30-foot-thick backfill into the 5-foot-thick drainage layer reduces its saturated hydraulic conductivity over time.

[1] These layers are not included in the HELP model for determination of the infiltration through the upper GCL. However their degradation properties will be included in the subsequent PORFLOW vadose zone modeling.

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6.0 CLOSURE CAP INFILTRATION

6.1 Degraded Layer Properties over Time

The SDF GCL closure cap initial (0 year) intact layer thickness and hydraulic property values from top to bottom are provided in Table 4.7-1. The degradation scenarios for each layer are provided in Table 5.4-1. Based upon the Table 5.4-1 degradation scenarios, the Table 4.7-1 initial SDF closure cap layer thickness and hydraulic property values have been modified to account for degradation at 100, 300, 550, 1,000, 1,800, 3,400, 5,600 and 10,000 years after closure of the SDF. The following discussions provide additional detail associated with determination of the degraded properties for the erosion barrier, upper GCL, middle backfill, upper drainage layer, lower drainage layer, and vault base drainage layer.

6.1.1 Erosion Barrier

Maintenance during the institutional control period prevents degradation of the erosion barrier. However pine forest succession and associated root penetration results in holes through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes after the roots decompose. It is assumed that the hydraulic conductivity of the infiltrating backfill increases one order of magnitude (i.e. from 1.0E-04 to 1.0E-03 cm/s) when it fills the hole since it will not be mechanically compacted at that time. The equivalent hydraulic properties of the overall erosion barrier change as the area of holes filled with backfill material increases with time. The equivalent hydraulic properties have been estimated over time by area proportioning the properties between that of the intact erosion barrier and infiltrating backfill.

6.1.2 Upper GCL

Maintenance during the institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the erosion barrier. This allows the overlying drainage layer to fill the holes after the roots decompose. The holes in the GCL essentially act as direct conduits from the upper drainage layer to the lower backfill layer. When saturated conditions occur in the drainage layer after major precipitation events, cones of depression are created around the holes in the GCL with a radius of influence much greater than the radius of the hole. This means that a small area of GCL holes can greatly reduce the lateral flow of water in the drainage layer and increase the vertical flow into the lower backfill. Due to the significant influence of holes in the GCL to the quantity of infiltration, the use of equivalent hydraulic properties is not appropriate, since it does not consider the radius of influence associated with holes. Therefore, within the HELP model the degraded GCL has been modeled as a geomembrane liner with leakage through holes. The HELP model considers both water flux through intact portions of the geomembrane using an “equivalent geomembrane hydraulic conductivity” and water flux through holes in the geomembrane. The HELP model does not assign a porosity, field capacity, or wilting point to geomembranes, however this is not considered essential to the GCL, since it is assumed that the GCL will remain fully saturated and it is below the depth where evapotranspiration is assumed to occur. The HELP model allows the input of up to 999,999 one square centimeter installation defects for a geomembrane liner. Therefore the calculated area of holes created by root penetration has been converted into an equivalent number of one square centimeter installation defects for input to the HELP model. Excellent contact is assumed between the GCL and underlying backfill layer as a HELP model input, since the GCL is put in dry and swells into the surrounding soil as it hydrates.

6.1.3 Middle Backfill and Upper Drainage Layer

It is assumed that water flux driven colloidal-clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the middle backfill saturated hydraulic conductivity to increase over time and that of the upper drainage layer to decrease over time. It has been assumed that clay migration occurs out of the backfill into the drainage layer with the water flux containing 63 mg/L of colloidal clay. Since both layers are of the same thickness and the middle backfill layer has limited clay content, it has been assumed that half the clay content of the backfill will migrate into the drainage layer. At which point the two layers essentially become the same material and material property changes cease. Based upon this it will be assumed that the endpoint saturated hydraulic conductivity of the layers will become that of the log mid-point between the initial backfill and upper drainage layer conditions. It will also be assumed that the endpoint porosity, field capacity, and wilting point will become the arithmetic average of the backfill and upper drainage layer. The hydraulic properties at times prior to the endpoint have been proportioned between that of the endpoint properties and the initial properties based upon the fraction of clay that has migrated out of the backfill.

6.1.4 Lower Drainage Layer

It is assumed that colloidal clay migration from the approximately 5-foot-thick overlying backfill into the 2-foot-thick lower drainage layer is driven by the water flux through the upper GCL. This water flux driven clay migration enters into the lower drainage layer and fills the lower drainage layer from the bottom up. This reduces the saturated hydraulic conductivity of the clay-filled portion from 1.0E-01 to 1.0E-04 cm/s (i.e. to the saturated hydraulic conductivity of the overlying backfill), while the conductivity of the clean portion remains at 1.0E-01 cm/s. As the thickness of the lower drainage layer filled with clay increases, the equivalent hydraulic conductivity of the entire layer decreases. The equivalent horizontal hydraulic conductivity for this layer has been determined from the following equation (Freeze and Cherry 1979):

$$K_h = \sum_{i=1}^{n} \frac{K_i \ d_i}{d} \qquad \text{(Eq. 6.1-1)}$$

where

K_h = equivalent horizontal saturated hydraulic conductivity,

K_i = horizontal saturated hydraulic conductivity of i^{th} layer,

d_i = thickness of i^{th} layer,

d = total thickness

This is different from that assumed for the upper drainage layer, since the lower drainage layer has significantly more backfill overlying it.

6.1.5 Vault Base Drainage Layer

It is assumed that colloidal clay migration, from the overlying backfill (approximately 30 feet) into the 5-foot-thick vault base drainage layer, is driven by the water flux through the upper GCL. This water-flux-driven clay migration enters into the vault base drainage layer and fills the lower drainage layer from the bottom up. The saturated hydraulic conductivity of the clay-filled portion is reduced from 1.0E-01 to 1.0E-04 cm/s (i.e. the saturated hydraulic conductivity of the overlying backfill layer), while the conductivity of the clean portion remains at 1.0E-01 cm/s. The thickness of the clay-filled portion increases with time, while the thickness of the clean portion decreases with time. This is essentially the same process as that described above for the lower drainage layer.

The calculations associated with determination of the layer thicknesses and hydraulic property values over time are provided in Appendix P. Table 6.1-1 provides the primary Appendix P, material property results (thickness, saturated hydraulic conductivity, and holes in the upper GCL), for layers which change with time and were utilized in subsequent HELP modeling. The porosity, field capacity, and wilting points are not provided in Table 6.1-1. Values for these parameters are provided in Appendix P.

Table 6.1-1. Material Property Summary Results for HELP Modeling from Appendix P

Year	Vegetation	Topsoil Layer Thickness (inches)	Erosion Barrier Saturated Hydraulic Conductivity (cm/s)	Middle Backfill Layer Saturated Hydraulic Conductivity (cm/s)
0	Bamboo	6	3.97E-04	1.00E-04
100	Bamboo	5.982	3.97E-04	1.20E-04
300	Pine Forest	5.946	3.98E-04	1.60E-04
550	Pine Forest	5.901	3.99E-04	2.30E-04
1,000	Pine Forest	5.82	4.01E-04	4.60E-04
1,800	Pine Forest	5.676	4.06E-04	1.60E-03
3,400	Pine Forest	5.388	4.15E-04	3.20E-03
5,600	Pine Forest	4.992	4.27E-04	3.20E-03
10,000	Pine Forest	4.2	4.51E-04	3.20E-03
Year	Upper Drainage Layer Saturated Hydraulic Conductivity (cm/s)	One Square Centimeter Holes in Upper GCL [1] (#/acre)	Lower Drainage Layer Saturated Hydraulic Conductivity (cm/s)	
0	1.00E-01	0	1.00E-01	
100	8.60E-02	0	1.00E-01	
300	6.30E-02	7,432	9.98E-02	
550	4.30E-02	26,013	9.91E-02	
1,000	2.10E-02	59,458	9.64E-02	
1,800	6.30E-03	118,916	9.01E-02	
3,400	3.20E-03	237,832	7.62E-02	
5,600	3.20E-03	401,341	5.68E-02	
10,000	3.20E-03	728,360	1.81E-02	

[1] Number of HELP model installation defects

6.2 Degraded Closure Cap Infiltration over Time

Table 6.1-1 and Appendix P data were utilized as input to the HELP model (USEPA 1994a and USEPA 1994b) in order to determine infiltration through the upper GCL at each degraded time step. The following appendices provide the detailed HELP model, input data and output files for each time step:

- Appendix Q, Degraded SDF GCL Closure Cap (100 Years): HELP Model Input Data and Output File (output file name: ZGCLD1ou.OUT)
- Appendix R, Degraded SDF GCL Closure Cap (300 Years): HELP Model Input Data and Output File (output file name: ZGCLD2ou.OUT)
- Appendix S, Degraded SDF GCL Closure Cap (550 Years): HELP Model Input Data and Output File (output file name: ZGCLD3ou.OUT)
- Appendix T, Degraded SDF GCL Closure Cap (1,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD4ou.OUT)
- Appendix U, Degraded SDF GCL Closure Cap (1,800 Years): HELP Model Input Data and Output File (output file name: ZGCLD5ou.OUT)
- Appendix V, Degraded SDF GCL Closure Cap (3,400 Years): HELP Model Input Data and Output File (output file name: ZGCLD6ou.OUT)
- Appendix W, Degraded SDF GCL Closure Cap (5,600 Years): HELP Model Input Data and Output File (output file name: ZGCLD7ou.OUT)
- Appendix X, Degraded SDF GCL Closure Cap (10,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD8ou.OUT)

The following outputs from this evaluation are necessary inputs to the subsequent PORFLOW vadose zone modeling:

- Infiltration through the upper GCL
- Saturated hydraulic conductivity of the 2-foot-thick lower Drainage Layer
- Saturated hydraulic conductivity of the 3-foot-thick Side Vertical Drainage Layer
- Saturated hydraulic conductivity of the 5-foot-thick Vault Base Drainage Layer

Table 6.2-1 provides a summary of these parameter values. The 3-foot Side Vertical Drainage Layer is assumed to have no degradation within the 10,000-year time frame. Rather than denoting the degradation of the Vault Base Drainage Layer with a single saturated hydraulic conductivity value, its degradation has been denoted as an upper thickness with a saturated hydraulic conductivity of 0.1 cm/s and a lower thickness with a saturated hydraulic conductivity of 0.0001 cm/s. Figure 6.2-1 additionally provides the infiltration through the upper GCL over time in graphical format.

Table 6.2-1. Inputs for PORFLOW Vadose Zone Modeling

Year	Infiltration through Upper GCL (in/yr)	Lower Drainage Layer Saturated Hydraulic Conductivity (cm/s)	Side Vertical Drainage Layer Saturated Hydraulic Conductivity (cm/s)	Thickness of Upper Portion of the Vault Base Drainage Layer with a K of 0.1 cm/s (feet)	Thickness of Lower Portion of the Vault Base Drainage Layer with a K of 0.0001 cm/s (feet)
0	0.29165	1.00E-01	1.00E-01	5	0
100	0.33135	1.00E-01	1.00E-01	4.9996	0.0004
300	2.48161	9.98E-02	1.00E-01	4.996	0.004
550	7.01335	9.91E-02	1.00E-01	4.98	0.02
1,000	11.55066	9.64E-02	1.00E-01	4.93	0.07
1,800	13.65308	9.01E-02	1.00E-01	4.8	0.2
3,400	14.00566	7.62E-02	1.00E-01	4.52	0.48
5,600	14.05202	5.68E-02	1.00E-01	4.14	0.86
10,000	14.09426	1.81E-02	1.00E-01	3.36	1.64

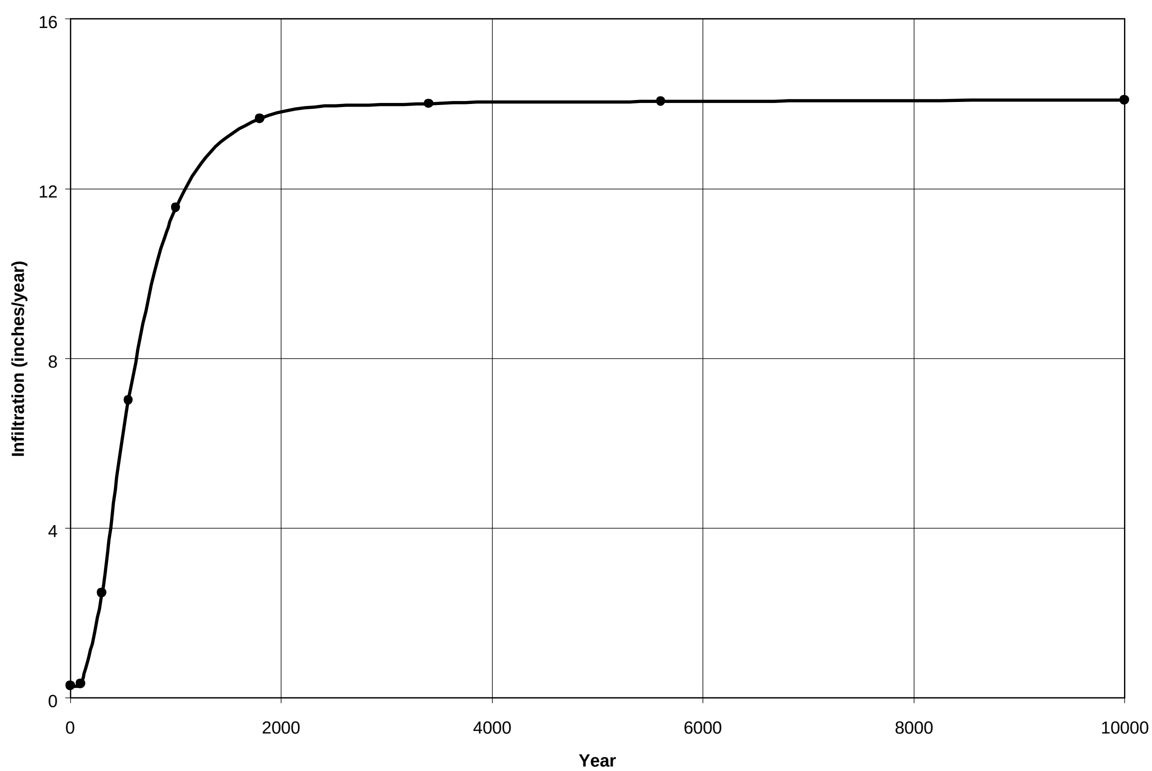

Figure 6.2-1. Infiltration through Upper GCL

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7.0 SUMMARY AND CONCLUSIONS

The conceptual design of the Saltstone Disposal Facility (SDF) closure cap has been revised. The closure cap drainage system will be configured in conformance with Figure 4.2-2. The final closure cap will consist of the following major components from the ground surface to the top of the vault roof (i.e. top to bottom) as shown in Figure 4.7-1:

- Bamboo vegetative cover to promote evapotranspiration,
- 0.15 m (6 inches) of vegetative soil (i.e., topsoil) at a three percent slope,
- 0.76 m (30 inches) of an upper backfill layer (i.e., structural fill),
- 0.3 m (12 inches) of an erosion barrier consisting of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches,
- 0.3 m (12 inches) of a middle backfill layer to provide additional water storage for the promotion of evapotranspiration in case the topsoil and upper backfill are eroded away,
- A geotextile filter fabric to minimize the migration of fines into the underlying drainage layer,
- 0.3 m (12 inches) of an upper drainage layer with an initial saturated hydraulic conductivity of 0.1 cm/s and a slope of three percent,
- 0.0051 m (0.2 inches) of a geosynthetic clay liner (GCL),
- A minimum 1.49 m (58.65 inches) of a lower backfill (this layer will vary in thickness) which is used to change the direction of slope by 90 degrees and increase the slope to three percent,
- A geotextile filter fabric to minimize the migration of fines into the underlying drainage layer,
- 0.61 m (24 inches) of a lower drainage layer with an initial saturated hydraulic conductivity of 0.1 cm/s and a slope of two percent conforming to that of the existing vault roof,
- 0.0051 m (0.2 inches) of a GCL,
- 0.91 m (36 inches) of a side vertical drainage layer along the vault sides layer with an initial saturated hydraulic conductivity of 0.1 cm/s, and
- 1.5 m (60 inches) of a vault base drainage layer with an initial saturated hydraulic conductivity of 0.1 cm/s.

The impact of pine forest succession, erosion, and colloidal clay migration as degradation mechanisms on the hydraulic properties of the closure cap layers over time has been estimated and the resulting infiltration through the closure cap has been evaluated. The primary changes caused by the degradation mechanisms that result in increased infiltration are the formation of holes in the upper GCL by pine forest succession and the reduction in the saturated hydraulic conductivity of the drainage layers due to colloidal clay migration into the layers. Erosion can also result in significant increases in infiltration if it causes the removal of soil layers, which provide water storage for the promotion of evapotranspiration.

For the institutional control to pine forest, land use scenario, infiltration through the upper GCL was estimated at approximately 0.29 inches/year under initial intact conditions. Such infiltration increased from approximately 0.33 inches/year at the end of institutional control (i.e. year 100) to approximately 11.6 inches/year at year 1000 in nearly a linear fashion. At year 1800 and thereafter the infiltration approached an asymptote of around 14.1 inches/year (see Figure 6.2-1). At year 1800 approximately 0.3 percent of the GCL area had holes due to root penetration resulting in an infiltration near that of typical background infiltration (i.e. as though the GCL were not there at all). A very small area of holes essentially controlled the hydraulic performance of the GCL.

Table 6.2-1 provides a summary of the necessary inputs to the subsequent PORFLOW vadose zone modeling including infiltration through the upper GCL and the saturated hydraulic conductivity of the lower drainage layer, side vertical drainage layer, and vault base drainage layer.

Performance of the closure cap relative to infiltration through the upper GCL could be further improved, if necessary, as follows:

- Increasing the depth of the GCL, which would results in smaller diameter root penetrations.
- Placing a suitable biobarrier above the GCL to prevent root penetration into the GCL.

Optimization of layers within the evapotranspiration zone for water storage to promote subsequent evapotranspiration could also possibly be a means of increasing the performance of the closure cap.

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9.0 APPENDICES

Appendix A **Augusta Synthetic Precipitation Modified with SRS Specific Average Monthly Precipitation Data over 100 Years (file name: Zprec.d4)** A-1

Appendix B **Augusta Synthetic Temperature Modified with SRS Specific Average Monthly Temperature Data over 100 Years (file name: Ztemp.d7)** B-1

Appendix C **Augusta Synthetic Solar Radiation Data over 100 Years (file name: Zsolar.d13)** C-1

Appendix D **Augusta Evapotranspiration Data (file name: Zevap.d11)** D-1

Appendix E **Current Kaolin Closure Cap: HELP Model Input Data and Output File (output file name: ZKAOout.OUT)** E-1

Appendix F **Replacement GCL Closure Cap: HELP Model Input Data and Output File (output file name: ZGCLout.OUT)** F-1

Appendix G **Replacement GCL Closure Cap without Vault Layers: HELP Model Input Data and Output File (output file name: ZGCLAout.OUT)** G-1

Appendix H **Replacement GCL Closure Cap with 300-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLBout.OUT)** H-1

Appendix I **Replacement GCL Closure Cap with 100-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLCout.OUT)** I-1

Appendix J **Drainage System Configuration, Soil Fill Volume and Ditch Lengths Calculations** J-1

Appendix K **Erosion Barrier Sizing and Material Property Calculations** K-1

Appendix L **Replacement GCL Closure Cap with Erosion Barrier: HELP Model Input Data and Output File (output file name: ZGCLDout.OUT)** L-1

Appendix M **Replacement GCL Closure Cap with Erosion Barrier without Overlying Layers: HELP Model Input Data and Output File (output file name: ZGCLEout.OUT)** M-1

Appendix N **Replacement GCL Closure Cap with Erosion Barrier without Overlying Layers Plus Middle Backfill Layer: HELP Model Input Data and Output File (output file name: ZGCLFout.OUT)** N-1

Appendix O **Intact SDF GCL Closure Cap (0 Years): HELP Model Input Data and Output File (output file name: ZGCLIout.OUT)** O-1

Appendix P **SDF GCL Closure Cap Degraded Property Value Calculations** P-1

Appendix Q **Degraded SDF GCL Closure Cap (100 Years): HELP Model Input Data and Output File (output file name: ZGCLD1ou.OUT)** Q-1
Appendix R **Degraded SDF GCL Closure Cap (300 Years): HELP Model Input Data and Output File (output file name: ZGCLD2ou.OUT)** R-1
Appendix S **Degraded SDF GCL Closure Cap (550 Years): HELP Model Input Data and Output File (output file name: ZGCLD3ou.OUT)** S-1
Appendix T **Degraded SDF GCL Closure Cap (1,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD4ou.OUT)** T-1
Appendix U **Degraded SDF GCL Closure Cap (1,800 Years): HELP Model Input Data and Output File (output file name: ZGCLD5ou.OUT)** U-1
Appendix V **Degraded SDF GCL Closure Cap (3,400 Years): HELP Model Input Data and Output File (output file name: ZGCLD6ou.OUT)** V-1
Appendix W **Degraded SDF GCL Closure Cap (5,600 Years): HELP Model Input Data and Output File (output file name: ZGCLD7ou.OUT)** W-1
Appendix X **Degraded SDF GCL Closure Cap (10,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD8ou.OUT)** X-1

Appendix A, Augusta Synthetic Precipitation Modified with SRS Specific Average Monthly Precipitation Data over 100 Years (file name: Zprec.d4)

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Appendix B, Augusta Synthetic Temperature Modified with SRS Specific Average Monthly Temperature Data over 100 Years (file name: Ztemp.d7)

This appendix is in CD format due to its size. Available upon request.

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Appendix C, Augusta Synthetic Solar Radiation Data over 100 Years (file name: Zsolar.d13)

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Appendix D, Augusta Evapotranspiration Data (file name: Zevap.d11)

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1
AUGUSTA               GEORGIA
33.22        68 323 3.5    22.     6.5  68.0 70.0 77.0 73.0
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Appendix E, Kaolin Closure Cap HELP Model Input Data and Output File (output file name: ZKAOout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	600 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 53.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
Kaolin	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
Kaolin	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)
Concrete Vault Roof	9	3 (barrier soil liner)
Clean Grout	10	1 (vertical percolation layer)
Saltstone	11	1 (vertical percolation layer)
Concrete Vault Floor	12	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	30		0.56	0.55	0.5	0.56
5	1	12		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	19.68		0.56	0.55	0.5	0.56
8	1	39.37		0.19	0.18	0.17	0.18
9	3	4		0.19	0.18	0.17	0.19
10	1	16		0.19	0.18	0.17	0.18
11	1	288		0.42	0.41	0.40	0.41
12	3	30		0.19	0.18	0.17	0.19

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	2	1.00E-01	600	3			
4	3	1.00E-07					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	1.00E-07					
8	1	1.00E-08					
9	3	1.00E-12					
10	1	1.00E-08					
11	1	5.00E-12					
12	3	1.00E-12					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				
9	3				
10	1				
11	1				
12	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZKAO.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZKAOout.OUT

TIME:  13:41     DATE:   9/ 8/2003

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

     TITLE:  SDF with Kaolin Hydraulic Barriers

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

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

                              LAYER  1
                              --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.4000 VOL/VOL
          FIELD CAPACITY             =      0.1100 VOL/VOL
          WILTING POINT              =      0.0580 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                              LAYER  2
                              --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =     30.00   INCHES
          POROSITY                   =      0.3700 VOL/VOL
          FIELD CAPACITY             =      0.2400 VOL/VOL
          WILTING POINT              =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   600.0    FEET

                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    30.00   INCHES
POROSITY                    =     0.5600 VOL/VOL
FIELD CAPACITY              =     0.5500 VOL/VOL
WILTING POINT               =     0.5000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.5600 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000E-06 CM/SEC

                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3700 VOL/VOL
FIELD CAPACITY              =     0.2400 VOL/VOL
WILTING POINT               =     0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                        LAYER  6
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     6.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     2.00   PERCENT
DRAINAGE LENGTH             =   100.0    FEET
```

```
                         LAYER  7
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     19.68   INCHES
POROSITY                     =      0.5600 VOL/VOL
FIELD CAPACITY               =      0.5500 VOL/VOL
WILTING POINT                =      0.5000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.5600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000E-06 CM/SEC

                         LAYER  8
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     39.37   INCHES
POROSITY                     =      0.1900 VOL/VOL
FIELD CAPACITY               =      0.1800 VOL/VOL
WILTING POINT                =      0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

                         LAYER  9
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      4.00   INCHES
POROSITY                     =      0.1900 VOL/VOL
FIELD CAPACITY               =      0.1800 VOL/VOL
WILTING POINT                =      0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999996000E-12 CM/SEC

                         LAYER 10
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     16.00   INCHES
POROSITY                     =      0.1900 VOL/VOL
FIELD CAPACITY               =      0.1800 VOL/VOL
WILTING POINT                =      0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC
```

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

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    288.00   INCHES
POROSITY                     =      0.4200 VOL/VOL
FIELD CAPACITY               =      0.4100 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.4100 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999998000E-11 CM/SEC

                    LAYER 12
                    --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     30.00   INCHES
POROSITY                     =      0.1900 VOL/VOL
FIELD CAPACITY               =      0.1800 VOL/VOL
WILTING POINT                =      0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999996000E-12 CM/SEC

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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
         AND A SLOPE LENGTH OF  600. FEET.

SCS RUNOFF CURVE NUMBER            =     53.40
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      2.750  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.500  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.320  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.524  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    174.507  INCHES
TOTAL INITIAL WATER                =    174.507  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.002
	0.026	0.091	0.016	0.006	0.002	0.000
STD. DEVIATIONS	0.018	0.000	0.025	0.000	0.002	0.013
	0.091	0.402	0.083	0.058	0.012	0.003

EVAPOTRANSPIRATION

TOTALS	1.577	2.093	3.072	3.552	3.665	4.140
	4.898	4.523	3.387	1.618	0.948	1.114
STD. DEVIATIONS	0.221	0.237	0.582	0.761	1.525	1.546
	1.589	1.379	1.040	0.607	0.207	0.206

LATERAL DRAINAGE COLLECTED FROM LAYER 3

TOTALS	2.4848	2.0047	1.8532	1.0712	0.2768	0.3025
	0.5594	0.7664	0.7046	0.7530	0.9169	1.5199
STD. DEVIATIONS	1.7495	1.5257	1.4823	1.0559	0.4504	0.5969
	0.8343	1.0433	1.0462	1.0915	1.2005	1.3094

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	0.1088	0.1025	0.1094	0.0924	0.0610	0.0362
	0.0549	0.0650	0.0611	0.0575	0.0644	0.0870
STD. DEVIATIONS	0.0247	0.0134	0.0163	0.0308	0.0365	0.0422
	0.0451	0.0477	0.0454	0.0496	0.0478	0.0432

LATERAL DRAINAGE COLLECTED FROM LAYER 6

TOTALS	0.0098	0.0088	0.0076	0.0049	0.0014	0.0014
	0.0024	0.0033	0.0030	0.0032	0.0039	0.0060
STD. DEVIATIONS	0.0070	0.0076	0.0059	0.0049	0.0017	0.0024
	0.0032	0.0041	0.0042	0.0047	0.0049	0.0050

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0983	0.0943	0.1019	0.0879	0.0597	0.0348
	0.0524	0.0617	0.0581	0.0543	0.0605	0.0807
STD. DEVIATIONS	0.0206	0.0104	0.0135	0.0285	0.0354	0.0406
	0.0429	0.0451	0.0427	0.0465	0.0448	0.0398

PERCOLATION/LEAKAGE THROUGH LAYER 9

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	2.9385	2.5424	2.1286	1.2770	0.3153	0.3561
	0.6372	0.8776	0.8437	0.8722	1.0792	1.7312
STD. DEVIATIONS	2.3444	2.0783	1.7453	1.3185	0.5130	0.7025
	0.9503	1.2034	1.2793	1.2947	1.4130	1.4915

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0028	0.0027	0.0022	0.0014	0.0004	0.0004
	0.0007	0.0009	0.0009	0.0009	0.0011	0.0017
STD. DEVIATIONS	0.0020	0.0024	0.0017	0.0014	0.0005	0.0007
	0.0009	0.0012	0.0012	0.0013	0.0015	0.0014

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	38.9764	38.9764	38.9764	38.9764	38.9764	38.9764
	38.9764	38.9764	38.9764	38.9765	38.9877	39.1551
STD. DEVIATIONS	3.9367	3.9366	3.9366	3.9366	3.9366	3.9366
	3.9366	3.9365	3.9365	3.9357	3.8236	2.1494

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	0.2497	0.2502	0.2507	0.2512	0.2517	0.2522
	0.2527	0.2532	0.2537	0.2542	0.2547	0.2552
STD. DEVIATIONS	0.1788	0.1790	0.1791	0.1792	0.1794	0.1795
	0.1797	0.1798	0.1800	0.1801	0.1802	0.1804

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	488145.2	100.00
RUNOFF	0.150	(0.4314)	1498.22	0.307
EVAPOTRANSPIRATION	34.587	(3.6267)	345261.66	70.729
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.21358	(5.51072)	131904.562	27.02158
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.90010	(0.18841)	8985.244	1.84069
AVERAGE HEAD ON TOP OF LAYER 4	1.300	(0.560)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.05562	(0.02278)	555.262	0.11375
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.84447	(0.17396)	8429.896	1.72692
AVERAGE HEAD ON TOP OF LAYER 7	0.001	(0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00013	(0.00001)	1.333	0.00027
AVERAGE HEAD ON TOP OF LAYER 9	38.992	(3.778)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00001	(0.00000)	0.125	0.00003
AVERAGE HEAD ON TOP OF LAYER 12	0.252	(0.180)		
CHANGE IN WATER STORAGE	0.894	(1.8150)	8927.78	1.829

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.641	26366.4102
DRAINAGE COLLECTED FROM LAYER 3	0.34039	3397.91162
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.006927	69.14656
AVERAGE HEAD ON TOP OF LAYER 4	31.091	
MAXIMUM HEAD ON TOP OF LAYER 4	44.664	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	168.6 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00255	25.45078
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.003405	33.99449
AVERAGE HEAD ON TOP OF LAYER 7	0.022	
MAXIMUM HEAD ON TOP OF LAYER 7	0.045	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	0.8 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00368
AVERAGE HEAD ON TOP OF LAYER 9	39.370	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00035
AVERAGE HEAD ON TOP OF LAYER 12	0.605	
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3693

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1147

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6122	0.2687
2	9.2094	0.3070
3	2.9619	0.2468
4	16.8000	0.5600
5	2.8800	0.2400
6	0.4809	0.0801
7	11.0208	0.5600
8	91.5443	2.3252
9	0.7600	0.1900
10	2.8860	0.1804
11	118.0860	0.4100
12	5.7000	0.1900
SNOW WATER	0.000	

****
****

Appendix F, GCL Closure Cap HELP Model Input Data and Output File (output file name: ZGCLout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	600 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 53.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
GCL	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
GCL	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)
Concrete Vault Roof	9	3 (barrier soil liner)
Clean Grout	10	1 (vertical percolation layer)
Saltstone	11	1 (vertical percolation layer)
Concrete Vault Floor	12	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	0.2		0.75	0.747	0.40	0.75
5	1	61.28		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	0.2		0.75	0.747	0.40	0.75
8	1	39.37		0.19	0.18	0.17	0.18
9	3	4		0.19	0.18	0.17	0.19
10	1	16		0.19	0.18	0.17	0.18
11	1	288		0.42	0.41	0.40	0.41
12	3	30		0.19	0.18	0.17	0.19

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	2	1.00E-01	600	3			
4	3	5.00E-09					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	5.00E-09					
8	1	1.00E-08					
9	3	1.00E-12					
10	1	1.00E-08					
11	1	5.00E-12					
12	3	1.00E-12					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				
9	3				
10	1				
11	1				
12	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCL.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLout.OUT

TIME:  14: 4     DATE:   9/ 8/2003

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

     TITLE:  SDF with GCL Hydraulic Barriers

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =      6.00   INCHES
           POROSITY                    =      0.4000 VOL/VOL
           FIELD CAPACITY              =      0.1100 VOL/VOL
           WILTING POINT               =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =     30.00   INCHES
           POROSITY                    =      0.3700 VOL/VOL
           FIELD CAPACITY              =      0.2400 VOL/VOL
           WILTING POINT               =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

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

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    600.0    FEET

                         LAYER  4
                         --------

               TYPE 3 - BARRIER SOIL LINER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                         LAYER  5
                         --------

           TYPE 1 - VERTICAL PERCOLATION LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     61.28   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  6
                         --------

             TYPE 2 - LATERAL DRAINAGE LAYER
               MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    100.0    FEET
```

```
                    LAYER  7
                    --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                    LAYER  8
                    --------

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    39.37   INCHES
POROSITY                    =     0.1900 VOL/VOL
FIELD CAPACITY              =     0.1800 VOL/VOL
WILTING POINT               =     0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999994000E-08 CM/SEC

                    LAYER  9
                    --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     4.00   INCHES
POROSITY                    =     0.1900 VOL/VOL
FIELD CAPACITY              =     0.1800 VOL/VOL
WILTING POINT               =     0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1900 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999996000E-12 CM/SEC

                    LAYER 10
                    --------

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    16.00   INCHES
POROSITY                    =     0.1900 VOL/VOL
FIELD CAPACITY              =     0.1800 VOL/VOL
WILTING POINT               =     0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999994000E-08 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    288.00   INCHES
   POROSITY                     =      0.4200 VOL/VOL
   FIELD CAPACITY               =      0.4100 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.4100 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999998000E-11 CM/SEC

                     LAYER 12
                     --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     30.00   INCHES
   POROSITY                     =      0.1900 VOL/VOL
   FIELD CAPACITY               =      0.1800 VOL/VOL
   WILTING POINT                =      0.1700 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.1900 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999996000E-12 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  600. FEET.

 SCS RUNOFF CURVE NUMBER              =     53.40
 FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE   =      2.750  ACRES
 EVAPORATIVE ZONE DEPTH               =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE    =      4.500  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE   =      8.320  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE   =      2.524  INCHES
 INITIAL SNOW WATER                   =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS     =    158.814  INCHES
 TOTAL INITIAL WATER                  =    158.814  INCHES
 TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.003    0.000    0.004    0.000    0.000    0.002
                           0.026    0.091    0.016    0.006    0.002    0.000

  STD. DEVIATIONS          0.018    0.000    0.025    0.000    0.002    0.013
                           0.091    0.402    0.083    0.058    0.012    0.003

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.093    3.072    3.552    3.665    4.140
                           4.898    4.523    3.387    1.618    0.948    1.114

  STD. DEVIATIONS          0.221    0.237    0.582    0.761    1.525    1.546
                           1.589    1.379    1.040    0.607    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                   2.5156   2.0329   1.8990   1.1200   0.3310   0.3276
                           0.5907   0.8023   0.7404   0.7845   0.9469   1.5559

  STD. DEVIATIONS          1.7225   1.4881   1.4548   1.0346   0.4554   0.6029
                           0.8376   1.0435   1.0421   1.0900   1.1974   1.3076

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                   0.0831   0.0667   0.0627   0.0390   0.0149   0.0135
                           0.0214   0.0281   0.0265   0.0277   0.0321   0.0509

  STD. DEVIATIONS          0.0600   0.0483   0.0451   0.0329   0.0139   0.0189
                           0.0261   0.0326   0.0332   0.0350   0.0370   0.0404

LATERAL DRAINAGE COLLECTED FROM LAYER  6
----------------------------------------
  TOTALS                   0.0632   0.0574   0.0647   0.0457   0.0168   0.0097
                           0.0165   0.0224   0.0214   0.0234   0.0265   0.0441

  STD. DEVIATIONS          0.0359   0.0328   0.0490   0.0498   0.0299   0.0173
                           0.0234   0.0276   0.0278   0.0315   0.0340   0.0372

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                   0.0055   0.0052   0.0057   0.0054   0.0051   0.0037
                           0.0037   0.0041   0.0041   0.0040   0.0038   0.0046

  STD. DEVIATIONS          0.0010   0.0003   0.0005   0.0006   0.0010   0.0018
                           0.0021   0.0021   0.0020   0.0022   0.0022   0.0020

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                   0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
                           0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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

PERCOLATION/LEAKAGE THROUGH LAYER 12

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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	2.9612	2.5731	2.1798	1.3331	0.3770	0.3855
	0.6729	0.9179	0.8851	0.9080	1.1145	1.7722
STD. DEVIATIONS	2.2668	2.0100	1.7106	1.2862	0.5187	0.7096
	0.9541	1.2017	1.2714	1.2926	1.4093	1.4894

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0180	0.0179	0.0184	0.0134	0.0048	0.0029
	0.0047	0.0064	0.0063	0.0067	0.0078	0.0126
STD. DEVIATIONS	0.0102	0.0101	0.0139	0.0146	0.0085	0.0051
	0.0067	0.0078	0.0082	0.0090	0.0100	0.0106

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	36.6549	36.7017	36.7318	36.7451	36.7596	36.7745
	36.7868	36.8013	36.8153	36.9449	36.9863	37.0511
STD. DEVIATIONS	9.7025	9.6681	9.6484	9.6246	9.5965	9.5579
	9.5181	9.4721	9.4285	9.1439	9.0721	8.9966

DAILY AVERAGE HEAD ON TOP OF LAYER 12

AVERAGES	0.2207	0.2211	0.2216	0.2221	0.2225	0.2230
	0.2234	0.2239	0.2244	0.2249	0.2253	0.2258
STD. DEVIATIONS	0.1681	0.1683	0.1684	0.1686	0.1687	0.1689
	0.1691	0.1692	0.1694	0.1695	0.1697	0.1698

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	488145.2	100.00
RUNOFF	0.150	(0.4314)	1498.22	0.307
EVAPOTRANSPIRATION	34.587	(3.6267)	345261.66	70.729
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.64682	(5.46763)	136229.328	27.90754
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.46665	(0.17502)	4658.361	0.95430
AVERAGE HEAD ON TOP OF LAYER 4	1.340	(0.553)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.41170	(0.16798)	4109.838	0.84193
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.05488	(0.00855)	547.854	0.11223
AVERAGE HEAD ON TOP OF LAYER 7	0.010	(0.004)		
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.00013	(0.00003)	1.265	0.00026
AVERAGE HEAD ON TOP OF LAYER 9	36.813	(9.418)		
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.00001	(0.00000)	0.125	0.00003
AVERAGE HEAD ON TOP OF LAYER 12	0.223	(0.169)		
CHANGE IN WATER STORAGE	0.105	(1.8211)	1045.84	0.214

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.641	26366.4102
DRAINAGE COLLECTED FROM LAYER 3	0.34038	3397.85840
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.026449	264.02802
AVERAGE HEAD ON TOP OF LAYER 4	30.903	
MAXIMUM HEAD ON TOP OF LAYER 4	44.441	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	168.2 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.01393	139.03853
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000275	2.74099
AVERAGE HEAD ON TOP OF LAYER 7	0.123	
MAXIMUM HEAD ON TOP OF LAYER 7	0.237	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	3.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000000	0.00368
AVERAGE HEAD ON TOP OF LAYER 9	39.370	
PERCOLATION/LEAKAGE THROUGH LAYER 12	0.000000	0.00035
AVERAGE HEAD ON TOP OF LAYER 12	0.560	
SNOW WATER	2.36	23561.8457
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3693	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1147	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6122	0.2687
2	9.2094	0.3070
3	2.9835	0.2486
4	0.1500	0.7500
5	14.7072	0.2400
6	0.4867	0.0811
7	0.1500	0.7500
8	12.5600	0.3190
9	0.7600	0.1900
10	2.8858	0.1804
11	118.0856	0.4100
12	5.7000	0.1900
SNOW WATER	0.000	

****
****

Appendix G, GCL Closure Cap without Vault Layer HELP Model Input Data and Output File (output file name: ZGCLAout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	600 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 53.4	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
GCL	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
GCL	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	0.2		0.75	0.747	0.40	0.75
5	1	61.28		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	0.2		0.75	0.747	0.40	0.75
8	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	2	1.00E-01	600	3			
4	3	5.00E-09					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	5.00E-09					
8	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLA.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLAout.OUT

TIME:  11:11     DATE:   9/ 9/2003

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

     TITLE:  SDF with GCL Hydraulic Barriers w/o Vault

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                   =      6.00   INCHES
          POROSITY                    =      0.4000 VOL/VOL
          FIELD CAPACITY              =      0.1100 VOL/VOL
          WILTING POINT               =      0.0580 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.1100 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                   =     30.00   INCHES
          POROSITY                    =      0.3700 VOL/VOL
          FIELD CAPACITY              =      0.2400 VOL/VOL
          WILTING POINT               =      0.1360 VOL/VOL
          INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
          EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

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

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   600.0    FEET

                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    61.28   INCHES
POROSITY                    =     0.3700 VOL/VOL
FIELD CAPACITY              =     0.2400 VOL/VOL
WILTING POINT               =     0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                        LAYER  6
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     6.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     2.00   PERCENT
DRAINAGE LENGTH             =   100.0    FEET
```

```
                         LAYER  7
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     0.20   INCHES
POROSITY                     =     0.7500 VOL/VOL
FIELD CAPACITY               =     0.7470 VOL/VOL
WILTING POINT                =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                         LAYER  8
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    39.37   INCHES
POROSITY                     =     0.1900 VOL/VOL
FIELD CAPACITY               =     0.1800 VOL/VOL
WILTING POINT                =     0.1700 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

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

NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
         SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
         GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
         AND A SLOPE LENGTH OF  600. FEET.

SCS RUNOFF CURVE NUMBER            =    53.40
FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =     2.750  ACRES
EVAPORATIVE ZONE DEPTH             =    22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =     4.500  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =     8.320  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =     2.524  INCHES
INITIAL SNOW WATER                 =     0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =    31.394  INCHES
TOTAL INITIAL WATER                =    31.394  INCHES
TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.003    0.000    0.004    0.000    0.000    0.002
                           0.026    0.091    0.016    0.006    0.002    0.000

  STD. DEVIATIONS          0.018    0.000    0.025    0.000    0.002    0.013
                           0.091    0.402    0.083    0.058    0.012    0.003

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.093    3.072    3.552    3.665    4.140
                           4.898    4.523    3.387    1.618    0.948    1.114

  STD. DEVIATIONS          0.221    0.237    0.582    0.761    1.525    1.546
                           1.589    1.379    1.040    0.607    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                   2.5156   2.0329   1.8990   1.1200   0.3310   0.3276
                           0.5907   0.8023   0.7404   0.7845   0.9469   1.5559

  STD. DEVIATIONS          1.7225   1.4881   1.4548   1.0346   0.4554   0.6029
                           0.8376   1.0435   1.0421   1.0900   1.1974   1.3076

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                   0.0831   0.0667   0.0627   0.0390   0.0149   0.0135
                           0.0214   0.0281   0.0265   0.0277   0.0321   0.0509

  STD. DEVIATIONS          0.0600   0.0483   0.0451   0.0329   0.0139   0.0189
                           0.0261   0.0326   0.0332   0.0350   0.0370   0.0404

LATERAL DRAINAGE COLLECTED FROM LAYER  6
----------------------------------------
  TOTALS                   0.0632   0.0574   0.0647   0.0457   0.0168   0.0097
                           0.0165   0.0224   0.0214   0.0234   0.0265   0.0441

  STD. DEVIATIONS          0.0359   0.0328   0.0490   0.0498   0.0299   0.0173
                           0.0234   0.0276   0.0278   0.0315   0.0340   0.0372

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                   0.0055   0.0052   0.0057   0.0054   0.0051   0.0037
                           0.0037   0.0041   0.0041   0.0040   0.0038   0.0046

  STD. DEVIATIONS          0.0010   0.0003   0.0005   0.0006   0.0010   0.0018
                           0.0021   0.0021   0.0020   0.0022   0.0022   0.0020

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                   0.0048   0.0046   0.0047   0.0042   0.0040   0.0036
                           0.0031   0.0039   0.0044   0.0048   0.0045   0.0046

  STD. DEVIATIONS          0.0022   0.0019   0.0019   0.0016   0.0015   0.0016
                           0.0017   0.0020   0.0022   0.0022   0.0021   0.0021
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	2.9612	2.5731	2.1798	1.3331	0.3770	0.3855
	0.6729	0.9179	0.8851	0.9080	1.1145	1.7722
STD. DEVIATIONS	2.2668	2.0100	1.7106	1.2862	0.5187	0.7096
	0.9541	1.2017	1.2714	1.2926	1.4093	1.4894

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0180	0.0179	0.0184	0.0134	0.0048	0.0029
	0.0047	0.0064	0.0063	0.0067	0.0078	0.0126
STD. DEVIATIONS	0.0102	0.0101	0.0139	0.0146	0.0085	0.0051
	0.0067	0.0078	0.0082	0.0090	0.0100	0.0106

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES		CU. FEET	PERCENT
PRECIPITATION	48.90	(7.734)	488145.2	100.00
RUNOFF	0.150	(0.4314)	1498.22	0.307
EVAPOTRANSPIRATION	34.587	(3.6267)	345261.66	70.729
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.64682	(5.46763)	136229.328	27.90754
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.46665	(0.17502)	4658.361	0.95430
AVERAGE HEAD ON TOP OF LAYER 4	1.340	(0.553)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.41170	(0.16798)	4109.838	0.84193
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.05488	(0.00855)	547.854	0.11223
AVERAGE HEAD ON TOP OF LAYER 7	0.010	(0.004)		
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.05136	(0.01570)	512.680	0.10503
CHANGE IN WATER STORAGE	0.053	(1.8213)	533.49	0.109

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.641	26366.4102
DRAINAGE COLLECTED FROM LAYER 3	0.34038	3397.85840
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.026449	264.02802
AVERAGE HEAD ON TOP OF LAYER 4	30.903	
MAXIMUM HEAD ON TOP OF LAYER 4	44.441	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	168.2 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.01393	139.03853
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000275	2.74099
AVERAGE HEAD ON TOP OF LAYER 7	0.123	
MAXIMUM HEAD ON TOP OF LAYER 7	0.237	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	3.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000454	4.53332
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3693
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1147

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6122	0.2687
2	9.2094	0.3070
3	2.9835	0.2486
4	0.1500	0.7500
5	14.7072	0.2400
6	0.4867	0.0811
7	0.1500	0.7500
8	7.4390	0.1889
SNOW WATER	0.000	

****
****

Appendix H, GCL Closure Cap with 300-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLBout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	300 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.70	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
GCL	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
GCL	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	0.2		0.75	0.747	0.40	0.75
5	1	61.28		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	0.2		0.75	0.747	0.40	0.75
8	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	2	1.00E-01	300	3			
4	3	5.00E-09					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	5.00E-09					
8	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLB.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLBout.OUT

TIME:  14:22     DATE:   9/ 9/2003

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

     TITLE:  SDF with GCL Hydraulic Barriers w/o Vault - 300 ft slope

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      6.00   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    300.0    FEET

                        LAYER  4
                        --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     61.28   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                        LAYER  6
                        --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      6.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    100.0    FEET
```

```
                           LAYER  7
                           --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =     0.20   INCHES
   POROSITY                    =     0.7500 VOL/VOL
   FIELD CAPACITY              =     0.7470 VOL/VOL
   WILTING POINT               =     0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                           LAYER  8
                           --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =    39.37   INCHES
   POROSITY                    =     0.1900 VOL/VOL
   FIELD CAPACITY              =     0.1800 VOL/VOL
   WILTING POINT               =     0.1700 VOL/VOL
   INITIAL SOIL WATER CONTENT  =     0.1800 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.999999994000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  300. FEET.

SCS RUNOFF CURVE NUMBER              =     55.70
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      2.750  ACRES
EVAPORATIVE ZONE DEPTH               =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.500  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.320  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.524  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     31.394  INCHES
TOTAL INITIAL WATER                  =     31.394  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.004    0.000    0.005    0.000    0.000    0.002
                           0.028    0.092    0.017    0.007    0.003    0.001

  STD. DEVIATIONS          0.022    0.000    0.029    0.000    0.004    0.017
                           0.095    0.407    0.090    0.059    0.018    0.005

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.093    3.072    3.552    3.663    4.141
                           4.898    4.522    3.385    1.619    0.948    1.114

  STD. DEVIATIONS          0.221    0.237    0.582    0.760    1.525    1.545
                           1.588    1.379    1.039    0.606    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                   2.7198   1.9175   1.9198   0.9387   0.2679   0.3500
                           0.6494   0.8286   0.7516   0.8016   1.0071   1.7041

  STD. DEVIATIONS          1.9146   1.5264   1.6505   0.9614   0.5082   0.6713
                           0.9538   1.1603   1.1657   1.1916   1.2786   1.4652

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                   0.0459   0.0336   0.0340   0.0188   0.0078   0.0073
                           0.0129   0.0159   0.0146   0.0151   0.0184   0.0298

  STD. DEVIATIONS          0.0290   0.0230   0.0249   0.0148   0.0083   0.0113
                           0.0155   0.0187   0.0186   0.0196   0.0205   0.0231

LATERAL DRAINAGE COLLECTED FROM LAYER  6
----------------------------------------
  TOTALS                   0.0377   0.0312   0.0281   0.0169   0.0041   0.0050
                           0.0093   0.0122   0.0111   0.0118   0.0148   0.0244

  STD. DEVIATIONS          0.0244   0.0241   0.0222   0.0175   0.0072   0.0099
                           0.0137   0.0164   0.0168   0.0173   0.0200   0.0214

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                   0.0053   0.0050   0.0054   0.0048   0.0038   0.0021
                           0.0032   0.0035   0.0034   0.0030   0.0033   0.0044

  STD. DEVIATIONS          0.0009   0.0004   0.0004   0.0011   0.0015   0.0020
                           0.0021   0.0022   0.0021   0.0024   0.0023   0.0020

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                   0.0042   0.0040   0.0041   0.0037   0.0035   0.0025
                           0.0023   0.0034   0.0040   0.0043   0.0038   0.0040

  STD. DEVIATIONS          0.0021   0.0018   0.0019   0.0016   0.0015   0.0015
                           0.0018   0.0021   0.0022   0.0023   0.0021   0.0019
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	1.5490	1.1978	1.0934	0.5524	0.1525	0.2060
	0.3699	0.4719	0.4423	0.4588	0.5927	0.9705
STD. DEVIATIONS	1.0904	0.9559	0.9400	0.5658	0.2894	0.3951
	0.5432	0.6608	0.6860	0.6873	0.7524	0.8344

DAILY AVERAGE HEAD ON TOP OF LAYER 7

AVERAGES	0.0107	0.0097	0.0080	0.0050	0.0012	0.0015
	0.0026	0.0035	0.0033	0.0033	0.0044	0.0069
STD. DEVIATIONS	0.0069	0.0075	0.0063	0.0052	0.0021	0.0029
	0.0039	0.0047	0.0049	0.0049	0.0059	0.0061

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	488145.2	100.00
RUNOFF	0.159 (0.4376)	1589.92	0.326
EVAPOTRANSPIRATION	34.584 (3.6252)	345236.75	70.724
LATERAL DRAINAGE COLLECTED FROM LAYER 3	13.85619 (5.60386)	138319.391	28.33571
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.25391 (0.08917)	2534.642	0.51924
AVERAGE HEAD ON TOP OF LAYER 4	0.671 (0.272)		
LATERAL DRAINAGE COLLECTED FROM LAYER 6	0.20657 (0.08364)	2062.071	0.42243
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.04729 (0.00857)	472.059	0.09670
AVERAGE HEAD ON TOP OF LAYER 7	0.005 (0.002)		
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.04386 (0.01447)	437.847	0.08970
CHANGE IN WATER STORAGE	0.050 (1.5780)	499.25	0.102

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.652	26478.3203
DRAINAGE COLLECTED FROM LAYER 3	0.66708	6659.09082
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.015959	159.31087
AVERAGE HEAD ON TOP OF LAYER 4	18.567	
MAXIMUM HEAD ON TOP OF LAYER 4	25.422	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	90.4 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00820	81.82230
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000232	2.31170
AVERAGE HEAD ON TOP OF LAYER 7	0.072	
MAXIMUM HEAD ON TOP OF LAYER 7	0.141	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	2.5 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000417	4.16049
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3689

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1147

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6127	0.2688
2	9.2087	0.3070
3	2.6521	0.2210
4	0.1500	0.7500
5	14.7072	0.2400
6	0.4851	0.0809
7	0.1500	0.7500
8	7.4293	0.1887
SNOW WATER	0.000	

****
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Appendix I, GCL Closure Cap with 100-foot Slope Lengths: HELP Model Input Data and Output File (output file name: ZGCLCout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	100 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 59.30	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
GCL	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
GCL	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	0.2		0.75	0.747	0.40	0.75
5	1	61.28		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	0.2		0.75	0.747	0.40	0.75
8	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	2	1.00E-01	100	3			
4	3	5.00E-09					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	5.00E-09					
8	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLC.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLCout.OUT

TIME:  14:29     DATE:   9/ 9/2003

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

     TITLE:  SDF with GCL Hydraulic Barriers w/o Vault - 100 ft slope

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      6.00   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   100.0    FEET

                       LAYER  4
                       --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                       LAYER  5
                       --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    61.28   INCHES
POROSITY                    =     0.3700 VOL/VOL
FIELD CAPACITY              =     0.2400 VOL/VOL
WILTING POINT               =     0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                       LAYER  6
                       --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     6.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0800 VOL/VOL
WILTING POINT               =     0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =     2.00   PERCENT
DRAINAGE LENGTH             =   100.0    FEET
```

```
                              LAYER  7
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =      0.20   INCHES
  POROSITY                     =      0.7500 VOL/VOL
  FIELD CAPACITY               =      0.7470 VOL/VOL
  WILTING POINT                =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                              LAYER  8
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =     39.37   INCHES
  POROSITY                     =      0.1900 VOL/VOL
  FIELD CAPACITY               =      0.1800 VOL/VOL
  WILTING POINT                =      0.1700 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.1800 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  100. FEET.

SCS RUNOFF CURVE NUMBER             =     59.30
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      2.750  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.500  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.320  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.524  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     31.394  INCHES
TOTAL INITIAL WATER                 =     31.394  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.008    0.000    0.007    0.000    0.001    0.004
                         0.030    0.097    0.021    0.009    0.005    0.002

  STD. DEVIATIONS        0.033    0.002    0.039    0.001    0.008    0.025
                         0.103    0.412    0.105    0.076    0.029    0.012

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.577    2.094    3.073    3.552    3.661    4.142
                         4.899    4.521    3.383    1.619    0.948    1.114

  STD. DEVIATIONS        0.221    0.236    0.583    0.761    1.526    1.545
                         1.588    1.376    1.040    0.606    0.206    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 2.8404   1.8064   1.9410   0.7881   0.2634   0.3693
                         0.6900   0.8272   0.7728   0.8094   1.0651   1.8093

  STD. DEVIATIONS        2.0166   1.4806   1.7564   0.8554   0.5610   0.6997
                         1.0203   1.2362   1.2608   1.2568   1.3137   1.5625

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                 0.0192   0.0137   0.0148   0.0081   0.0033   0.0035
                         0.0060   0.0070   0.0063   0.0065   0.0083   0.0132

  STD. DEVIATIONS        0.0105   0.0076   0.0090   0.0052   0.0040   0.0048
                         0.0066   0.0076   0.0077   0.0079   0.0081   0.0090

LATERAL DRAINAGE COLLECTED FROM LAYER  6
----------------------------------------
  TOTALS                 0.0138   0.0095   0.0097   0.0045   0.0013   0.0018
                         0.0033   0.0042   0.0037   0.0040   0.0051   0.0087

  STD. DEVIATIONS        0.0098   0.0078   0.0085   0.0048   0.0026   0.0034
                         0.0049   0.0059   0.0060   0.0061   0.0065   0.0076

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                 0.0051   0.0047   0.0051   0.0042   0.0020   0.0017
                         0.0026   0.0029   0.0025   0.0025   0.0030   0.0042

  STD. DEVIATIONS        0.0009   0.0006   0.0008   0.0014   0.0016   0.0018
                         0.0021   0.0021   0.0020   0.0023   0.0022   0.0019

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                 0.0038   0.0035   0.0037   0.0033   0.0031   0.0017
                         0.0018   0.0027   0.0033   0.0036   0.0031   0.0034

  STD. DEVIATIONS        0.0019   0.0017   0.0018   0.0016   0.0015   0.0014
                         0.0016   0.0018   0.0019   0.0022   0.0019   0.0018
```

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES                0.5392   0.3758   0.3685   0.1546   0.0500   0.0724
                            0.1310   0.1570   0.1516   0.1536   0.2089   0.3435

    STD. DEVIATIONS         0.3828   0.3080   0.3334   0.1678   0.1065   0.1373
                            0.1937   0.2347   0.2473   0.2386   0.2577   0.2966

  DAILY AVERAGE HEAD ON TOP OF LAYER  7
  -------------------------------------
    AVERAGES                0.0039   0.0030   0.0028   0.0013   0.0004   0.0005
                            0.0009   0.0012   0.0011   0.0011   0.0015   0.0025

    STD. DEVIATIONS         0.0028   0.0024   0.0024   0.0014   0.0007   0.0010
                            0.0014   0.0017   0.0018   0.0017   0.0019   0.0022

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                      INCHES           CU. FEET       PERCENT
                                -------------------  -------------   ---------
 PRECIPITATION                   48.90    (   7.734)    488145.2     100.00

 RUNOFF                           0.184   (  0.4500)      1840.76      0.377

 EVAPOTRANSPIRATION              34.582   (  3.6301)    345217.16     70.720

 LATERAL DRAINAGE COLLECTED      13.98232 (  5.63497)   139578.500   28.59364
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH      0.11001 (  0.03372)     1098.130     0.22496
   LAYER  4

 AVERAGE HEAD ON TOP              0.226 (    0.091)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED       0.06947 (  0.02813)      693.469    0.14206
   FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH      0.04051 (  0.00806)      404.381     0.08284
   LAYER  7

 AVERAGE HEAD ON TOP              0.002 (    0.001)
   OF LAYER  7

 PERCOLATION/LEAKAGE THROUGH      0.03717 (  0.01300)      371.090     0.07602
   LAYER  8

 CHANGE IN WATER STORAGE          0.045   (  1.3391)       444.28      0.091
```

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.676	26710.3457
DRAINAGE COLLECTED FROM LAYER 3	1.24822	12460.30660
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.006415	64.03636
AVERAGE HEAD ON TOP OF LAYER 4	7.344	
MAXIMUM HEAD ON TOP OF LAYER 4	9.882	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	32.7 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00360	35.90605
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000197	1.96719
AVERAGE HEAD ON TOP OF LAYER 7	0.032	
MAXIMUM HEAD ON TOP OF LAYER 7	0.063	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	1.2 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000412	4.11374
SNOW WATER	2.36	23561.8457
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3683	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1147	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6121	0.2687
2	9.2096	0.3070
3	2.1126	0.1760
4	0.1500	0.7500
5	14.7072	0.2400
6	0.4828	0.0805
7	0.1500	0.7500
8	7.4201	0.1885
SNOW WATER	0.000	

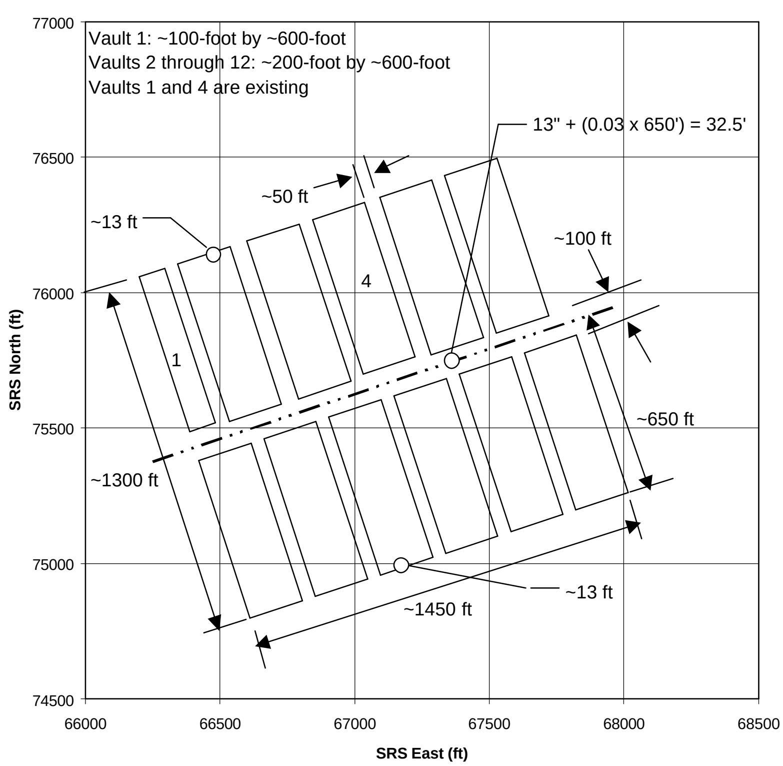
****
****

Appendix J, Drainage System Configuration, Soil Fill Volume and Ditch Lengths Calculations

Relative soil fill volumes and drainage ditch lengths have been determined for each of the drainage system configurations. From Table 4.1-1 the minimum thickness of material over the vault has been determined to be approximately 13 feet. The calculated fill volume ignores the fill between vaults and outside the ~1300-foot by ~1450-foot footprint, since it is essentially the same for all configurations.

Replacement GCL Closure Cap	
Layer	Minimum Thickness (inches)
Topsoil	6
Backfill	30
Drainage Layer	12
GCL	0.2
Backfill	61.28
Drainage Layer	6
GCL	0.2
Clean Grout	39.37
Total	~155 inches (~13 feet)

600-Foot, Slope Length Drainage System Configuration Soil Fill Volume and Drainage Ditch Length Calculation (also see Figure 4.2-1):



Fill volume = (13’ × (1300’ × 1450’)) + 2 × (½ × 650’ × (32.5’ – 13’) × 1450’)

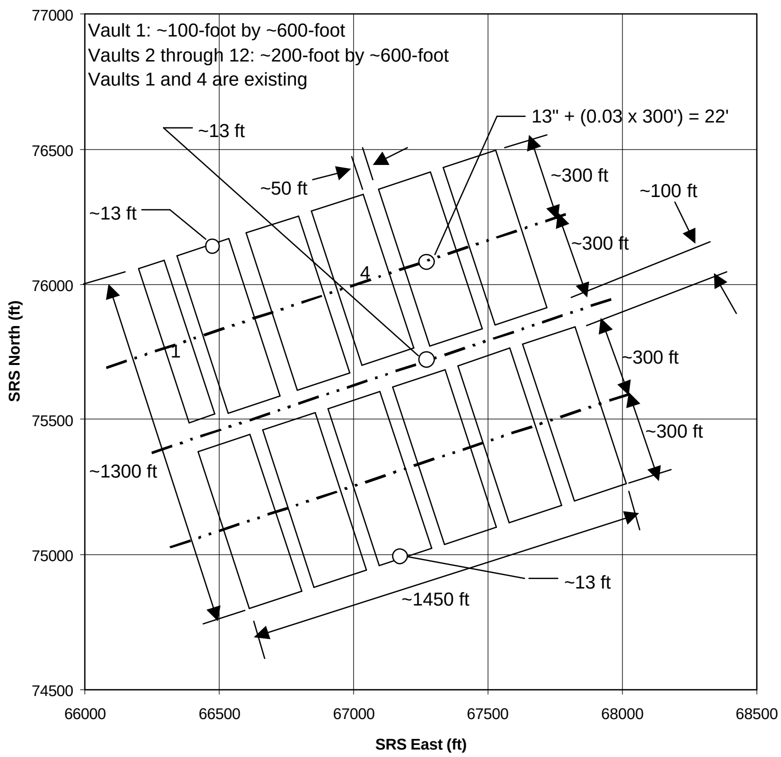
Fill volume = 42,883,750 ft^3 ÷ 27 yd^3 / ft^3

Fill volume ≈ 1,588,300 yd^3

Ditch length (also see Figure 4.2-1) = (2 × 1450’) + 1300’

Ditch length = 4,200 ft

300-Foot, Slope Length Drainage System Configuration Soil Fill Volume and Drainage Ditch Length Calculation (also see Figure 4.2-2):



Fill volume = (13’ × (1300’ × 1450’)) + 4 × (½ × 300’ × (22’ – 13’) × 1450’)

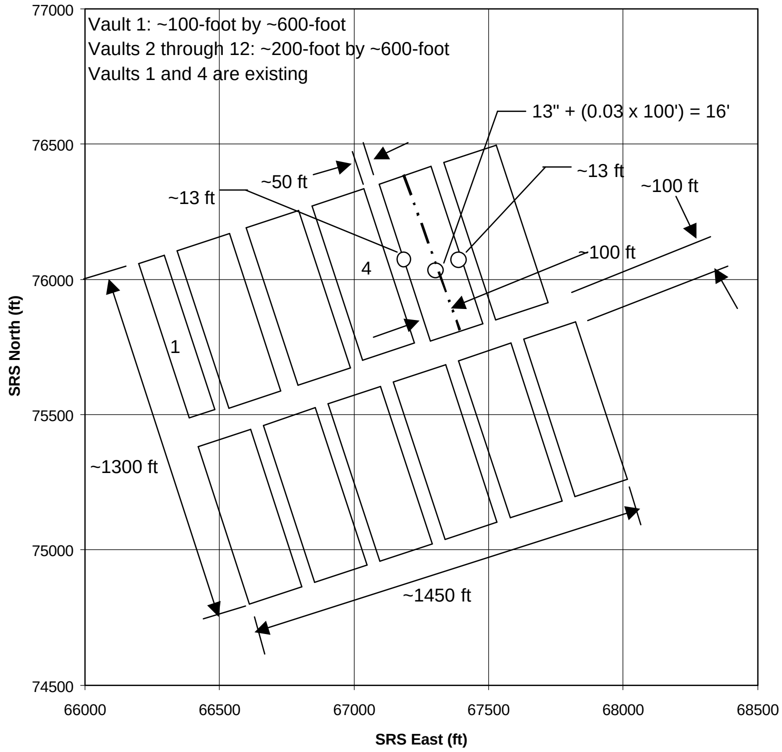
Fill volume = 32,335,000 ft^3 ÷ 27 yd^3 / ft^3

Fill volume ≈ 1,197,600 yd^3

Ditch length (also see Figure 4.2-2) = (3 × 1450’) + 1300’

Ditch length = 5,650 ft

100-Foot, Slope Length Drainage System Configuration Soil Fill Volume and Drainage Ditch Length Calculation (also see Figure 4.2-3):



Fill volume = (13’ × (1300’ × 1450’)) + 24 × (½ × 100’ × (16’ – 13’) × 600’)

Fill volume = 26,665,000 ft^3 ÷ 27 yd^3 / ft^3

Fill volume ≈ 987,600 yd^3

Ditch length (also see Figure 4.2-3) = (14 × 650’) + (3 × 1450’)

Ditch length = 13,450 ft

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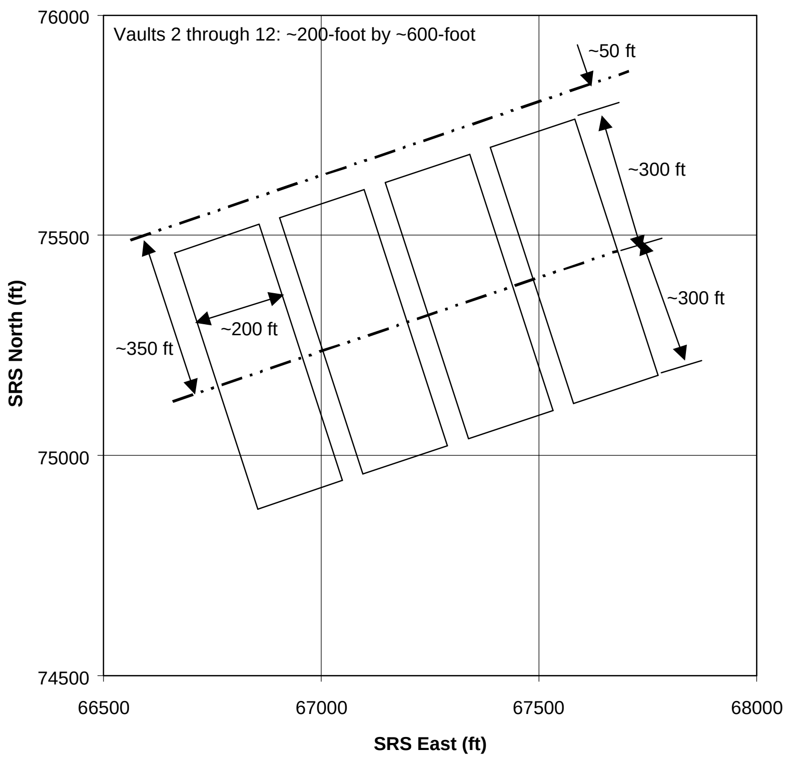
Appendix K, Erosion Barrier Sizing and Material Properties

The erosion barrier has been sized based upon the maximum precipitation event for a 10,000-year return period. The maximum precipitation event for a 10,000-year return period is 3.3 inches over a 15-minute accumulation period (Table XIX from Weber et al. (1998)). The figure below shows that the maximum drainage length is 350 feet over a 200-foot wide vault.



Determine the maximum flow (Q in ft^3/s) resulting from the 3.3-inch over a 15-minute accumulation period rainfall event:

To be conservative it has been assumed that all rainfall results in runoff and that there is no lag period due to the 350-foot flow path (that is all the rainfall over the entire area immediately becomes discharge out the end of the area).

$$Q = \frac{(P/12\ in/ft) \times (350' \times 200')}{D \times 60\ \min/hr \times 60\ s/\min}$$, where P = precipitation in inches and D = duration in hours

$$Q = 1.62\frac{P}{D}$$, where P = 3.3 inches and D = 15 minutes = 0.25 hours

$$Q = 1.62\frac{3.3}{0.25}\ ft^3/s$$, over a 200-foot width

$Q = 21.4 \text{ ft}^3/\text{s}$, over a 200-foot width

Determine the approximate depth of flow using Manning's equation (Clark et al. 1977):

$V = \frac{1.49}{n} R^{2/3} S^{1/2}$, where V = velocity, fps; n = coefficient of roughness;

R = hydraulic radius, ft; and S = slope

$V = Q/A$, where V = velocity, ft/s; Q = flow, ft^3/s; A = area, ft^2

$Q = 21.4 \text{ ft}^3/\text{s}$, over a 200-foot width (i.e. b)

$A = bd$, where b = width, ft; d = depth, ft

$A = 200d \;\; ft^2$

insert values:

$$V = 21.4 \;\; ft^3/s \Big/ 200d \;\; ft^2$$

Assume the use of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches. From Figure 7.29 of Goldman (1986): n = 0.033

$$R = A/wetted \;\; perimeter = A/(b + 2d)$$

$$R = 200d/(200 + 2d)$$

3% slope (see Section 2.0): S = 0.03

insert values:

$$\frac{21.4}{200d} = \frac{1.49}{0.033}\left(\frac{200d}{200 + 2d}\right)^{2/3} (0.03)^{1/2}$$

$$0.0137 = d\left(\frac{200d}{200 + 2d}\right)^{2/3}$$

Given d	0.0137
0.1	0.0215
0.08	0.0148
0.075	0.0133
0.076	0.0136

d ≈ 0.076

Determine if the use of a 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches is satisfactory to perform as an erosion barrier for a 10,000-year return period, maximum precipitation event:

b/d = 200'/0.076' = 2632, therefore b/d > 50.

From Figure 7.30 of Goldman (1986): Since the b/d > 50 then the P/R is greater than 60.

From Figure 7.31 of Goldman (1986): With a slope (S) of 0.03, a flow (Q) of 21.4 ft^3/s, and a P/R > 60, the minimum d_{50} of the stone must be approximately 3 inches.

Therefore the use of a 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches is satisfactory to perform as an erosion barrier for a 10,000-year return period, maximum precipitation event.

The selection of the 2-inch to 6-inch granite stone as an erosion barrier is also satisfactory versus Figure C-3 of Logan 1997.

Based upon NCSU 1991 the 2-inch to 6-inch granite stone is a common sized erosion control stone. NCSU 1991 also indicates the minimum thickness of the erosion control stone must be 1.5 times the maximum stone diameter. That is the thickness must be at least 9 inches for a maximum 6-inch stone. A 12-inch thickness of 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches will be utilized as the erosion barrier.

Determine the combined soil material properties for the 2-inch to 6-inch granite stone filled with CLSM or Flowable Fill:

The porosity of the 2-inch to 6-inch granite stone with a d_{50} (i.e. median size) of 4 inches is taken as 0.397 based upon the porosity of poorly graded gravel from USEPA 1994a and USEPA 1994b.

Typical CLSM or Flowable Fill properties based upon a May 8, 2003 personal conversation with Christine A. Langton:

Typical CLSM consists of sand with a porosity of 30%, with the pore space filled with 50% porosity binder and has a saturated hydraulic conductivity of 1.0E-03 cm/s.

Based upon this information the following are the assumed properties of the CLSM:

Property	Property Value
Saturated Hydraulic Conductivity	1.0E-03 cm/s
Porosity	$0.30 \times 0.50 = 0.15$
Field Capacity [1]	0.14
Wilting Point [1]	0.13

[1] Field capacity is assumed to be 0.01 less than the porosity, and the wilting point is assumed to be 0.01 less than the field capacity based upon the porosity-wilting point-field capacity relationship of the clean grout and concrete vault roof and floor, which like the CLSM uses cement as the binder.

The matrix of an individual granite stone itself is considered impermeable and non-porous. The porosity of a layer of granite stone is considered to be 0.397. When the granite stone porosity is filled with CLSM, the resultant hydraulic properties, which are area or volume based, become that of the CLSM times the granite stone porosity. The resultant hydraulic properties are shown below:

Property	Property Value
Saturated Hydraulic Conductivity	1.0E-03 cm/s $\times$ 0.397 = 3.97E-04 cm/s
Porosity	$0.15 \times 0.397 = 0.06$
Field Capacity [1]	$0.14 \times 0.397 = 0.056$
Wilting Point [1]	$0.13 \times 0.397 = 0.052$

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Appendix L, GCL Closure Cap with Erosion Barrier: HELP Model Input Data and Output File (output file name: ZGCLDout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	300 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.70	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Gravel Drainage	4	2 (lateral drainage layer)
GCL	5	3 (barrier soil liner)
Backfill	6	1 (vertical percolation layer)
Gravel Drainage	7	2 (lateral drainage layer)
GCL	8	3 (barrier soil liner)
Clean Grout	9	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.056	0.052	0.056
4	2	12		0.38	0.08	0.013	0.08
5	3	0.2		0.75	0.747	0.40	0.75
6	1	49.28		0.37	0.24	0.136	0.24
7	2	6		0.38	0.08	0.013	0.08
8	3	0.2		0.75	0.747	0.40	0.75
9	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.97E-04					
4	2	1.00E-01	300	3			
5	3	5.00E-09					
6	1	1.00E-04					
7	2	1.00E-01	100	2			
8	3	5.00E-09					
9	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	2				
5	3				
6	1				
7	2				
8	3				
9	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLDout.OUT

TIME:  13:14     DATE:   9/11/2003

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

     TITLE:  SDF GCL Closure Cap with Erosion Barrier

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =      6.00   INCHES
           POROSITY                    =      0.4000 VOL/VOL
           FIELD CAPACITY              =      0.1100 VOL/VOL
           WILTING POINT               =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =     30.00   INCHES
           POROSITY                    =      0.3700 VOL/VOL
           FIELD CAPACITY              =      0.2400 VOL/VOL
           WILTING POINT               =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0600 VOL/VOL
FIELD CAPACITY               =      0.0560 VOL/VOL
WILTING POINT                =      0.0520 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0560 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.396999996000E-03 CM/SEC

                         LAYER  4
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    300.0    FEET

                         LAYER  5
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                         LAYER  6
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     49.28   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

```
                              LAYER  7
                              --------

                  TYPE 2 - LATERAL DRAINAGE LAYER
                    MATERIAL TEXTURE NUMBER   0
    THICKNESS                    =     6.00   INCHES
    POROSITY                     =     0.3800 VOL/VOL
    FIELD CAPACITY               =     0.0800 VOL/VOL
    WILTING POINT                =     0.0130 VOL/VOL
    INITIAL SOIL WATER CONTENT   =     0.0800 VOL/VOL
    EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
    SLOPE                        =     2.00   PERCENT
    DRAINAGE LENGTH              =   100.0    FEET

                              LAYER  8
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
    THICKNESS                    =     0.20   INCHES
    POROSITY                     =     0.7500 VOL/VOL
    FIELD CAPACITY               =     0.7470 VOL/VOL
    WILTING POINT                =     0.4000 VOL/VOL
    INITIAL SOIL WATER CONTENT   =     0.7500 VOL/VOL
    EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                              LAYER  9
                              --------

                  TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
    THICKNESS                    =    39.37   INCHES
    POROSITY                     =     0.1900 VOL/VOL
    FIELD CAPACITY               =     0.1800 VOL/VOL
    WILTING POINT                =     0.1700 VOL/VOL
    INITIAL SOIL WATER CONTENT   =     0.1800 VOL/VOL
    EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

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

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
           AND A SLOPE LENGTH OF  300. FEET.

 SCS RUNOFF CURVE NUMBER            =    55.70
 FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =     2.750  ACRES
 EVAPORATIVE ZONE DEPTH             =    22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =     4.500  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =     8.320  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =     2.524  INCHES
 INITIAL SNOW WATER                 =     0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =    29.186  INCHES
 TOTAL INITIAL WATER                =    29.186  INCHES
 TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.004	0.000	0.005	0.000	0.000	0.002
	0.028	0.092	0.017	0.007	0.003	0.001
STD. DEVIATIONS	0.022	0.000	0.029	0.000	0.004	0.017
	0.095	0.407	0.090	0.059	0.018	0.005

EVAPOTRANSPIRATION

TOTALS	1.577	2.093	3.072	3.552	3.663	4.141
	4.898	4.522	3.385	1.619	0.948	1.114
STD. DEVIATIONS	0.221	0.237	0.582	0.760	1.525	1.545
	1.588	1.379	1.039	0.606	0.207	0.206

LATERAL DRAINAGE COLLECTED FROM LAYER 4

TOTALS	2.7170	1.9209	1.9205	0.9442	0.2679	0.3494
	0.6484	0.8294	0.7509	0.8010	1.0050	1.7014
STD. DEVIATIONS	1.9146	1.5272	1.6493	0.9645	0.5076	0.6708
	0.9529	1.1598	1.1644	1.1900	1.2786	1.4634

PERCOLATION/LEAKAGE THROUGH LAYER 5

TOTALS	0.0458	0.0336	0.0340	0.0189	0.0078	0.0073
	0.0129	0.0159	0.0145	0.0151	0.0183	0.0297
STD. DEVIATIONS	0.0290	0.0231	0.0248	0.0149	0.0083	0.0113
	0.0155	0.0186	0.0186	0.0196	0.0205	0.0231

LATERAL DRAINAGE COLLECTED FROM LAYER 7

TOTALS	0.0377	0.0313	0.0281	0.0169	0.0041	0.0050
	0.0092	0.0122	0.0111	0.0117	0.0148	0.0243
STD. DEVIATIONS	0.0245	0.0241	0.0223	0.0175	0.0072	0.0099
	0.0137	0.0164	0.0168	0.0172	0.0200	0.0213

PERCOLATION/LEAKAGE THROUGH LAYER 8

TOTALS	0.0053	0.0050	0.0054	0.0048	0.0038	0.0021
	0.0032	0.0035	0.0034	0.0030	0.0033	0.0044
STD. DEVIATIONS	0.0009	0.0004	0.0004	0.0011	0.0015	0.0020
	0.0021	0.0022	0.0021	0.0024	0.0023	0.0020

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0042	0.0040	0.0041	0.0037	0.0035	0.0025
	0.0023	0.0034	0.0040	0.0043	0.0038	0.0040
STD. DEVIATIONS	0.0021	0.0018	0.0019	0.0016	0.0015	0.0015
	0.0018	0.0021	0.0022	0.0023	0.0021	0.0019

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 5

AVERAGES	1.5474	1.2000	1.0938	0.5557	0.1526	0.2056
	0.3693	0.4724	0.4419	0.4590	0.5914	0.9690
STD. DEVIATIONS	1.0904	0.9567	0.9393	0.5676	0.2891	0.3948
	0.5427	0.6605	0.6852	0.6889	0.7525	0.8334

DAILY AVERAGE HEAD ON TOP OF LAYER 8

AVERAGES	0.0107	0.0098	0.0080	0.0050	0.0012	0.0015
	0.0026	0.0035	0.0033	0.0033	0.0044	0.0069
STD. DEVIATIONS	0.0070	0.0075	0.0063	0.0052	0.0021	0.0029
	0.0039	0.0047	0.0049	0.0049	0.0059	0.0061

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	488145.2	100.00
RUNOFF	0.159 (0.4376)	1589.92	0.326
EVAPOTRANSPIRATION	34.584 (3.6252)	345236.75	70.724
LATERAL DRAINAGE COLLECTED FROM LAYER 4	13.85602 (5.60343)	138317.703	28.33536
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.25393 (0.08919)	2534.904	0.51929
AVERAGE HEAD ON TOP OF LAYER 5	0.671 (0.272)		
LATERAL DRAINAGE COLLECTED FROM LAYER 7	0.20659 (0.08366)	2062.242	0.42246
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.04730 (0.00857)	472.150	0.09672
AVERAGE HEAD ON TOP OF LAYER 8	0.005 (0.002)		
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.04387 (0.01447)	437.938	0.08971
CHANGE IN WATER STORAGE	0.050 (1.5846)	500.72	0.103

****

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.652	26478.3203
DRAINAGE COLLECTED FROM LAYER 4	0.66742	6662.50342
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.017625	175.93739
AVERAGE HEAD ON TOP OF LAYER 5	20.526	
MAXIMUM HEAD ON TOP OF LAYER 5	27.534	
LOCATION OF MAXIMUM HEAD IN LAYER 4 (DISTANCE FROM DRAIN)	94.3 FEET	
DRAINAGE COLLECTED FROM LAYER 7	0.00825	82.39084
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000232	2.31596
AVERAGE HEAD ON TOP OF LAYER 8	0.073	
MAXIMUM HEAD ON TOP OF LAYER 8	0.142	
LOCATION OF MAXIMUM HEAD IN LAYER 7 (DISTANCE FROM DRAIN)	2.5 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000417	4.16577
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3689

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1147

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6127	0.2688
2	9.2087	0.3070
3	0.7200	0.0600
4	2.6188	0.2182
5	0.1500	0.7500
6	11.8272	0.2400
7	0.4851	0.0809
8	0.1500	0.7500
9	7.4293	0.1887
SNOW WATER	0.000	

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Appendix M, GCL Closure Cap with Erosion Barrier without Layer Above: HELP Model Input Data and Output File (output file name: ZGCLEout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	300 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.70	

Layer	Layer Number	Layer Type
Erosion Barrier	1	1 (vertical percolation layer)
Gravel Drainage	2	2 (lateral drainage layer)
GCL	3	3 (barrier soil liner)
Backfill	4	1 (vertical percolation layer)
Gravel Drainage	5	2 (lateral drainage layer)
GCL	6	3 (barrier soil liner)
Clean Grout	7	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	12		0.06	0.056	0.052	0.056
2	2	12		0.38	0.08	0.013	0.08
3	3	0.2		0.75	0.747	0.40	0.75
4	1	49.28		0.37	0.24	0.136	0.24
5	2	6		0.38	0.08	0.013	0.08
6	3	0.2		0.75	0.747	0.40	0.75
7	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.97E-04					
2	2	1.00E-01	300	3			
3	3	5.00E-09					
4	1	1.00E-04					
5	2	1.00E-01	100	2			
6	3	5.00E-09					
7	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	2				
3	3				
4	1				
5	2				
6	3				
7	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLE.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLEout.OUT

TIME:  13:20     DATE:   9/11/2003

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

     TITLE:  SDF GCL Closure Cap with Erosion Barrier w/o Layers Above

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

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

                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.0600 VOL/VOL
           FIELD CAPACITY             =      0.0560 VOL/VOL
           WILTING POINT              =      0.0520 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0560 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.396999996000E-03 CM/SEC

                                  LAYER  2
                                  --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     12.00   INCHES
           POROSITY                   =      0.3800 VOL/VOL
           FIELD CAPACITY             =      0.0800 VOL/VOL
           WILTING POINT              =      0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.0800 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000001000     CM/SEC
           SLOPE                      =      3.00   PERCENT
           DRAINAGE LENGTH            =    300.0    FEET
```

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                    LAYER  3
                    --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                    LAYER  4
                    --------

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     49.28   INCHES
POROSITY                    =      0.3700 VOL/VOL
FIELD CAPACITY              =      0.2400 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                    LAYER  5
                    --------

        TYPE 2 - LATERAL DRAINAGE LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      6.00   INCHES
POROSITY                    =      0.3800 VOL/VOL
FIELD CAPACITY              =      0.0800 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    100.0    FEET

                    LAYER  6
                    --------

          TYPE 3 - BARRIER SOIL LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

```
                              LAYER  7
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     39.37   INCHES
   POROSITY                     =      0.1900 VOL/VOL
   FIELD CAPACITY               =      0.1800 VOL/VOL
   WILTING POINT                =      0.1700 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.1800 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  300. FEET.

SCS RUNOFF CURVE NUMBER            =     55.70
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      2.750  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      1.472  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      4.520  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      0.754  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     21.326  INCHES
TOTAL INITIAL WATER                =     21.326  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR

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

 NOTE:  EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
          AUGUSTA               GEORGIA

     STATION LATITUDE                        =  33.22 DEGREES
     MAXIMUM LEAF AREA INDEX                 =   3.50
     START OF GROWING SEASON (JULIAN DATE)   =     68
     END OF GROWING SEASON (JULIAN DATE)     =    323
     EVAPORATIVE ZONE DEPTH                  =  22.0  INCHES
     AVERAGE ANNUAL WIND SPEED               =   6.50 MPH
     AVERAGE 1ST QUARTER RELATIVE HUMIDITY   =  68.00 %
     AVERAGE 2ND QUARTER RELATIVE HUMIDITY   =  70.00 %
     AVERAGE 3RD QUARTER RELATIVE HUMIDITY   =  77.00 %
     AVERAGE 4TH QUARTER RELATIVE HUMIDITY   =  73.00 %
```

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90
RUNOFF						
TOTALS	0.006	0.004	0.003	0.000	0.001	0.001
	0.016	0.108	0.025	0.024	0.002	0.000
STD. DEVIATIONS	0.058	0.038	0.022	0.000	0.005	0.009
	0.084	0.489	0.176	0.242	0.024	0.000
EVAPOTRANSPIRATION						
TOTALS	1.358	1.587	2.054	1.861	2.218	2.878
	3.281	2.874	2.255	1.246	1.005	1.119
STD. DEVIATIONS	0.349	0.324	0.608	0.649	0.868	1.060
	1.009	0.967	0.807	0.582	0.378	0.258

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	3.0387	2.0814	2.6351	1.2252	1.3185	1.8157
	2.4332	2.4101	2.1355	1.6761	1.6490	2.1015
STD. DEVIATIONS	1.8462	1.3747	1.7448	0.9330	1.2766	1.3091
	1.6307	1.5874	1.5994	1.5751	1.2951	1.4246

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.0509	0.0361	0.0449	0.0234	0.0245	0.0320
	0.0418	0.0418	0.0372	0.0301	0.0293	0.0367
STD. DEVIATIONS	0.0280	0.0209	0.0265	0.0142	0.0198	0.0201
	0.0250	0.0247	0.0249	0.0245	0.0202	0.0215

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0425	0.0341	0.0372	0.0227	0.0184	0.0260
	0.0349	0.0372	0.0319	0.0260	0.0253	0.0307
STD. DEVIATIONS	0.0234	0.0237	0.0220	0.0185	0.0171	0.0195
	0.0228	0.0226	0.0221	0.0239	0.0209	0.0208

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0055	0.0050	0.0055	0.0052	0.0048	0.0048
	0.0053	0.0054	0.0052	0.0050	0.0047	0.0054
STD. DEVIATIONS	0.0005	0.0003	0.0003	0.0005	0.0013	0.0011
	0.0009	0.0005	0.0008	0.0010	0.0014	0.0005

PERCOLATION/LEAKAGE THROUGH LAYER 7

TOTALS	0.0052	0.0047	0.0049	0.0047	0.0047	0.0044
	0.0049	0.0052	0.0051	0.0051	0.0046	0.0048
STD. DEVIATIONS	0.0016	0.0014	0.0014	0.0013	0.0014	0.0014
	0.0016	0.0015	0.0014	0.0014	0.0014	0.0015

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	1.7338	1.3021	1.5053	0.7212	0.7523	1.0705
	1.3934	1.3887	1.2671	0.9607	0.9723	1.1970
STD. DEVIATIONS	1.0598	0.8672	1.0037	0.5496	0.7292	0.7739
	0.9408	0.9359	0.9662	0.9151	0.7672	0.8117

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.0121	0.0106	0.0106	0.0067	0.0052	0.0076
	0.0099	0.0106	0.0094	0.0074	0.0075	0.0088
STD. DEVIATIONS	0.0067	0.0074	0.0063	0.0054	0.0049	0.0057
	0.0065	0.0064	0.0065	0.0068	0.0062	0.0059

****

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	488145.2	100.00
RUNOFF	0.191 (0.5795)	1903.15	0.390
EVAPOTRANSPIRATION	23.736 (2.5079)	236943.02	48.539
LATERAL DRAINAGE COLLECTED FROM LAYER 2	24.51993 (6.02946)	244770.219	50.14291
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.42872 (0.09264)	4279.733	0.87673
AVERAGE HEAD ON TOP OF LAYER 3	1.189 (0.294)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.36676 (0.09191)	3661.148	0.75001
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.06188 (0.00375)	617.755	0.12655
AVERAGE HEAD ON TOP OF LAYER 6	0.009 (0.002)		
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.05833 (0.01465)	582.280	0.11928
CHANGE IN WATER STORAGE	0.029 (0.9482)	285.46	0.058

****

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	2.764	27590.2207
DRAINAGE COLLECTED FROM LAYER 2	0.65872	6575.71533
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.015045	150.18440
AVERAGE HEAD ON TOP OF LAYER 3	17.492	
MAXIMUM HEAD ON TOP OF LAYER 3	23.943	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	87.6 FEET	
DRAINAGE COLLECTED FROM LAYER 5	0.00903	90.15614
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.000238	2.37423
AVERAGE HEAD ON TOP OF LAYER 6	0.080	
MAXIMUM HEAD ON TOP OF LAYER 6	0.155	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	2.6 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000396	3.94843
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2055
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0343

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	0.7232	0.0603
2	3.4047	0.2837
3	0.1500	0.7500
4	11.8282	0.2400
5	0.4873	0.0812
6	0.1500	0.7500
7	7.4420	0.1890
SNOW WATER	0.000	

****
****

Appendix N, GCL Closure Cap with Erosion Barrier without Layer Above Plus Additional Backfill Layer: HELP Model Input Data and Output File (output file name: ZGCLFout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.75 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	**CN Input Parameter Value**
Slope =	3 %
Slope length =	300 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.70	

Layer	Layer Number	Layer Type
Erosion Barrier	1	1 (vertical percolation layer)
Backfill	2	1 (vertical percolation layer)
Gravel Drainage	3	2 (lateral drainage layer)
GCL	4	3 (barrier soil liner)
Backfill	5	1 (vertical percolation layer)
Gravel Drainage	6	2 (lateral drainage layer)
GCL	7	3 (barrier soil liner)
Clean Grout	8	1 (vertical percolation layer)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	12		0.06	0.056	0.052	0.056
2	1	12		0.37	0.24	0.136	0.24
3	2	12		0.38	0.08	0.013	0.08
4	3	0.2		0.75	0.747	0.40	0.75
5	1	37.28		0.37	0.24	0.136	0.24
6	2	6		0.38	0.08	0.013	0.08
7	3	0.2		0.75	0.747	0.40	0.75
8	1	39.37		0.19	0.18	0.17	0.18

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	3.97E-04					
2	1	1.00E-04					
3	2	1.00E-01	300	3			
4	3	5.00E-09					
5	1	1.00E-04					
6	2	1.00E-01	100	2			
7	3	5.00E-09					
8	1	1.00E-08					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	2				
4	3				
5	1				
6	2				
7	3				
8	1				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLF.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLFout.OUT

TIME:  14:30     DATE:   9/11/2003

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

     TITLE:  SDF GCL CC with EB w/o Layers Above + Backfill Layer

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =    12.00   INCHES
           POROSITY                     =     0.0600 VOL/VOL
           FIELD CAPACITY               =     0.0560 VOL/VOL
           WILTING POINT                =     0.0520 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.0560 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.396999996000E-03 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =    12.00   INCHES
           POROSITY                     =     0.3700 VOL/VOL
           FIELD CAPACITY               =     0.2400 VOL/VOL
           WILTING POINT                =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

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

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3800 VOL/VOL
FIELD CAPACITY              =      0.0800 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    300.0    FEET

                         LAYER  4
                         --------

              TYPE 3 - BARRIER SOIL LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

                         LAYER  5
                         --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     37.28   INCHES
POROSITY                    =      0.3700 VOL/VOL
FIELD CAPACITY              =      0.2400 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                         LAYER  6
                         --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      6.00   INCHES
POROSITY                    =      0.3800 VOL/VOL
FIELD CAPACITY              =      0.0800 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =      2.00   PERCENT
DRAINAGE LENGTH             =    100.0    FEET
```

```
                              LAYER  7
                              --------

                    TYPE 3 - BARRIER SOIL LINER
                    MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     0.20   INCHES
   POROSITY                     =     0.7500 VOL/VOL
   FIELD CAPACITY               =     0.7470 VOL/VOL
   WILTING POINT                =     0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

                              LAYER  8
                              --------

                TYPE 1 - VERTICAL PERCOLATION LAYER
                    MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    39.37   INCHES
   POROSITY                     =     0.1900 VOL/VOL
   FIELD CAPACITY               =     0.1800 VOL/VOL
   WILTING POINT                =     0.1700 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.1800 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999994000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  300. FEET.

 SCS RUNOFF CURVE NUMBER            =     55.70
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      2.750  ACRES
 EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      3.072  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      4.420  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      1.984  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     21.326  INCHES
 TOTAL INITIAL WATER                =     21.326  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.004    0.000    0.006    0.001    0.000    0.002
                         0.040    0.134    0.044    0.010    0.000    0.000

  STD. DEVIATIONS        0.031    0.000    0.055    0.009    0.000    0.016
                         0.141    0.564    0.242    0.081    0.000    0.001

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.659    2.104    2.895    2.496    2.881    3.557
                         3.996    3.546    2.743    1.474    1.054    1.275

  STD. DEVIATIONS        0.215    0.276    0.719    0.936    1.179    1.355
                         1.303    1.177    0.965    0.671    0.274    0.191

LATERAL DRAINAGE COLLECTED FROM LAYER  3
----------------------------------------
  TOTALS                 2.7984   1.7403   1.9427   0.7366   0.7235   1.1164
                         1.6743   1.7017   1.5392   1.2998   1.4241   1.9197

  STD. DEVIATIONS        1.9382   1.5057   1.7343   0.8774   1.0945   1.1278
                         1.4276   1.5065   1.4854   1.5479   1.3494   1.4770

PERCOLATION/LEAKAGE THROUGH LAYER  4
------------------------------------
  TOTALS                 0.0470   0.0308   0.0341   0.0153   0.0142   0.0204
                         0.0296   0.0303   0.0276   0.0238   0.0255   0.0336

  STD. DEVIATIONS        0.0296   0.0229   0.0264   0.0139   0.0175   0.0176
                         0.0222   0.0231   0.0228   0.0249   0.0211   0.0226

LATERAL DRAINAGE COLLECTED FROM LAYER  6
----------------------------------------
  TOTALS                 0.0393   0.0290   0.0279   0.0143   0.0097   0.0158
                         0.0243   0.0258   0.0227   0.0191   0.0216   0.0281

  STD. DEVIATIONS        0.0252   0.0249   0.0229   0.0165   0.0148   0.0168
                         0.0204   0.0216   0.0207   0.0222   0.0217   0.0218

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
  TOTALS                 0.0052   0.0048   0.0051   0.0043   0.0034   0.0038
                         0.0046   0.0049   0.0047   0.0042   0.0042   0.0050

  STD. DEVIATIONS        0.0011   0.0007   0.0011   0.0016   0.0020   0.0018
                         0.0016   0.0013   0.0014   0.0019   0.0017   0.0013

PERCOLATION/LEAKAGE THROUGH LAYER  8
------------------------------------
  TOTALS                 0.0044   0.0041   0.0043   0.0040   0.0038   0.0033
                         0.0043   0.0049   0.0048   0.0047   0.0039   0.0042

  STD. DEVIATIONS        0.0018   0.0016   0.0017   0.0016   0.0017   0.0018
                         0.0020   0.0020   0.0018   0.0018   0.0016   0.0017
```

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  4
  -------------------------------------
    AVERAGES                1.5955  1.0877  1.1064  0.4335  0.4121  0.6570
                            0.9535  0.9695  0.9060  0.7481  0.8383  1.0933

    STD. DEVIATIONS         1.1091  0.9449  0.9877  0.5164  0.6233  0.6637
                            0.8131  0.8590  0.8749  0.9132  0.7948  0.8412

  DAILY AVERAGE HEAD ON TOP OF LAYER  7
  -------------------------------------
    AVERAGES                0.0112  0.0091  0.0079  0.0042  0.0028  0.0046
                            0.0069  0.0073  0.0067  0.0054  0.0064  0.0080

    STD. DEVIATIONS         0.0072  0.0078  0.0065  0.0049  0.0042  0.0049
                            0.0058  0.0062  0.0061  0.0063  0.0064  0.0062

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                     INCHES          CU. FEET      PERCENT
                               -------------------  -------------  ---------
 PRECIPITATION                  48.90    (   7.734)    488145.2     100.00

 RUNOFF                          0.242   (  0.6679)      2417.56      0.495

 EVAPOTRANSPIRATION             29.682   (  2.9830)    296295.75     60.698

 LATERAL DRAINAGE COLLECTED     18.61667 (  6.14783)   185840.937   38.07083
   FROM LAYER  3

 PERCOLATION/LEAKAGE THROUGH     0.33195 (  0.09598)     3313.694     0.67883
   LAYER  4

 AVERAGE HEAD ON TOP             0.900 (    0.298)
   OF LAYER  4

 LATERAL DRAINAGE COLLECTED      0.27766 (  0.09292)     2771.740    0.56781
   FROM LAYER  6

 PERCOLATION/LEAKAGE THROUGH     0.05421 (  0.00663)      541.156     0.11086
   LAYER  7

 AVERAGE HEAD ON TOP             0.007 (    0.002)
   OF LAYER  7

 PERCOLATION/LEAKAGE THROUGH     0.05068 (  0.01463)      505.949     0.10365
   LAYER  8

 CHANGE IN WATER STORAGE         0.031   (  1.1480)       313.35      0.064
```

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	68579.773
RUNOFF	3.050	30444.9980
DRAINAGE COLLECTED FROM LAYER 3	0.68773	6865.29834
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.021956	219.17435
AVERAGE HEAD ON TOP OF LAYER 4	25.619	
MAXIMUM HEAD ON TOP OF LAYER 4	33.687	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	104.6 FEET	
DRAINAGE COLLECTED FROM LAYER 6	0.00934	93.25857
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000240	2.39750
AVERAGE HEAD ON TOP OF LAYER 7	0.082	
MAXIMUM HEAD ON TOP OF LAYER 7	0.160	
LOCATION OF MAXIMUM HEAD IN LAYER 6 (DISTANCE FROM DRAIN)	2.7 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 8	0.000392	3.91279
SNOW WATER	2.36	23561.8457

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2009
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0902

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	0.8125	0.0677
2	3.3621	0.2802
3	3.1156	0.2596
4	0.1500	0.7500
5	8.9477	0.2400
6	0.4874	0.0812
7	0.1500	0.7500
8	7.4393	0.1890
SNOW WATER	0.000	

****
****

Appendix O, Intact SDF GCL Closure Cap (0 Years): HELP Model Input Data and Output File (output file name: ZGCLIout.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	6		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.056	0.052	0.056
4	1	12		0.37	0.24	0.136	0.24
5	2	12		0.38	0.08	0.013	0.08
6	3	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.38	0.08	0.013	0.08
9	3	0.2		0.75	0.747	0.40	0.75

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.97E-04					
4	1	1.00E-04					
5	2	1.00E-01	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-01	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3				
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLI.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLIout.OUT

TIME:   8:22     DATE:   9/16/2003

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

     TITLE:  Intact SDF GCL Closure Cap - 0 years

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

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

                                   LAYER  1
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =      6.00   INCHES
           POROSITY                     =      0.4000 VOL/VOL
           FIELD CAPACITY               =      0.1100 VOL/VOL
           WILTING POINT                =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     30.00   INCHES
           POROSITY                     =      0.3700 VOL/VOL
           FIELD CAPACITY               =      0.2400 VOL/VOL
           WILTING POINT                =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0600 VOL/VOL
FIELD CAPACITY              =      0.0560 VOL/VOL
WILTING POINT               =      0.0520 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0560 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.396999996000E-03 CM/SEC

                        LAYER  4
                        --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3700 VOL/VOL
FIELD CAPACITY              =      0.2400 VOL/VOL
WILTING POINT               =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                        LAYER  5
                        --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3800 VOL/VOL
FIELD CAPACITY              =      0.0800 VOL/VOL
WILTING POINT               =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    350.0    FEET

                        LAYER  6
                        --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   INCHES
POROSITY                    =      0.7500 VOL/VOL
FIELD CAPACITY              =      0.7470 VOL/VOL
WILTING POINT               =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

```
                            LAYER  7
                            --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
    THICKNESS                   =    58.65   INCHES
    POROSITY                    =     0.3700 VOL/VOL
    FIELD CAPACITY              =     0.2400 VOL/VOL
    WILTING POINT               =     0.1360 VOL/VOL
    INITIAL SOIL WATER CONTENT  =     0.2400 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                            LAYER  8
                            --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
    THICKNESS                   =    24.00   INCHES
    POROSITY                    =     0.3800 VOL/VOL
    FIELD CAPACITY              =     0.0800 VOL/VOL
    WILTING POINT               =     0.0130 VOL/VOL
    INITIAL SOIL WATER CONTENT  =     0.0800 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.100000001000     CM/SEC
    SLOPE                       =     2.00   PERCENT
    DRAINAGE LENGTH             =   125.0    FEET

                            LAYER  9
                            --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
    THICKNESS                   =     0.20   INCHES
    POROSITY                    =     0.7500 VOL/VOL
    FIELD CAPACITY              =     0.7470 VOL/VOL
    WILTING POINT               =     0.4000 VOL/VOL
    INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
    EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

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

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
           AND A SLOPE LENGTH OF  350. FEET.

 SCS RUNOFF CURVE NUMBER            =    55.20
 FRACTION OF AREA ALLOWING RUNOFF   =   100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =     2.009  ACRES
 EVAPORATIVE ZONE DEPTH             =    22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =     4.500  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =     8.320  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =     2.524  INCHES
 INITIAL SNOW WATER                 =     0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =    28.668  INCHES
 TOTAL INITIAL WATER                =    28.668  INCHES
 TOTAL SUBSURFACE INFLOW            =     0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.004    0.000    0.004    0.000    0.000    0.002
                           0.027    0.092    0.017    0.006    0.003    0.001

  STD. DEVIATIONS          0.021    0.000    0.028    0.000    0.003    0.016
                           0.094    0.406    0.089    0.059    0.017    0.005

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.093    3.072    3.552    3.663    4.139
                           4.899    4.522    3.384    1.619    0.948    1.114

  STD. DEVIATIONS          0.222    0.236    0.582    0.761    1.526    1.543
                           1.587    1.377    1.037    0.606    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                   2.5799   2.0256   1.9424   1.1514   0.3866   0.3164
                           0.5761   0.8312   0.7442   0.7852   0.9193   1.5559

  STD. DEVIATIONS          1.8903   1.5304   1.5549   1.0167   0.4639   0.6078
                           0.8494   1.0755   1.0607   1.1041   1.2425   1.3882

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                   0.0502   0.0403   0.0393   0.0251   0.0114   0.0085
                           0.0136   0.0183   0.0168   0.0172   0.0195   0.0314

  STD. DEVIATIONS          0.0334   0.0270   0.0273   0.0180   0.0087   0.0118
                           0.0159   0.0199   0.0195   0.0206   0.0229   0.0255

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                   0.0406   0.0379   0.0340   0.0236   0.0076   0.0053
                           0.0094   0.0140   0.0129   0.0135   0.0158   0.0251

  STD. DEVIATIONS          0.0271   0.0262   0.0258   0.0213   0.0081   0.0103
                           0.0139   0.0177   0.0181   0.0189   0.0221   0.0225

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                   0.0054   0.0051   0.0056   0.0052   0.0047   0.0030
                           0.0036   0.0039   0.0039   0.0036   0.0036   0.0044

  STD. DEVIATIONS          0.0010   0.0003   0.0004   0.0008   0.0013   0.0020
                           0.0021   0.0021   0.0020   0.0023   0.0022   0.0020
```

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES              1.7142   1.4774   1.2906   0.7906   0.2569   0.2172
                          0.3828   0.5523   0.5110   0.5217   0.6312   1.0338

    STD. DEVIATIONS       1.2560   1.1235   1.0331   0.6981   0.3082   0.4173
                          0.5644   0.7146   0.7282   0.7336   0.8531   0.9224

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES              0.0145   0.0148   0.0121   0.0087   0.0027   0.0020
                          0.0034   0.0050   0.0047   0.0048   0.0058   0.0089

    STD. DEVIATIONS       0.0096   0.0102   0.0092   0.0078   0.0029   0.0038
                          0.0049   0.0063   0.0066   0.0067   0.0081   0.0080

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

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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                   INCHES           CU. FEET      PERCENT
                             -------------------  -------------  ---------
 PRECIPITATION                48.90    (   7.734)    356612.3     100.00

 RUNOFF                        0.157   (  0.4361)      1144.49      0.321

 EVAPOTRANSPIRATION           34.585   (  3.6256)    252214.09     70.725

 LATERAL DRAINAGE COLLECTED   13.81415 (  5.55476)   100742.070   28.24975
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH   0.29165 (  0.10183)     2126.873    0.59641
   LAYER  6

 AVERAGE HEAD ON TOP           0.782 (    0.314)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED    0.23978 (  0.09591)     1748.605   0.49034
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH   0.05183 (  0.00844)      378.011    0.10600
   LAYER  9

 AVERAGE HEAD ON TOP           0.007 (    0.003)
   OF LAYER  9

 CHANGE IN WATER STORAGE       0.053   (  1.8302)       385.10     0.108

*******************************************************************************
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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.651	19332.4668
DRAINAGE COLLECTED FROM LAYER 5	0.56662	4132.19678
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.013443	98.03295
AVERAGE HEAD ON TOP OF LAYER 6	15.608	
MAXIMUM HEAD ON TOP OF LAYER 6	22.471	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	90.6 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00843	61.48439
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000249	1.81695
AVERAGE HEAD ON TOP OF LAYER 9	0.093	
MAXIMUM HEAD ON TOP OF LAYER 9	0.181	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	3.1 FEET	
SNOW WATER	2.36	17212.9980
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3691	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1147	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6123	0.2687
2	9.2093	0.3070
3	0.7200	0.0600
4	4.1110	0.3426
5	1.9966	0.1664
6	0.1500	0.7500
7	14.0760	0.2400
8	1.9235	0.0801
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix P, SDF GCL Closure Cap Degraded Property Value Calculations

The SDF GCL closure cap initial (0 year) layer thickness and hydraulic property values from top to bottom are provided in Table 4.7-1. The degradation scenarios for each layer are provided in Table 5.4-1. Based upon the Table 5.4-1 degradation scenarios, the Table 4.7-1 initial SDF closure cap layer thickness and hydraulic property values have been modified to account for degradation at 100, 300, 550, 1,000, 1,800, 3,400, 5,600 and 10,000 years after closure of the SDF.

Topsoil and Upper Backfill Layer Thickness:

From Section 5.2 the soil loss in terms of depth of loss per year for the topsoil and upper backfill was estimated to be 1.8E-04 inches/year and 1.1 E-04 inches/year, respectively.

Topsoil Thickness Over Time Calculation:

Year	Thickness
0	6” – (0 years × 1.8E-04 inches/year) = 6”
100	6” – (100 years × 1.8E-04 inches/year) = 5.982”
300	6” – (300 years × 1.8E-04 inches/year) = 5.946”
550	6” – (550 years × 1.8E-04 inches/year) = 5.901”
1,000	6” – (1000 years × 1.8E-04 inches/year) = 5.820”
1,800	6” – (1800 years × 1.8E-04 inches/year) = 5.676”
3,400	6” – (3400 years × 1.8E-04 inches/year) = 5.388”
5,600	6” – (5600 years × 1.8E-04 inches/year) = 4.992”
10,000	6” – (10000 years × 1.8E-04 inches/year) = 4.2”

Since the topsoil does not completely erode away within the 10,000 years of interest, no reduction in the upper backfill layer occurs.

Erosion Barrier Hydraulic Properties:

Maintenance during institutional control period prevents degradation of the erosion control barrier. Subsequent to the institutional control period, pine forest succession will results in root penetration through the erosion control barrier. This does not impact its ability to function as an erosion barrier, however it allows the overlying backfill to fill the holes after the roots decompose. It is assumed that the hydraulic conductivity of the infiltrating backfill increases one order of magnitude (i.e. from 1.0E-04 to 1.0E-03 cm/s) when it falls into the hole since it will not be mechanically compacted at that time. The hydraulic properties of the erosion barrier as a whole change as the backfill material fills the root penetration holes.

From Section 5.1 the following assumptions relative to the succession of bamboo by a pine forest that impact the erosion barrier hydraulic properties were made:

- 200 years after the end of institutional control it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre).
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

Very little erosion of the topsoil is estimated for the institutional control to pine forest, land use scenario, within the 10,000 years of interest. Therefore the estimated thickness of the topsoil layer at 10,000 years (~4 inches) has been utilized to determine the area of the holes in the erosion barrier created by root penetration. This is a conservative assumption.

Area of holes in erosion barrier due to root penetration:

Average Erosion Barrier Depth (see Table 4.7-1) = 4” + 30” + ½(12”) = 40” ≈ 3.3’

Root Diameter for 4-6’ roots at 3.3’:

3” diameter at 1’ depth and 0.25” at 6’

$$(3''-0.25'')/(6'-1') = 0.55''/\ ft$$

Diameter = 0.25” + [(6’ – 3.3’) × 0.55”/ft] = 1.74”

Area of for 4-6’ roots at 3.3’:

Area = $4 \times \frac{1}{4}\pi D^2 = \pi D^2 = \pi(1.74'')^2 = 9.5\ in^2$

Root Diameter for 1-12’ root at 3.3’:

3” diameter at 1’ depth and 0.25” at 12’

$$(3''-0.25'')/(12'-1') = 0.25''/\ ft$$

Diameter = 0.25” + [(12’ – 3.3’) × 0.25”/ft] = 2.4”

Area of for 1-12’ roots at 3.3’:

Area = $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi(2.4'')^2 = 4.5\ in^2$

Total area of holes in erosion barrier per tree:

Total area = $9.5\ in^2 + 4.5\ in^2 = 14\ in^2 \times ft^2/144\ in^2 \approx 0.1\ ft^2$/tree

Total area of holes per acre per 100 years:

400 trees/acre/100 years

Total area = $0.1\ ft^2$/tree × 400 trees/acre/100 years = $40\ ft^2$/ acre/100 years

Year	Area of holes in erosion barrier / acre
0	0
100	0
300 [1]	$40\ ft^2$/ acre
550	$40\ ft^2$/ acre + [(550 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $140\ ft^2$/ acre
1,000	$40\ ft^2$/ acre + [(1000 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $320\ ft^2$/ acre
1,800	$40\ ft^2$/ acre + [(1800 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $640\ ft^2$/ acre
3,400	$40\ ft^2$/ acre + [(3400 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $1280\ ft^2$/ acre
5,600	$40\ ft^2$/ acre + [(5600 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $2160\ ft^2$/ acre
10,000	$40\ ft^2$/ acre + [(10000 yrs – 300 yrs) × $40\ ft^2$/ acre/100 years = $3920\ ft^2$/ acre

[1] 200 years after the end of institutional control (i.e. at year 300) it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre). It is assumed that each “generation” of roots becomes instantaneous voids at the 100-year turnover period.

Year	Fraction (f) of erosion barrier area comprising holes
0	0 ÷ 43560 ft^2/ acre = 0
100	0 ÷ 43560 ft^2/ acre = 0
300	40 ft^2/ acre ÷ 43560 ft^2/ acre = 0.00092
550	140 ft^2/ acre ÷ 43560 ft^2/ acre = 0.00321
1,000	320 ft^2/ acre ÷ 43560 ft^2/ acre = 0.00735
1,800	640 ft^2/ acre ÷ 43560 ft^2/ acre = 0.0147
3,400	1280 ft^2/ acre ÷ 43560 ft^2/ acre = 0.0294
5,600	2160 ft^2/ acre ÷ 43560 ft^2/ acre = 0.0496
10,000	3920 ft^2/ acre ÷ 43560 ft^2/ acre = 0.08999

The equivalent horizontal hydraulic conductivity for horizontal flow in a series of horizontal layers with different saturated hydraulic conductivities can be determined from the following equation (Freeze and Cherry 1979):

$$K_h = \sum_{i=1}^{n} \frac{K_i \; d_i}{d}$$

, where K_h = equivalent horizontal saturated hydraulic conductivity, K_i = horizontal saturated hydraulic conductivity of i^{th} layer, d_i = thickness of i^{th} layer, d = total thickness

In a similar manner the equivalent vertical hydraulic conductivity for vertical flow in a horizontal zone containing areas of materials with different saturated hydraulic conductivities can be determined based upon an area proportionality as follows:

$$K_v = \sum_{i=1}^{n} \frac{K_i \; A_i}{A}$$

, where K_v = equivalent vertical saturated hydraulic conductivity, K_i = vertical saturated hydraulic conductivity of i^{th} layer, A_i = Area of i^{th} layer, A = total area

The following are the input saturated hydraulic conductivities:

For backfill that drops into holes in the erosion barrier = 1.0E-03 cm/s

Intact erosion barrier = 3.97E-04 cm/s

The fraction (F) provided above is equivalent to A_i/A for the backfill that drops into holes in the erosion barrier and one minus the fraction (1 – F) is equivalent to A_i/A for the for the intact erosion barrier, making the equation:

K_v = (1.0E-03 × F) + (3.97E-04 × (1 – F))

Year	K_v
0	(1.0E-03 cm/s × 0) + (3.97E-04 cm/s × (1 – 0)) = 3.97E-04 cm/s
100	(1.0E-03 cm/s × 0) + (3.97E-04 cm/s × (1 – 0)) = 3.97E-04 cm/s
300	(1.0E-03 cm/s × 0.00092) + (3.97E-04 cm/s × (1 – 0.00092)) = 3.98 E-04 cm/s
550	(1.0E-03 cm/s × 0.00321) + (3.97E-04 cm/s × (1 – 0.00321)) = 3.99E-04 cm/s
1,000	(1.0E-03 cm/s × 0.00735) + (3.97E-04 cm/s × (1 – 0.00735)) = 4.01E-04 cm/s
1,800	(1.0E-03 cm/s × 0.0147) + (3.97E-04 cm/s × (1 – 0.0147)) = 4.06E-04 cm/s
3,400	(1.0E-03 cm/s × 0.0294) + (3.97E-04 cm/s × (1 – 0.0294)) = 4.15E-04 cm/s
5,600	(1.0E-03 cm/s × 0.0496) + (3.97E-04 cm/s × (1 – 0.0496)) = 4.27E-04 cm/s
10,000	(1.0E-03 cm/s × 0.08999) + (3.97E-04 cm/s × (1 – 0.08999)) = 4.51E-04 cm/s

In an analogous manner the equivalent porosity (n), field capacity (FC), and wilting point (WP) can be determined based upon an area proportionality as follows:

$$n = \sum_{i=1}^{n} n_i \; A_i$$

$$FC = \sum_{i=1}^{n} FC_i \; A_i$$

$$WP = \sum_{i=1}^{n} WP_i \; A_i$$

The following are the input properties:

Material	Porosity	Field Capacity	Wilting Point
Backfill	0.37	0.24	0.136
Erosion Barrier	0.06	0.056	0.052

Year	n
0	$(0.37 \times 0) + (0.06 \times (1 - 0)) = 0.06$
100	$(0.37 \times 0) + (0.06 \times (1 - 0)) = 0.06$
300	$(0.37 \times 0.00092) + (0.06 \times (1 - 0.00092)) = 0.06$
550	$(0.37 \times 0.00321) + (0.06 \times (1 - 0.00321)) = 0.061$
1,000	$(0.37 \times 0.00735) + (0.06 \times (1 - 0.00735)) = 0.062$
1,800	$(0.37 \times 0.0147) + (0.06 \times (1 - 0.0147)) = 0.065$
3,400	$(0.37 \times 0.0294) + (0.06 \times (1 - 0.0294)) = 0.069$
5,600	$(0.37 \times 0.0496) + (0.06 \times (1 - 0.0496)) = 0.075$
10,000	$(0.37 \times 0.08999) + (0.06 \times (1 - 0.08999)) = 0.088$

Year	FC
0	$(0.24 \times 0) + (0.056 \times (1 - 0)) = 0.056$
100	$(0.24 \times 0) + (0.056 \times (1 - 0)) = 0.056$
300	$(0.24 \times 0.00092) + (0.056 \times (1 - 0.00092)) = 0.562$
550	$(0.24 \times 0.00321) + (0.056 \times (1 - 0.00321)) = 0.0566$
1,000	$(0.24 \times 0.00735) + (0.056 \times (1 - 0.00735)) = 0.0574$
1,800	$(0.24 \times 0.0147) + (0.056 \times (1 - 0.0147)) = 0.0587$
3,400	$(0.24 \times 0.0294) + (0.056 \times (1 - 0.0294)) = 0.0614$
5,600	$(0.24 \times 0.0496) + (0.056 \times (1 - 0.0496)) = 0.0651$
10,000	$(0.24 \times 0.08999) + (0.056 \times (1 - 0.08999)) = 0.0726$

Year	WP
0	$(0.136 \times 0) + (0.052 \times (1 - 0)) = 0.052$
100	$(0.136 \times 0) + (0.052 \times (1 - 0)) = 0.052$
300	$(0.136 \times 0.00092) + (0.052 \times (1 - 0.00092)) = 0.521$
550	$(0.136 \times 0.00321) + (0.052 \times (1 - 0.00321)) = 0.0523$
1,000	$(0.136 \times 0.00735) + (0.052 \times (1 - 0.00735)) = 0.0526$
1,800	$(0.136 \times 0.0147) + (0.052 \times (1 - 0.0147)) = 0.0532$
3,400	$(0.136 \times 0.0294) + (0.052 \times (1 - 0.0294)) = 0.0545$
5,600	$(0.136 \times 0.0496) + (0.052 \times (1 - 0.0496)) = 0.0562$
10,000	$(0.136 \times 0.08999) + (0.052 \times (1 - 0.08999)) = 0.0596$

Summary Erosion Barrier Hydraulic Properties with Time:

Year	K_v	n	FC	WP
0	3.97E-04 cm/s	0.06	0.056	0.052
100	3.97E-04 cm/s	0.06	0.056	0.052
300	3.98 E-04 cm/s	0.06	0.562	0.521
550	3.99E-04 cm/s	0.061	0.0566	0.0523
1,000	4.01E-04 cm/s	0.062	0.0574	0.0526
1,800	4.06E-04 cm/s	0.065	0.0587	0.0532
3,400	4.15E-04 cm/s	0.069	0.0614	0.0545
5,600	4.27E-04 cm/s	0.075	0.0651	0.0562
10,000	4.51E-04 cm/s	0.088	0.0726	0.0596

Upper GCL Holes:

Maintenance during the institutional control period prevents degradation of the upper GCL. However pine forest succession and associated root penetration results in holes through the erosion barrier. This allows the overlying drainage layer to fill the holes after the roots decompose. The holes in the GCL essentially act as direct conduits from the upper drainage layer to the lower backfill layer. When saturated conditions occur in the drainage layer after major precipitation events, cones of depression are created around the holes in the GCL with a radius of influence much greater than the radius of the hole. This means that a small area of GCL holes can greatly reduce the lateral flow of water in the drainage layer and increase the vertical flow into the lower backfill.

From Section 5.1 the following assumptions were made relative to the succession of bamboo by a pine forest that result in root penetration into the upper GCL:

- 200 years after the end of institutional control it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre).
- Complete turnover of the 400 mature trees per acre occurs every 100 years (in a staggered manner).
- There are 400 mature trees per acre with 4 roots to 6 feet and 1 root to 12 feet. The roots are 3 inches in diameter at a depth of 1 foot and 0.25 inches in diameter at either 6 or 12 feet, whichever is applicable.

Very little erosion of the topsoil is estimated for the institutional control to pine forest, land use scenario, within the 10,000 years of interest. Therefore the estimated thickness of the topsoil layer at 10,000 years (~4 inches) has been utilized to determine the area of the holes in the upper GCL created by root penetration. This is a conservative assumption.

Area of holes in upper GCL due to root penetration:

Upper GCL Depth (see Table 4.7-1) = 4” + 30” + 12” + 12” + 12” = 70” ≈ 5.8’

Root Diameter for 4-6’ roots at 5.8’:

3” diameter at 1’ depth and 0.25” at 6’

$$(3''-0.25'')/(6'-1') = 0.55''/\ ft$$

Diameter = 0.25” + [(6’ – 5.8’) × 0.55”/ft] = 0.36”

Area of for 4-6’ roots at 5.8’:

Area = $4 \times \frac{1}{4}\pi D^2 = \pi D^2 = \pi(0.36'')^2 = 0.41\ in^2$

Root Diameter for 1-12’ root at 3.3’:

3” diameter at 1’ depth and 0.25” at 12’

$$(3''-0.25'')/(12'-1') = 0.25''/\ ft$$

Diameter = 0.25” + [(12’ – 5.8’) $\times$ 0.25”/ft] = 1.8”

Area of for 1-12’ roots at 3.3’:

Area = $\frac{1}{4}\pi D^2 = \frac{1}{4}\pi(1.8\text{”})^2 = 2.54\ in^2$

Total area of holes in erosion barrier per tree:

Total area = $0.41\ in^2 + 2.54\ in^2 = 2.95\ in^2 \times ft^2/144\ in^2 \approx 0.02\ ft^2$/tree

Total area of holes per acre per 100 years:

400 trees/acre/100 years

Total area = 0.02 ft^2/tree $\times$ 400 trees/acre/100 years = 8 ft^2/ acre/100 years

Year	Area of holes in upper GCL / acre due to root penetration
0	0
100	0
300 [1]	8 ft^2/ acre
550	8 ft^2/ acre + [(550 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 28 ft^2/ acre
1,000	8 ft^2/ acre + [(1000 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 64 ft^2/ acre
1,800	8 ft^2/ acre + [(1800 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 128 ft^2/ acre
3,400	8 ft^2/ acre + [(3400 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 256 ft^2/ acre
5,600	8 ft^2/ acre + [(5600 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 432 ft^2/ acre
10,000	8 ft^2/ acre + [(10000 yrs – 300 yrs) $\times$ 8 ft^2/ acre/100 years = 784 ft^2/ acre

[1] 200 years after the end of institutional control (i.e. at year 300) it is assumed that the entire cap is covered with pine (i.e. 400 mature trees per acre)

Number of one-square-centimeter holes in upper GCL per acre due to root penetration (each HELP model installation defect for a flexible membrane liner (FML) is assumed to be one square centimeter):

1 cm^2 = 0.001076391 ft^2 so 0.001076391 ft^2/installation defect

Year	Percent of GCL area degraded due to root penetration
0	0
100	0
300	(8 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.018
550	(28 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.064
1,000	(64 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.15
1,800	(128 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.29
3,400	(256 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.59
5,600	(432 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 0.99
10,000	(784 ft^2/ acre $\div$ 43560 ft^2/ acre) $\times$ 100 = 1.8

Year	# of installation defects in upper GCL / acre due to root penetration
0	0
100	0
300	8 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 7,432
550	28 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 26,013
1,000	64 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 59,458
1,800	128 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 118,916
3,400	256 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 237,832
5,600	432 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 401,341
10,000	784 ft^2/ acre ÷ 0.001076391 ft^2/installation defect = 728,360

Middle Backfill Layer and Upper Drainage Layer Hydraulic Properties:

It is assumed that colloidal clay migration from the 1-foot-thick middle backfill to the underlying 1-foot-thick upper drainage layer causes the middle backfill saturated hydraulic conductivity to increase over time and that of the upper drainage layer to decrease over time.

Determine mass of clay to fill upper drainage layer void volume (0.38):

Assume clay bulk density is 1.1 g/cm^3

Look at a 1-ft^2 area of the 1-foot-thick upper drainage layer (i.e. 1 ft^3)

Void volume = 0.38 × 1 ft^3 = 0.38 ft^3

Clay mass per ft^3 = 1.1 g/cm^3 × 0.38 ft^3 × 2.831685E-02 m^3/ft^3 × 1,000,000 cm^3/m^3 = 11,836.3 g

Determine available clay mass in the middle backfill layer:

Assume that the middle backfill layer consists of 20% clay and 80% sand with a dry bulk density of 104-lbs/ ft^3.

Clay mass = 104 lbs/ft^3 × 0.20 × 453.59 g/lbs = 9,434.7 g/ft^3

There is not enough clay in the middle backfill layer to fill the upper drainage layer. Therefore it will be assumed that half the clay content of the middle backfill migrates into the upper drainage layer, at which point the two layers essentially become the same material and material property changes cease. Based upon this it will be assumed that the endpoint saturated hydraulic conductivity of the layers will become that of the log mid-point between the initial backfill and upper drainage layer conditions. It will also be assumed that the endpoint porosity, field capacity, and wilting point will become the arithmetic average of the backfill and upper drainage layer.

Endpoint hydraulic properties:

Intact hydraulic properties:

Hydraulic Parameter	Middle Backfill	Upper Drainage Layer
K	1.0E-04 cm/s	1.0E-01
n	0.37	0.38
FC	0.24	0.08
WP	0.136	0.013

Endpoint saturated hydraulic conductivity:

Middle backfill: K_{MB} = 0.0001; log K_{MB} = -4

Upper drainage layer: K_{UDL} = 0.1; log K_{UDL} = -1

Log mid-point: $$\frac{Log\ K_{MB} + Log\ K_{UDL}}{2} = \frac{-1 + (-4)}{2} = -2.5$$

$K_E = 10^{-2.5} = 3.2E\text{-}03$ cm/s

Endpoint n, FC, and WP:

n = (0.37 + 0.38)/2 = 0.375

FC = (0.24 + 0.08)/2 = 0.16

WP = (0.136 + 0.013)/2 = 0.0745

It will be assumed that the clay migrates out of the middle backfill into the upper drainage layer with the water flux containing 63 mg/L of colloidal clay. It will also be assumed that the time to achieve the endpoint conditions will be based upon the estimated water flux into the upper drainage layer and migration of half the clay content of the middle backfill layer (i.e. 9,434.7 g/ft^3 ÷ 2 = 4717.4 g/ft^3).

Determine flux of water into the upper drainage layer:

Section 4.7 intact SDF GCL HELP Modeling determined the following average annual flux of water into the upper drainage layer (see Appendix O):

Precipitation = 48.90 inches/year

Runoff = 0.157 inches/year

Evapotranspiration = 34.585 inches/year

Flux of water into upper drainage layer = Precipitation – (Runoff + Evapotranspiration)

Flux of water into upper drainage layer = 48.90 in/yr – (0.157 in/yr + 34.585 in/yr)

Flux of water into upper drainage layer = 14.158 in/yr

The above flux is based upon the best case cap conditions; therefore, will redetermine the flux based upon the worse case conditions as follows:

- 10,000 year eroded topsoil at 4.2 inches (see above)
- 10,000 year erosion barrier conditions with K = 4.51E-04 cm/s; n = 0.088; FC = 0.0726; WP = 0.0596 (see above)
- Middle backfill and upper drainage layer at end state conditions with K = 3.2E-03 cm/s; n = 0.375; FC = 0.16; WP = 0.0745 (see above)
- Upper GCL with 728,360 holes
- Lower drainage layer with intact backfill properties

The detailed HELP model input data and output file associated with the worse case conditions is provided at the end of this appendix. The following are the pertinent values extracted from the output file:

Precipitation = 48.90 inches/year

Runoff = 0.173 inches/year

Evapotranspiration = 34.553 inches/year

Flux of water into upper drainage layer = Precipitation – (Runoff + Evapotranspiration)

Flux of water into upper drainage layer = 48.90 in/yr – (0.173 in/yr + 34.553 in/yr)

Flux of water into upper drainage layer = 14.174 in/yr

There is not much difference between the flux into the upper drainage layer with either the intact or worse case conditions. Therefore, a water flux into the upper drainage layer of ~14.2 in/yr will be used for determination of the time when the endpoint properties are reached.

Determine yearly clay migration into the upper drainage layer:

Flux into upper drainage layer = 14.2 in/yr

Colloidal clay concentration = 63 mg/L

Flux through a 1 ft^2 area = 14.2 in/yr $\times$ ft/12 in $\times$ 1 ft^2 = 1.18 ft^2/yr

Clay flux = 1.18 ft^2/yr $\times$ 63 mg/L $\times$ 2.831685E-02 m^3/ ft^3 $\times$ 1000L/ m^3 = 2,105 mg/yr = 2.1 g/yr

Determine time it takes for the 4717.4 g of clay to migrate from the middle backfill layer to the upper drainage layer:

Time = 4717.4 g ÷ 2.1 g/yr = 2,246 years

Determine middle backfill and upper drainage layer hydraulic property variation with time:

It will be assumed that the K of the middle backfill layer is increasing log linearly with time from 1.0E-04 cm/s to 3.2E-03 cm/s, until year 2,246 at which time the K becomes static. Conversely it will be assumed that the K of the upper drainage layer is decreasing log linearly with time from 1.0E-01 cm/s to 3.2E-03 cm/s, until year 2,246 at which time the K becomes static. Porosity (n), FC, and WP will be assumed to behave similarly but in an arithmetic linear manner.

Initial and End State hydraulic properties:

Hydraulic Parameter	Initial Middle Backfill	Initial Upper Drainage Layer	End State at 2,246 years
K	1.0E-04 cm/s	1.0E-01	3.2E-03 cm/s
n	0.37	0.38	0.375
FC	0.24	0.08	0.16
WP	0.136	0.013	0.0745

Determine fraction change for each year:

Year	Fraction
0	0 ÷ 2246 = 0
100	100 ÷ 2246 = 0.0445
300	300 ÷ 2246 = 0.1336
550	550 ÷ 2246 = 0.2449
1,000	1000 ÷ 2246 = 0.4452
1,800	1800 ÷ 2246 = 0.8014
3,400	1.0
5,600	1.0
10,000	1.0

Determine variation in K, n, FC, and WP with time in the middle backfill:

Year	Fraction, F	K [1]	n [2]	FC [3]	WP [4]
0	0	0.0001	0.37	0.24	0.136
100	0.0445	0.00012	0.37	0.236	0.133
300	0.1336	0.00016	0.371	0.229	0.128
550	0.2449	0.00023	0.371	0.220	0.121
1,000	0.4452	0.00046	0.372	0.204	0.109
1,800	0.8014	0.0016	0.374	0.176	0.0867
3,400	1.0	0.0032	0.375	0.16	0.0745
5,600	1.0	0.0032	0.375	0.16	0.0745
10,000	1.0	0.0032	0.375	0.16	0.0745

[1] $K = 10^{[-4+((-2.5-(-4))F)]} = 10^{(-4+1.5F)}$

[2] n = 0.37 + (0.375 – 0.37)F

[3] FC = 0.24 – (0.24 – 0.16)F

[4] WP = 0.136 – (0.136 – 0.0745)F

Determine variation in K, n, FC, and WP with time in the upper drainage layer:

Year	Fraction, F	K [1]	n [2]	FC [3]	WP [4]
0	0	0.1	0.38	0.08	0.013
100	0.0445	0.086	0.38	0.084	0.016
300	0.1336	0.063	0.379	0.089	0.021
550	0.2449	0.043	0.379	0.10	0.028
1,000	0.4452	0.021	0.378	0.116	0.040
1,800	0.8014	0.0063	0.376	0.144	0.062
3,400	1.0	0.0032	0.375	0.16	0.0745
5,600	1.0	0.0032	0.375	0.16	0.0745
10,000	1.0	0.0032	0.375	0.16	0.0745

[1] $K = 10^{[-1+((-2.5-(-1))F)]} = 10^{(-1-1.5F)}$

[2] n = 0.38 - (0.38 – 0.375)F

[3] FC = 0.08 – (0.16 – 0.08)F

[4] WP = 0.013 – (0.0745 – 0.013)F

Lower Drainage Layer Hydraulic Properties:

It is assumed that colloidal clay migration from the overlying backfill is driven by the water flux through the upper GCL. This water flux driven clay migration enters into the 2-foot thick lower drainage layer and fills the lower drainage layer from the bottom up. This reduces the saturated hydraulic conductivity of the clay filled portion from 1.0E-01 to 1.0E-04 cm/s (i.e. the saturated hydraulic conductivity of the overlying backfill layer). As the thickness of the lower drainage layer filled with clay increases the overall hydraulic conductivity of the layer decreases. This is different from that assumed for the upper drainage layer since the lower drainage layer has significantly more backfill overlying it. The HELP model was run for each year with all of the previously degraded properties (see above) without degradation of the lower drainage layer in order to determine the infiltration through the upper GCL. The results are as follows:

Year	Infiltration through upper GCL (inches/year)
0	0.29165
100	0.33135
300	2.48161
550	7.01335
1,000	11.55066
1,800	13.65308
3,400	14.00566
5,600	14.05202
10,000	14.09426

It is assumed that there is a linear increase in the infiltration over time between data points.

Determine cumulative volume of water through the lower drainage layer over time:

Year	Infiltration through upper GCL (inches/year)	Time Step Volume [1] (inches)	Cumulative Volume [2] (inches)	Cumulative Volume over one ft^2 area [3] (ft^3)
0	0.29165	0	0	0
100	0.33135	31.15	31.15	2.6
300	2.48161	281.296	312.45	26.0
550	7.01335	1186.87	1499.32	124.9
1,000	11.55066	4176.90	5676.22	473.0
1,800	13.65308	10081.496	15757.72	1313.1
3,400	14.00566	22126.99	37884.71	3157.0
5,600	14.05202	30863.448	68748.16	5729.0
10,000	14.09426	61921.816	130669.98	10889.2

[1] $V = [I_1 \times (T_2 - T_1)] + [1/2 \times (I_2 - I_1)(T_2 - T_1)]$, where I = infiltration at time step 1 or 2; T = time at time step 1 or 2

[2] Cumulative Volume = Previous cumulative volume + Volume at current time step

[3] Cumulative Volume over one ft^2 area = (Cumulative Volume ÷ 12 in/ft) × 1 ft^2

Determine mass of clay to fill lower drainage layer void volume (0.38):

Assume clay bulk density is 1.1 g/cm^3

Look at a 1-ft^2 area of the 2-foot-thick upper drainage layer (i.e. 2 ft^3)

Void volume = 0.38 × 2 ft^3 = 0.76 ft^3

Clay mass per ft^3 = 1.1 g/cm^3 × 0.76 ft^3 × 2.831685E-02 m^3/ft^3 × 1,000,000 cm^3/m^3 = 23,672.9 g

Determine total flux of water into the lower drainage layer required to completely fill it with clay:

It will be assumed that the clay migrates out of the lower backfill into the lower drainage layer with the water flux containing 63 mg/L of colloidal clay.

$$V = \frac{23{,}672.9\ g \times 1000\ mg/g}{63\ mg/L \times 28.31685\ L/ft^2} = 13{,}269.8\ ft^2$$

Determine the mass of clay that has migrated into the lower drainage layer at the end of each time step:

Year	Mass of clay into lower drainage layer
0	0
100	2.6 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 4.6 g
300	26.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 46.4 g
550	124.9 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 222.8 g
1,000	473.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 843.8 g
1,800	1313.1 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 2,342.5 g
3,400	3157.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 5,632.0 g
5,600	5729.0 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 10,220.3 g
10,000	10889.2 $ft^3 \times$ 63 mg/L $\times$ 28.31685 L/ $ft^3 \times$ g/1000 mg = 19, 425.9 g

Determine the fraction of the lower drainage layer filled at the end of each time step:

Year	Fraction of the lower drainage layer filled
0	0
100	4.6 g $\div$ 23,672.9 g = 0.000194
300	46.4 g $\div$ 23,672.9 g = 0.00196
550	222.8 g $\div$ 23,672.9 g = 0.00941
1,000	843.8 g $\div$ 23,672.9 g = 0.0356
1,800	2,342.5 g $\div$ 23,672.9 g = 0.0990
3,400	5,632.0 g $\div$ 23,672.9 g = 0.238
5,600	10,220.3 g $\div$ 23,672.9 g = 0.432
10,000	19, 425.9 g $\div$ 23,672.9 g = 0.820

The following are the hydraulic properties of the clean and clay filled portion of the lower drainage layer:

Material	Saturated Hydraulic Conductivity	Porosity	Field Capacity	Wilting Point
Clean	1.0E-01	0.38	0.08	0.013
Clay filled	1.0E-04	0.22 (see below)	0.21 (see below)	0.20 (see below)

Determine the porosity of the clay filled portion of the lower drainage layer:

Porosity of the clay:

Assumed clay bulk density, ρ_b = 1.1 g/cm^2

Assumed clay particle density, ρ_p = 2.6 g/cm^2

Resulting clay porosity, $n = 1 - \frac{\rho_b}{\rho_s} = 1 - \frac{1.1\ g/cm^2}{2.6\ g/cm^2} = 0.58$

Porosity of the clay filled portion = Porosity of clean portion $\times$ porosity of clay

Porosity of the clay filled portion = 0.38 $\times$ 0.58 = 0.22

Determine the field capacity and wilting point of the clay filled portion of the lower drainage layer:

Will assume that the field capacity and wilting point of the clay fill portion has the same ratio versus its porosity of 0.22 as the equivalent ratio for kaolin clay.

From WSRC 2002 the following kaolin properties are found: n = 0.56; FC = 0.55; WP = 0.50

FC = 0.22 $\times$ (0.55 $\div$ 0.56) $\approx$ 0.21

WP = 0.22 $\times$ (0.50 $\div$ 0.56) $\approx$ 0.20

Determine the equivalent horizontal hydraulic conductivity of the lower drainage layer over time:

The equivalent horizontal hydraulic conductivity for horizontal flow in a series of horizontal layers with different saturated hydraulic conductivities can be determined from the following equation (Freeze and Cherry 1979):

$K_h = \sum_{i=1}^{n} \frac{K_i \ d_i}{d}$, where K_h = equivalent horizontal saturated hydraulic conductivity, K_i = horizontal saturated hydraulic conductivity of i[th] layer, d_i = thickness of i[th] layer, d = total thickness

The fraction, F, equals d_i / d for the clay filled portion and d_i / d for the clean drainage layer material equals (1 – F), making the equation:

$$K_h = \left(K_{filled} \times F\right) + \left[K_{clean} \times (1 - F)\right]$$

Year	Equivalent K
0	0.1
100	(0.0001 × 0.000194) + [0.1 × (1 - 0.000194)] = 0.1
300	(0.0001 × 0.00196) + [0.1 × (1 - 0.00196)] = 0.0998
550	(0.0001 × 0.00941) + [0.1 × (1 - 0.00941)] = 0.0991
1,000	(0.0001 × 0.0356) + [0.1 × (1 - 0.0356)] = 0.0964
1,800	(0.0001 × 0.0990) + [0.1 × (1 - 0.0990)] = 0.0901
3,400	(0.0001 × 0.238) + [0.1 × (1 - 0.238)] = 0.0762
5,600	(0.0001 × 0.432) + [0.1 × (1 - 0.432)] = 0.0568
10,000	(0.0001 × 0.820) + [0.1 × (1 - 0.820)] = 0.0181

Determine the equivalent n, FC, and WP for the lower drainage layer over time:

In an analogous manner to that for K, the equivalent n, FC, and WP can be determined based upon the fraction filled as follows:

$$n = \left(n_{filled} \times F\right) + \left[n_{clean} \times (1 - F)\right]$$

$$FC = \left(FC_{filled} \times F\right) + \left[FC_{clean} \times (1 - F)\right]$$

$$WP = \left(WP_{filled} \times F\right) + \left[WP_{clean} \times (1 - F)\right]$$

Year	Equivalent n
0	(0.22 × 0) + [0.38 × (1 - 0)] = 0.38
100	(0.22 × 0.000194) + [0.38 × (1 - 0.000194)] = 0.38
300	(0.22 × 0.00196) + [0.38 × (1 - 0.00196)] = 0.38
550	(0.22 × 0.00941) + [0.38 × (1 - 0.00941)] = 0.378
1,000	(0.22 × 0.0356) + [0.38 × (1 - 0.0356)] = 0.374
1,800	(0.22 × 0.0990) + [0.38 × (1 - 0.0990)] = 0.364
3,400	(0.22 × 0.238) + [0.38 × (1 - 0.238)] = 0.342
5,600	(0.22 × 0.432) + [0.38 × (1 - 0.432)] = 0.311
10,000	(0.22 × 0.820) + [0.38 × (1 - 0.820)] = 0.249

Year	Equivalent FC
0	$(0.21 \times 0) + [0.08 \times (1 - 0)] = 0.08$
100	$(0.21 \times 0.000194) + [0.08 \times (1 - 0.000194)] = 0.08$
300	$(0.21 \times 0.00196) + [0.08 \times (1 - 0.00196)] = 0.0802$
550	$(0.21 \times 0.00941) + [0.08 \times (1 - 0.00941)] = 0.0812$
1,000	$(0.21 \times 0.0356) + [0.08 \times (1 - 0.0356)] = 0.0846$
1,800	$(0.21 \times 0.0990) + [0.08 \times (1 - 0.0990)] = 0.0929$
3,400	$(0.21 \times 0.238) + [0.08 \times (1 - 0.238)] = 0.111$
5,600	$(0.21 \times 0.432) + [0.08 \times (1 - 0.432)] = 0.136$
10,000	$(0.21 \times 0.820) + [0.08 \times (1 - 0.820)] = 0.187$

Year	Equivalent WP
0	$(0.20 \times 0) + [0.013 \times (1 - 0)] = 0.013$
100	$(0.20 \times 0.000194) + [0.013 \times (1 - 0.000194)] = 0.013$
300	$(0.20 \times 0.00196) + [0.013 \times (1 - 0.00196)] = 0.0134$
550	$(0.20 \times 0.00941) + [0.013 \times (1 - 0.00941)] = 0.0148$
1,000	$(0.20 \times 0.0356) + [0.013 \times (1 - 0.0356)] = 0.0196$
1,800	$(0.20 \times 0.0990) + [0.013 \times (1 - 0.0990)] = 0.0315$
3,400	$(0.20 \times 0.238) + [0.013 \times (1 - 0.238)] = 0.0575$
5,600	$(0.20 \times 0.432) + [0.013 \times (1 - 0.432)] = 0.0938$
10,000	$(0.20 \times 0.820) + [0.013 \times (1 - 0.820)] = 0.166$

Summary Lower Drainage Layer Hydraulic Properties with Time:

Year	K	n	FC	WP
0	0.1	0.38	0.08	0.013
100	0.1	0.38	0.08	0.013
300	0.0998	0.38	0.0802	0.0134
550	0.0991	0.378	0.0812	0.0148
1,000	0.0964	0.374	0.0846	0.0196
1,800	0.0901	0.364	0.0929	0.0315
3,400	0.0762	0.342	0.111	0.0575
5,600	0.0568	0.311	0.136	0.0938
10,000	0.0181	0.249	0.187	0.166

The HELP model was rerun for each time step with all of the degraded properties (see above) including that of the lower drainage layer. Infiltration through the upper GCL did not change with the addition of the degraded lower drainage layer properties. Therefore the above estimated lower drainage layer hydraulic properties over time are verified.

Vault Base Drainage Layer Hydraulic Properties:

It is assumed that colloidal clay migration from the overlying backfill is driven by the water flux through the upper GCL. This water-flux-driven clay migration enters into the 5-foot-thick vault base drainage layer and fills the lower drainage layer from the bottom up. The saturated hydraulic conductivity of the clay filled portion is reduced from 1.0E-01 to 1.0E-04 cm/s (i.e. the saturated hydraulic conductivity of the overlying backfill layer), while the conductivity of the clean portion remains at 1.0E-01 cm/s. The thickness of the clay filled portion increases with time while the thickness of the clean portion decreases with time. This is essentially the same process as described above for the lower drainage layer.

The infiltration through the upper GCL and the cumulative water flux into the vault base drainage layer remains the same as that calculated for the lower drainage layer above.

Determine mass of clay to fill the vault base drainage layer void volume (0.38):

Assume clay bulk density is 1.1 g/cm^3

Look at a 1-ft^2 area of the 5-foot thick the vault base drainage layer (i.e. 2 ft^3)

Void volume = $0.38 \times 5\ ft^3 = 1.9\ ft^3$

Clay mass per ft^3 = $1.1\ g/cm^3 \times 1.9\ ft^3 \times 2.831685E\text{-}02\ m^3/ft^3 \times 1{,}000{,}000\ cm^3/m^3$ = 59,182.2 g

The mass of clay that has migrated into the vault base drainage layer remains the same as that calculated for the lower drainage layer above.

Determine the fraction of the vault base drainage layer filled at the end of each time step:

Year	Fraction, F, of the vault base drainage layer filled
0	0
100	4.6 g ÷ 59,182.2 g = 0.000078
300	46.4 g ÷ 59,182.2 g = 0.000784
550	222.8 g ÷ 59,182.2 g = 0.00376
1,000	843.8 g ÷ 59,182.2 g = 0.0142
1,800	2,342.5 g ÷ 59,182.2 g = 0.0396
3,400	5,632.0 g ÷ 59,182.2 g = 0.0952
5,600	10,220.3 g ÷ 59,182.2 g = 0.173
10,000	19, 425.9 g ÷ 59,182.2 g = 0.328

Determine thickness of the 0.1 and 0.0001 cm/s layers at the end of each time step:

Year	Fraction, F, of the vault base drainage layer filled	0.1 cm/s layer thickness (ft) [1]	0.0001 cm/s layer thickness (ft) [2]
0	0	5	0
100	0.000078	4.9996	0.0004
300	0.000784	4.996	0.004
550	0.00376	4.98	0.02
1,000	0.0142	4.93	0.07
1,800	0.0396	4.8	0.2
3,400	0.0952	4.52	0.48
5,600	0.173	4.14	0.86
10,000	0.328	3.36	1.64

[1] Thickness = 5’ – (5’ × F)

[2] Thickness = 5’ × F

Worse Case Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 in
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4.2		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.088	0.0726	0.0596	0.0726
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6	3	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.37	0.24	0.136	0.24
9	3	0.2		0.75	0.747	0.40	0.75

Worse Case Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.51E-04					
4	1	3.20E-03					
5	2	3.20E-03	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-04	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	728,360	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data is missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLW.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLWout.OUT

TIME:  14:27     DATE:  10/ 6/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - Worse Case

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =      4.20   INCHES
           POROSITY                     =      0.4000 VOL/VOL
           FIELD CAPACITY               =      0.1100 VOL/VOL
           WILTING POINT                =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     30.00   INCHES
           POROSITY                     =      0.3700 VOL/VOL
           FIELD CAPACITY               =      0.2400 VOL/VOL
           WILTING POINT                =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

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

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.0880 VOL/VOL
FIELD CAPACITY             =      0.0726 VOL/VOL
WILTING POINT              =      0.0596 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.0726 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.451000000000E-03 CM/SEC

                    LAYER  4
                    --------

      TYPE 1 - VERTICAL PERCOLATION LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.3750 VOL/VOL
FIELD CAPACITY             =      0.1600 VOL/VOL
WILTING POINT              =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.319999992000E-02 CM/SEC

                    LAYER  5
                    --------

        TYPE 2 - LATERAL DRAINAGE LAYER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                  =     12.00   INCHES
POROSITY                   =      0.3750 VOL/VOL
FIELD CAPACITY             =      0.1600 VOL/VOL
WILTING POINT              =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.  =  0.319999992000E-02 CM/SEC
SLOPE                      =      3.00   PERCENT
DRAINAGE LENGTH            =    350.0    FEET

                    LAYER  6
                    --------

        TYPE 4 - FLEXIBLE MEMBRANE LINER
          MATERIAL TEXTURE NUMBER   0
THICKNESS                  =      0.20   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.  =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY        =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS   = 728360.00   HOLES/ACRE
FML PLACEMENT QUALITY      =  1 - PERFECT
```

```
                         LAYER  7
                         --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =     58.65   INCHES
 POROSITY                    =      0.3700 VOL/VOL
 FIELD CAPACITY              =      0.2400 VOL/VOL
 WILTING POINT               =      0.1360 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =     24.00   INCHES
 POROSITY                    =      0.3700 VOL/VOL
 FIELD CAPACITY              =      0.2400 VOL/VOL
 WILTING POINT               =      0.1360 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
 SLOPE                       =      2.00   PERCENT
 DRAINAGE LENGTH             =    125.0    FEET

                         LAYER  9
                         --------

                 TYPE 3 - BARRIER SOIL LINER
                 MATERIAL TEXTURE NUMBER   0
 THICKNESS                   =      0.20   INCHES
 POROSITY                    =      0.7500 VOL/VOL
 FIELD CAPACITY              =      0.7470 VOL/VOL
 WILTING POINT               =      0.4000 VOL/VOL
 INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
 EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

 SCS RUNOFF CURVE NUMBER            =     55.20
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      2.009  ACRES
 EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      4.734  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      8.266  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      2.664  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     32.359  INCHES
 TOTAL INITIAL WATER                =     32.359  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.004    0.000    0.005    0.000    0.000    0.002
                         0.033    0.099    0.018    0.009    0.003    0.000

  STD. DEVIATIONS        0.021    0.000    0.029    0.000    0.003    0.015
                         0.115    0.424    0.085    0.067    0.018    0.002

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.585    2.110    3.137    3.591    3.566    4.120
                         4.883    4.499    3.370    1.618    0.952    1.122

  STD. DEVIATIONS        0.215    0.225    0.555    0.789    1.525    1.538
                         1.587    1.382    1.044    0.605    0.210    0.203

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                 0.0079   0.0052   0.0055   0.0023   0.0007   0.0011
                         0.0020   0.0024   0.0022   0.0023   0.0029   0.0050

  STD. DEVIATIONS        0.0056   0.0041   0.0049   0.0023   0.0015   0.0020
                         0.0029   0.0034   0.0036   0.0035   0.0037   0.0044

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 2.8038   1.8404   1.9674   0.8279   0.2591   0.3796
                         0.7187   0.8545   0.7910   0.8131   1.0467   1.7918

  STD. DEVIATIONS        2.0029   1.4735   1.7573   0.8155   0.5192   0.7056
                         1.0195   1.2089   1.2672   1.2426   1.3257   1.5611

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 0.2207   0.2632   0.3174   0.3109   0.2581   0.1838
                         0.1480   0.1370   0.1300   0.1291   0.1321   0.1492

  STD. DEVIATIONS        0.1756   0.1800   0.1850   0.1734   0.1516   0.1132
                         0.0818   0.0845   0.0940   0.0941   0.1243   0.1367

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                 1.0174   1.1266   1.3416   1.3221   1.1973   0.9601
                         0.8524   0.8012   0.7551   0.7582   0.7381   0.7976

  STD. DEVIATIONS        0.5718   0.5471   0.5407   0.4924   0.4503   0.3592
                         0.2974   0.3134   0.3371   0.3449   0.4123   0.4612
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.1634	0.1175	0.1146	0.0498	0.0151	0.0228
	0.0418	0.0498	0.0476	0.0474	0.0630	0.1044
STD. DEVIATIONS	0.1169	0.0942	0.1026	0.0491	0.0303	0.0425
	0.0595	0.0706	0.0764	0.0725	0.0799	0.0911

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	38.3925	46.6901	50.6913	51.6248	45.2187	37.4340
	32.1341	30.1913	29.3991	28.5602	28.7324	30.0568
STD. DEVIATIONS	21.6894	22.7490	20.5114	19.3009	17.0829	14.0804
	11.2791	11.8901	13.2142	13.0847	16.1611	17.4932

****

****

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	356612.3	100.00
RUNOFF	0.173 (0.4629)	1265.20	0.355
EVAPOTRANSPIRATION	34.553 (3.5906)	251980.06	70.659
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.03954 (0.01593)	288.350	0.08086
PERCOLATION/LEAKAGE THROUGH LAYER 6	14.09426 (5.66986)	102784.766	28.82255
AVERAGE HEAD ON TOP OF LAYER 6	0.070 (0.028)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	2.37960 (1.12309)	17353.602	4.86624
PERCOLATION/LEAKAGE THROUGH LAYER 9	11.66760 (3.65666)	85087.969	23.86008
AVERAGE HEAD ON TOP OF LAYER 9	37.427 (11.803)		
CHANGE IN WATER STORAGE	0.087 (3.8811)	637.08	0.179

****

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

              PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                 (INCHES)      (CU. FT.)
                                                ----------    -------------
      PRECIPITATION                                6.87         50100.645

      RUNOFF                                       2.776        20246.8516

      DRAINAGE COLLECTED FROM LAYER  5             0.00545         39.76341

      PERCOLATION/LEAKAGE THROUGH LAYER  6         1.940647     14152.49800

      AVERAGE HEAD ON TOP OF LAYER  6              3.510

      MAXIMUM HEAD ON TOP OF LAYER  6              6.196

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                40.8 FEET

      DRAINAGE COLLECTED FROM LAYER  8             0.02117        154.35295

      PERCOLATION/LEAKAGE THROUGH LAYER  9         0.070454       513.79761

      AVERAGE HEAD ON TOP OF LAYER  9             82.650

      MAXIMUM HEAD ON TOP OF LAYER  9             98.720

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)                98.6 FEET

      SNOW WATER                                   2.36         17212.9980


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.3670

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.1211

       ***  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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.2341	0.2938
2	9.0002	0.3000
3	0.8712	0.0726
4	2.9197	0.2433
5	2.3784	0.1982
6	0.0000	0.0000
7	15.8591	0.2704
8	8.6824	0.3618
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

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Appendix Q, Degraded SDF GCL Closure Cap (100 Years): HELP Model Input Data and Output File (output file name: ZGCLD1ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.982		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.056	0.052	0.056
4	1	12		0.37	0.236	0.133	0.236
5	2	12		0.38	0.084	0.016	0.084
6	3	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.38	0.08	0.013	0.08
9	3	0.2		0.75	0.747	0.40	0.75

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.97E-04					
4	1	1.20E-04					
5	2	8.60E-02	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.00E-01	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3				
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD1.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD1ou.OUT

TIME:   8:49     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 100 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.98   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.0600 VOL/VOL
FIELD CAPACITY              =     0.0560 VOL/VOL
WILTING POINT               =     0.0520 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0560 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.396999996000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3700 VOL/VOL
FIELD CAPACITY              =     0.2360 VOL/VOL
WILTING POINT               =     0.1330 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.2360 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.119999997000E-03 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3800 VOL/VOL
FIELD CAPACITY              =     0.0840 VOL/VOL
WILTING POINT               =     0.0160 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0840 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.860000029000E-01 CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   350.0    FEET

                         LAYER  6
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   INCHES
POROSITY                    =     0.7500 VOL/VOL
FIELD CAPACITY              =     0.7470 VOL/VOL
WILTING POINT               =     0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     58.65   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.3800 VOL/VOL
FIELD CAPACITY               =      0.0800 VOL/VOL
WILTING POINT                =      0.0130 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.100000001000     CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    125.0    FEET

                         LAYER  9
                         --------

                TYPE 3 - BARRIER SOIL LINER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER            =     55.20
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      2.009  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.502  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.319  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.525  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     28.666  INCHES
TOTAL INITIAL WATER                =     28.666  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.004    0.000    0.004    0.000    0.000    0.002
                         0.027    0.092    0.017    0.006    0.003    0.001

  STD. DEVIATIONS        0.021    0.000    0.028    0.000    0.003    0.016
                         0.094    0.406    0.088    0.059    0.017    0.005

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.577    2.093    3.072    3.552    3.660    4.142
                         4.896    4.523    3.384    1.618    0.948    1.114

  STD. DEVIATIONS        0.221    0.237    0.582    0.761    1.523    1.545
                         1.589    1.378    1.039    0.606    0.207    0.206

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                 2.5455   2.0415   1.9385   1.1790   0.3970   0.3152
                         0.5653   0.8271   0.7442   0.7822   0.9133   1.5293

  STD. DEVIATIONS        1.8588   1.5218   1.5257   1.0308   0.4545   0.5965
                         0.8228   1.0571   1.0435   1.0898   1.2287   1.3589

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 0.0569   0.0465   0.0448   0.0290   0.0127   0.0097
                         0.0151   0.0207   0.0190   0.0195   0.0221   0.0354

  STD. DEVIATIONS        0.0382   0.0315   0.0311   0.0214   0.0098   0.0132
                         0.0178   0.0226   0.0221   0.0234   0.0261   0.0288

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 0.0457   0.0444   0.0398   0.0282   0.0098   0.0062
                         0.0107   0.0161   0.0149   0.0157   0.0182   0.0286

  STD. DEVIATIONS        0.0298   0.0306   0.0304   0.0245   0.0129   0.0117
                         0.0156   0.0202   0.0205   0.0217   0.0251   0.0251

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                 0.0054   0.0052   0.0056   0.0052   0.0047   0.0033
                         0.0036   0.0040   0.0040   0.0037   0.0037   0.0045

  STD. DEVIATIONS        0.0010   0.0003   0.0004   0.0007   0.0014   0.0019
                         0.0021   0.0022   0.0020   0.0023   0.0022   0.0020
```

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES               1.9666  1.7344  1.4983  0.9436  0.3067  0.2517
                           0.4368  0.6390  0.5941  0.6043  0.7291  1.1815

    STD. DEVIATIONS        1.4361  1.3117  1.1801  0.8330  0.3511  0.4762
                           0.6357  0.8167  0.8331  0.8420  0.9809  1.0498

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES               0.0163  0.0173  0.0141  0.0103  0.0035  0.0023
                           0.0038  0.0057  0.0055  0.0056  0.0067  0.0102

    STD. DEVIATIONS        0.0106  0.0119  0.0108  0.0090  0.0046  0.0043
                           0.0056  0.0072  0.0075  0.0077  0.0092  0.0089

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                    INCHES            CU. FEET       PERCENT
                               -------------------  -------------   ---------
 PRECIPITATION                  48.90    (   7.734)    356612.3     100.00

 RUNOFF                          0.157   (  0.4362)      1144.46      0.321

 EVAPOTRANSPIRATION             34.581   (  3.6269)    252185.72     70.717

 LATERAL DRAINAGE COLLECTED     13.77803 (  5.52914)   100478.648   28.17588
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH     0.33135 (  0.11735)     2416.419    0.67760
   LAYER  6

 AVERAGE HEAD ON TOP             0.907 (    0.364)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED      0.27822 (  0.11109)     2028.967    0.56896
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.05309 (  0.00864)      387.179    0.10857
   LAYER  9

 AVERAGE HEAD ON TOP             0.008 (    0.003)
   OF LAYER  9

 CHANGE IN WATER STORAGE         0.053   (  1.8719)       387.35      0.109

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

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.651	19333.9180
DRAINAGE COLLECTED FROM LAYER 5	0.50148	3657.14722
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.016976	123.80245
AVERAGE HEAD ON TOP OF LAYER 6	19.763	
MAXIMUM HEAD ON TOP OF LAYER 6	27.958	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	102.2 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.00939	68.45795
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000258	1.88236
AVERAGE HEAD ON TOP OF LAYER 9	0.104	
MAXIMUM HEAD ON TOP OF LAYER 9	0.201	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	3.4 FEET	
SNOW WATER	2.36	17212.9980

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3690

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1148

*** 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  100
    ----------------------------------------------------------------------
                 LAYER        (INCHES)       (VOL/VOL)
                 -----        --------       ---------
                   1            1.6084         0.2689

                   2            8.9941         0.2998

                   3            0.7200         0.0600

                   4            4.2398         0.3533

                   5            2.1154         0.1763

                   6            0.1500         0.7500

                   7           14.0760         0.2400

                   8            1.9237         0.0802

                   9            0.1500         0.7500

               SNOW WATER       0.000

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

Appendix R, Degraded SDF GCL Closure Cap (300 Years): HELP Model Input Data and Output File (output file name: ZGCLD2ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.946		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.06	0.0562	0.0521	0.0562
4	1	12		0.371	0.229	0.128	0.229
5	2	12		0.379	0.089	0.021	0.089
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.38	0.0802	0.0134	0.0802
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.98E-04					
4	1	1.60E-04					
5	2	6.30E-02	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	9.98E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	7,432	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD2.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD2ou.OUT

TIME:   8:52     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 300 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.95   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.0600 VOL/VOL
FIELD CAPACITY              =      0.0562 VOL/VOL
WILTING POINT               =      0.0521 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0562 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.398000004000E-03 CM/SEC

                       LAYER  4
                       --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3710 VOL/VOL
FIELD CAPACITY              =      0.2290 VOL/VOL
WILTING POINT               =      0.1280 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.2360 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.159999996000E-03 CM/SEC

                       LAYER  5
                       --------

               TYPE 2 - LATERAL DRAINAGE LAYER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     12.00   INCHES
POROSITY                    =      0.3790 VOL/VOL
FIELD CAPACITY              =      0.0890 VOL/VOL
WILTING POINT               =      0.0210 VOL/VOL
INITIAL SOIL WATER CONTENT  =      0.0890 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.630000010000E-01 CM/SEC
SLOPE                       =      3.00   PERCENT
DRAINAGE LENGTH             =    350.0    FEET

                       LAYER  6
                       --------

               TYPE 4 - FLEXIBLE MEMBRANE LINER
                 MATERIAL TEXTURE NUMBER   0
THICKNESS                   =      0.20   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.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    =   7432.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                             LAYER  7
                             --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =     58.65   INCHES
   POROSITY                    =      0.3700 VOL/VOL
   FIELD CAPACITY              =      0.2400 VOL/VOL
   WILTING POINT               =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC

                             LAYER  8
                             --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =     24.00   INCHES
   POROSITY                    =      0.3800 VOL/VOL
   FIELD CAPACITY              =      0.0802 VOL/VOL
   WILTING POINT               =      0.0134 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.0802 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.997999981000E-01 CM/SEC
   SLOPE                       =      2.00   PERCENT
   DRAINAGE LENGTH             =    125.0    FEET

                             LAYER  9
                             --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                   =      0.20   INCHES
   POROSITY                    =      0.7500 VOL/VOL
   FIELD CAPACITY              =      0.7470 VOL/VOL
   WILTING POINT               =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT  =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.   =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     55.20
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      2.009  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.507  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.318  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.528  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     28.579  INCHES
TOTAL INITIAL WATER                 =     28.579  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.004	0.000	0.004	0.000	0.000	0.002
	0.027	0.092	0.017	0.006	0.003	0.001
STD. DEVIATIONS	0.021	0.000	0.029	0.000	0.003	0.016
	0.094	0.406	0.088	0.059	0.017	0.005

EVAPOTRANSPIRATION

TOTALS	1.577	2.094	3.076	3.555	3.652	4.140
	4.894	4.521	3.385	1.619	0.948	1.115
STD. DEVIATIONS	0.221	0.236	0.582	0.761	1.525	1.546
	1.587	1.377	1.040	0.606	0.207	0.205

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	2.1177	1.7411	1.6344	1.0238	0.3573	0.2655
	0.4746	0.6924	0.6322	0.6611	0.7641	1.2695
STD. DEVIATIONS	1.5429	1.2726	1.2560	0.8742	0.3804	0.4939
	0.6807	0.8748	0.8651	0.9074	1.0243	1.1235

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.4508	0.3710	0.3469	0.2185	0.0772	0.0582
	0.1019	0.1477	0.1356	0.1415	0.1628	0.2696
STD. DEVIATIONS	0.3319	0.2770	0.2666	0.1893	0.0798	0.1041
	0.1437	0.1849	0.1849	0.1928	0.2167	0.2377

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	0.1492	0.2355	0.3831	0.3660	0.3619	0.2471
	0.1024	0.0708	0.0937	0.1328	0.1214	0.1424
STD. DEVIATIONS	0.1565	0.2204	0.2688	0.1985	0.2105	0.1878
	0.1143	0.0867	0.1128	0.1580	0.1458	0.1792

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0062	0.0067	0.0088	0.0084	0.0085	0.0066
	0.0050	0.0046	0.0047	0.0052	0.0048	0.0055
STD. DEVIATIONS	0.0021	0.0024	0.0026	0.0021	0.0024	0.0030
	0.0025	0.0025	0.0026	0.0030	0.0029	0.0030

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES             2.2414   2.0227   1.7250   1.1211   0.3768   0.2893
                         0.5006   0.7302   0.6925   0.6987   0.8327   1.3389

    STD. DEVIATIONS      1.6527   1.5128   1.3271   0.9757   0.4012   0.5383
                         0.7180   0.9226   0.9534   0.9623   1.1163   1.1849

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES             0.0532   0.0921   0.1366   0.1348   0.1290   0.0910
                         0.0365   0.0252   0.0345   0.0473   0.0447   0.0508

    STD. DEVIATIONS      0.0558   0.0861   0.0958   0.0731   0.0750   0.0692
                         0.0408   0.0309   0.0416   0.0563   0.0537   0.0639

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
---------------------------------------------------------------------------
                                     INCHES            CU. FEET      PERCENT
                               -------------------  -------------  ---------
 PRECIPITATION                 48.90    (   7.734)     356612.3     100.00

 RUNOFF                         0.157   (  0.4360)       1142.94      0.320

 EVAPOTRANSPIRATION            34.576   (  3.6265)     252147.97     70.706

 LATERAL DRAINAGE COLLECTED    11.63364 (  4.64305)     84840.266   23.79062
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH    2.48161 (  0.98951)     18097.584    5.07486
   LAYER  6

 AVERAGE HEAD ON TOP            1.047 (    0.420)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED     2.40636 (  0.86395)     17548.785    4.92097
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH    0.07483 (  0.01330)       545.702    0.15302
   LAYER  9

 AVERAGE HEAD ON TOP            0.073 (    0.026)
   OF LAYER  9

 CHANGE IN WATER STORAGE        0.053   (  2.0529)        386.61      0.108

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

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.650	19324.0488
DRAINAGE COLLECTED FROM LAYER 5	0.36774	2681.83008
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.137018	999.22949
AVERAGE HEAD ON TOP OF LAYER 6	21.132	
MAXIMUM HEAD ON TOP OF LAYER 6	29.528	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	105.3 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.05302	386.69153
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.000668	4.87426
AVERAGE HEAD ON TOP OF LAYER 9	0.586	
MAXIMUM HEAD ON TOP OF LAYER 9	1.062	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	11.7 FEET	
SNOW WATER	2.36	17212.9980
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3687	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1149	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.6025	0.2695
2	9.2029	0.3068
3	0.7200	0.0600
4	3.9763	0.3314
5	2.1856	0.1821
6	0.0000	0.0000
7	14.1165	0.2407
8	1.9268	0.0803
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix S, Degraded SDF GCL Closure Cap (550 Years): HELP Model Input Data and Output File (output file name: ZGCLD3ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.901		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.061	0.0566	0.0523	0.0566
4	1	12		0.371	0.220	0.121	0.220
5	2	12		0.379	0.10	0.028	0.1
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.378	0.0812	0.0148	0.0812
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	3.99E-04					
4	1	2.30E-04					
5	2	4.30E-02	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	9.91E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	26,013	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD3.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD3ou.OUT

TIME:   8:56     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 550 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =      5.90   INCHES
           POROSITY                    =      0.4000 VOL/VOL
           FIELD CAPACITY              =      0.1100 VOL/VOL
           WILTING POINT               =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =     30.00   INCHES
           POROSITY                    =      0.3700 VOL/VOL
           FIELD CAPACITY              =      0.2400 VOL/VOL
           WILTING POINT               =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.0610 VOL/VOL
FIELD CAPACITY               =     0.0566 VOL/VOL
WILTING POINT                =     0.0523 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.0566 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.399000011000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.3710 VOL/VOL
FIELD CAPACITY               =     0.2200 VOL/VOL
WILTING POINT                =     0.1210 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.2200 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.230000005000E-03 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =    12.00   INCHES
POROSITY                     =     0.3790 VOL/VOL
FIELD CAPACITY               =     0.1000 VOL/VOL
WILTING POINT                =     0.0280 VOL/VOL
INITIAL SOIL WATER CONTENT   =     0.1000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.430000015000E-01 CM/SEC
SLOPE                        =     3.00   PERCENT
DRAINAGE LENGTH              =   350.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     0.20   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.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =  26013.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =     58.65   INCHES
POROSITY                       =      0.3700 VOL/VOL
FIELD CAPACITY                 =      0.2400 VOL/VOL
WILTING POINT                  =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =     24.00   INCHES
POROSITY                       =      0.3780 VOL/VOL
FIELD CAPACITY                 =      0.0812 VOL/VOL
WILTING POINT                  =      0.0148 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.0812 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.991000012000E-01 CM/SEC
SLOPE                          =      2.00   PERCENT
DRAINAGE LENGTH                =    125.0    FEET

                         LAYER  9
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                      =      0.20   INCHES
POROSITY                       =      0.7500 VOL/VOL
FIELD CAPACITY                 =      0.7470 VOL/VOL
WILTING POINT                  =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.499999997000E-08 CM/SEC

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

  NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
           SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
           GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
           AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     55.20
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      2.009  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.513  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.317  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.532  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     28.543  INCHES
TOTAL INITIAL WATER                 =     28.543  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                   0.004    0.000    0.004    0.000    0.000    0.002
                           0.027    0.092    0.017    0.006    0.003    0.001

  STD. DEVIATIONS          0.021    0.000    0.029    0.000    0.003    0.016
                           0.094    0.406    0.088    0.059    0.016    0.005

EVAPOTRANSPIRATION
------------------
  TOTALS                   1.577    2.094    3.079    3.558    3.650    4.139
                           4.893    4.520    3.384    1.619    0.948    1.115

  STD. DEVIATIONS          0.221    0.236    0.580    0.760    1.523    1.545
                           1.588    1.375    1.040    0.606    0.206    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                   1.3117   1.0473   0.9958   0.6038   0.2068   0.1623
                           0.2957   0.4251   0.3853   0.4046   0.4710   0.7898

  STD. DEVIATIONS          0.9568   0.7774   0.7858   0.5221   0.2338   0.3091
                           0.4280   0.5432   0.5387   0.5628   0.6342   0.7027

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                   1.2956   1.0347   0.9818   0.5972   0.2053   0.1615
                           0.2925   0.4197   0.3811   0.4005   0.4649   0.7786

  STD. DEVIATIONS          0.9510   0.7771   0.7749   0.5212   0.2295   0.3041
                           0.4211   0.5347   0.5319   0.5576   0.6244   0.6919

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                   0.6723   1.0012   1.0465   0.9610   0.7297   0.4740
                           0.2835   0.2159   0.3116   0.3907   0.3969   0.4056

  STD. DEVIATIONS          0.6714   0.8699   0.6095   0.6457   0.3324   0.2306
                           0.2194   0.2775   0.4290   0.3768   0.4891   0.4777

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                   0.0110   0.0139   0.0151   0.0141   0.0122   0.0093
                           0.0072   0.0059   0.0068   0.0078   0.0078   0.0080

  STD. DEVIATIONS          0.0069   0.0086   0.0058   0.0062   0.0032   0.0028
                           0.0032   0.0039   0.0051   0.0049   0.0056   0.0056
```

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES                2.0314  1.7787  1.5395  0.9670  0.3196  0.2591
                            0.4569  0.6569  0.6160  0.6267  0.7521  1.2204

    STD. DEVIATIONS         1.4919  1.3366  1.2157  0.8456  0.3613  0.4936
                            0.6614  0.8393  0.8628  0.8752  1.0126  1.0857

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES                0.2413  0.3943  0.3757  0.3565  0.2620  0.1758
                            0.1018  0.0775  0.1156  0.1402  0.1472  0.1456

    STD. DEVIATIONS         0.2410  0.3425  0.2188  0.2395  0.1193  0.0855
                            0.0788  0.0996  0.1591  0.1353  0.1814  0.1715

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                    INCHES            CU. FEET      PERCENT
                              -------------------   -------------   ---------
 PRECIPITATION                 48.90    (   7.734)     356612.3     100.00

 RUNOFF                         0.157   (  0.4365)       1141.85     0.320

 EVAPOTRANSPIRATION            34.578   (  3.6238)     252165.81    70.711

 LATERAL DRAINAGE COLLECTED     7.09920 (  2.84009)     51772.109   14.51776
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH    7.01335 (  2.80824)     51146.031    14.34220
   LAYER  6

 AVERAGE HEAD ON TOP            0.935 (    0.375)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED     6.88868 (  2.59252)     50236.863   14.08725
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH    0.11920 (  0.02870)       869.304     0.24377
   LAYER  9

 AVERAGE HEAD ON TOP            0.211 (    0.080)
   OF LAYER  9

 CHANGE IN WATER STORAGE        0.058   (  2.4880)        426.37     0.120

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

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.656	19366.0430
DRAINAGE COLLECTED FROM LAYER 5	0.25135	1833.02441
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.400892	2923.57617
AVERAGE HEAD ON TOP OF LAYER 6	19.491	
MAXIMUM HEAD ON TOP OF LAYER 6	27.642	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	101.6 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.19766	1441.48608
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.002041	14.88242
AVERAGE HEAD ON TOP OF LAYER 9	2.200	
MAXIMUM HEAD ON TOP OF LAYER 9	3.506	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	25.4 FEET	
SNOW WATER	2.36	17212.9980

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3689

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1151

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5981	0.2708
2	9.1937	0.3065
3	0.7320	0.0610
4	3.8436	0.3203
5	2.3004	0.1917
6	0.0000	0.0000
7	14.5746	0.2485
8	1.9971	0.0832
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix T, Degraded SDF GCL Closure Cap (1,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD4ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.820		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.062	0.0574	0.0526	0.0574
4	1	12		0.372	0.204	0.109	0.204
5	2	12		0.378	0.116	0.040	0.116
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.374	0.0846	0.0196	0.0846
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.01E-04					
4	1	4.60E-04					
5	2	2.10E-02	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	9.64E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	59,458	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:     D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:       D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:   D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:     D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:   D:\HELP3\Hsdfgcl\ZGCLD4.D10
OUTPUT DATA FILE:            D:\HELP3\Hsdfgcl\ZGCLD4ou.OUT

TIME:   9:00     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 1,000 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =      5.82   INCHES
           POROSITY                   =      0.4000 VOL/VOL
           FIELD CAPACITY             =      0.1100 VOL/VOL
           WILTING POINT              =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     30.00   INCHES
           POROSITY                   =      0.3700 VOL/VOL
           FIELD CAPACITY             =      0.2400 VOL/VOL
           WILTING POINT              =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0620 VOL/VOL
FIELD CAPACITY               =      0.0574 VOL/VOL
WILTING POINT                =      0.0526 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0574 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.400999998000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3720 VOL/VOL
FIELD CAPACITY               =      0.2040 VOL/VOL
WILTING POINT                =      0.1090 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2040 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.460000010000E-03 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3780 VOL/VOL
FIELD CAPACITY               =      0.1160 VOL/VOL
WILTING POINT                =      0.0400 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1160 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.209999997000E-01 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    350.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   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.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     =  59458.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                              LAYER  7
                              --------

                 TYPE 1 - VERTICAL PERCOLATION LAYER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     58.65   INCHES
   POROSITY                     =      0.3700 VOL/VOL
   FIELD CAPACITY               =      0.2400 VOL/VOL
   WILTING POINT                =      0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                              LAYER  8
                              --------

                   TYPE 2 - LATERAL DRAINAGE LAYER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     24.00   INCHES
   POROSITY                     =      0.3740 VOL/VOL
   FIELD CAPACITY               =      0.0846 VOL/VOL
   WILTING POINT                =      0.0196 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.0846 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.964000002000E-01 CM/SEC
   SLOPE                        =      2.00   PERCENT
   DRAINAGE LENGTH              =    125.0    FEET

                              LAYER  9
                              --------

                     TYPE 3 - BARRIER SOIL LINER
                     MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =      0.20   INCHES
   POROSITY                     =      0.7500 VOL/VOL
   FIELD CAPACITY               =      0.7470 VOL/VOL
   WILTING POINT                =      0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

 SCS RUNOFF CURVE NUMBER              =     55.20
 FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE   =      2.009  ACRES
 EVAPORATIVE ZONE DEPTH               =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE    =      4.523  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE   =      8.315  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE   =      2.538  INCHES
 INITIAL SNOW WATER                   =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS     =     28.625  INCHES
 TOTAL INITIAL WATER                  =     28.625  INCHES
 TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                0.004    0.000    0.004    0.000    0.000    0.002
                        0.027    0.092    0.017    0.006    0.002    0.001

  STD. DEVIATIONS       0.020    0.000    0.029    0.000    0.003    0.015
                        0.094    0.406    0.089    0.058    0.016    0.005

EVAPOTRANSPIRATION
------------------
  TOTALS                1.578    2.095    3.081    3.560    3.648    4.138
                        4.893    4.521    3.381    1.619    0.949    1.116

  STD. DEVIATIONS       0.220    0.236    0.581    0.761    1.525    1.545
                        1.587    1.378    1.039    0.604    0.207    0.205

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                0.4858   0.3661   0.3587   0.2026   0.0677   0.0598
                        0.1119   0.1549   0.1379   0.1470   0.1731   0.2964

  STD. DEVIATIONS       0.3540   0.2793   0.2968   0.1810   0.0872   0.1157
                        0.1633   0.2028   0.2002   0.2105   0.2333   0.2650

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                2.1889   1.6505   1.6166   0.9131   0.3065   0.2706
                        0.5053   0.6984   0.6221   0.6627   0.7804   1.3356

  STD. DEVIATIONS       1.5959   1.2636   1.3381   0.8144   0.3921   0.5210
                        0.7348   0.9131   0.9014   0.9476   1.0505   1.1933

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                1.4559   1.7588   1.6753   1.4717   0.9103   0.6010
                        0.4010   0.4491   0.5680   0.6623   0.6817   0.7409

  STD. DEVIATIONS       1.3850   1.3851   1.0134   1.0160   0.4010   0.3243
                        0.3562   0.5865   0.7171   0.6888   0.8706   0.8176

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                0.0188   0.0216   0.0215   0.0194   0.0141   0.0107
                        0.0086   0.0083   0.0095   0.0107   0.0109   0.0115

  STD. DEVIATIONS       0.0140   0.0138   0.0099   0.0100   0.0041   0.0036
                        0.0042   0.0068   0.0079   0.0078   0.0092   0.0089
```

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	1.5374	1.2708	1.1354	0.6624	0.2142	0.1956
	0.3541	0.4901	0.4509	0.4650	0.5660	0.9379
STD. DEVIATIONS	1.1213	0.9732	0.9402	0.5916	0.2759	0.3784
	0.5166	0.6417	0.6546	0.6659	0.7628	0.8385

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	0.5373	0.7120	0.6183	0.5612	0.3359	0.2292
	0.1480	0.1657	0.2166	0.2444	0.2600	0.2734
STD. DEVIATIONS	0.5112	0.5612	0.3740	0.3875	0.1480	0.1237
	0.1314	0.2165	0.2735	0.2542	0.3320	0.3017

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	356612.3	100.00
RUNOFF	0.156 (0.4367)	1140.65	0.320
EVAPOTRANSPIRATION	34.579 (3.6205)	252175.06	70.714
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.56195 (1.02898)	18683.477	5.23916
PERCOLATION/LEAKAGE THROUGH LAYER 6	11.55066 (4.63679)	84235.125	23.62093
AVERAGE HEAD ON TOP OF LAYER 6	0.690 (0.277)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	11.37598 (4.35941)	82961.266	23.26372
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.16573 (0.04640)	1208.630	0.33892
AVERAGE HEAD ON TOP OF LAYER 9	0.359 (0.138)		
CHANGE IN WATER STORAGE	0.061 (2.8082)	443.13	0.124

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

             PEAK DAILY VALUES FOR YEARS    1 THROUGH  100
   ------------------------------------------------------------------------
                                                 (INCHES)      (CU. FT.)
                                                ----------   -------------
      PRECIPITATION                                6.87         50100.645

      RUNOFF                                       2.657        19373.1191

      DRAINAGE COLLECTED FROM LAYER  5             0.11856        864.59436

      PERCOLATION/LEAKAGE THROUGH LAYER  6         0.677909      4943.76416

      AVERAGE HEAD ON TOP OF LAYER  6             14.763

      MAXIMUM HEAD ON TOP OF LAYER  6             21.297

      LOCATION OF MAXIMUM HEAD IN LAYER  5
            (DISTANCE FROM DRAIN)                 87.9 FEET

      DRAINAGE COLLECTED FROM LAYER  8             0.37032       2700.58594

      PERCOLATION/LEAKAGE THROUGH LAYER  9         0.003773        27.51429

      AVERAGE HEAD ON TOP OF LAYER  9              4.237

      MAXIMUM HEAD ON TOP OF LAYER  9              6.106

      LOCATION OF MAXIMUM HEAD IN LAYER  8
            (DISTANCE FROM DRAIN)                 34.9 FEET

      SNOW WATER                                   2.36         17212.9980


      MAXIMUM VEG. SOIL WATER (VOL/VOL)                    0.3686

      MINIMUM VEG. SOIL WATER (VOL/VOL)                    0.1154

       ***  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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5989	0.2747
2	9.1686	0.3056
3	0.7440	0.0620
4	3.5945	0.2995
5	2.4451	0.2038
6	0.0000	0.0000
7	14.9080	0.2542
8	2.0927	0.0872
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix U, Degraded SDF GCL Closure Cap (1,800 Years): HELP Model Input Data and Output File (output file name: ZGCLD5ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.676		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.065	0.0587	0.0532	0.0587
4	1	12		0.374	0.176	0.0867	0.176
5	2	12		0.376	0.144	0.062	0.144
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.364	0.0929	0.0315	0.0929
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.06E-04					
4	1	1.60E-03					
5	2	6.30E-03	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	9.01E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	118,916	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD5.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD5ou.OUT

TIME:   9: 3     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 1,800 years

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

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

                                  LAYER  1
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =      5.68   INCHES
           POROSITY                    =      0.4000 VOL/VOL
           FIELD CAPACITY              =      0.1100 VOL/VOL
           WILTING POINT               =      0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.100000005000E-02 CM/SEC

                                  LAYER  2
                                  --------

                    TYPE 1 - VERTICAL PERCOLATION LAYER
                        MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =     30.00   INCHES
           POROSITY                    =      0.3700 VOL/VOL
           FIELD CAPACITY              =      0.2400 VOL/VOL
           WILTING POINT               =      0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.0650 VOL/VOL
FIELD CAPACITY              =     0.0587 VOL/VOL
WILTING POINT               =     0.0532 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.0587 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.406000006000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3740 VOL/VOL
FIELD CAPACITY              =     0.1760 VOL/VOL
WILTING POINT               =     0.0867 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1760 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.159999996000E-02 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =    12.00   INCHES
POROSITY                    =     0.3760 VOL/VOL
FIELD CAPACITY              =     0.1440 VOL/VOL
WILTING POINT               =     0.0620 VOL/VOL
INITIAL SOIL WATER CONTENT  =     0.1440 VOL/VOL
EFFECTIVE SAT. HYD. COND.   =  0.630000001000E-02 CM/SEC
SLOPE                       =     3.00   PERCENT
DRAINAGE LENGTH             =   350.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                   =     0.20   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.   =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY         =     0.00   HOLES/ACRE
FML INSTALLATION DEFECTS    = 118916.00   HOLES/ACRE
FML PLACEMENT QUALITY       =  1 - PERFECT
```

```
                          LAYER  7
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     58.65   INCHES
POROSITY                     =      0.3700 VOL/VOL
FIELD CAPACITY               =      0.2400 VOL/VOL
WILTING POINT                =      0.1360 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                          LAYER  8
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     24.00   INCHES
POROSITY                     =      0.3640 VOL/VOL
FIELD CAPACITY               =      0.0929 VOL/VOL
WILTING POINT                =      0.0315 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0929 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.900999978000E-01 CM/SEC
SLOPE                        =      2.00   PERCENT
DRAINAGE LENGTH              =    125.0    FEET

                          LAYER  9
                          --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   INCHES
POROSITY                     =      0.7500 VOL/VOL
FIELD CAPACITY               =      0.7470 VOL/VOL
WILTING POINT                =      0.4000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER             =     55.20
FRACTION OF AREA ALLOWING RUNOFF    =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE  =      2.009  ACRES
EVAPORATIVE ZONE DEPTH              =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE   =      4.542  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE  =      8.310  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE  =      2.549  INCHES
INITIAL SNOW WATER                  =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS    =     28.824  INCHES
TOTAL INITIAL WATER                 =     28.824  INCHES
TOTAL SUBSURFACE INFLOW             =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.002
	0.027	0.092	0.017	0.006	0.002	0.001
STD. DEVIATIONS	0.016	0.000	0.029	0.000	0.003	0.014
	0.094	0.408	0.088	0.058	0.015	0.005

EVAPOTRANSPIRATION

TOTALS	1.579	2.097	3.087	3.556	3.644	4.139
	4.894	4.522	3.383	1.619	0.949	1.116
STD. DEVIATIONS	0.220	0.234	0.583	0.762	1.519	1.547
	1.589	1.377	1.040	0.606	0.207	0.205

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0894	0.0632	0.0642	0.0323	0.0105	0.0112
	0.0211	0.0281	0.0246	0.0263	0.0320	0.0558
STD. DEVIATIONS	0.0646	0.0495	0.0551	0.0303	0.0164	0.0215
	0.0311	0.0381	0.0379	0.0389	0.0424	0.0493

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.6610	1.8812	1.9091	0.9605	0.3124	0.3346
	0.6295	0.8362	0.7329	0.7828	0.9519	1.6609
STD. DEVIATIONS	1.9250	1.4735	1.6393	0.9008	0.4873	0.6388
	0.9246	1.1334	1.1268	1.1574	1.2612	1.4664

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	1.8756	2.1016	1.9705	1.6633	0.9572	0.6289
	0.4376	0.5656	0.7234	0.7758	0.8144	0.9320
STD. DEVIATIONS	1.7519	1.6093	1.2536	1.1503	0.4281	0.3945
	0.4366	0.7513	0.8506	0.8506	1.0381	1.0191

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0242	0.0265	0.0258	0.0224	0.0152	0.0114
	0.0092	0.0099	0.0117	0.0123	0.0128	0.0140
STD. DEVIATIONS	0.0188	0.0170	0.0131	0.0121	0.0046	0.0046
	0.0052	0.0088	0.0097	0.0098	0.0115	0.0115

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES                 0.9433   0.7309   0.6766   0.3516   0.1102   0.1223
                             0.2228   0.2962   0.2681   0.2773   0.3485   0.5887

    STD. DEVIATIONS          0.6826   0.5728   0.5814   0.3302   0.1728   0.2341
                             0.3279   0.4019   0.4129   0.4104   0.4621   0.5200

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES                 0.7406   0.9100   0.7781   0.6787   0.3780   0.2566
                             0.1728   0.2234   0.2952   0.3063   0.3323   0.3680

    STD. DEVIATIONS          0.6918   0.6975   0.4950   0.4693   0.1690   0.1609
                             0.1724   0.2967   0.3471   0.3359   0.4236   0.4024

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

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

    AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-------------------------------------------------------------------------------
                                   INCHES            CU. FEET       PERCENT
                               -------------------  -------------  ---------
 PRECIPITATION                  48.90    (   7.734)    356612.3     100.00

 RUNOFF                          0.156   (  0.4381)      1135.75      0.318

 EVAPOTRANSPIRATION             34.584   (  3.6265)    252209.37     70.724

 LATERAL DRAINAGE COLLECTED      0.45863 (  0.18503)     3344.612     0.93788
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH    13.65308 (  5.50420)    99567.406    27.92035
   LAYER  6

 AVERAGE HEAD ON TOP             0.411 (    0.166)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED     13.44591 (  5.20792)    98056.617   27.49670
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.19519 (  0.05803)     1423.475     0.39917
   LAYER  9

 AVERAGE HEAD ON TOP             0.453 (    0.176)
   OF LAYER  9

 CHANGE IN WATER STORAGE         0.061   (  2.8720)       442.46      0.124

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

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.667	19449.0215
DRAINAGE COLLECTED FROM LAYER 5	0.03444	251.16452
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.092747	7969.04639
AVERAGE HEAD ON TOP OF LAYER 6	12.010	
MAXIMUM HEAD ON TOP OF LAYER 6	17.469	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	78.4 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.50442	3678.58789
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.005420	39.52737
AVERAGE HEAD ON TOP OF LAYER 9	6.174	
MAXIMUM HEAD ON TOP OF LAYER 9	8.292	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	41.0 FEET	
SNOW WATER	2.36	17212.9980

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3687
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1159

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.5646	0.2756
2	8.9357	0.2979
3	0.7800	0.0650
4	3.2249	0.2687
5	2.7333	0.2278
6	0.0000	0.0000
7	15.2129	0.2594
8	2.2901	0.0954
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix V, Degraded SDF GCL Closure Cap (3,400 Years): HELP Model Input Data and Output File
(output file name: ZGCLD6ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches

CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	5.388		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.069	0.0614	0.0545	0.0614
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.342	0.111	0.0575	0.111
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.15E-04					
4	1	3.20E-03					
5	2	3.20E-03	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	7.62E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	237,832	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD6.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD6ou.OUT

TIME:   9: 5     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 3,400 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     5.39   INCHES
           POROSITY                     =     0.4000 VOL/VOL
           FIELD CAPACITY               =     0.1100 VOL/VOL
           WILTING POINT                =     0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =    30.00   INCHES
           POROSITY                     =     0.3700 VOL/VOL
           FIELD CAPACITY               =     0.2400 VOL/VOL
           WILTING POINT                =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0690 VOL/VOL
FIELD CAPACITY               =      0.0614 VOL/VOL
WILTING POINT                =      0.0545 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0614 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.414999988000E-03 CM/SEC

                         LAYER  4
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC

                         LAYER  5
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    350.0    FEET

                         LAYER  6
                         --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   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.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     = 237832.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                              LAYER  7
                              --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    58.65   INCHES
   POROSITY                     =     0.3700 VOL/VOL
   FIELD CAPACITY               =     0.2400 VOL/VOL
   WILTING POINT                =     0.1360 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.2400 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                              LAYER  8
                              --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =    24.00   INCHES
   POROSITY                     =     0.3420 VOL/VOL
   FIELD CAPACITY               =     0.1110 VOL/VOL
   WILTING POINT                =     0.0575 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.1110 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.762000009000E-01 CM/SEC
   SLOPE                        =     2.00   PERCENT
   DRAINAGE LENGTH              =   125.0    FEET

                              LAYER  9
                              --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
   THICKNESS                    =     0.20   INCHES
   POROSITY                     =     0.7500 VOL/VOL
   FIELD CAPACITY               =     0.7470 VOL/VOL
   WILTING POINT                =     0.4000 VOL/VOL
   INITIAL SOIL WATER CONTENT   =     0.7500 VOL/VOL
   EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

 SCS RUNOFF CURVE NUMBER            =     55.20
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      2.009  ACRES
 EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      4.580  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      8.302  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      2.572  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     29.259  INCHES
 TOTAL INITIAL WATER                =     29.259  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.004	0.000	0.004	0.000	0.000	0.002
	0.027	0.093	0.017	0.007	0.002	0.001
STD. DEVIATIONS	0.020	0.000	0.029	0.000	0.003	0.013
	0.096	0.409	0.088	0.058	0.013	0.004

EVAPOTRANSPIRATION

TOTALS	1.581	2.099	3.101	3.560	3.625	4.136
	4.894	4.513	3.379	1.619	0.949	1.118
STD. DEVIATIONS	0.217	0.232	0.571	0.772	1.518	1.549
	1.592	1.379	1.038	0.607	0.209	0.204

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0237	0.0161	0.0167	0.0077	0.0025	0.0030
	0.0058	0.0074	0.0065	0.0069	0.0086	0.0151
STD. DEVIATIONS	0.0170	0.0126	0.0146	0.0074	0.0045	0.0057
	0.0085	0.0103	0.0103	0.0104	0.0112	0.0132

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.7646	1.8825	1.9500	0.8989	0.2899	0.3553
	0.6753	0.8606	0.7603	0.8041	1.0086	1.7557
STD. DEVIATIONS	1.9836	1.4714	1.6963	0.8667	0.5264	0.6658
	0.9875	1.2025	1.1988	1.2112	1.3047	1.5367

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	1.9490	2.0914	2.0145	1.6529	0.9734	0.6590
	0.4858	0.5916	0.7183	0.8028	0.8427	0.9815
STD. DEVIATIONS	1.8104	1.6351	1.2986	1.1008	0.4154	0.3773
	0.4394	0.7657	0.8171	0.8524	1.0358	1.0559

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0287	0.0304	0.0300	0.0254	0.0172	0.0130
	0.0108	0.0115	0.0130	0.0143	0.0148	0.0165
STD. DEVIATIONS	0.0228	0.0203	0.0160	0.0136	0.0052	0.0050
	0.0059	0.0103	0.0109	0.0113	0.0134	0.0138

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

  DAILY AVERAGE HEAD ON TOP OF LAYER  6
  -------------------------------------
    AVERAGES               0.4922   0.3673   0.3470   0.1651   0.0514   0.0652
                           0.1201   0.1531   0.1397   0.1431   0.1854   0.3125

    STD. DEVIATIONS        0.3534   0.2874   0.3022   0.1596   0.0937   0.1225
                           0.1759   0.2142   0.2206   0.2157   0.2401   0.2737

  DAILY AVERAGE HEAD ON TOP OF LAYER  9
  -------------------------------------
    AVERAGES               0.9100   1.0706   0.9405   0.7974   0.4545   0.3179
                           0.2268   0.2762   0.3465   0.3748   0.4065   0.4583

    STD. DEVIATIONS        0.8452   0.8365   0.6063   0.5310   0.1940   0.1820
                           0.2051   0.3575   0.3942   0.3980   0.4997   0.4930

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

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

     AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS    1 THROUGH  100
-----------------------------------------------------------------------------
                                     INCHES           CU. FEET      PERCENT
                               -------------------  -------------  ---------
 PRECIPITATION                  48.90    (   7.734)    356612.3     100.00

 RUNOFF                          0.156   (  0.4407)      1139.60      0.320

 EVAPOTRANSPIRATION             34.574   (  3.6245)    252134.03     70.703

 LATERAL DRAINAGE COLLECTED      0.12003 (  0.04835)      875.319    0.24545
   FROM LAYER  5

 PERCOLATION/LEAKAGE THROUGH    14.00566 (  5.63632)   102138.695   28.64138
   LAYER  6

 AVERAGE HEAD ON TOP             0.212 (    0.085)
   OF LAYER  6

 LATERAL DRAINAGE COLLECTED     13.76275 (  5.33310)   100367.187  28.14462
   FROM LAYER  8

 PERCOLATION/LEAKAGE THROUGH     0.22568 (  0.06910)     1645.811    0.46151
   LAYER  9

 AVERAGE HEAD ON TOP             0.548 (    0.213)
   OF LAYER  9

 CHANGE IN WATER STORAGE         0.062   (  2.8684)       450.35      0.126

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

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.662	19412.7109
DRAINAGE COLLECTED FROM LAYER 5	0.01214	88.54077
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.415487	10322.67680
AVERAGE HEAD ON TOP OF LAYER 6	7.815	
MAXIMUM HEAD ON TOP OF LAYER 6	12.723	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	64.8 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.56690	4134.20117
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.007065	51.52361
AVERAGE HEAD ON TOP OF LAYER 9	8.108	
MAXIMUM HEAD ON TOP OF LAYER 9	10.377	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	45.9 FEET	
SNOW WATER	2.36	17212.9980

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3701
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1169

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.4834	0.2753
2	8.9056	0.2969
3	0.8280	0.0690
4	2.9014	0.2418
5	2.7029	0.2252
6	0.0000	0.0000
7	15.5620	0.2653
8	2.9016	0.1209
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix W, Degraded SDF GCL Closure Cap (5,600 Years): HELP Model Input Data and Output File (output file name: ZGCLD7ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4.992		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.075	0.0651	0.0562	0.0651
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.311	0.136	0.0938	0.136
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.27E-04					
4	1	3.20E-03					
5	2	3.20E-03	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	5.68E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	401,341	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD7.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD7ou.OUT

TIME:   9: 8     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 5,600 years

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

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

                                   LAYER  1
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =     4.99   INCHES
           POROSITY                   =     0.4000 VOL/VOL
           FIELD CAPACITY             =     0.1100 VOL/VOL
           WILTING POINT              =     0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
           THICKNESS                  =    30.00   INCHES
           POROSITY                   =     0.3700 VOL/VOL
           FIELD CAPACITY             =     0.2400 VOL/VOL
           WILTING POINT              =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.  =  0.999999975000E-04 CM/SEC
```

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

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0750 VOL/VOL
FIELD CAPACITY               =      0.0651 VOL/VOL
WILTING POINT                =      0.0562 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0651 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.426999992000E-03 CM/SEC

                          LAYER  4
                          --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC

                          LAYER  5
                          --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    350.0    FEET

                          LAYER  6
                          --------

                TYPE 4 - FLEXIBLE MEMBRANE LINER
                  MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   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.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     = 401341.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =     58.65   INCHES
  POROSITY                     =      0.3700 VOL/VOL
  FIELD CAPACITY               =      0.2400 VOL/VOL
  WILTING POINT                =      0.1360 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =     24.00   INCHES
  POROSITY                     =      0.3110 VOL/VOL
  FIELD CAPACITY               =      0.1360 VOL/VOL
  WILTING POINT                =      0.0938 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.1360 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.568000004000E-01 CM/SEC
  SLOPE                        =      2.00   PERCENT
  DRAINAGE LENGTH              =    125.0    FEET

                         LAYER  9
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
  THICKNESS                    =      0.20   INCHES
  POROSITY                     =      0.7500 VOL/VOL
  FIELD CAPACITY               =      0.7470 VOL/VOL
  WILTING POINT                =      0.4000 VOL/VOL
  INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
  EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

SCS RUNOFF CURVE NUMBER            =     55.20
FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE =      2.009  ACRES
EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE  =      4.631  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE =      8.290  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE =      2.603  INCHES
INITIAL SNOW WATER                 =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS   =     29.860  INCHES
TOTAL INITIAL WATER                =     29.860  INCHES
TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR AUGUSTA GEORGIA AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

RUNOFF

TOTALS	0.003	0.000	0.004	0.000	0.000	0.002
	0.028	0.093	0.017	0.007	0.002	0.000
STD. DEVIATIONS	0.019	0.000	0.028	0.000	0.002	0.012
	0.100	0.411	0.087	0.060	0.015	0.002

EVAPOTRANSPIRATION

TOTALS	1.582	2.103	3.112	3.569	3.609	4.130
	4.891	4.513	3.378	1.618	0.950	1.119
STD. DEVIATIONS	0.217	0.231	0.562	0.785	1.518	1.542
	1.589	1.379	1.042	0.606	0.208	0.203

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.0141	0.0095	0.0100	0.0044	0.0014	0.0019
	0.0035	0.0043	0.0040	0.0041	0.0052	0.0091
STD. DEVIATIONS	0.0102	0.0075	0.0088	0.0043	0.0027	0.0035
	0.0050	0.0061	0.0063	0.0063	0.0066	0.0079

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	2.7781	1.8684	1.9583	0.8656	0.2712	0.3684
	0.6866	0.8518	0.7805	0.8120	1.0225	1.7885
STD. DEVIATIONS	2.0085	1.4720	1.7317	0.8440	0.5263	0.6882
	0.9860	1.2058	1.2393	1.2311	1.3041	1.5600

LATERAL DRAINAGE COLLECTED FROM LAYER 8

TOTALS	1.9719	2.0635	2.0082	1.6234	0.9544	0.6436
	0.4792	0.6151	0.7256	0.8062	0.8413	1.0119
STD. DEVIATIONS	1.8388	1.6055	1.3245	1.0723	0.4069	0.3670
	0.4342	0.7782	0.7910	0.8563	1.0306	1.0615

PERCOLATION/LEAKAGE THROUGH LAYER 9

TOTALS	0.0377	0.0388	0.0384	0.0319	0.0210	0.0157
	0.0132	0.0154	0.0170	0.0185	0.0189	0.0219
STD. DEVIATIONS	0.0303	0.0264	0.0219	0.0177	0.0067	0.0061
	0.0072	0.0129	0.0131	0.0142	0.0171	0.0175

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.2936	0.2163	0.2069	0.0943	0.0286	0.0402
	0.0725	0.0899	0.0852	0.0857	0.1116	0.1890
STD. DEVIATIONS	0.2124	0.1707	0.1832	0.0922	0.0556	0.0752
	0.1043	0.1275	0.1354	0.1302	0.1425	0.1650

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	1.2340	1.4157	1.2575	1.0504	0.5978	0.4165
	0.3001	0.3852	0.4695	0.5049	0.5445	0.6338
STD. DEVIATIONS	1.1485	1.0962	0.8286	0.6925	0.2549	0.2375
	0.2720	0.4873	0.5112	0.5362	0.6670	0.6648

AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	356612.3	100.00
RUNOFF	0.157 (0.4452)	1146.36	0.321
EVAPOTRANSPIRATION	34.575 (3.6198)	252143.97	70.705
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.07148 (0.02880)	521.255	0.14617
PERCOLATION/LEAKAGE THROUGH LAYER 6	14.05202 (5.65533)	102476.742	28.73618
AVERAGE HEAD ON TOP OF LAYER 6	0.126 (0.051)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	13.74419 (5.34387)	100231.836	28.10667
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.28840 (0.08852)	2103.225	0.58978
AVERAGE HEAD ON TOP OF LAYER 9	0.734 (0.285)		
CHANGE IN WATER STORAGE	0.064 (2.8478)	465.71	0.131

****

PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.683	19567.9727
DRAINAGE COLLECTED FROM LAYER 5	0.00877	63.95421
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.722040	12558.27250
AVERAGE HEAD ON TOP OF LAYER 6	5.645	
MAXIMUM HEAD ON TOP OF LAYER 6	9.536	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	54.1 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.74638	5443.08887
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.011310	82.48127
AVERAGE HEAD ON TOP OF LAYER 9	13.100	
MAXIMUM HEAD ON TOP OF LAYER 9	15.981	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	56.1 FEET	
SNOW WATER	2.36	17212.9980
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3698	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1183	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.4343	0.2873
2	9.0274	0.3009
3	0.7812	0.0651
4	2.8254	0.2355
5	2.7453	0.2288
6	0.0000	0.0000
7	15.5165	0.2646
8	3.7662	0.1569
9	0.1500	0.7500
SNOW WATER	0.000	

****
****

Appendix X, Degraded SDF GCL Closure Cap (10,000 Years): HELP Model Input Data and Output File (output file name: ZGCLD8ou.OUT)

Input Data:

Input Parameter (HELP Model Query)	Generic Input Parameter Value
Landfill area =	2.009 acres
Percent of area where runoff is possible =	100%
Do you want to specify initial moisture storage? (Y/N)	Y
Amount of water or snow on surface =	0 inches
CN Input Parameter (HELP Model Query)	CN Input Parameter Value
Slope =	3 %
Slope length =	350 ft
Soil Texture =	5 (HELP model default soil texture)
Vegetation =	4 (i.e., a good stand of grass)
HELP Model Computed Curve Number = 55.20	

Layer	Layer Number	Layer Type
Topsoil	1	1 (vertical percolation layer)
Upper Backfill	2	1 (vertical percolation layer)
Erosion Barrier	3	1 (vertical percolation layer)
Middle Backfill	4	1 (vertical percolation layer)
Upper Drainage Layer	5	2 (lateral drainage layer)
Upper GCL	6	3 (barrier soil liner)
Lower Backfill	7	1 (vertical percolation layer)
Lower Drainage Layer	8	2 (lateral drainage layer)
Lower GCL	9	3 (barrier soil liner)

	Layer Type	Layer Thickness (in)	Soil Texture No.	Total Porosity (Vol/Vol)	Field Capacity (Vol/Vol)	Wilting Point (Vol/Vol)	Initial Moisture (Vol/Vol)
1	1	4.2		0.4	0.11	0.058	0.11
2	1	30		0.37	0.24	0.136	0.24
3	1	12		0.088	0.0726	0.0596	0.0726
4	1	12		0.375	0.16	0.0745	0.16
5	2	12		0.375	0.16	0.0745	0.16
6 *	4	0.2		0.75	0.747	0.40	0.75
7	1	58.65		0.37	0.24	0.136	0.24
8	2	24		0.249	0.187	0.166	0.187
9	3	0.2		0.75	0.747	0.40	0.75

* The input porosity, field capacity, and wilting point values of the upper GCL are ignored by the HELP model, since the upper GCL is designated as an geomembrane in order for the HELP model to take into account the holes produced by root penetration.

Input Data (continued):

	Layer Type	Sat. Hyd. Conductivity (cm/sec)	Drainage Length (ft)	Drain Slope (%)	Leachate Recirc. (%)	Recirc. to Layer (#)	Subsurface Inflow (in/yr)
1	1	1.00E-03					
2	1	1.00E-04					
3	1	4.51E-04					
4	1	3.20E-03					
5	2	3.20E-03	350	3			
6	3	5.00E-09					
7	1	1.00E-04					
8	2	1.81E-02	125	2			
9	3	5.00E-09					

	Layer Type	Geomembrane Pinhole Density (#/acre)	Geomembrane Instal. Defects (#/acre)	Geomembrane Placement Quality	Geotextile Transmissivity (cm^2/sec)
1	1				
2	1				
3	1				
4	1				
5	2				
6	3	0	728,360	1	
7	1				
8	2				
9	3				

The lack of values in the table for particular parameters in particular layers denotes that no HELP model input was required for that parameter in that layer. No data are missing from the table.

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

PRECIPITATION DATA FILE:    D:\HELP3\Hweather\ZPREC.D4
TEMPERATURE DATA FILE:      D:\HELP3\Hweather\ZTEMP.D7
SOLAR RADIATION DATA FILE:  D:\HELP3\Hweather\ZSOLAR.D13
EVAPOTRANSPIRATION DATA:    D:\HELP3\Hweather\ZEVAP.D11
SOIL AND DESIGN DATA FILE:  D:\HELP3\Hsdfgcl\ZGCLD8.D10
OUTPUT DATA FILE:           D:\HELP3\Hsdfgcl\ZGCLD8ou.OUT

TIME:   9:10     DATE:   9/16/2003

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

     TITLE:  Degraded SDF GCL Closure Cap - 10,000 years

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

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

                                   LAYER  1
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =     4.20   INCHES
           POROSITY                     =     0.4000 VOL/VOL
           FIELD CAPACITY               =     0.1100 VOL/VOL
           WILTING POINT                =     0.0580 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.1100 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.100000005000E-02 CM/SEC

                                   LAYER  2
                                   --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                    =    30.00   INCHES
           POROSITY                     =     0.3700 VOL/VOL
           FIELD CAPACITY               =     0.2400 VOL/VOL
           WILTING POINT                =     0.1360 VOL/VOL
           INITIAL SOIL WATER CONTENT   =     0.2400 VOL/VOL
           EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC
```

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                      LAYER  3
                      --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.0880 VOL/VOL
FIELD CAPACITY               =      0.0726 VOL/VOL
WILTING POINT                =      0.0596 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0726 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.451000000000E-03 CM/SEC

                      LAYER  4
                      --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC

                      LAYER  5
                      --------

            TYPE 2 - LATERAL DRAINAGE LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =     12.00   INCHES
POROSITY                     =      0.3750 VOL/VOL
FIELD CAPACITY               =      0.1600 VOL/VOL
WILTING POINT                =      0.0745 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1600 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.319999992000E-02 CM/SEC
SLOPE                        =      3.00   PERCENT
DRAINAGE LENGTH              =    350.0    FEET

                      LAYER  6
                      --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                    =      0.20   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.    =  0.499999997000E-08 CM/SEC
FML PINHOLE DENSITY          =      0.00   HOLES/ACRE
FML INSTALLATION DEFECTS     = 728360.00   HOLES/ACRE
FML PLACEMENT QUALITY        =  1 - PERFECT
```

```
                         LAYER  7
                         --------

              TYPE 1 - VERTICAL PERCOLATION LAYER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                    =     58.65   INCHES
 POROSITY                     =      0.3700 VOL/VOL
 FIELD CAPACITY               =      0.2400 VOL/VOL
 WILTING POINT                =      0.1360 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.2400 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.999999975000E-04 CM/SEC

                         LAYER  8
                         --------

                TYPE 2 - LATERAL DRAINAGE LAYER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                    =     24.00   INCHES
 POROSITY                     =      0.2490 VOL/VOL
 FIELD CAPACITY               =      0.1870 VOL/VOL
 WILTING POINT                =      0.1660 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.1870 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.181000009000E-01 CM/SEC
 SLOPE                        =      2.00   PERCENT
 DRAINAGE LENGTH              =    125.0    FEET

                         LAYER  9
                         --------

                  TYPE 3 - BARRIER SOIL LINER
                  MATERIAL TEXTURE NUMBER   0
 THICKNESS                    =      0.20   INCHES
 POROSITY                     =      0.7500 VOL/VOL
 FIELD CAPACITY               =      0.7470 VOL/VOL
 WILTING POINT                =      0.4000 VOL/VOL
 INITIAL SOIL WATER CONTENT   =      0.7500 VOL/VOL
 EFFECTIVE SAT. HYD. COND.    =  0.499999997000E-08 CM/SEC

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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE # 5 WITH A
          GOOD STAND OF GRASS, A SURFACE SLOPE OF  3.%
          AND A SLOPE LENGTH OF  350. FEET.

 SCS RUNOFF CURVE NUMBER            =     55.20
 FRACTION OF AREA ALLOWING RUNOFF   =    100.0    PERCENT
 AREA PROJECTED ON HORIZONTAL PLANE =      2.009  ACRES
 EVAPORATIVE ZONE DEPTH             =     22.0    INCHES
 INITIAL WATER IN EVAPORATIVE ZONE  =      4.734  INCHES
 UPPER LIMIT OF EVAPORATIVE STORAGE =      8.266  INCHES
 LOWER LIMIT OF EVAPORATIVE STORAGE =      2.664  INCHES
 INITIAL SNOW WATER                 =      0.000  INCHES
 INITIAL WATER IN LAYER MATERIALS   =     31.087  INCHES
 TOTAL INITIAL WATER                =     31.087  INCHES
 TOTAL SUBSURFACE INFLOW            =      0.00   INCHES/YEAR
```

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
AUGUSTA GEORGIA

STATION LATITUDE	=	33.22 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.50
START OF GROWING SEASON (JULIAN DATE)	=	68
END OF GROWING SEASON (JULIAN DATE)	=	323
EVAPORATIVE ZONE DEPTH	=	22.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	6.50 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	68.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	70.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	77.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	73.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.38	3.95	4.68	2.91	3.56	4.99
5.43	5.41	3.93	3.12	2.96	3.45

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
46.30	50.00	57.20	64.30	72.10	78.40
81.60	80.30	75.20	65.10	56.70	48.80

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR AUGUSTA GEORGIA
AND STATION LATITUDE = 33.30 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.56	3.57	4.76	2.74	3.60	4.97
	5.81	5.32	4.41	2.99	2.75	3.41
STD. DEVIATIONS	2.44	1.60	2.47	1.31	2.12	2.60
	2.83	2.95	2.54	2.28	1.72	1.90

```
RUNOFF
------
  TOTALS                 0.004    0.000    0.005    0.000    0.000    0.002
                         0.033    0.099    0.018    0.009    0.003    0.000

  STD. DEVIATIONS        0.021    0.000    0.029    0.000    0.003    0.015
                         0.115    0.424    0.085    0.067    0.018    0.002

EVAPOTRANSPIRATION
------------------
  TOTALS                 1.585    2.110    3.137    3.591    3.566    4.120
                         4.883    4.499    3.370    1.618    0.952    1.122

  STD. DEVIATIONS        0.215    0.225    0.555    0.789    1.525    1.538
                         1.587    1.382    1.044    0.605    0.210    0.203

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
  TOTALS                 0.0079   0.0052   0.0055   0.0023   0.0007   0.0011
                         0.0020   0.0024   0.0022   0.0023   0.0029   0.0050

  STD. DEVIATIONS        0.0056   0.0041   0.0049   0.0023   0.0015   0.0020
                         0.0029   0.0034   0.0036   0.0035   0.0037   0.0044

PERCOLATION/LEAKAGE THROUGH LAYER  6
------------------------------------
  TOTALS                 2.8038   1.8404   1.9674   0.8279   0.2591   0.3796
                         0.7187   0.8545   0.7910   0.8131   1.0467   1.7918

  STD. DEVIATIONS        2.0029   1.4735   1.7573   0.8155   0.5192   0.7056
                         1.0195   1.2089   1.2672   1.2426   1.3257   1.5611

LATERAL DRAINAGE COLLECTED FROM LAYER  8
----------------------------------------
  TOTALS                 1.9736   1.9994   1.9510   1.5291   0.8980   0.5776
                         0.4455   0.6065   0.7441   0.7779   0.8165   1.0142

  STD. DEVIATIONS        1.8265   1.5093   1.3296   0.9924   0.4009   0.3624
                         0.4556   0.8032   0.7591   0.8502   1.0118   1.0684

PERCOLATION/LEAKAGE THROUGH LAYER  9
------------------------------------
  TOTALS                 0.1034   0.1056   0.1039   0.0836   0.0518   0.0350
                         0.0283   0.0365   0.0432   0.0450   0.0468   0.0569

  STD. DEVIATIONS        0.0873   0.0726   0.0634   0.0494   0.0208   0.0188
                         0.0236   0.0411   0.0381   0.0424   0.0503   0.0535
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AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.1634	0.1175	0.1146	0.0498	0.0151	0.0228
	0.0418	0.0498	0.0476	0.0474	0.0630	0.1044
STD. DEVIATIONS	0.1169	0.0942	0.1026	0.0491	0.0303	0.0425
	0.0595	0.0706	0.0764	0.0725	0.0799	0.0911

DAILY AVERAGE HEAD ON TOP OF LAYER 9

AVERAGES	3.7248	4.1970	3.7447	3.0778	1.7650	1.1728
	0.8750	1.1856	1.4935	1.5093	1.6359	1.9592
STD. DEVIATIONS	3.3062	3.0193	2.4042	1.9340	0.7878	0.7344
	0.8943	1.5565	1.4925	1.6074	1.9704	2.0268

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 100

	INCHES	CU. FEET	PERCENT
PRECIPITATION	48.90 (7.734)	356612.3	100.00
RUNOFF	0.173 (0.4629)	1265.20	0.355
EVAPOTRANSPIRATION	34.553 (3.5906)	251980.06	70.659
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.03954 (0.01593)	288.350	0.08086
PERCOLATION/LEAKAGE THROUGH LAYER 6	14.09426 (5.66986)	102784.766	28.82255
AVERAGE HEAD ON TOP OF LAYER 6	0.070 (0.028)		
LATERAL DRAINAGE COLLECTED FROM LAYER 8	13.33332 (5.20292)	97235.484	27.26644
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.73988 (0.25802)	5395.670	1.51304
AVERAGE HEAD ON TOP OF LAYER 9	2.195 (0.832)		
CHANGE IN WATER STORAGE	0.061 (2.7057)	447.49	0.125

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	6.87	50100.645
RUNOFF	2.776	20246.8516
DRAINAGE COLLECTED FROM LAYER 5	0.00545	39.76341
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.940647	14152.49800
AVERAGE HEAD ON TOP OF LAYER 6	3.510	
MAXIMUM HEAD ON TOP OF LAYER 6	6.196	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	40.8 FEET	
DRAINAGE COLLECTED FROM LAYER 8	0.89797	6548.63184
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.051842	378.06299
AVERAGE HEAD ON TOP OF LAYER 9	60.763	
MAXIMUM HEAD ON TOP OF LAYER 9	71.881	
LOCATION OF MAXIMUM HEAD IN LAYER 8 (DISTANCE FROM DRAIN)	92.3 FEET	
SNOW WATER	2.36	17212.9980
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3670	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1211	

*** 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 100

LAYER	(INCHES)	(VOL/VOL)
1	1.2341	0.2938
2	9.0002	0.3000
3	0.8712	0.0726
4	2.9197	0.2433
5	2.3784	0.1982
6	0.0000	0.0000
7	15.8591	0.2704
8	4.8106	0.2004
9	0.1500	0.7500
SNOW WATER	0.000	

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