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MEMORANDUM

ATTN: Karen Ueno	**DATE:** September 11, 2012
COMPANY: US EPA Region 9	**GLA PROJECT NO.:** 2011.A057
FROM: Scott Purdy – GLA	
THROUGH: Jeff Pintenich – BC, Chris Lund - GBB	
SUBJECT: Ordot Dump Closure – Task 5 – Evaluation of Site Development Alternatives	
PAGES: 12 (+ Attachments)	

1.0 – INTRODUCTION

As part of Task 5 of the Ordot Dump Closure project, the scope of work for the BC Team includes working collaboratively with the Receiver to establish an overall development plan for the final closure of the Ordot Dump site. The design alternatives and proposed configuration of the Dump were discussed previously with the US EPA Region 9 as well as the Guam EPA and Receiver at the July 23, 2012 meeting in San Francisco. The regulatory agencies were in general agreement with the preferred cover system (described in Section 2.2.2, below), pending receipt of a satisfactory equivalency demonstration and this document.

The purpose of this Memorandum is to facilitate a conceptual evaluation of 1) the final cover system configuration and material alternatives and 2) the site development and grading plan for the Ordot Dump Closure. The Memorandum outlines the pros and cons of each proposed alternative and presents the preferred design alternative. Additionally, since two of the options considered, including the preferred concept, are different from the regulatory prescriptive cover, an equivalency demonstration is presented. Factors considered while developing this plan include but are not limited to the final waste limit, Dump geometry, the preferred cover system, monitoring systems, stormwater control and management facilities, costs, and end-use goals. In addition, design features specific to the Guam region including high seismicity and high winds/precipitation from typhoons were also considered.

2.0 – FINAL COVER EVALUATION

2.1 – REGULATORY STANDARDS

The Ordot Dump is an unlined solid waste facility that falls under the regulatory guidelines described in the Code of Federal Regulations (CFR), Title 40 – Protection of the Environment, Part 258 – Criteria for Municipal Solid Waste Landfills (as adopted by the Guam Administrative Rules and Regulations, Title 22, Division 4). Closure design is addressed in Subpart F of 40 CFR 258 titled, 'Closure and Post-Closure Care,' which reads as follows:

"§258.60 Closure Criteria.

- *(a) Owners or operators of all MSWLF units must install a final cover system that is designed to minimize infiltration and erosion. The final cover system must be designed and constructed to:*
  - *(1) Have a permeability less than or equal to the permeability of any bottom liner system or natural subsoils present, or a permeability no greater than $1x10^{-5}$ cm/sec, whichever is less, and*
  - *(2) Minimize infiltration through the closed MSWLF by the use of an infiltration layer that contains a minimum 18 inches of earthen material, and*
  - *(3) Minimize erosion of the final cover by use of an erosion layer that contains a minimum 6 inches of earthen material that is capable of sustaining native plant growth.*
- *(b) The Director of an approved State may approve an alternative final cover design that includes:*
  - *(1) An infiltration layer that achieves an equivalent reduction in infiltration as the infiltration layer specified in paragraphs (a)(1) and (a)(2) of this section, and*
  - *(2) An erosion layer that provides equivalent protection from wind and water erosion as the erosion layer specified in paragraph (a)(3) of this section."*

These same criteria are required by the Guam Environmental Protection Agency (GEPA) in § 23601 of Title 22, Division 4, Chapter 23, Article 6 of the Guam Administrative Rules and Regulations (GARR).

2.2 – FINAL COVER OPTIONS

In the BC Team's Task 5 scope of work, three different options for a final cover system were specified for evaluation. Those three options are as follows:

1) Prescriptive soil cover system;
2) Geomembrane cover system (soil covered); and
3) Exposed geomembrane cover with optional solar energy collection capability.

The general characteristics of each of these options are described in the following sections.

2.2.1 – Prescriptive Soil Cover System

The minimum required soil cover system for an unlined waste facility is consistent with the prescriptive cover described above and consists of the following, from top to bottom:

- 6-inch-thick erosion layer,
- 18-inch-thick low permeability layer ($k \leq 1.0 \times 10^{-5}$ cm/sec),
- 12-inch-thick foundation layer

2.2.2 – Alternative Geomembrane Cover System (Soil Covered)

The covered geomembrane final cover configuration being considered consists of the following from top to bottom:

- 6-inch-thick erosion layer (Geocell with crushed coral stone infill)
- Geocomposite or geotextile drainage/protection layer

- Geomembrane layer
- Geocomposite landfill gas/leachate interception layer
- 12-inch-thick soil foundation layer

The geocomposite drainage layer on top of the geomembrane will provide drainage on the side slopes, and the geocomposite drainage layer underneath the geomembrane will serve as a collection layer for leachate seeps as well as a gas-relief layer in coordination with the landfill gas collection system. The specified material type for the geomembrane will depend on several factors relating to the site development plan, which is discussed below in Section 2.4.

2.2.3 – Alternative Exposed Geomembrane Cover System with Optional Solar Energy Collection

The exposed geomembrane configuration under consideration would be the same as the soil covered geomembrane system without the erosion and top geocomposite drainage layers. Similar to the previous closure design for the site (Dueñas/URS, 2005), the geomembrane would only be exposed on steep side slopes, whereas the benches and top deck would retain soil cover capable of supporting vegetation on top of the geomembrane. As described in Dueñas/URS (2005), a geogrid layer would be placed over the exposed portions of geomembrane to allow vine plants to become established on the slope and to provide support during high winds.

The exposed geomembrane cover alternative presents the option to incorporate a solar energy collection system. Solar energy collection is gaining popularity with landfill closures and is accomplished by bonding thin, flexible photovoltaic (PV) sheets to a thermoplastic polyolefin (TPO) geomembrane to capture solar energy. The solar energy collection alternative is further discussed in Section 2.4, below.

2.3 – EQUIVALENCY DEMONSTRATION

As discussed at the July 23, 2012 meeting with the US EPA Region 9, Guam EPA and Receiver, the alternative geomembrane cover is desired over the prescriptive soil cover at the Ordot Dump for a number of reasons including constructability concerns about placing and maintaining soils on steep slopes, and for enhanced protection of human health and the environment due to reduction in erosion and infiltration. During the July 23, 2012 meeting, the requirement of an equivalency demonstration was confirmed by the US EPA for an alternative geomembrane cover at the Ordot Dump. Prior to discussing our evaluation of cover material and grading alternatives, the equivalency demonstration is presented to show that an alternative geomembrane cover will meet the regulatory criteria presented herein.

Both the federal regulations at 40 CFR 258.60(b) and the GARR at § 23601(b) contain provisions that allow for the use of alternatives to the prescriptive standard for landfill closures given that the proposed alternative will provide equivalent protection from water infiltration and erosion. To demonstrate equivalency between an alternative geomembrane cover and the prescriptive soil cover, the cover layer performance was compared using the Hydrologic Evaluation of Landfill Performance (HELP) model, Version 3.07. A description of the HELP model, input parameters, and results are described below.

2.3.1 – HELP Model Description

The HELP model was first generated in 1983 by the U.S. Army Corps of Engineers (USCOE) under a contract with the USEPA. The HELP computer program is a quasi-two-dimensional, deterministic, water balance model that utilizes daily climate data, soil and refuse characteristics, and cover/liner system design data to predict the movement of water into, within, and out of landfill boundaries. Documentation of Version 3.0 of the HELP model can be found in Schroeder et al. (1994).

2.3.2 – Model Input

The two simulated cover profiles are consistent with those outlined in Sections 2.2.1 and 2.2.2, above. A 5-foot-thick layer of waste was modeled beneath the foundation layer of each cover profile in order to simulate the interaction between the cover system and the underlying waste and to alleviate lower boundary condition effects.

The material properties used for each layer are shown in **Table 1** and also in the HELP model output files attached to this Memorandum. HELP model defaults were used for characterizing: the erosion layer, barrier soil, crushed coral stone material, geocomposite, geomembrane, native silt interim cover/foundation layer material, and waste. Adjustments were made to the defaults where appropriate, based on laboratory testing or field observation performed by GLA. For example, the 12-inch- thick foundation/interim cover layer (included in both covers) was represented with the predominant silts around the site with an average saturated permeability of 5.0×10^{-5} cm/s based on laboratory testing of borrow materials under low confining pressures, performed by GLA (2012). The crushed coral sand/gravel infill of the 6-inch geocell erosion layer was assigned a saturated permeability of 5.5×10^{-3} cm/s, based on the geometric mean of laboratory testing results reported in Dueñas (2005) and GLA (2012) for this material. The geomembrane was specified as a 60 mil LLDPE with 'good' placement quality, 3 installation defects and 3 pinholes per acre, which is higher than the recommended 1 flaw per acre for "intensely monitored projects" (Giroud and Bonaparte, 1989).

Five years of daily precipitation and temperature data were synthetically generated in the model based on average monthly input values to produce a conservative 5-year simulation period. The average monthly values used as input were calculated as the mean plus 2 standard deviations above the mean precipitation measured from the nearby Guam International Airport Weather Station (Station ID 914226) during it's 65 year period of record. The simulated time period ranged in annual precipitation from 97.9 inches to 143.9 inches with an average annual precipitation of 125.7 inches. The average annual precipitation that was simulated is 2 standard deviations above the measured average annual precipitation of 89.8 inches at this weather station. The maximum daily event modeled was 11.1 inches. Daily solar radiation values were also synthetically generated within the HELP model using the site latitude of 13.43 degrees. Average annual wind speed and quarterly relative humidity were calculated based on daily data from the Guam International Airport.

For the prescriptive cover, it was assumed that the 6-inch erosion layer would support vegetative growth. Given the tropical climate and the relative ease of establishing vegetative growth in Guam, a leaf area index (LAI) of 3.0 was assigned, indicating a 'good' stand of grass.

To be conservative, zero vegetation (LAI = 0.0) was assumed for the geomembrane cover with the crushed coral infill geocell erosion layer.

TABLE 1 – SUMMARY OF SIMULATED MATERIAL PROPERTIES

LAYER DESCRIPTION	THICKNESS (INCHES)	HYDRAULIC CONDUCTIVITY (CM/SEC)	POROSITY (VOL/VOL)	FIELD CAPACITY (VOL/VOL)	WILTING POINT (VOL/VOL)
Prescriptive Soil Cover					
Coral Gravel Erosion Layer	6	5.5×10^{-3}	0.397	0.032	0.013
Barrier Soil Layer	18	1.0×10^{-5}	0.427	0.418	0.367
Silt Foundation Layer	12	5.0×10^{-5}	0.461	0.360	0.203
Waste	60	1.0×10^{-3}	0.671	0.292	0.077
Geomembrane Cover (with soil cover)					
Coral Gravel (Geo-Cell Infill)	6	5.5×10^{-3}	0.397	0.032	0.013
Geocomposite	0.24	33.0	0.850	0.010	0.005
60-mil LLDPE	0.06	4.0×10^{-13}	NA	NA	NA
Geocomposite	0.24	33.0	0.850	0.010	0.005
Silt Foundation Layer	12	5.0×10^{-5}	0.461	0.360	0.203
Waste	60	1.0×10^{-3}	0.671	0.292	0.077

2.3.3 – Infiltration Model Results

Water balance predictions are shown in **Table 2** as well as the attached HELP output files. Percolation/leakage (also referred to as waste infiltration) predictions reflect the amount of water that flowed through each respective cover system and into the waste. The average annual leakage through the prescriptive cover was predicted at 53.8 inches/year, and the average annual leakage through the soil-covered alternative geomembrane cover was 1.6 inches/year. Thus, the inclusion of a geomembrane cover for closure of the Ordot Dump is expected to reduce water infiltration into the waste by more than an order of magnitude relative to the prescriptive soil cover. For purposes of this analysis, the exposed geomembrane cover configuration was not modeled, and is assumed to perform in a similar manner to the soil-covered geomembrane cover system.

TABLE 2 – HELP MODEL RESULTS

Simulated Cover System	Cover Percolation/Leakage Predictions (Inches/Yr.)					
	Year 1	Year 2	Year 3	Year 4	Year 5	Average Annual
Prescriptive Soil Cover	57.6	63.1	44.9	44.0	59.2	53.8
Alternative Geomembrane Cover (with Soil Cover)	1.8	1.8	1.3	1.3	1.7	1.6

Based on the assumptions stated in this analysis, it can be concluded that a geomembrane cover system used for closure of the Ordot Dump site will allow less infiltration of water into the waste than the prescriptive soil cover system, thus satisfying the equivalency criterion of both 40 CFR 258.60(b) and § 23601(b) of GARR.

2.4 – GEOMEMBRANE MATERIALS EVALUATION

Two of the final cover options include a geomembrane, so the next step in the final cover evaluation process is to determine which type of geomembrane material is best suited for the Ordot Dump Closure. There are many different types of materials and manufacturers to consider. The key factors to consider during the geomembrane material selection process include the following:

- Material type and costs
- Ultraviolet light (UV) radiation and chemical resistance
- Installation and seaming
- Tensile and damage-resistance properties (e.g., tear and puncture resistance)
- Thickness
- Interface shear strength (smooth versus textured)
- Flexible solar energy collection panels

2.4.1 – Material Types

The following five geomembrane materials are commonly used in landfill applications and their respective properties are discussed in detail below:

- Ethylene Interpolymer Alloy, EIA 8138 XR-5 (trade name XR-5)
- Coolguard HRL (KEE – Elvaloy® Terpolymer)
- Polyvinyl Chloride (PVC)
- High Density and Linear Low Density Polyethylene (HDPE and LLDPE)
- Reinforced Polypropylene (RPP)

EIA, Coolguard – EIA and Coolguard are robust membranes comprised of sophisticated blends of polymer resins that are designed to be resistant to UV and many chemicals, which makes them good candidates for an exposed geomembrane application. These two materials are scrim reinforced and have high tensile, tear, and puncture strengths. The costs of these materials are nearly double the cost of the other geomembrane materials, and since the other materials are suitable in landfill cover applications, EIA and Coolguard can be ruled out based on cost alone.

Polyvinyl Chloride (PVC) – PVC geomembranes are extremely flexible materials that are more expensive than the polyethylene geomembranes on a per mil basis, though, generally PVC geomembranes are specified to be thinner. PVC can be a cost effective option due to the fact that solvent welding of seams can be performed without specialty installation crews. PVC is the least resistant to chemical, UV exposure and sun-generated heat of the materials under consideration, and thus can be ruled out as the recommended material type considering the desired longevity of the cover system for the Ordot Dump Closure.

Polyethylenes (HDPE & LLDPE) – HDPE and LLDPE are commonly used materials in the industry and have been successfully employed in landfill liner and cover applications for many years. Typical material and installation costs are similar for both HDPE and LLDPE with LLDPE being slightly more costly. HDPE and LLDPE are installed using proven and testable fusion and extrusion welding installation techniques. HDPE has better resistance to UV than LLDPE, and is often recommended for use in exposed liner applications. HDPE is a stiffer material, whereas LLDPE is more flexible and has better multi-axial elongation properties to resist potential differential settlement. Additionally, LLDPE typically provides slightly higher interface frictional resistance. Both HDPE and LLDPE can be manufactured with a textured surface on one or both sides.

The flexibility and elongation properties of LLDPE are preferable in a landfill cover application due to the material's ability to accommodate the differential settlement that occurs within the waste mass. Thus, LLDPE is the preferred polyethylene for the geomembrane cover system at the Ordot Dump, particularly for a soil-covered membrane system. For an exposed membrane cover system, HDPE is the recommended polyethylene to provide better longevity and resistance to UV.

Reinforced Polypropylene (RPP) – Like EIA and Coolguard, RPP is also a durable product with superior chemical and UV resistance properties and is designed to be left exposed. RPP geomembranes have tensile characteristics that make them a material of choice for use in exposed geomembrane applications subject to wind action. One distinct advantage of RPP over HDPE or LLDPE is its ability to withstand temperature fluctuations without expanding and contracting due to its scrim reinforcing. This phenomenon is common with the polyethylene geomembranes, often causing wrinkles to form during installation, which in some cases have to be cut and repaired, adding to installation costs and time. The cost of RPP is approximately an additional $0.15/sq. ft. relative to HDPE or LLDPE; however, the lack of wrinkle development and repair during installation can offset the material cost and speed up construction time. Therefore, RPP is recommended as a possible alternative for the Ordot Dump Closure, and should be further evaluated.

2.4.2 – Thickness

Typical thicknesses for polyethylene geomembranes are 40-mils, 60-mils, and 80-mils. In general, as thickness increases, tensile strength, tear strength, and puncture resistance increase, as well as the height of heat-induced wrinkles. For a soil-covered geomembrane system, the preferred industry standard for similar applications is 60-mil thickness for polyethylene geomembranes. However, in an exposed membrane application, a thicker 80-mil membrane would provide additional resistance to exposure and would be recommended. A polyethylene geomembrane thickness of 40-mil has been used on non-exposed covers, but with flatter slopes and less potential for differential settlement. Therefore, we recommend at least

60-mils for a polyethylene geomembrane for the Ordot Dump Closure. For the more robust RPP geomembrane system, 45-mil is the industry standard for thickness.

2.4.3 – Smooth versus Textured Geomembranes

Polyethylene geomembrane liners are often textured on one or both sides to provide increased frictional resistance. This is often required in slope applications to achieve satisfactory interface frictional resistance with resultant higher factors of safety against instability. The majority of the Ordot Dump surface consists of steep side slopes, for which a double-textured geomembrane will be needed to maintain stable slope conditions in the case of a covered geomembrane, or single-textured in the case of an exposed geomembrane. The cost differential between smooth and textured polyethylene is less than approximately 5%. One disadvantage of RPP is that it is not available with a textured surface, thus providing lower interface shear strength with surrounding materials. Interface shear strength testing of recommended materials will be conducted and discussed in the 40% design document.

2.4.4 – Flexible Solar Membrane

Solar energy collection is gaining popularity with landfill closures and is accomplished by bonding thin, flexible photovoltaic (PV) sheets to the surface of the geomembrane to capture solar energy. This approach is referred to as a flexible solar membrane (FSM) cover and may be viable in an exposed geomembrane application. PV sheets are reported to produce up to 150kW per acre of direct current capacity. Guam's abundant sunshine as well as the island's reliance on imported petroleum products to meet electricity demands makes an FSM cover an attractive alternative. However, the potential for high winds and damage from flying debris during a typhoon present a risk factor to an FSM cover. Additionally, vegetative growth on and around the Dump would impede solar energy collection and present additional maintenance requirements. Furthermore, the largest producer of flexible solar panels (Uni-Solar) has recently declared bankruptcy, which has left Carlisle struggling to find a suitable partner for solar cap production. Therefore, it is not recommended to incorporate a FSM cover into the closure of the Ordot Dump.

3.0 – GRADING OPTIONS

The existing geometry of the Ordot Dump is characterized by short steep slopes of 1 horizontal to 1 vertical (1H:1V) to near vertical in some areas with approximate 15-foot-wide benches every 10 to 15 vertical feet. The overall slope geometry of the Dump ranges from 2.6H:1V to 3H:1V, including the benches. The overall slope height from the toe to the top deck on the northern and eastern sides of the Dump are approximately 75 feet and 100 feet, respectively. The southern and western facing slopes are longer and higher with approximate slope heights nearing 200 vertical feet from toe to top deck.

The BC Team evaluated two fundamental design alternatives for a site development plan, which include the following:

1) Re-grading Option – to flatten the steep slopes of the Dump by re-grading the waste to a shallower sideslope and reducing the number of benches prior to construction of the capping system for closure; and

2) Existing Geometry Option – to utilize the existing geometry of the Dump with minimal re-grading, using innovative design and construction approaches to generate a stable and effective design.

While the placement of some fill material will be required for the re-grading option, the proposed geometry will be accomplished by re-grading the existing waste to the extent possible which will allow the placement of a soil foundation layer to protect the geomembrane. Areas along the southern and western sides may require some buttress fill and/or a mechanically-stabilized earth wall against near vertical limits of waste. A 'significant soil fill' option was also considered to achieve more conventional final slopes, though this option was ruled out based on the fact that the desired final slope configuration may be achieved with re-grading and placement of a lesser amount of fill. The pros and cons of the re-grading and existing geometry options are discussed below.

OPTION 1 – RE-GRADING DUMP TO 'CONVENTIONAL' SIDE SLOPES

The first option involves re-grading the existing slopes and reducing the number of benches. The slopes between benches will be re-graded to a maximum of 2H:1V with 18- to 25-foot-wide benches separated a maximum of 50 feet vertically. This will result in some existing waste being re-graded and used to construct benches or moved to the top deck of the Dump for disposal. **The re-grading option is based on a soil-covered geomembrane cover system**. The following lists the advantages and disadvantages associated with the re-grading option.

Pros (Advantages)

- Shallower slopes allow for the construction of a foundation layer for the cover system
- Shallower slopes allow the geomembrane to be placed with an overlying soil cover (not exposed) as long as erosion control is achieved
- Wider benches provide necessary space for construction access, post-closure site access, stormwater drainage control, and anchorage of geosynthetics
- Shallower side-slopes than the current geometry provides a more stable cover system
- Geomembrane wind uplift is not a concern due to the inclusion of a soil cover
- The geomembrane is protected from short- and long-term physical damage from windblown debris, UV degradation, and oxidation, resulting in a longer lifespan
- This design is more conventional and thus allows for relatively straightforward technical review and permitting
- The inclusion of a soil cover will allow for the development of vegetation, which provides additional erosion resistance, wildlife habitat, and enhanced aesthetics
- Shallower slopes allow for easier post-closure maintenance activities and cover repair
- Shallower side slopes and wider benches allow for easier and more consistent geomembrane and geocomposite installation
- A thinner geomembrane material is feasible if not exposed, which results in a cost reduction
- The soil cover will allow the use of LLDPE instead of HDPE, which is preferred due to its elongation properties and ability to accommodate differential settlement

- The soil cover will reduce the peak rate of stormwater runoff versus an exposed geomembrane cover

Cons (Disadvantages)

- Considerable earthwork is needed to reshape the waste pile
- Sideslope and global stability may be compromised due to disturbance of long-term stable slopes (although flattening the slopes will most likely improve stability)
- The existing cover will either have to be removed before re-grading the waste, and then replaced, or the existing cover will be lost into the mass grading, with placement of new soil cover/foundation layer from borrow materials after completion of the regrading
- Earthworks during inclement weather may be challenging, affecting productivity and the construction schedule
- Concern for erosion in heavy rain during earthwork construction
- Potential odors during excavation and relocation of waste
- Potential windblown litter issues during re-grading of waste
- Leachate generation may increase during exposure of waste to rain while re-grading (existing intermediate cover will be temporarily removed)
- The possibility of fire when waste is exposed during re-grading
- Extended construction schedule
- Higher soil volumes required for soil cover (versus the exposed option)

Neutral impacts

- Landfill gas management not impacted
- Leachate management not impacted

OPTION 2 – MAINTAIN EXISTING DUMP GEOMETRY

Option 2 involves a design approach that accommodates the existing geometry of the Dump, incorporating existing elements into the capping system. Some grading of benches will be required to facilitate stormwater management. Due to the steep existing slopes, a geomembrane with a soil cover is not feasible with this option, thus **this option is predicated upon an exposed geomembrane cover**.

Pros (Advantages)

- Cost savings due to reduced earthworks volumes
- Construction duration potentially shortened
- Reduced soil volume for cover – top deck and benches only
- Reduced concerns for soil erosion
- Decreased short-term environmental and health impacts during construction (relative to the re-grade option)

Cons (Disadvantages)

- Exposed geomembrane is the only practical option with this geometry due to steep slopes
- Soil cover cannot be considered, except on the top deck and benches
- Cannot construct an adequate cover foundation layer on many of the existing side slopes due to steepness
- Narrower benches pose challenges for site access, stormwater drainage system, and geosynthetic anchoring
- Exposed geomembrane is susceptible, short and long-term, to physical damage by windblown debris in high wind and typhoon conditions
- Exposed geomembrane is subject to wind uplift
- Access to slope areas is more difficult with narrower benches
- Extremely challenging geomembrane installation on side slopes, increased cost
- Potential for a more contentious permitting due to unconventional design/slopes
- Geomembrane ballast and/or anchoring on benches will be challenging
- Exposed geomembrane will be subject to oxidation and ultraviolet exposure, resulting in a reduced life span relative to the buried geomembrane option
- A thicker geomembrane material will be recommended to provide better protection against damage from exposure, resulting in a slight cost increase
- HDPE will be recommended over LLDPE, thus losing some of the advantages of LLDPE, as outlined above in Section 2.4
- Higher peak rate of stormwater runoff will require a more robust stormwater drainage system including larger sedimentation basins

Neutral impacts

- Landfill gas management not impacted
- Leachate management not impacted

4.0 – CONCLUSIONS

Preferred Alternative – Option 1 with Geocell Reinforced Soil Cover over Geomembrane

Based on the alternatives comparison outlined above, the advantages presented for Option 1 are greater in number than the advantages presented for Option 2, and the disadvantages for Option 2 are greater in number than the disadvantages for Option 1. Wider benches and shallower side slopes are recommended to provide a safe and effective closure design. Thus, the recommended alternative is to re-grade the existing slopes between benches, thereby reducing the total number of benches from 11 on the southern and western slopes to 4 or 5. The benches would be spaced no more than 50 vertical feet apart with a width of 18 to 25 feet. Intermediate slopes will be inclined at a maximum of 2H:1V, for an overall slope of approximately 2.5H:1V or flatter. The re-grading will not require significant fill to be imported, but rather localized cutting and filling of waste to provide the proposed bench layout. Additional fill soils will likely be obtained from the property directly to the north of the Dump across Dero Road. The idea is to accommodate the existing overall geometry and make it more stable and usable by limiting the number of existing, narrow benches and steep intra-slopes between benches. A buttress fill and/or a mechanically- stabilized earth wall are under consideration for this grading option, and will be incorporated, if needed, for enhanced stability and/or space requirements. A conceptual cross section of the proposed grading plan versus the existing slope geometry is attached in **Figure 3**.

Based on our evaluation, the exposed geomembrane liner option is too susceptible to wind uplift and damage resulting from the high winds associated with typhoons as well as long term degradation. A soil cover over the geomembrane is preferable. However, a soil cover will erode on 2H:1V slopes, and the spacing between benches would result in the need for a variance from the Guam regulations for cut and fills (22 GARR, Division II, Chapter 10). Therefore, the BC Team is recommending that a geocell filled with crushed coral stone material be placed over the geomembrane on the side slopes. The geocell will be anchored on the benches with the use of concrete deadman anchors and the bench cover soils. This configuration provides stability and erosion resistance on the steep slopes, while providing the desired geomembrane protection against wind uplift and damage. The side-slope liner system would then be as follows, from top to bottom, and a conceptual detail drawing is attached as **Figure 4**:

- Geocell filled with crushed coral stone material (vegetated)
- Drainage geocomposite
- 60-mil LLDPE or 45-mil RPP geomembrane
- LFG relief and leachate seep collection geocomposite
- Soil foundation layer
- Existing waste

Finally, based on the discussion above, the recommended options for geomembrane material type are 1) double textured 60-mil LLDPE, or 2) 45-mil RPP. Alternatively, HDPE may also be an acceptable option if there is trouble with procurement of either LLDPE or RPP. These geomembrane materials are typically under warranty for 20 years and are generally anticipated to last in excess of 100 years. A detailed evaluation of these material types including laboratory interface shear strength testing and a final recommendation will be described in the 40% design document.

5.0 – References

Dueñas & Associates and URS Corporation (2005). "Design Report," 100% Submittal, Ordot Dump, Ordot-Chalan Pago, Guam, July 2005.

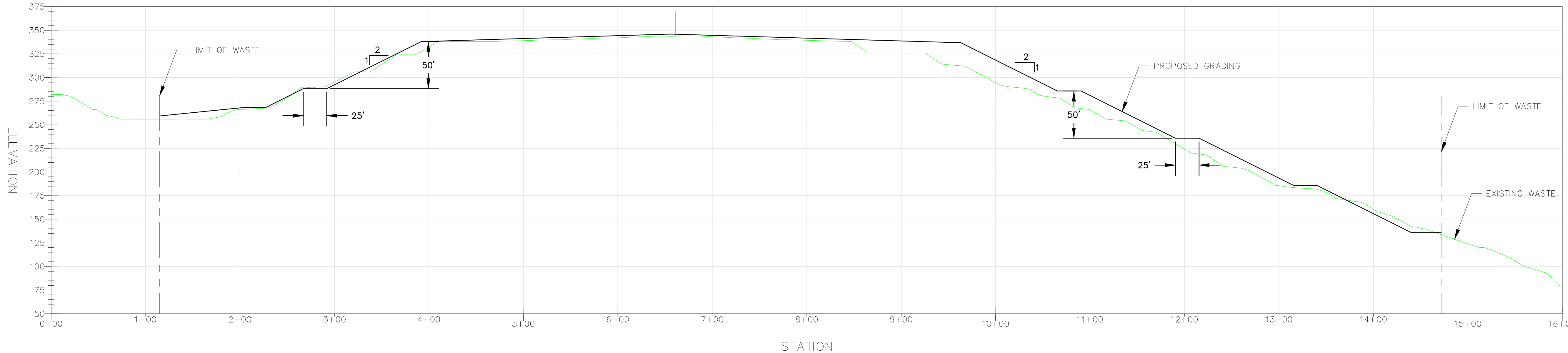
Geo-Logic Associates (2012). Geotechnical Investigation Report, Ordot Dump, Ordot-Chalan Pago, Guam, Project No. 2011.A057, June 2012.

Giroud, J.P and Bonaparte, R. (1989). "Leakage Through Liners Constructed with Geomembranes – Part II," Journal of Geotextiles and Geomembranes, Vol. 8(2), pp. 71-111.

Guam Administrative Rules and Regulations (GARR), Title 22, Division II, Chapter 10 "Guam Soil Erosion and Sediment Control Regulation," § 10111.

Guam Administrative Rules and Regulations (GARR), Title 22, Division 4, Chapter 23, Article 6, § 23601.

Schroeder, P., Lloyd, C. and Zappi, P. (1994). The hydrologic evaluation of landfill performance (HELP) model user's guide for version 3.0. Environmental Protection Agency, Cincinnati, OH.



SECTION A-A'

HORIZ 1" = 60'
VERT 1" = 60'

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
A	07/20/12	ISSUED FOR REVEIW	WC	JVR	JVR	JVR

DATE OF ISSUE: 07/20/2012
DESIGNED BY: JVR
DRAWN BY: WC
CHECKED BY: JVR
APPROVED BY: JVR

Geo-Logic ASSOCIATES

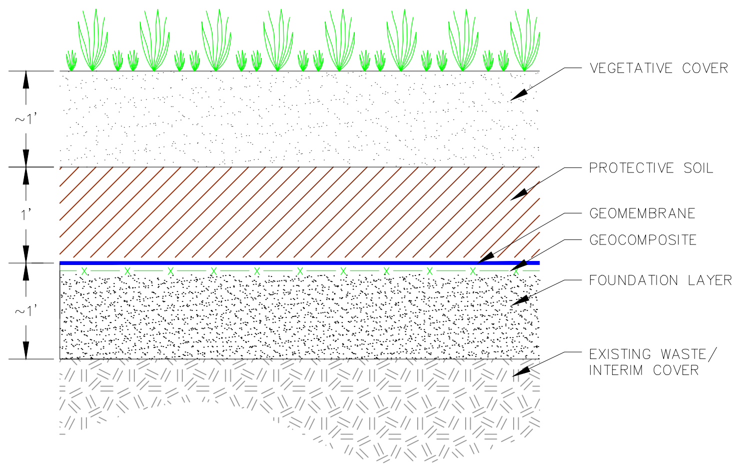
ORDOT DUMP
TEMPORARY COVER SYSTEM DESIGN
ORDOT-CHALAN PAGO, GUAM

CROSS SECTIONS

FIGURE NO. 3
PROJECT NO. 2011.A057

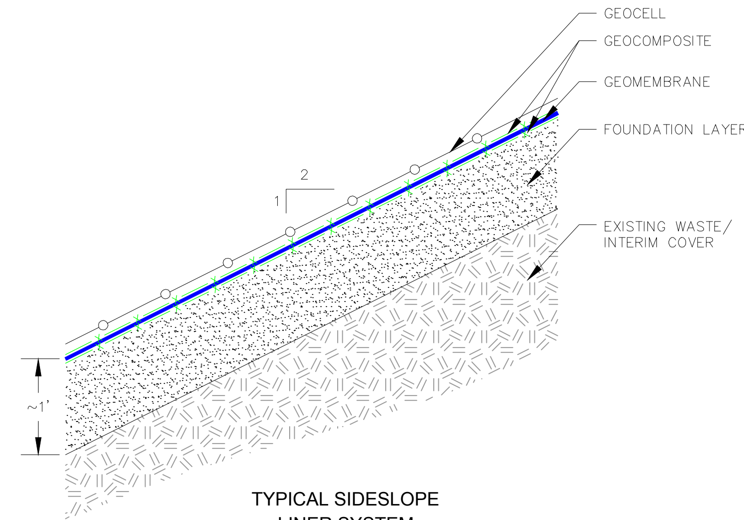
LOCATION: N:\Ordot\Task 5 - Site Development Alternative\CAD\Working Drawings\DESIGN.dwg DATE: 7/19/2012 2:01 PM PLOT SCALE = 1:1.99341803 PLOTTED BY: WICH CHOOMWISET

ISSUED FOR REVIEW



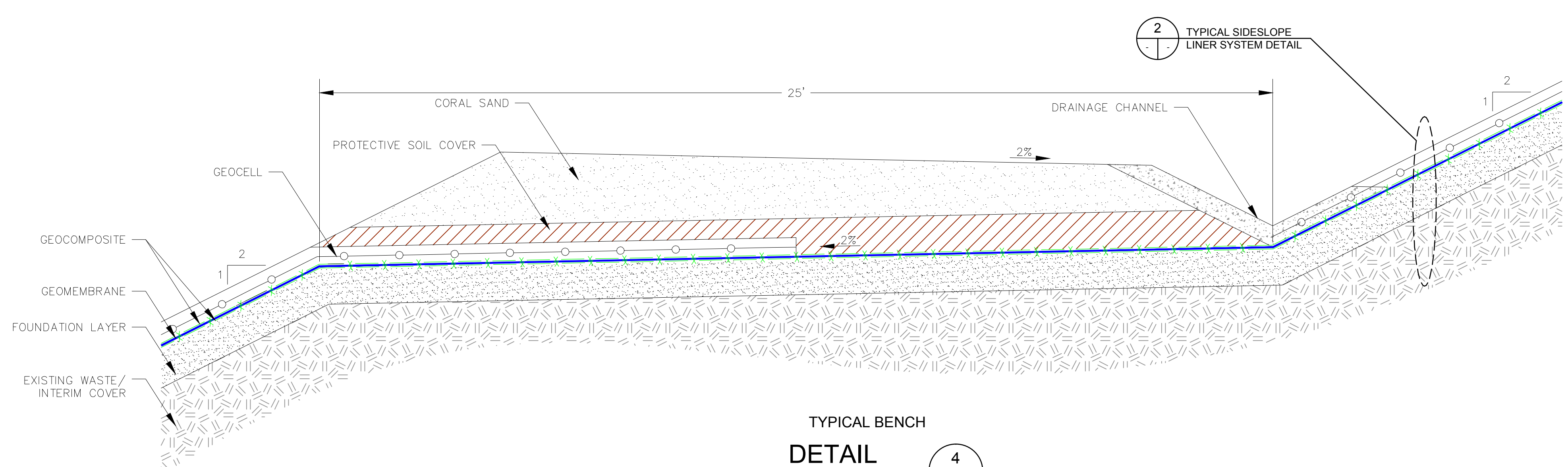
TYPICAL TOP DECK
LINER SYSTEM

DETAIL 1
1" = 1'



TYPICAL SIDESLOPE
LINER SYSTEM

DETAIL 2
1" = 1'



TYPICAL BENCH

DETAIL 4
1" = 2'

REV. NO.	DATE	DESCRIPTION	DRAWN BY	DESIGNED BY	CHECKED BY	APPROVED BY
A	07/20/12	ISSUED FOR REVEIW	WC	JVR	JVR	JVR

DATE OF ISSUE: 07/20/2012
DESIGNED BY: JVR
DRAWN BY: WC
CHECKED BY: JVR
APPROVED BY: JVR

Geo-Logic ASSOCIATES

ORDOT DUMP
EVALUATION OF SITE DEVELOPMENT ALTERNATIVES
ORDOT-CHALAN PAGO, GUAM

DETAILS

FIGURE NO. 4

PROJECT NO. 2011.A057

LOCATION: N:\Ordot\Task 5 - Site Development Alternative\CAD\Working Drawings\DETAILS.dwg DATE: 7/19/2012 11:32 AM PLOT SCALE = 1:2 PLOTTED BY: WICH CHOOMWISET

ISSUED FOR REVIEW

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**                                                                          **
**                                                                          **
**                HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE             **
**                  HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)              **
**                    DEVELOPED BY ENVIRONMENTAL LABORATORY                 **
**                      USAE WATERWAYS EXPERIMENT STATION                   **
**               FOR USEPA RISK REDUCTION ENGINEERING LABORATORY            **
**                                                                          **
**                                                                          **
******************************************************************************
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PRECIPITATION DATA FILE:    C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELPV3~1.07\USER\ordot2rc.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELPV3~1.07\USER\ordot2rc.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELPV3~1.07\USER\ordot2rc.OUT


TIME:   9: 0     DATE:   9/ 7/2012


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

     TITLE:  Ordot Dump_Cover Design_RCRA

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


                                  LAYER  1
                                  --------

                     TYPE 1 - VERTICAL PERCOLATION LAYER
                         MATERIAL TEXTURE NUMBER   0
          THICKNESS                  =      6.00   INCHES
          POROSITY                   =      0.3970 VOL/VOL
          FIELD CAPACITY             =      0.0320 VOL/VOL
          WILTING POINT              =      0.0130 VOL/VOL
          INITIAL SOIL WATER CONTENT =      0.0668 VOL/VOL
          EFFECTIVE SAT. HYD. COND.  =  0.549999997000E-02 CM/SEC


                                  LAYER  2
                                  --------

                         TYPE 3 - BARRIER SOIL LINER
```

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


                          LAYER  3
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER   0
THICKNESS                      =     12.00   INCHES
POROSITY                       =      0.4610 VOL/VOL
FIELD CAPACITY                 =      0.3600 VOL/VOL
WILTING POINT                  =      0.2030 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.4129 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.499999987000E-04 CM/SEC

                          LAYER  4
                          --------

             TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  18
THICKNESS                      =     60.00   INCHES
POROSITY                       =      0.6710 VOL/VOL
FIELD CAPACITY                 =      0.2920 VOL/VOL
WILTING POINT                  =      0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT     =      0.3092 VOL/VOL
EFFECTIVE SAT. HYD. COND.      =  0.100000005000E-02 CM/SEC


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

 NOTE:  SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
          SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE
          GROUND CONDITIONS, A SURFACE SLOPE OF  3.% AND
          A SLOPE LENGTH OF  148. FEET.

SCS RUNOFF CURVE NUMBER              =     71.50
FRACTION OF AREA ALLOWING RUNOFF     =    100.0    PERCENT
AREA PROJECTED ON HORIZONTAL PLANE   =      1.000  ACRES
EVAPORATIVE ZONE DEPTH               =      6.0    INCHES
INITIAL WATER IN EVAPORATIVE ZONE    =      0.401  INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE   =      2.382  INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE   =      0.078  INCHES
INITIAL SNOW WATER                   =      0.000  INCHES
INITIAL WATER IN LAYER MATERIALS     =     31.593  INCHES
TOTAL INITIAL WATER                  =     31.593  INCHES
TOTAL SUBSURFACE INFLOW              =      0.00   INCHES/YEAR


            EVAPOTRANSPIRATION AND WEATHER DATA
```

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
Ordot Guam

STATION LATITUDE	=	13.43 DEGREES
MAXIMUM LEAF AREA INDEX	=	3.00
START OF GROWING SEASON (JULIAN DATE)	=	1
END OF GROWING SEASON (JULIAN DATE)	=	365
EVAPORATIVE ZONE DEPTH	=	6.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	9.00 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	71.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	81.90 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	80.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR MIAMI FLORIDA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
6.32	5.00	3.63	4.72	7.03	9.00
14.73	20.36	19.06	17.31	11.92	7.87

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HONOLULU HAWAII

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
80.10	80.00	80.60	81.60	82.20	82.50
81.90	81.60	81.50	81.70	81.70	81.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HONOLULU HAWAII
AND STATION LATITUDE = 13.43 DEGREES

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ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	139.98	508127.344	100.00
RUNOFF	46.972	170510.016	33.56
EVAPOTRANSPIRATION	35.407	128527.945	25.29

PERC./LEAKAGE THROUGH LAYER 2	57.600403	209089.469	41.15
AVG. HEAD ON TOP OF LAYER 2	1.0899		
PERC./LEAKAGE THROUGH LAYER 4	57.600399	209089.453	41.15
CHANGE IN WATER STORAGE	0.000	0.000	0.00
SOIL WATER AT START OF YEAR	31.592	114680.734	
SOIL WATER AT END OF YEAR	31.592	114680.734	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.083	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT
PRECIPITATION	143.90	522356.875	100.00
RUNOFF	44.964	163217.859	31.25
EVAPOTRANSPIRATION	36.167	131285.766	25.13
PERC./LEAKAGE THROUGH LAYER 2	63.092545	229025.937	43.84
AVG. HEAD ON TOP OF LAYER 2	1.2786		
PERC./LEAKAGE THROUGH LAYER 4	61.980923	224990.750	43.07
CHANGE IN WATER STORAGE	0.789	2862.670	0.55
SOIL WATER AT START OF YEAR	31.592	114680.734	
SOIL WATER AT END OF YEAR	32.381	117543.406	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.180	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT

PRECIPITATION	107.09	388736.750	100.00
RUNOFF	28.574	103722.070	26.68
EVAPOTRANSPIRATION	33.548	121780.930	31.33
PERC./LEAKAGE THROUGH LAYER 2	44.967957	163233.687	41.99
AVG. HEAD ON TOP OF LAYER 2	0.8062		
PERC./LEAKAGE THROUGH LAYER 4	47.745171	173314.969	44.58
CHANGE IN WATER STORAGE	-2.777	-10081.197	-2.59
SOIL WATER AT START OF YEAR	32.381	117543.406	
SOIL WATER AT END OF YEAR	29.604	107462.211	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.028	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	97.95	355558.562	100.00
RUNOFF	19.658	71358.766	20.07
EVAPOTRANSPIRATION	34.287	124462.141	35.00
PERC./LEAKAGE THROUGH LAYER 2	44.004852	159737.609	44.93
AVG. HEAD ON TOP OF LAYER 2	0.7419		
PERC./LEAKAGE THROUGH LAYER 4	42.793209	155339.344	43.69
CHANGE IN WATER STORAGE	1.212	4398.223	1.24
SOIL WATER AT START OF YEAR	29.604	107462.211	
SOIL WATER AT END OF YEAR	30.816	111860.430	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.097	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	139.77	507365.000	100.00
RUNOFF	44.824	162709.937	32.07
EVAPOTRANSPIRATION	35.461	128724.836	25.37
PERC./LEAKAGE THROUGH LAYER 2	59.242764	215051.234	42.39
AVG. HEAD ON TOP OF LAYER 2	1.0733		
PERC./LEAKAGE THROUGH LAYER 4	58.980396	214098.844	42.20
CHANGE IN WATER STORAGE	0.505	1831.492	0.36
SOIL WATER AT START OF YEAR	30.816	111860.430	
SOIL WATER AT END OF YEAR	31.320	113691.922	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.097	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.50	4.36	2.46	2.63	9.45	11.05
	17.40	21.00	15.82	12.92	16.90	5.24
STD. DEVIATIONS	2.60	4.73	0.98	2.36	2.92	2.53
	3.89	13.25	3.79	6.16	10.72	3.67
RUNOFF						
TOTALS	1.469	0.907	0.000	0.369	2.395	0.344
	5.347	9.613	2.775	4.135	9.032	0.612
STD. DEVIATIONS	1.541	1.643	0.001	0.824	1.664	0.356
	3.719	10.598	2.065	4.191	7.618	1.365
EVAPOTRANSPIRATION						
TOTALS	1.422	1.338	1.310	1.419	3.480	5.195

	4.875	4.763	4.447	3.104	2.323	1.298
STD. DEVIATIONS	0.484	0.597	0.466	0.923	1.083	0.721
	0.818	0.615	0.537	0.707	0.578	0.429

PERCOLATION/LEAKAGE THROUGH LAYER 2

TOTALS	2.8927	2.8567	1.0369	1.0070	3.4189	5.1059
	6.3026	7.0627	7.9833	6.4534	5.6653	3.9963
STD. DEVIATIONS	0.8327	2.4451	0.7294	0.9427	0.5095	2.0779
	1.2335	2.3974	1.5015	2.3037	2.5817	2.5896

PERCOLATION/LEAKAGE THROUGH LAYER 4

TOTALS	2.8654	3.1250	1.9613	0.5812	2.5614	3.8001
	5.8617	7.0603	6.7651	8.3785	5.6306	5.2293
STD. DEVIATIONS	1.3756	2.2729	1.6455	0.6573	2.1659	1.9847
	1.7618	1.0904	1.3300	1.2484	2.7817	2.2051

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 2

AVERAGES	0.5576	0.7375	0.1129	0.1667	0.7139	0.9952
	1.4019	1.5528	1.9421	1.5130	1.4994	0.7829
STD. DEVIATIONS	0.1857	0.7762	0.1935	0.2442	0.1866	0.7287
	0.5409	0.9207	0.5518	0.7575	0.8724	0.8031

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES		CU. FEET	PERCENT
PRECIPITATION	125.74	(21.503)	456428.9	100.00
RUNOFF	36.998	(12.2048)	134303.72	29.425
EVAPOTRANSPIRATION	34.974	(1.0431)	126956.32	27.815
PERCOLATION/LEAKAGE THROUGH LAYER 2	53.78170	(8.72306)	195227.578	42.77283
AVERAGE HEAD ON TOP OF LAYER 2	0.998	(0.221)		
PERCOLATION/LEAKAGE THROUGH	53.82002	(8.15499)	195366.672	42.80331

LAYER 4

CHANGE IN WATER STORAGE	-0.054	(1.5845)	-197.76	-0.043

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	11.11	40329.297
RUNOFF	9.824	35661.0195
PERCOLATION/LEAKAGE THROUGH LAYER 2	0.453537	1646.34021
AVERAGE HEAD ON TOP OF LAYER 2	6.000	
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.599324	2175.54517
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.3970
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

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FINAL WATER STORAGE AT END OF YEAR 5

LAYER	(INCHES)	(VOL/VOL)
1	0.3202	0.0534
2	7.6860	0.4270
3	4.3267	0.3606
4	18.9873	0.3165
SNOW WATER	0.000	

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**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.07  (1 NOVEMBER 1997)                **
**                  DEVELOPED BY ENVIRONMENTAL LABORATORY                   **
**                    USAE WATERWAYS EXPERIMENT STATION                     **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D4
TEMPERATURE DATA FILE:      C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D7
SOLAR RADIATION DATA FILE:  C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D13
EVAPOTRANSPIRATION DATA:    C:\PROGRA~1\HELPV3~1.07\USER\ORDOT2.D11
SOIL AND DESIGN DATA FILE:  C:\PROGRA~1\HELPV3~1.07\USER\ordot2gm.D10
OUTPUT DATA FILE:           C:\PROGRA~1\HELPV3~1.07\USER\ordot2gm.OUT


TIME:   8:54     DATE:   9/ 7/2012


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     TITLE:  Ordot Dump_Closure Design_60mil LLDPE

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


                                  LAYER  1
                                  --------

                      TYPE 1 - VERTICAL PERCOLATION LAYER
                          MATERIAL TEXTURE NUMBER   0
           THICKNESS                   =      6.00   INCHES
           POROSITY                    =      0.3970 VOL/VOL
           FIELD CAPACITY              =      0.0320 VOL/VOL
           WILTING POINT               =      0.0130 VOL/VOL
           INITIAL SOIL WATER CONTENT  =      0.0130 VOL/VOL
           EFFECTIVE SAT. HYD. COND.   =  0.549999997000E-02 CM/SEC


                                  LAYER  2
                                  --------

                        TYPE 2 - LATERAL DRAINAGE LAYER
                          MATERIAL TEXTURE NUMBER  34
```

```
THICKNESS                     =      0.24   INCHES
POROSITY                      =      0.8500 VOL/VOL
FIELD CAPACITY                =      0.0100 VOL/VOL
WILTING POINT                 =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0100 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =   33.0000000000     CM/SEC
SLOPE                         =      3.00   PERCENT
DRAINAGE LENGTH               =    148.0    FEET


                        LAYER  3
                        --------

            TYPE 4 - FLEXIBLE MEMBRANE LINER
              MATERIAL TEXTURE NUMBER  36
THICKNESS                     =      0.06   INCHES
POROSITY                      =      0.0000 VOL/VOL
FIELD CAPACITY                =      0.0000 VOL/VOL
WILTING POINT                 =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY           =      3.00   HOLES/ACRE
FML INSTALLATION DEFECTS      =      3.00   HOLES/ACRE
FML PLACEMENT QUALITY         =  3 - GOOD


                        LAYER  4
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  34
THICKNESS                     =      0.24   INCHES
POROSITY                      =      0.8500 VOL/VOL
FIELD CAPACITY                =      0.0100 VOL/VOL
WILTING POINT                 =      0.0050 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.0659 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =   33.0000000000     CM/SEC


                        LAYER  5
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER   0
THICKNESS                     =     12.00   INCHES
POROSITY                      =      0.4610 VOL/VOL
FIELD CAPACITY                =      0.3600 VOL/VOL
WILTING POINT                 =      0.2030 VOL/VOL
INITIAL SOIL WATER CONTENT    =      0.3568 VOL/VOL
EFFECTIVE SAT. HYD. COND.     =  0.499999987000E-04 CM/SEC


                        LAYER  6
                        --------

          TYPE 1 - VERTICAL PERCOLATION LAYER
              MATERIAL TEXTURE NUMBER  18
```

THICKNESS	=	60.00 INCHES
POROSITY	=	0.6710 VOL/VOL
FIELD CAPACITY	=	0.2920 VOL/VOL
WILTING POINT	=	0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2856 VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.100000005000E-02 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE #21 WITH BARE GROUND CONDITIONS, A SURFACE SLOPE OF 3.% AND A SLOPE LENGTH OF 148. FEET.

SCS RUNOFF CURVE NUMBER	=	71.50	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	1.000	ACRES
EVAPORATIVE ZONE DEPTH	=	6.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	0.078	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	2.382	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	0.078	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	21.513	INCHES
TOTAL INITIAL WATER	=	21.513	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM Ordot Guam

STATION LATITUDE	=	13.43 DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00
START OF GROWING SEASON (JULIAN DATE)	=	1
END OF GROWING SEASON (JULIAN DATE)	=	365
EVAPORATIVE ZONE DEPTH	=	6.0 INCHES
AVERAGE ANNUAL WIND SPEED	=	9.00 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	71.30 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	73.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	81.90 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	80.00 %

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING COEFFICIENTS FOR MIAMI FLORIDA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
6.32	5.00	3.63	4.72	7.03	9.00

14.73	20.36	19.06	17.31	11.92	7.87

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HONOLULU HAWAII

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
80.10	80.00	80.60	81.60	82.20	82.50
81.90	81.60	81.50	81.70	81.70	81.00

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR HONOLULU HAWAII
AND STATION LATITUDE = 13.43 DEGREES

****

ANNUAL TOTALS FOR YEAR 1

	INCHES	CU. FEET	PERCENT
PRECIPITATION	139.98	508127.344	100.00
RUNOFF	11.564	41975.988	8.26
EVAPOTRANSPIRATION	33.092	120122.375	23.64
DRAINAGE COLLECTED FROM LAYER 2	93.5299	339513.437	66.82
PERC./LEAKAGE THROUGH LAYER 3	1.794955	6515.686	1.28
AVG. HEAD ON TOP OF LAYER 3	0.0067		
PERC./LEAKAGE THROUGH LAYER 6	2.200221	7986.802	1.57
CHANGE IN WATER STORAGE	-0.405	-1471.115	-0.29
SOIL WATER AT START OF YEAR	21.515	78100.078	
SOIL WATER AT END OF YEAR	21.110	76628.961	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.177	0.00

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ANNUAL TOTALS FOR YEAR 2

	INCHES	CU. FEET	PERCENT

	INCHES	CU. FEET	PERCENT
PRECIPITATION	143.90	522356.875	100.00
RUNOFF	10.279	37312.449	7.14
EVAPOTRANSPIRATION	34.949	126866.398	24.29
DRAINAGE COLLECTED FROM LAYER 2	96.9064	351770.281	67.34
PERC./LEAKAGE THROUGH LAYER 3	1.765258	6407.885	1.23
AVG. HEAD ON TOP OF LAYER 3	0.0070		
PERC./LEAKAGE THROUGH LAYER 6	2.233611	8108.009	1.55
CHANGE IN WATER STORAGE	-0.468	-1700.129	-0.33
SOIL WATER AT START OF YEAR	21.110	76628.961	
SOIL WATER AT END OF YEAR	20.642	74928.836	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.129	0.00

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ANNUAL TOTALS FOR YEAR 3

	INCHES	CU. FEET	PERCENT
PRECIPITATION	107.09	388736.750	100.00
RUNOFF	11.975	43468.027	11.18
EVAPOTRANSPIRATION	30.422	110432.219	28.41
DRAINAGE COLLECTED FROM LAYER 2	63.3990	230138.250	59.20
PERC./LEAKAGE THROUGH LAYER 3	1.294270	4698.202	1.21
AVG. HEAD ON TOP OF LAYER 3	0.0046		
PERC./LEAKAGE THROUGH LAYER 6	1.477356	5362.803	1.38
CHANGE IN WATER STORAGE	-0.183	-664.597	-0.17
SOIL WATER AT START OF YEAR	20.642	74928.836	
SOIL WATER AT END OF YEAR	20.458	74264.234	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00

ANNUAL WATER BUDGET BALANCE	0.0000	0.040	0.00

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ANNUAL TOTALS FOR YEAR 4

	INCHES	CU. FEET	PERCENT
PRECIPITATION	97.95	355558.562	100.00
RUNOFF	4.939	17927.027	5.04
EVAPOTRANSPIRATION	31.407	114008.977	32.06
DRAINAGE COLLECTED FROM LAYER 2	60.2746	218796.656	61.54
PERC./LEAKAGE THROUGH LAYER 3	1.329447	4825.893	1.36
AVG. HEAD ON TOP OF LAYER 3	0.0043		
PERC./LEAKAGE THROUGH LAYER 6	1.495804	5429.769	1.53
CHANGE IN WATER STORAGE	-0.166	-603.876	-0.17
SOIL WATER AT START OF YEAR	20.458	74264.234	
SOIL WATER AT END OF YEAR	20.292	73660.359	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	0.029	0.00

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ANNUAL TOTALS FOR YEAR 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	139.77	507365.000	100.00
RUNOFF	15.924	57803.937	11.39
EVAPOTRANSPIRATION	33.737	122464.336	24.14
DRAINAGE COLLECTED FROM LAYER 2	88.3894	320853.656	63.24
PERC./LEAKAGE THROUGH LAYER 3	1.662330	6034.257	1.19
AVG. HEAD ON TOP OF LAYER 3	0.0064		
PERC./LEAKAGE THROUGH LAYER 6	1.937196	7032.021	1.39

CHANGE IN WATER STORAGE	-0.217	-788.849	-0.16
SOIL WATER AT START OF YEAR	20.292	73660.359	
SOIL WATER AT END OF YEAR	20.075	72871.516	
SNOW WATER AT START OF YEAR	0.000	0.000	0.00
SNOW WATER AT END OF YEAR	0.000	0.000	0.00
ANNUAL WATER BUDGET BALANCE	0.0000	-0.093	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 5

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.50	4.36	2.46	2.63	9.45	11.05
	17.40	21.00	15.82	12.92	16.90	5.24
STD. DEVIATIONS	2.60	4.73	0.98	2.36	2.92	2.53
	3.89	13.25	3.79	6.16	10.72	3.67
RUNOFF						
TOTALS	0.339	0.190	0.000	0.097	0.601	0.072
	1.452	3.881	0.463	0.728	3.013	0.098
STD. DEVIATIONS	0.360	0.355	0.001	0.217	0.647	0.079
	1.548	4.500	0.375	0.681	2.506	0.216
EVAPOTRANSPIRATION						
TOTALS	1.547	1.433	1.248	1.194	2.889	4.528
	4.443	4.296	4.229	2.802	2.348	1.764
STD. DEVIATIONS	0.716	0.768	0.461	0.915	0.988	0.588
	0.839	0.598	0.459	0.773	0.640	0.802
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	3.9182	3.1827	1.0402	1.4418	5.6868	6.0189
	11.0047	12.7231	10.6154	9.6785	11.5031	3.6866
STD. DEVIATIONS	1.6875	3.3969	0.6948	1.5793	1.6177	2.2054
	3.2765	8.8558	3.0938	5.3972	7.4944	3.1056
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.0806	0.0706	0.0439	0.0467	0.1117	0.1474
	0.1993	0.2126	0.2163	0.1832	0.1667	0.0903

STD. DEVIATIONS	0.0254	0.0478	0.0170	0.0301	0.0222	0.0331
	0.0501	0.0889	0.0495	0.0765	0.0878	0.0582

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.0892	0.0806	0.0564	0.0409	0.1206	0.1962
	0.2408	0.2337	0.2713	0.2300	0.1848	0.1244
STD. DEVIATIONS	0.0417	0.0526	0.0240	0.0296	0.0248	0.0722
	0.1048	0.0888	0.0785	0.1238	0.0973	0.0882

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	0.0033	0.0030	0.0009	0.0013	0.0048	0.0053
	0.0094	0.0108	0.0093	0.0082	0.0101	0.0031
STD. DEVIATIONS	0.0014	0.0032	0.0006	0.0014	0.0014	0.0019
	0.0028	0.0075	0.0027	0.0046	0.0066	0.0026

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1 THROUGH 5

	INCHES	CU. FEET	PERCENT
PRECIPITATION	125.74 (21.503)	456428.9	100.00
RUNOFF	10.936 (3.9608)	39697.48	8.697
EVAPOTRANSPIRATION	32.721 (1.8128)	118778.85	26.024
LATERAL DRAINAGE COLLECTED FROM LAYER 2	80.49985 (17.34005)	292214.437	64.02190
PERCOLATION/LEAKAGE THROUGH LAYER 3	1.56925 (0.24039)	5696.384	1.24803
AVERAGE HEAD ON TOP OF LAYER 3	0.006 (0.001)		
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.86884 (0.36741)	6783.881	1.48630
CHANGE IN WATER STORAGE	-0.288 (0.1388)	-1045.71	-0.229

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 5

	(INCHES)	(CU. FT.)
PRECIPITATION	11.11	40329.297
RUNOFF	5.867	21297.6133
DRAINAGE COLLECTED FROM LAYER 2	4.59551	16681.69140
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.036164	131.27429
AVERAGE HEAD ON TOP OF LAYER 3	0.121	
MAXIMUM HEAD ON TOP OF LAYER 3	0.238	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	2.9 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 6	0.045282	164.37460
SNOW WATER	0.00	0.0000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.2513
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0130

*** 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 5

LAYER	(INCHES)	(VOL/VOL)
1	0.1348	0.0225
2	0.0031	0.0132
3	0.0000	0.0000
4	0.0163	0.0691
5	4.1450	0.3454
6	15.7733	0.2629
SNOW WATER	0.000	

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