Duke Energy

Marshall Steam Station

Catawba County, NC

Received
NOV 2004
Solid Waste Section

Flue Gas Desulfurization (FGD) Residue Landfill

Permit Application

.0503(2)(d)(ii)(A) Compliance Demonstration Report

Addendum

November 12, 2004

SCANNED
5/14/14

APPROVED
DIVISION OF WASTE MANAGEMENT
SOLID WASTE SECTION
DATE 1/14/05 BY
MRO
18-09

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PO Box 1244
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SCANNED 5/14/14

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November 12, 2004

Prepared by:

NORTH CAROLINA PROFESSIONAL SEAL 17661 ENGINEER WILLIAM M. MILLER

Nov. 12, 2004

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Executive Summary

This Addendum to the original compliance demonstration report was prepared to address questions and comments provided by NCDENR in a letter dated September 20, 2004. This Addendum provides the demonstration that the design for the Marshall Flue Gas Desulfurization (FGD) residue landfill will ensure that 2L groundwater standards are not exceeded at the compliance boundary. This conclusion was reached by review of the site-specific conditions, leaching tests performed on the FGD residue, and by the use of groundwater modeling.

The design evaluated in this demonstration ensures that the ground water standards established under 15A NCAC 2L will not be exceeded.

The design evaluated in this demonstration requires:

1. the active landfill will receive FGD residue for a 5 year period.

2. an engineered cover will be placed on the completed landfill at the end of the 5 year period.

3. The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer. A detail showing the cover system is shown on drawing MM 6551.00-0001.001.

4. The drainage collected by the geocomposite drainage net will drain to the erosion control benches, as well as draining to the anchor trench. This will limit the drainage length of the geocomposite to no greater than 300 feet. The location of the erosion control benches is shown on drawing M-6024-06.00.

Other than the engineered cover described above, there are no special engineering features or considerations that must be included or maintained in site construction, operation, maintenance and closure.

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Description of Addendum

This addendum presents changes to the original Compliance Demonstration Report [Reference 10] as a result of comments by NCDNER. A copy of the NCDENR comments are found in Attachment 7.

In general, the comments from NCDENR applicable to the Compliance Demonstration were related to the HELP Model and properties of the materials to be placed in the landfill. A copy of the Duke responses to the NCDENR comments is found in Attachment 8.

In response to the NCDENR comments, the HELP analyses were performed with additional thickness of material to represent the different stages of waste placement. These HELP analyses were include an operational soil cover of 8 inches of soil after 10 feet of FGD residue placement.

The revised infiltration values were then used as input in the MYGRT fate and transport analyses.

NCDENR also requested that arsenic be modeled to evaluate compliance at the 2L compliance boundary.

The MYGRT fate and transport model results found that the conclusion of the previous Compliance Demonstration report remains valid.

Notes:

1. *Changes from the original Compliance Demonstration text are marked with a vertical line in the right margin.*
2. *There were no changes in the following Attachments. Copies of these Attachments are not included in this Addendum.*
   Attachment 1, 2, 4
3. *The only change to Attachment 5 was the calculated thickness of the unsaturated zone. Only the affected sheet is included as Attachment 5.*
4. *The Estimated Seasonal High Groundwater profile shown on Figure 2 had incorrectly shown the profile to be higher than projected. The corrected profile is shown on Figure 2 Revision 1*

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Attachment 1	FGD Scrubber Sludge Testing (Revision 1), Duke Power Coal Fired Steam Stations in North Carolina, S&ME Project No. 1264-03-57, February 2004.
Attachment 2	Geochemical Evaluation of Flue Gas Desulfurization Scrubber Waste, letter from William J, Deutsch, Senior Geochemist, Battelle Pacific Northwest Laboratory to Bill Miller, Duke Energy, dated June 23, 2003.
Attachment 3	HELP Model Input Data and Results
Attachment 4	MYGRT Manual
Attachment 5	Input Data for MYGRT Model Runs
Attachment 6	MYGRT Model Inputs and Results
Attachment 7	Letter from Ellen Lorscheider, NCDENR to Allen Stowe, Duke Power, dated September 20, 2004.
Attachment 8	Letter from Allen Stowe, Duke Power, to Ellen Lorscheider, NCDENR, dated November 15, 2004.

Note: The information contained in Attachments 1, 2, and 4 was used in the preparation of this report. The parties indicated on the covers of these reports prepared these reports and documents. The engineering certification on the cover page of this report does not imply that the engineering certification of this report includes certification of these particular documents.

There were no changes in the following Attachments: Attachment 1, 2, 4. Copies of these Attachments are not included in this Addendum.

The only change to Attachment 5 was the calculated thickness of the unsaturated zone. Only a copy the affected sheet is included as Attachment 5.

1.0 Regulatory Requirements

The regulatory requirements for the design of a solid waste, industrial landfill are found in North Carolina Administrative Code, Title 15A, Chapter 13 Solid Waste Management, Section .0503 Siting and Design Requirements for Disposal Sites. In particular, Section .0504(2)(d)(ii) requires that:

> *(A) a design that will ensure that the ground water standards established under 15A NCAC 2L will not be exceeded in the uppermost aquifer at the compliance boundary established by the Division in accordance with 15A NCAC 2L. The design shall be based upon modeling methods acceptable to the Division, which shall include, at a minimum, the following factors:*
>
> > *(I) the hydrogeologic characteristics of the facility and surrounding lands;*
> > *(II) the climatic factors of the area; and*
> > *(III) the volume and physical and chemical characteristics of the leachate; or*
>
> *(B) a design with a leachate collection system, a closure cap system, and a composite liner system consisting of two components: the upper component shall consist of a minimum 30-ml flexible membrane (FML), and the lower components shall consist of at least a two-foot layer of compacted soil with a hydraulic conductivity of no more than 1 X 10^{-7}cm/sec. FML components consisting of high density polyethylene (HDPE) shall be at least 60-ml thick. The FML component shall be installed in direct and uniform contact with the compacted soil component.*

This report was prepared to demonstrate that the conceptual design submitted in the Duke Power, Marshall Steam Station, Catawba County, N.C., Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, Site Suitability Information August 29, 2003 [Reference 1] will ensure that the ground water standards established under 15A NCAC 2L will not be exceeded in the uppermost aquifer at the compliance boundary established by the Division in accordance with 15A NCAC 2L.

2.0 Description of Flue Gas Desulphurization (FGD) System

The Clean Smokestacks Act passed in 2002 requires significant reductions in emissions from coal-fired power plants operating in North Carolina. NC utilities must reduce the actual emissions of nitrous oxides (NO_X) by 77% by the year 2009 and must reduce actual sulfur dioxide (SO_2) emissions by 49% by the year 2009 and by 73% by 2013. As part of Duke Power's effort to meet the SO_2 reduction requirements, a Flue Gas Desulphurization (FGD) system will be installed at the Marshall Steam Station. Duke will also install similar FGD systems at other power plants located in NC. Duke's intent is that a large portion of the residue from this process will be utilized in beneficial products and the remainder will be placed in the proposed FGD residue landfill.

The FGD system contracted for installation at Marshall is a Wet Scrubber system. In a Wet Scrubber system the SO_2 component of the flue gas produced from the coal combustion process is removed by reaction with a limestone-water slurry.

The particular system to be used at Marshall will collect the flue gas after it passes through the electrostatic precipitator and route the gas into the lower end of a vertical tank. As the gas rises through the tank to the outlet at the top, the gas passes through a spray header. An atomized slurry of water and limestone droplets is continually sprayed through this header into the stream of flue gas. The SO_2 in the flue gas reacts with the calcium in the limestone and produces SO_3. The SO_3 slurry falls to the bottom of the tank where a stream of air is injected to oxidize the slurry to form gypsum ($CaSO_4 \cdot H_2O$). The gypsum slurry is then drawn off to a hydroclone and subsequently routed to a vacuum belt filter. The liquid waste from this process will be treated as wastewater.

Duke is presently investigating beneficial uses for the FGD residue (gypsum). If these options are determined to be viable, the FGD residue meeting the material requirements for the beneficial uses will not be disposed in the landfill. FGD residue material that does not meet the specifications for the end use product will be placed in the landfill.

3.0 Description of Conceptual Design

The conceptual design for the proposed gypsum landfill is shown on the drawings included in the construction plan application, submitted on April 1, 2004. The landfill will consist of a gypsum monofill, utilizing gypsum produced at the Marshall Steam Station and at other Duke plants located within NC. The gypsum will be transported to the landfill by truck, where it will be placed and compacted.

The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer.

The vegetative layer protects the geomembrane and geocomposite from ultraviolet degradation, desiccation, freeze-thaw, wind, and vectors. The vegetative layer will be stabilized and seeded appropriately to prevent erosion.

4.0 Description of Demonstration Approach

The general approach to demonstrate compliance with 2L standards was:

Step 1. Perform SPLP leaching tests on the FGD residue (gypsum) and determine if gypsum leachate constituents exceed the NCAC T15A 2L groundwater standards.

Step 2. Develop conceptual groundwater flow model of site.

Step 3. Use of HELP model to determine the infiltration rates expected at the landfill. These values will be the rate of leachate that will infiltrate into the soil beneath the landfill.

Step 4. Determine the groundwater concentrations of the leachate at the compliance boundary with use of the MYGRT model.

Step 5. Compare the modeled groundwater concentrations to NCAC T15A 2L standards.

5.0 SPLP Leaching Analyses Performed on FGD Residue Samples

5.1.1 Gypsum Samples

As described in Reference 1, the typical parameters for the FGD material produced by the scrubber system to be used at Marshall are:

Typical FGD Residue Parameters

Gypsum	93% to 95%
Sulfite	0.35%
CO_3	1.3%
CaF_2	0.2%
Inerts	2.5% to 3.5%
Fly ash Content	0.5% to 0.8%
pH	6.0 to 8.3
Unit Weight	76 lb/ft^3 to 97 lb/ft^3
Specific Gravity	2.35
Moisture	10% to 12%

FGD residue material that is not suitable for beneficial use will be placed in the landfill. In addition to this material, material will periodically be removed from the clarifier stage of the waste-water treatment system and placed in the landfill. The material from the clarifier stage will be the same composition as the FGD residue, but will consist of smaller particles.

Gypsum samples obtained from two power plants were obtained by Duke for analysis. These plants are identified as the CO Plant and the HC Plant.[1] The CO Plant uses a FGD process designed by the same vendor supplying the Marshall FGD system and has similar system design parameters. The CO plant also uses coal that is similar in origin to the coal used by Marshall.

These FGD residue samples were sent to the Pacific Northwest National Laboratory (PNNL)[2] for geochemical evaluation. This evaluation included SPLP[3] leaching studies, analysis of solid samples by x-ray diffraction (XRD), and calculation of saturation indices to identify minerals in equilibrium with the solution phase.

[1] At the time the material was obtained, Duke had not finalized the equipment vendor selection. Therefore material from two different vendors was obtained for these analyses.
[2] PNNL is managed by the US Department of Energy and operated by Battelle.
[3] USEPA Method 1312.

To better understand the changes in leachate over time, sequential leaching tests were performed. The report is provided in Attachment 2. The results from the report are summarized below:

> *The total dissolved solids and sulfate concentrations exceeded the 2L standards for both types of waste in all leachates by factors of about 4 and 6, respectively. The initial leaches of both waste types exceeded the fluoride 2L standard by a factor of about 2; however, the fluoride concentrations decreased with subsequent leaches and either dropped below or were very close to the standard of 2 mg/L by the fifth leach. The arsenic concentrations in all leachates started below the 2L standard of 0.01 mg/L, but the concentrations increased with subsequent leaches and exceeded the standard by a small amount in all cases after the second or third leach. XRD analysis showed that the dominant mineral in the waste was gypsum ($CaSO_4{:}2H_2O$). Saturation index calculations confirm that gypsum is controlling the calcium and sulfate concentrations in the leachate and producing the major ions in solution.*

5.1.2 Comparison of Results of SPLP Leaching Analyses to 2L Standards

The comparison of the results of the leaching analyses to the NCAC T15A 2L Groundwater Standards is presented in Table 5-1. As this table shows, the concentrations of sulfate (SO_4) and fluoride (Fl_2) exceed the 2L groundwater standards in the initial leaches.

As described in the report summary, arsenic was found to leach at concentrations above the 2L standard in subsequent leaches. This will be discussed in *Section 9.1Constituents Requiring Modeling.*

Table 5-1 Results of SPLP Analyses of Gypsum Samples from CO and HC Plants

Analyte	Units	NCAC 2L Groundwater Standards	Maximum Value from Initial Leaches	CO Plant Leach #1	CO Plant Leach Dup #1	HC Plant Leach #1
pH	std units	6.5 to 8.5	7.35	7.35	7.31	7.14
Arsenic	mg/L	0.010	<0.010	<0.010	<0.010	<0.010
Barium	mg/L	2.0	0.0507	0.0411	0.0429	0.0507
Boron	mg/L	0.32	0.162	0.149	0.162	0.13
Cadmium	mg/L	0.005	<0.0020	<0.0020	<0.00020	<0.0020
Calcium	mg/L	n/a	614	597	614	612
Chloride	mg/L	250.0	5.33	5.33	4.98	3.67
Chromium	mg/L	0.05	<0.0060	<0.0060	<0.0060	<0.0060
Copper	mg/L	1.0	0.0035	0.0031	0.0035	<0.0030
Fluoride	mg/L	2.0	**4.45**	**4.45**	**4.02**	**3.05**
Iron	mg/L	0.3	0.051	<0.020	0.051	0.026
Lead	mg/L	0.015	<0.0050	<0.0050	<0.0050	<0.0050
Magnesium	mg/L	n/a	1.73	1.6	1.73	1.23
Manganese	mg/L	0.05	0.0292	0.0286	0.0292	0.0187
Mercury	mg/L	0.0011	<0.00020	<0.00020	<0.00020	<0.00020
Nickel	mg/L	0.1	<0.010	<0.010	<0.010	<0.010
Potassium	mg/L	n/a	0	<1.0	<1.0	<1.0
Selenium	mg/L	0.05	<0.010	<0.010	<0.010	<0.010
Silver	mg/L	0.018	<0.0050	<0.0050	<0.0050	<0.0050
Sodium	mg/L	n/a	2.83	0.93	0.94	2.83
Sulfate, SO_4	mg/L	250.0	**1510**	**1,490**	**1,500**	**1,510**
TDS	mg/L	n/a	2200	2,160	2,180	2,200
Zinc	mg/L	2.1	0.0157	0.012	0.0133	0.0157

Bold denotes concentrations greater than NCAC 2L groundwater standards.

6.0 Site Conceptual Hydrogeologic Model

6.1 Site Climatic Information

The site is located in southeastern Catawba County. Catawba County has long, hot summers because moist tropical air from the Gulf of Mexico persistently covers the area. Winters are cool and fairly short. Precipitation is fairly heavy throughout the year. The climatic information provided in Table 6-1 taken from Soil Survey of Catawba County, North Carolina, United States Department of Agriculture [Reference 2].

Table 6-1 Catawba County Average Daily Temperature and Precipitation

	Average Daily Temperature (°F)	Average Monthly Precipitation (inches)
January	41	4.1
February	42	4.1
March	49	4.7
April	59	3.8
May	67	3.6
June	75	3.9
July	77	5.0
August	76	5.6
September	70.5	3.8
October	60.5	3.4
November	49	3.1
December	41.5	4.1
Annual Average	59	49.2

6.2 Site Soil

The Soil Survey of Catawba County, North Carolina, United States Department of Agriculture [Reference 2] describes the site surface soils in the area of the landfill as Cecil sandy loam. The NC Erosion and Sediment Control Planning and Design Manual [Reference 3] classifies these soils into Hydrologic Group B soils.

6.3 Site Geology

The site geology is described in the hydrogeology report for the site, Reference 4.

6.4 Site Hydrogeology

The site hydrogeology is described in Reference 4.

6.5 Site Conceptual Hydrogeologic Model

6.5.1 Description of Site Conditions

As described in Reference 4, the geology and groundwater flow at the site are consistent with the conceptual groundwater model of the Piedmont region as described by Legrand [Reference 5]. The key points of this conceptual model for determining the direction of groundwater flow at the landfill site are:

- The topography of the water table is crudely similar to that of the land surface, but its relief is less.
- The path of natural ground-water movement is relatively short and is almost invariably restricted to the zone underlying the gross topographic slope extending from the surface divide to the stream. Only under extremely rare conditions does ground water pass beneath a perennial stream to a more distant stream. Thus, the concept of a local slope-aquifer system applies. [Reference 5, page 321]
- Environmental concerns relating to water supply or waste disposal are commonly related to only one slope aquifer system. However, if a pumping well or a contamination zone is near a hilltop, both slope aquifer systems are likely to be involved. [Reference 5, page 325]

As shown on Figure 1, the FGD landfill will be located on Duke Power property, northwest of the Marshall plant and to the west of the Marshall Ash Basin.

- The landfill is located to the east of a railroad line, running north-to-south.
- Located to the west of this railroad line is Sherrill's Ford Road, which runs north-south along a surface water divide.
- Located within the landfill footprint and to the east of the railroad line is a surface water drainage feature. This feature drains to the south, to an intermittent stream that drains to Beaverdam Creek, which drains to Lake Norman. A berm or ridge of earthen material was placed across the drainage feature at some point in the past. This berm extends west to east across the flow of the drainage feature. As described in Reference 4, page 2, to the north of the berm, the flow in this reach of the drainage feature is controlled by rainfall and storage in the wetlands, with the stream appearing to dry up during dry periods. To the south of the ridge or berm, the stream channel appears to become a groundwater discharge feature.
- There is a topographic divide running NNW through the landfill footprint, along Steam Plant Road.
- Surface drainage to the west of Steam Plant Road drains to the surface drainage feature and surface drainage to the east of Steam Plant Road drains to the Marshall Ash Basin.

As described in the site hydrogeological study (Hydrogeological Study FGD Scrubber Landfill, Duke Power – Marshall Steam Station, Terrell, North Carolina, S&ME Project No: 1264-02-578, May 30, 2003), the subsurface conditions in the landfill area consist of residual soils and partially weathered rock which have been formed by the in-place weathering of the parent rock.

As described in Reference 4, the material in the subsurface at the site is divided into four layers:

1. Residuum – Weathered, unconsolidated material found beneath the topsoil. The residuum encountered in the landfill borings ranged from silty clays to clayey silts to sandy silts. The residuum extended to depths ranging form 2.5 to 14 feet below land surface and is located above the groundwater surface.
2. Saprolite – A product of weathered rock and usually contains some characteristics of the parent rock. This unconsolidated material usually grades with depth to partially weathered rock (described below) or bedrock. This material is classified as silts to clayey silts and sandy silty to silty sands. The saprolite at the site extends to depths ranging from 13.5 to 58.5 feet below land surface. .
3. Partially Weathered Rock (PWR) – PWR is defined as material exhibiting Standard penetration Resistances in excess of 100 blows per foot and is often classified as penetrable, residual materials typically classified as coarse to fine silty sands to medium to fine sandy silts. The PWR extended to depths ranging from 25.5 to 90 feet below land surface.
4. Bedrock – When sampled, the bedrock at the site was found to be granite, schist and gneiss. Horizontal to high-angle fractures are present in the upper ten feet of bedrock. Bedrock was encountered at depths ranging from 25.5 to 79.5 feet below land surface.

6.5.2 Groundwater Flow

As is typical in the groundwater systems located in the Piedmont region and consistent with the conceptual model of groundwater flow in the Piedmont region, groundwater at the landfill site occurs within the residuum and saprolite under unconfined aquifer conditions. The predominant groundwater discharge areas are expected to be the ash basins located to the east of the landfill.

As depicted on Figure 2 of 7 and Figure 3 of 7 (Reference 4), the groundwater flow at this site is generally from the northwest of the landfill footprint towards the east and southeast in the direction of the Ash Basin arms located east of the landfill. The groundwater flow underneath the landfill footprint is generally defined by two discharge locations: a discharge to the northernmost arm of the Ash Basin, near boring B-1 and by a discharge to the southern arm of the Ash Basin, near boring MS-2.

6.5.3 Discussion of 2L Compliance Boundary

The compliance boundary is defined by NCAC 2L 0.107 (b) as:

> *(b) For disposal systems individually permitted on or after December 30, 1983, a compliance boundary shall be established 250 feet from the waste boundary, or 50 feet within the property boundary, whichever point is closer to the source.*

Since it is greater than 300 feet from the footprint of the proposed landfill to the nearest property boundary in the direction of groundwater flow, a distance of 250 feet from the footprint will be used to evaluate compliance with 2L groundwater standards.

7.0 Conceptual Description of Modeling Approach

The modeling approach selected to demonstrate compliance of the landfill design was:

1) The Hydrologic Evaluation of Landfill Performance (HELP) model was used to predict quantities of water infiltrating through the landfill and into the soil beneath the landfill during the Operational Period,[4] (prior to placement of the engineered cover). The HELP model was also used to predict the quantities of water infiltrating through the completed landfill and into the soil beneath the landfill during the Closed Period,[5] after the placement of the engineered cover.

2) The MYGRT model was used to predict the fate and transport of constituents leaching into the groundwater during the Operational Period and during the Closed Period.

[4] The Operational Period refers to the period of landfill operation prior to the placement of the engineered cover.

[5] The Closed Period is the period of time after the placement of the engineered cover.

8.0 HELP Model Description and Results

8.1 Description of HELP Program

The Hydological Evaluation of Landfill Performance (HELP) program is a quasi-two-dimensional hydrologic model for conducting water balance analyses of landfills, cover systems, and other solid waste containment facilities. The model accepts weather, soil and design data and uses solution techniques that account for the effects of surface storage, snowmelt, runoff, infiltration, evapotranspiration, vegetative growth, soil moisture storage, lateral subsurface drainage, leachate recirculation, unsaturated vertical drainage, and leakage through soil, geomembrane or composite liners.

Landfill systems including various combinations of vegetation, cover soils, waste cells, lateral drain layers, low permeability barrier soils, and synthetic geomembrane liners may be modeled. The model facilitates rapid estimation of the amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage that may be expected to result from the operation of a wide variety of landfill designs. The primary purpose of the model is to assist in the comparison of design alternatives. The model is a tool for both designers and permit writers. [Reference 6]

The HELP model requires general climate data for computing potential evapotranspiration; daily climatologic data; soil characteristics; and design specifications to perform the analysis. The required general climate data include growing season, average annual wind speed, average quarterly relative humidities, normal mean monthly temperatures, maximum leaf area index, evaporative zone depth and latitude. Default values for these parameters were compiled or developed from the "Climates of the States" (Ruffner, 1985) and "Climatic Atlas of the United States" (National Oceanic and Atmospheric Administration, 1974) for 183 U.S. cities. Daily climatologic (weather) data requirements include precipitation, mean temperature and total global solar radiation. Daily rainfall data may be input by the user, generated stochastically, or taken from the model's historical data base. The model contains parameters for generating synthetic precipitation for 139 U.S. cities. The historical data base contains five years of daily precipitation data for 102 U.S. cities. Daily temperature and solar radiation data are generated stochastically or may be input by the user.

Necessary soil data include porosity, field capacity, wilting point, saturated hydraulic conductivity, initial moisture storage, and Soil Conservation Service (SCS) runoff curve number for antecedent moisture condition II. The model contains default soil characteristics for 42 material types for use when measurements or site-specific estimates are not available. The porosity, field capacity, wilting point and saturated hydraulic conductivity are used to estimate the soil water evaporation coefficient and Brooks-Corey soil moisture retention parameters. Design specifications include such items as the slope and maximum drainage distance for lateral drainage layers; layer thickness; layer description; area; leachate recirculation procedure; subsurface inflows; surface characteristics; and geomembrane characteristics.

8.2 HELP Model Version:

The HELP model used for this demonstration is HELP Version 3.07.[6] HELP was developed by the USAE Waterways Experiment Station. Also used as reference material were the HELP User's Guide for Version 3, [Reference 7] and the HELP Engineering Documentation for Version 3 [Reference 6].

8.3 HELP Model Inputs:

8.3.1 Weather Data

The HELP model uses data developed by NOAA for growing season dates, average annual wind speed, average quarterly relative humidity, and normal mean monthly temperatures. The user selects a location from the database and the values are used to generate synthetic data for the desired length of time. The values used in this analysis were from the Charlotte, NC location, with the following items modified as described.

1. The average daily temperatures and monthly average rainfall values from Catawba County (from Table 6-1) were used.
2. The maximum leaf area index (LAI) used in the Operational Condition cases was 0 (a LAI of 0 is associated with bare soils). The LAI for the Closed Condition case was 2.0 (a LAI of 2.0 is associated with a fair stand of grass).
3. The evaporative zone depth used for the Operational Condition cases was 10 inches. The evaporative zone depth used for the Closed Condition case was 13 inches.
4. The latitude and longitude for the site was used.

8.3.2 Runoff Curve Numbers – Operational Condition Cases

The runoff curve numbers were selected to provide conservative results. The runoff curve number used in the Operational Condition cases was calculated by HELP based on selecting a default soil type with similar properties for wilting point and field capacity. The process used by HELP in calculating the curve number is explained in Section 4.2 of Reference 6. Default soil # 8 was used, with a surface slope of 2% and a slope length of 300 feet. The resulting curve number calculated by HELP was 72.3.

8.3.3 Runoff Curve Numbers – Closed Condition Case

To provide conservatism for the longer term infiltration, a curve number was selected that would generate less runoff than the curve number selected by HELP for the Operational Condition. The curve number was selected based on the site soil being classified as Hydrologic Group B soils. The curve number was modified by HELP, based on a surface slope of 12% and a slope length of 300 feet.

Condition	Land Use/Cover Description (from Table 8.03b, Reference 3)	Curve Number
Closed Condition	Area will have maintained grass cover. Selected CN for "open spaces, lawns, parks, golf courses, etc."	61 (Initial) 63.8 (modified)

[6] The weather files used to generate the temperature and rainfall data are dated 1999.

8.4 Cases Modeled with HELP

Two periods were modeled with HELP. These periods are:

- Operational Period – models the infiltration that occurs during the period of gypsum placement.
- Closed Period – models the infiltration that occurs after placement of the engineered cover.

8.4.1 Operational Period

The landfill was modeled during the operational period (the 5 year period of gypsum placement) to determine the quantity of infiltration that would pass through the gypsum, becoming leachate. The properties described in the previous sections were used, along with a 100 year period of simulated weather conditions to determine the amount of infiltration that would occur.

Separate HELP runs were made at the thicknesses listed below to evaluate the infiltration at different thicknesses of material. As described in the Construction Plan Application [Reference 8], after 10 feet of gypsum are placed, an 8 inch layer of site soil will be placed. The HELP runs for the Operational Period include an 8 inch layer of site soil placed over each 10 foot layer of gypsum.

The thicknesses listed below are nominal thicknesses representing only the thickness of the gypsum layer. A nominal elevation of 740' was selected as the base grade for the landfill.

HELP Run Thickness	Approximate Upper Elevation of Soil Cover Layer
10 feet	750 feet
20 feet	760 feet
40 feet	780 feet
60 feet	800 feet

The layers modeled in the 20 foot HELP run for this condition are shown in the following schematic. A similar scheme was used for all HELP runs for the Operational Period, with additional layers added to model the other thicknesses.

Marshall FGD Residue Landfill
HELP Model Layers
Operational Period

Description of Layer	Thickness of Layer
Intermediate Soil Cover	8 inches
FGD Residue	10 feet
Intermediate Soil Cover	8 inches
FGD Residue	10 feet
Layer 7 Undisturbed Site Soil	4 feet

8.4.2 Closed Period

The landfill was modeled during the Closed Period (after placement of engineered cover) to determine the quantity of leachate that would infiltrate through the assumed holes in the engineered cover.

The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane beneath a geocomposite drainage net. The cap will be topped with two feet of soil for vegetative growth. The geomembrane is a barrier layer that prevents rainwater from entering the waste cell of

the landfill. The geocomposite drainage net allows water that percolates through the vegetative layer to drain laterally to a collection system.

A detail showing the cover system is shown on drawing MM 6551.00-0001.001 Revision B. The drainage collected by the geocomposite drainage net will drain to the erosion control benches and to the anchor trench. The location of the erosion control benches is shown on drawing M-6024-06.00, Revision C. These drawings are included as part of the Construction Plan Application Submittal [Reference 8]. The average slope of the geocomposite drainage net is 12.5%. The horizontal distance used for the length of flow for this layer is 300 feet. (See M-6024-06.00).

The vegetative layer protects the geomembrane and geocomposite from ultraviolet degradation, desiccation, freeze-thaw, wind, and vectors. The vegetative layer shall be stabilized and seeded appropriately to prevent erosion. Native material cut from open areas within the landfill will be used for the vegetative layer. Debris will be removed, and the soil will be amended as needed.

The low density polyethylene (LDPE) geomembrane layer modeled has a hydraulic conductivity of 4.0E-13 cm/sec. The assumed placement quality for the geomembrane cover is good. This will be assured through a QA/QC program developed in coordination with the manufacturer and NCDENR.

The assumed number of holes in the cover used in the HELP analyses is:

- pinhole density is 1 hole/acre
- installation defects are 7 holes/acre[7]

The period modeled was 100 years. This is the maximum period of time that can be run with HELP.

[7] NCDENR requested that the number of holes per acre be increased from the 5 holes/acres, used in the previous analysis, for a total of 8 holes per acres.

The layers modeled in HELP for the Closed Period are shown in the following schematic.

Marshall FGD Residue Landfill
HELP Model Layers
Closed-Period

Description of Layer	Thickness of layer
Layer 1 **Compacted Site Soil - Upper Vegetated Layer**	0.75 ft
Layer 2 **Compacted Site Soil - Lower Vegetated Layer**	1.25 ft
Layer 3 **Drainage Net**	0.0164 ft
Layer 4 **Low Density Polyethylene Geomembrane**	40 mil (.0033 ft)
Layer 5 **Compacted Site Soil**	1.5 ft
Layer 6 **FGD Residue**	10 feet
Layers 7 through 20 **Alternating layers of** **8" Intermediate Soil Layer** **10 feet FGD Residue**	84.7 ft

8.5 Soil and FGD Residue Properties

The soil and gypsum properties that are used in the HELP analyses were developed from tests performed on soil samples collected during the site investigation and from gypsum samples provided by the scrubber equipment vendor.

Properties for Vegetative Soil Layer

The soil properties from borings located within the landfill footprint or adjacent to the footprint were used to determine porosity, field capacity, wilting point, and hydraulic conductivity parameters for the vegetative soil layer. These values are shown in the following tables.

The vegetative soil layer will be constructed from material excavated from the landfill footprint area and compacted as the vegetative cover layer. Therefore, the remolded samples reflect the properties for this layer.

Table 8-1 Vegetative Soil Layer – Hydraulic Conductivity and Void Ratio

Boring	Depth	Hydraulic Conductivity, k (cm/sec)	Porosity, n
B-1	0'-10'	1.2E-05	0.40
B-2	0'-10'	3.7E-06	0.44
B-4	0'-10'	4.9E-06	0.41
B-5	0'-10'	6.1E-06	0.47
B-7	0'-10'	1.7E-05	0.49
	Arithmetic Mean	8.8E-06	0.44
	Geometric Mean	7.4E-06	0.44

The geometric mean value was used in the HELP analysis.

If default soil properties are used, the HELP program automatically adjusts the saturated hydraulic conductivity in the top half of the evaporative zone to account for root penetration by surface vegetation.

Since the soil properties for the vegetated soil layer are not default HELP properties, the saturated hydraulic conductivity in the top half of the evaporative zone must be adjusted to account for root penetration by surface vegetation. An 18" thick evaporative zone was used. Therefore, the adjusted hydraulic conductivity was used on the upper 9" layer. This vegetated saturated hydraulic conductivity, $(K_s)_v$, is calculated by Equation A-10 in Reference 6. The value for $(K_s)_v$ used in the HELP analysis is 2.2E-05 cm/sec.

HELP requires values for field capacity and wilting point. These values are calculated based on the percentages of sand and clay present in the soil.

Table 8-2 Vegetative Soil Layer – Percentage of Sand and Clay

Boring	Sample ID	USCS Soil Classification	Depth	% Sand (USDA) 0.05 - 2.0 mm	% Clay (USDA) <0.002 mm
MS-7	S-2	CH	8.5' - 10'	19.0%	53.2%
B-1	S-1	CL	3.5' - 5'	44.0%	28.7%
B-3	S-4	MH	18.5' - 20'	32.2%	7.5%
B-4	S-1	MH	3.5' - 5'	32.4%	29.9%
B-5	S-2	SM	8.5' - 10'	57.5%	5.6%
B-6	S-1	SM	3.5' -5'	56.2%	17.6%
			Arithmetic Mean	40%	24%
			Geometric Mean	38%	18%

Table 8-3 Vegetative Soil Layer – Values Used In HELP

	Hydraulic Conductivity, k (cm/sec)	Porosity, n	Field Capacity (HELP Eqn A-3)	Wilting Point (HELP Eqn A-4)
Upper Vegetative Layer	2.2E-05	0.44	0.242	0.122
Lower Vegetative Layer	7.4E-06	0.44	0.242	0.122

Note: The equations (Eqn. A-3 and A-4) used for these calculations are found in the HELP Users Manual, Appendix A.

Properties for Intermediate Soil Cover Layer

As described in the Construction Plan Application, after 10 feet of FGD residue has been placed, an 8" thick soil layer will be placed as intermediate cover.

The soil properties from borings located within the landfill footprint or adjacent to the footprint were used to determine porosity, field capacity, and wilting point for the Intermediate Soil Layer. These values are shown in the following tables.

The hydraulic conductivity is taken to be equal to that used for the uppermost, vegetative layer of the final cover.

Table 8-4 Intermediate Soil Cover – Hydraulic Conductivity and Void Ratio

Boring	Depth	Porosity @ Maximum Dry Density	Specific Gravity	Maximum Dry Density (lb/ft^3) (Note 1)	Porosity @ 92% Max Dry Density (Note 2)
B-1	0'-10'	0.34	2.63	108.4	0.39
B-2	0'-10'	0.46	2.67	89.7	0.50
B-3	0'-10'	0.45	2.68	92.4	0.49
B-4	0'-10'	0.48	2.73	88.0	0.52
B-5	0'-10'	0.47	2.75	90.9	0.51
B-6	0'-10'	0.44	2.66	93.0	0.48
B-7	0'-10'	0.51	2.77	84.8	0.55
	Arithmetic Mean	0.45	-	-	0.49
	Geometric Mean	0.45	-	-	0.49

Note 1: The maximum dry unit weight is from Appendix III of the S&ME Hydrogeologic Study. These values were obtained from proctor tests on site soils.

Note 2: The porosity at 92% compaction was calculated using the specific gravity of the sample and dry density of the sample.

Porosity = 1 - (0.92 x maximum dry density) / (Specific gravity x density of water)

Table 8-5 Intermediate Soil Cover – Properties Used in HELP

Hydraulic Conductivity, k (cm/sec)	Porosity	Field Capacity (HELP Eqn A-3)	Wilting Point (HELP Eqn A-4)
2.20E-05	0.49	0.242	0.122

Properties for Gypsum Layer

Samples of the gypsum material were sent to the geotechnical firm S&ME Inc. for testing. The results of the lab analyses on these samples is found in the report, FGD Scrubber Sludge Testing, (Revision 1) Duke Power Coal Fired Steam Stations in North Carolina, S&ME Project No. 1264-03-57, February 2004. A copy of this report is included as Attachment 1.

Lab analyses were performed on these samples to determine the following properties:

- Grain size Distribution
- Atterburg Limits
- Specific Gravity
- Natural Moisture
- pH
- Standard Proctor Compaction
- Remolded Permeability
- Consolidation Properties (C_c)
- Total Porosity
- Triaxial Shear Strength

The grain size analyses, void ratio, porosity, and saturated hydraulic conductivity's from these analyses were used in the HELP model analyses.

Table 8-6 FGD Residue – Hydraulic Conductivity and Void Ratio

Remolded Sample Conditions	Porosity (at 8 ksf)	Hydraulic Conductivity, k (cm/sec)
90% compaction @ 12% moisture	0.43	5.09E-04
92% compaction @ 25% moisture	0.41	2.25E-04
95% compaction @ 19% moisture	0.4	2.53E-04

Table 8-7 FGD Residue – Values Used In HELP

Hydraulic Conductivity, k (cm/sec)	Porosity[8], n	Field Capacity (HELP Eqn A-3)	Wilting Point (HELP Eqn A-4)
2.53E-04	0.47	0.180	0.055

[8] NCDENR requested that a porosity of 0.47 be used with 90% compaction.

Properties for Soil Layer Beneath the Landfill

The soil properties from borings located within the landfill footprint or adjacent to the footprint were used to determine porosity, field capacity, wilting point, and hydraulic conductivity parameters for the layer of soil located beneath the FGD residue. These values are shown in the following tables.

Note: Including the 8" thick layers of Intermediate Soil Cover caused the limit for layers in HELP to be exceeded in the Post Operational Condition HELP analysis. HELP has a 20 layer limitation. In the Post Operational Condition the soil layer beneath the lowest FGD residue is omitted. This should result in negligible differences in the analytical results.

Table 8-8 Soil Layer Beneath FGD – Hydraulic Conductivity and Void Ratio

Boring	Cross Section (Reference 4)	Hydraulic Conductivity, k (ft/day)	Hydraulic Conductivity, k (cm/sec)	Total Porosity, n
MS-11	A-A	5.0E-01	1.8E-04	0.43
MS-8	A-A	5.5E-01	1.9E-04	0.43
B-2	A-A	5.0E-01	1.8E-04	0.43
MS-10	G-G	4.0E-01	1.4E-04	0.42
OW-1	G-G	1.6E+00	5.6E-04	0.43
OW-2	G-G	1.0E+00	3.5E-04	0.43
MS-7	G-G	8.7E-01	3.1E-04	0.43
MS-6	G-G	2.9E-01	1.0E-04	0.42
	Arithmetic Mean	7.1E-01	2.5E-04	0.43
	Geometric Mean	6.2E-01	2.2E-04	0.43

Values for hydraulic conductivity and total porosity are taken from Table 5, Reference 4.

The geometric mean value was used in the HELP analysis.

Table 8-9 Soil Layer Beneath FGD – Percentage of Sand and Clay

Boring	Sample ID	Depth	Per Cent Sand (USDA) 0.05 - 2.0 mm	Per Cent Clay (USDA) <0.002 mm
MS-7	S-2	8.5' - 10'	19.0	53.2
MS-7	S-4	18.5' - 20'	67.7	1.6
MS-8	S-5	23.5'-25'	65.7	2.6
B-3	S-4	18.5' - 20'	32.2	7.5
B-6	S-12	58.5' - 60'	65.4	3.4
		Arithmetic Mean	46.2	16.2
		Geometric Mean	40.6	6.3

Table 8-10 Soil Layer Beneath FGD Residue – Values Used in HELP

Hydraulic Conductivity, k (cm/sec)	Total Porosity, n	Field Capacity (HELP Eqn A-3)	Wilting Point (HELP Eqn A-4)
2.2E-04	0.43	0.252	0.115

8.6 HELP Model Results

8.6.1 Infiltration During Operational Period

The HELP model calculated that the average annual infiltration through the landfill and into the saturated zone during the operational period is:

Table 8-11 HELP Model Results

Thickness of FGD Residue	Infiltration During Operational Period (in/yr)
10 feet	18.64
20 feet	18.64
40 feet	18.53
60 feet	18.36

The maximum value for infiltration (18.64 in/yr = 1.55 ft/yr) will be used in the MYGRT analyses for the Operational Period.

These values are based on 100 years of simulated weather conditions.

Note that these results are based on conservative input values for the uppermost soil layer. These conservative conditions are evidenced by the low values for runoff calculated in the HELP analyses These HELP runs calculate about 2.4 inches/year of runoff. This should produce unrealistically large, but conservative values for infiltration.

8.6.2 Infiltration During Closed Period

The HELP model calculated that the average annual infiltration rate through the engineered cover (HELP Layer 4) is 0.00061 inches/year. This value will be used in the MYGRT analyses for the infiltration value during the closed period. These results indicate the effectiveness of the engineered cover to reduce infiltration through the landfill.

These values are based on 100 years of simulated weather conditions.

Copies of the HELP input data and results are located in Attachment 3.

9.0 MYGRT Model Description and Results

The MYGRT software predicts the migration of both inorganic and organic solutes in the unsaturated and saturated zones down gradient of sources. The processes included are advection, dispersion, retardation, and decay. The code can simulate problems in one, two, or three dimensions using either horizontal or vertical views. The model uses inputs such as seepage velocity, dispersion and retardation factors.

The reviewer should refer to the MYGRT manual for detailed definition of the inputs and for the description of the computational processes used by MYGRT. A copy of the MYGRT manual is included as Attachment 4.

MYGRT Version 3.0 was used for these analyses. [Reference 9]

9.1 Constituents Requiring Modeling

The comparison of the results of the leaching analyses to the NCAC T15A 2L Groundwater Standards is presented in Table 5-1. As this table shows, the concentrations of sulfate (SO_4) and fluoride (Fl_2) exceed the 2L groundwater standards in the initial leaches. As described in the PNNL report summary, arsenic was found to leach at concentrations above the 2L standard in subsequent leaches.

As described in the site suitability information, the design requires that the landfill will be capped with an impermeable cover after 5 years. Table 9-1 provides the approximate number of years of infiltration required to be equivalent to one SPLP leach, based on a 1 foot thickness of gypsum and the infiltration rate calculated by HELP.

As Table 9-1 shows, even for a 1 foot thick layer of gypsum, it would take approximately 16 years for the volume of infiltration experienced to be equivalent to the volume of liquid in the initial SPLP leach (based on the 20:1 mass ratio used in the SPLP test). The 5 year period that the landfill will be uncapped is well below the time required for a volume equivalent to the initial SPLP leach to be exchanged through the landfill. Therefore, only the constituents whose concentrations exceed the NCAC 2L groundwater standards (sulfate and fluoride) in the initial SPLP leaches will require modeling. As described above, arsenic will also be modeled.

As noted in Attachment 7, NCDER requests that arsenic be modeled to evaluate a leachate concentration of 0.018 mg/l. As noted in section *5.0 SPLP Leaching Analyses Performed on FGD Residue Samples,* arsenic did not appear in the initial leach at a concentration in excess of the 2L groundwater standard. As shown in Table 2-1, the period of time represented by the initial leach exceeds the 5 year period of operation prior to the placement of the engineered cover. Therefore, it is not expected that arsenic would be present in the leachate at levels in excess of the 2L standard before the landfill is capped with the synthetic cover. However, to address the issue, arsenic will be modeled.

The concentrations for the other constituents in the initial SPLP leaches were below the 2L standards. Therefore, only SO_4, Fl_2, and As will require further evaluation in this demonstration. The concentrations of these constituents used in the MYGRT analyses are presented in Table 9-2.

Table 9-1 Approximate Number of Years per SPLP Leach

In SPLP test a 20:1 liquid to solid (mass) ratio is used.

The table below presents the approximate number of years to represent one SPLP leach, based on only a 1 foot thickness of gypsum and the infiltration from the HELP analyses.

Specific Gravity of gypsum = 2.35
Porosity of gypsum = 0.47

Infiltration when gypsum is not covered with synthetic cap = 18.64 in/year = 1.55 ft/yr

Approximate Number of Years per SPLP Leach

Thickness	Mass of Gypsum	Mass of Water (From Infiltration for 20:1 ratio)	Volume of Infiltration (Volume of water for 20:1 ratio)	Number of Years per Leach (Volume of Infiltration ÷ 1.55 ft /yr/ft^2)
ft	lbs	lbs	ft^3	Years
1	78	1560	25	16

Table 9-2 Source Concentrations Used in MYGRT Model

	Results from SPLP Leaching	Concentration Used in MYGRT	NCAC 2L Groundwater Standard
Arsenic, As	0.018 mg/l	0.018 mg/l	0.010 mg/l
Sulfate, SO_4	1510 mg/l	1600 mg/l	250 mg/l
Fluoride, Fl_2	4.45 mg/l	5 mg/l	2.0 mg/l

9.2 Description of Model Runs

Two cross sections of the site were modeled in MYGRT to evaluate compliance with 2L standards. The groundwater flow at this site is generally from the northwest of the landfill footprint towards the east and southeast in the direction of the Ash Basin arms located east of the landfill. The groundwater flow underneath the landfill footprint is generally defined by two discharge locations: a discharge to the northernmost arm of the Ash Basin, near boring B-1 and by a discharge to the southern arm of the Ash Basin, near boring MS-2.

The groundwater flow along these cross sections, underneath the landfill footprint and towards these two discharge locations was modeled in MYGRT to determine the concentrations of SO_4 and Fl_2 at the compliance boundary.

The borings used to determine the cross section characteristics are listed below.

<u>MYGRT Run 1 - Cross Section 1-1 (See Figure 1 and Figure 2)</u>
MS-11 to MS-7 to B-6 to B-5 to MS-2

<u>MYGRT Run 2 - Cross Section 2-2 (See Figure 1 and Figure 2)</u>
MS-10 to B-2 to B-1

9.3 Model Inputs

The landfill area is represented as a source with an input length and width. The source concentrations are entered as a function of time. For the modeling used in this demonstration, the 3-D modeling scenario was used. Since the FGD material is placed a minimum of 4 feet above the saturated zone, the source (the FGD Residue) was considered to be located at the top of the unsaturated zone. The model calculated the concentrations after the constituents pass through the unsaturated zone and into the saturated zone.

Table 9-3 provides a list of the parameters and provides references to the sources for the MYGRT input parameters.

SO_4 and Fl_2 are generally considered to be conservative substances. Therefore, no attenuation by the site soils is assumed to occur and a K_d value of 0 mL/g is used in the MYGRT analyses. Arsenic would likely experience some degree of adsorption to site soils, however, the Kd for arsenic is conservatively assumed to be equal to zero.

MYGRT has the capability to change the infiltration rate at a specified time, so the Operational and the Closed conditions can be modeled in the same MYGRT model run. The infiltration value for the Operational period was used for 5 years (year 2006 through year 2010). The infiltration value was then changed to the infiltration value for the Closed period (for years 2011 and beyond).

Modeling Period

As described in Section 8.6.2, after placement of the engineered cover, the infiltration decreases to 0.00039 inches/year. If this number is used to calculate the approximate number of years of infiltration to equal the volume of liquid in one SPLP leach, the number of years required for the volume of one SPLP leach to move through an 80 foot thick layer of gypsum is too large to be meaningful.

Therefore, for the MYGRT analyses the period of time for the source concentrations to be active was arbitrarily selected to be 3000 years. The infiltration value was decreased from the values calculated by HELP for the Operational Period (years 2006 to 2010) to the value for the Closed Period in year 2011.

The MYGRT analyses showed the concentrations decreasing to steady state values after year 2100 (approximately). The attainment of steady state values indicates that the length of time used for the source term is valid.

Table 9-3 MYGRT Model Input Parameters

Input Parameter	Units	Source of Input	Values for MYGRT Cross Section 1-1	Values for MYGRT Cross Section 2-2
Unsaturated Zone Parameters				
Width of Source	ft	Figure 1	1440	1440
Length of Source Parallel with Aquifer Flow Direction	ft	Figure 1	1300	760
Input Source Concentration, SO_4	mg/l	Table 9-2	1600	1600
Input Source Concentration, Fl_2	mg/l	Table 9-2	5	5
Input Source Concentration, As	mg/l	Table 9-2	0.018	0.018
Infiltration Rate - Operational Period Years 2006 to 2010	ft/year	HELP Table 8-11	1.55	1.55
Infiltration Rate - Closed Period Years 2011 to 3000	ft/year	HELP, See Note 1	0.0001	0.0001
Volumetric Moisture Content of Soil (Unsaturated)	vol/vol	Attachment 5	0.25	0.25
Depth to water table below source	ft	Attachment 5 See Note 2	4	14.5
Rd, Unsaturated layer, SO_4, Fl_2, As		See Note 3	1	1
Saturated Zone Parameters				
Hydraulic Gradient	ft/ft		0.01	0.03
Hydraulic Conductivity	ft/yr	Attachment 5	219.4	183.9
n_e, effective porosity		Attachment 5	0.28	0.27
Scale Distance for Dispersion Calculation	ft	See Note 4	250	250
Aquifer Thickness	ft	Attachment 5, Note 5	27.8	24.3
Solute Plume Properties				
Bulk Density	g/ml	Note 6	N/A	N/A
K_d for SO_4,Fl_2, As	ml/g	See Note 6	0	0

Table 9-3 MYGRT Model Input Parameters

Notes:

1. HELP calculated an infiltration rate of 0.00061 inches/year after placement of the engineered cover. This calculates to a value of 0.00003 ft/yr. A value of 0.0001 ft is conservatively used in the MYGRT analyses for infiltration during the closed period.
2. As found in Attachment 5, the depths to groundwater (below the excavated bottom of the landfill) are 5' (for Section 1-1) and 14.5 (for Section 2-2). The depth to groundwater used in the MYGRT analyses for Section 1-1 is 4 feet and 14.5' for Section 2-2.[9]
3. No attenuation due to adsorption onto the soil is assumed to occur with SO_4, Fl_2, or As therefore the K_d term would be = 0 and the Rd, retardation factor, would be equal to 1.
4. The scale distance for dispersion calculations used is 250 feet. The longitudinal, transverse, and vertical coefficients are calculated by MYGRT as follows:

Longitudinal Dispersion Coefficient	1/10th of scale distance multiplied by the seepage velocity
Transverse Dispersion Coefficient	1/10th of horizontal dispersion coefficient
Vertical Dispersion Coefficient	1/100th horizontal dispersion coefficient

5. The geometric mean value for thickness of the aquifer was used for each cross section. This value is based on the minimum measured groundwater elevation for the wells. These groundwater elevations are found in Attachment 5.
6. MYGRT uses the bulk density and K_d to calculate a retardation factor. Since no attenuation due to adsorption onto the soil is assumed to occur with SO_4, As, or Fl_2, the K_d term would be = 0 and the retardation factor would be equal to 1.

[9] The value of 6' for depth to the water table was conservatively used in the original demonstration report for Section 2-2.

10.0 MYGRT Model Results and Comparison to 2L Standards

The results from the MYGRT runs are located in Attachment 6. The results are summarized in the table below.

These results are calculated at the compliance boundary and at a depth below the groundwater surface that is equal to the depth of the aquifer. MYGRT calculates the source plume mixing depth and compares the calculated depth to the input aquifer thickness. If the plume mixing depth is greater than the aquifer thickness, the MYGRT completely mixes the source plume across the depth of the aquifer. In both cross sections, the plume mixing depth was greater than the aquifer thickness, so the source plume was completely mixed across the depth(s) of the aquifer(s).

Table 10-1 MYGRT Model Results

Constituent	MYGRT Cross Section 1-1 Maximum Concentration from MYGRT model at Compliance Boundary	MYGRT Cross Section 2-2 Maximum Concentration from MYGRT model at Compliance Boundary	NCAC 2L Groundwater Standard
Sulfate	197 mg/L	228 mg/L	250.0 mg/L
Fluoride	0.62 mg/L	0.71	2.0 mg/L
Arsenic	0.002 mg/L	0.003 mg/L	0.010 mg/L

As shown in Table 10-1, the design of the landfill ensures the concentrations of SO_4, As, and Fl_2 are below the NCAC 2L groundwater standards at the compliance boundary.

11.0 Conclusions

As shown in Section 10.0, the design evaluated in this demonstration ensures that the ground water standards established under 15A NCAC 2L will not be exceeded.

The design evaluated in this demonstration requires:

1. the active landfill will receive FGD residue for a 5 year period.

2. an engineered cover will be placed on the completed landfill at the end of the 5 year period.

3. The engineered cover will consist of a textured 40 mil low density polyethylene geomembrane layer beneath a geocomposite drainage net. The cap and geocomposite drainage net will be topped with two feet of soil for vegetative growth. The geomembrane layer will minimize infiltration of precipitation into the waste. The geocomposite drainage net will provide lateral drainage for water that percolates through the vegetative layer. A detail showing the cover system is shown on drawing MM 6551.00-0001.001 Revision B.

4. The drainage collected by the geocomposite drainage net will drain to the erosion control benches, as well as draining to the anchor trench. This will limit the drainage length of the geocomposite to no greater than 300 feet. The location of the erosion control benches is shown on drawing M-6024-06.00, Revision C.

Other than the engineered cap described above, there are no special engineering features or considerations that must be included or maintained in site construction, operation, maintenance and closure.

These original conclusions remain valid for the conditions evaluated in this Addendum.

12.0 References

Note: The information and sources listed below were used in the preparation of this report. The parties listed in the references prepared these reports and documents. The engineering certification on the cover page does not imply that the engineering certification of this report includes certification of these particular references.

1 Duke Power, Marshall Steam Station, Catawba County, N.C., Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, Site Suitability Information, August 29, 2003, Volume 1. Also see Addendum 1, dated November 12, 2004.

2 Soil Survey of Catawba County, North Carolina, United States Department of Agriculture, Issued October 1975.

3 *North Carolina Erosion and Sediment Control Planning and Design Manual, May 1994.*

4 Duke Power, Marshall Steam Station, Catawba County, N.C., Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, Site Suitability Information, August 29, 2003, Hydrogeologic Study, S&ME Project No. 1264-02-578, Volume 2. Also see Addendum 1, dated October 29, 2004.

5 *A Conceptual Model of Ground Water Settings in the Piedmont Region*, Harry E. LeGrand, in Groundwater in the Piedmont: Proceedings of a Conference on Ground Water in the Piedmont of the Eastern United States, October 16-18, 1989, Daniel, White, and Stone.

6 THE HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE (HELP) MODEL, *ENGINEERING DOCUMENTATION FOR VERSION 3,* Environmental Laboratory, U.S. Army Corps of Engineers, Waterways Experiment Station, Vicksburg, MS.

7 *The Hydrologic Evaluation of Landfill Performance (HELP) Model – User's Guide for Version 3*, USEPA September 1994.

8 Construction Plan Application, Duke Power Marshall Steam Station, Flue Gas Desulfurization (FGD) Residue Landfill, Catawba County, NC, submitted by letter dated April 1, 2004.

9 *User's Guide for MYGRT Version 3.0:Software for Simulating Migration of Organic and Inorganic Chemicals in Groundwater*, Electric Power Research Institute, 1998, TR-111748, Prepared by Tetra Tech and Ish Inc.

10 Duke Energy Marshall Steam Station, Catawba County, NC, Flue Gas Desulfurization (FGD) Residue Landfill Permit Application, .0503(2)(d)(ii)(A) Compliance Demonstration Report, March 31, 2004.

Attachment 3

HELP Model
Input Data and Results

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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:\DATA\WMM\HELP34\MSSRAIN.D4
TEMPERATURE DATA FILE:        c:\data\wmm\help34\MSSTEMP.D7
SOLAR RADIATION DATA FILE:    c:\data\wmm\help34\MSSRAD.D13
EVAPOTRANSPIRATION DATA:      c:\data\wmm\help34\MSS60FT.D11
SOIL AND DESIGN DATA FILE:    c:\data\wmm\help34\MSS-10FT.D10
OUTPUT DATA FILE:             c:\data\wmm\help34\mss-10ft.OUT


TIME:  13:10     DATE:  11/12/2004


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     TITLE:  MSS FGD LF- 10 ft Height

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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 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2757	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2306	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 49

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.2520	VOL/VOL
WILTING POINT	=	0.1150	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2670	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-03	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	72.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	33.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.637	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.860	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.086	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	42.691	INCHES
TOTAL INITIAL WATER	=	42.691	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CHARLOTTE NORTH CAROLINA

STATION LATITUDE	=	35.60	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	83	
END OF GROWING SEASON (JULIAN DATE)	=	312	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.10	4.10	4.70	3.80	3.60	3.90
5.00	5.60	3.80	3.40	3.10	4.10

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
41.00	42.00	49.00	59.00	67.00	75.00
77.00	76.00	70.50	60.50	49.00	41.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA
AND STATION LATITUDE = 35.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.00	4.06	4.67	4.27	3.64	4.31
	5.01	5.15	3.58	3.23	3.08	4.25
STD. DEVIATIONS	1.99	1.84	2.23	1.97	1.79	2.10
	2.36	3.06	2.62	2.06	1.67	1.89
RUNOFF						
TOTALS	0.196	0.207	0.201	0.152	0.107	0.149
	0.174	0.422	0.260	0.195	0.078	0.228
STD. DEVIATIONS	0.356	0.510	0.436	0.284	0.294	0.284
	0.400	0.604	0.580	0.371	0.203	0.375
EVAPOTRANSPIRATION						
TOTALS	1.653	1.885	2.683	2.930	2.793	3.066
	3.519	2.852	2.185	1.764	1.480	1.417
STD. DEVIATIONS	0.303	0.376	0.513	0.884	0.966	1.171
	1.161	1.045	0.914	0.680	0.462	0.221
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	1.5023	1.7313	2.1391	2.0283	1.8082	1.5046
	1.2618	1.1859	1.3061	1.5365	1.3390	1.2999
STD. DEVIATIONS	1.0101	1.0856	1.1153	1.0259	0.7475	0.6122
	0.4720	0.5593	0.8187	0.9344	0.6707	0.6541

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	49.24	(7.134)	5898304.5	100.00
RUNOFF	2.369	(1.4508)	283785.12	4.811
EVAPOTRANSPIRATION	28.226	(2.8008)	3381174.50	57.325
PERCOLATION/LEAKAGE THROUGH LAYER 3	18.64306	(4.20626)	2233252.250	37.86261
CHANGE IN WATER STORAGE	0.001	(3.4306)	91.43	0.002

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.58	668428.187
RUNOFF	2.990	358143.0620
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.346285	41481.48440
SNOW WATER	3.87	463700.5000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4860

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1466

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2429	0.2804
2	27.1133	0.2259
3	13.4112	0.2794
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:\DATA\WMM\HELP34\MSSRAIN.D4
TEMPERATURE DATA FILE:       c:\data\wmm\help34\MSSTEMP.D7
SOLAR RADIATION DATA FILE:   c:\data\wmm\help34\MSSRAD.D13
EVAPOTRANSPIRATION DATA:     c:\data\wmm\help34\MSS60FT.D11
SOIL AND DESIGN DATA FILE:   c:\data\wmm\help34\MSS-20FT.D10
OUTPUT DATA FILE:            c:\data\wmm\help34\mss-20ft.OUT


TIME:  13:15     DATE:  11/12/2004


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     TITLE:  MSS FGD LF- 20 ft Height

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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 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2757	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2306	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3563	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2175	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 49

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.2520	VOL/VOL
WILTING POINT	=	0.1150	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2519	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-03	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	72.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	33.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.637	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.860	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.086	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	70.916	INCHES
TOTAL INITIAL WATER	=	70.916	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CHARLOTTE NORTH CAROLINA

STATION LATITUDE	=	35.60	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	83	
END OF GROWING SEASON (JULIAN DATE)	=	312	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.10	4.10	4.70	3.80	3.60	3.90
5.00	5.60	3.80	3.40	3.10	4.10

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
41.00	42.00	49.00	59.00	67.00	75.00
77.00	76.00	70.50	60.50	49.00	41.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA
AND STATION LATITUDE = 35.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.00	4.06	4.67	4.27	3.64	4.31
	5.01	5.15	3.58	3.23	3.08	4.25
STD. DEVIATIONS	1.99	1.84	2.23	1.97	1.79	2.10
	2.36	3.06	2.62	2.06	1.67	1.89
RUNOFF						
TOTALS	0.196	0.207	0.201	0.152	0.107	0.149
	0.174	0.422	0.260	0.195	0.078	0.228
STD. DEVIATIONS	0.356	0.510	0.436	0.284	0.294	0.284
	0.400	0.604	0.580	0.371	0.203	0.375
EVAPOTRANSPIRATION						
TOTALS	1.653	1.885	2.683	2.930	2.793	3.066
	3.519	2.852	2.185	1.764	1.480	1.417
STD. DEVIATIONS	0.303	0.376	0.513	0.884	0.966	1.171
	1.161	1.045	0.914	0.680	0.462	0.221
PERCOLATION/LEAKAGE THROUGH LAYER 5						
TOTALS	1.3544	1.2928	1.6360	1.7607	1.9889	1.8577
	1.7391	1.5381	1.3367	1.3101	1.3840	1.4371
STD. DEVIATIONS	0.6260	0.7021	1.0049	0.9978	1.0096	0.7368
	0.5975	0.4855	0.4351	0.5343	0.7191	0.6790

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	49.24	(7.134)	5898304.5	100.00
RUNOFF	2.369	(1.4508)	283785.12	4.811
EVAPOTRANSPIRATION	28.226	(2.8008)	3381174.50	57.325
PERCOLATION/LEAKAGE THROUGH LAYER 5	18.63551	(4.39187)	2232348.250	37.84729
CHANGE IN WATER STORAGE	0.008	(4.6306)	995.70	0.017

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.58	668428.187
RUNOFF	2.990	358143.0620
PERCOLATION/LEAKAGE THROUGH LAYER 5	0.258274	30938.67970
SNOW WATER	3.87	463700.5000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4860

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1466

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2429	0.2804
2	27.1133	0.2259
3	2.9611	0.3701
4	26.9668	0.2247
5	12.4632	0.2596
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:\DATA\WMM\HELP34\MSSRAIN.D4
TEMPERATURE DATA FILE:        c:\data\wmm\help34\MSSTEMP.D7
SOLAR RADIATION DATA FILE:    c:\data\wmm\help34\MSSRAD.D13
EVAPOTRANSPIRATION DATA:      c:\data\wmm\help34\MSS60FT.D11
SOIL AND DESIGN DATA FILE:    c:\data\wmm\help34\MSS-40FT.D10
OUTPUT DATA FILE:             c:\data\wmm\help34\mss-40ft.OUT


TIME:  13:18     DATE:  11/12/2004


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     TITLE:  MSS FGD LF- 40 ft Height

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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 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2757	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2306	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3563	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2175	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3264	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1869	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 7

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2940	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 8

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1799	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 49

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.2520	VOL/VOL
WILTING POINT	=	0.1150	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2520	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-03	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	72.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	33.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.637	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.860	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.086	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	119.905	INCHES
TOTAL INITIAL WATER	=	119.905	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CHARLOTTE NORTH CAROLINA

STATION LATITUDE	=	35.60	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	83	
END OF GROWING SEASON (JULIAN DATE)	=	312	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.10	4.10	4.70	3.80	3.60	3.90
5.00	5.60	3.80	3.40	3.10	4.10

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
41.00	42.00	49.00	59.00	67.00	75.00
77.00	76.00	70.50	60.50	49.00	41.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA
AND STATION LATITUDE = 35.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.00	4.06	4.67	4.27	3.64	4.31
	5.01	5.15	3.58	3.23	3.08	4.25
STD. DEVIATIONS	1.99	1.84	2.23	1.97	1.79	2.10
	2.36	3.06	2.62	2.06	1.67	1.89
RUNOFF						
TOTALS	0.196	0.207	0.201	0.152	0.107	0.149
	0.174	0.422	0.260	0.195	0.078	0.228
STD. DEVIATIONS	0.356	0.510	0.436	0.284	0.294	0.284
	0.400	0.604	0.580	0.371	0.203	0.375
EVAPOTRANSPIRATION						
TOTALS	1.653	1.885	2.683	2.930	2.793	3.066
	3.519	2.852	2.185	1.764	1.480	1.417
STD. DEVIATIONS	0.303	0.376	0.513	0.884	0.966	1.171
	1.161	1.045	0.914	0.680	0.462	0.221
PERCOLATION/LEAKAGE THROUGH LAYER 9						
TOTALS	1.4481	1.3233	1.4746	1.4329	1.4936	1.4335
	1.6010	1.7838	1.7032	1.7031	1.5730	1.5557
STD. DEVIATIONS	0.4899	0.4971	0.5521	0.5797	0.7307	0.7797
	0.8572	0.8329	0.7468	0.6012	0.5296	0.4315

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	49.24	(7.134)	5898304.5	100.00
RUNOFF	2.369	(1.4508)	283785.12	4.811
EVAPOTRANSPIRATION	28.226	(2.8008)	3381174.50	57.325
PERCOLATION/LEAKAGE THROUGH LAYER 9	18.52582	(4.74545)	2219208.000	37.62451
CHANGE IN WATER STORAGE	0.118	(5.8776)	14135.27	0.240

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.58	668428.187
RUNOFF	2.990	358143.0620
PERCOLATION/LEAKAGE THROUGH LAYER 9	0.237444	28443.39650
SNOW WATER	3.87	463700.5000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4860

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1466

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2429	0.2804
2	27.1133	0.2259
3	2.9611	0.3701
4	26.9668	0.2247
5	3.0274	0.3784
6	26.0096	0.2167
7	3.1875	0.3984
8	26.7660	0.2230
9	13.4302	0.2798
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:\DATA\WMM\HELP34\MSSRAIN.D4
TEMPERATURE DATA FILE:        c:\data\wmm\help34\MSSTEMP.D7
SOLAR RADIATION DATA FILE:    c:\data\wmm\help34\MSSRAD.D13
EVAPOTRANSPIRATION DATA:      c:\data\wmm\help34\MSS60FT.D11
SOIL AND DESIGN DATA FILE:    c:\data\wmm\help34\MSS-60FT.D10
OUTPUT DATA FILE:             c:\data\wmm\help34\mss-60ft.OUT


TIME:  12:28     DATE:  11/12/2004


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     TITLE:  MSS FGD LF- 60 ft Height

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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 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2757	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2306	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 3

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3563	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2175	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 5

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3264	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 6

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1870	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 7

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2942	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 8

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2438	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 12

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 13

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 49

THICKNESS	=	48.00	INCHES
POROSITY	=	0.4300	VOL/VOL
FIELD CAPACITY	=	0.2520	VOL/VOL
WILTING POINT	=	0.1150	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2520	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-03	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT SOIL DATA BASE USING SOIL TEXTURE # 8 WITH A GOOD STAND OF GRASS, A SURFACE SLOPE OF 2.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	72.30	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	33.000	ACRES
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	2.637	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	4.860	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.086	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	167.008	INCHES
TOTAL INITIAL WATER	=	167.008	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM CHARLOTTE NORTH CAROLINA

STATION LATITUDE	=	35.60	DEGREES
MAXIMUM LEAF AREA INDEX	=	0.00	
START OF GROWING SEASON (JULIAN DATE)	=	83	
END OF GROWING SEASON (JULIAN DATE)	=	312	
EVAPORATIVE ZONE DEPTH	=	10.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.10	4.10	4.70	3.80	3.60	3.90
5.00	5.60	3.80	3.40	3.10	4.10

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
41.00	42.00	49.00	59.00	67.00	75.00
77.00	76.00	70.50	60.50	49.00	41.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA
AND STATION LATITUDE = 35.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.00	4.06	4.67	4.27	3.64	4.31
	5.01	5.15	3.58	3.23	3.08	4.25
STD. DEVIATIONS	1.99	1.84	2.23	1.97	1.79	2.10
	2.36	3.06	2.62	2.06	1.67	1.89
RUNOFF						
TOTALS	0.196	0.207	0.201	0.152	0.107	0.149
	0.174	0.422	0.260	0.195	0.078	0.228
STD. DEVIATIONS	0.356	0.510	0.436	0.284	0.294	0.284
	0.400	0.604	0.580	0.371	0.203	0.375
EVAPOTRANSPIRATION						
TOTALS	1.653	1.885	2.683	2.930	2.793	3.066
	3.519	2.852	2.185	1.764	1.480	1.417
STD. DEVIATIONS	0.303	0.376	0.513	0.884	0.966	1.171
	1.161	1.045	0.914	0.680	0.462	0.221
PERCOLATION/LEAKAGE THROUGH LAYER 13						
TOTALS	1.6579	1.4642	1.5481	1.4497	1.4870	1.4314
	1.5003	1.5696	1.4899	1.5545	1.5480	1.6579
STD. DEVIATIONS	0.6430	0.5470	0.5615	0.4596	0.4859	0.4999
	0.5043	0.6503	0.6606	0.7169	0.7663	0.7071

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	49.24	(7.134)	5898304.5	100.00
RUNOFF	2.369	(1.4508)	283785.12	4.811
EVAPOTRANSPIRATION	28.226	(2.8008)	3381174.50	57.325
PERCOLATION/LEAKAGE THROUGH LAYER 13	18.35825	(4.54142)	2199134.250	37.28418
CHANGE IN WATER STORAGE	0.286	(6.0870)	34209.41	0.580

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.58	668428.187
RUNOFF	2.990	358143.0620
PERCOLATION/LEAKAGE THROUGH LAYER 13	0.195103	23371.34770
SNOW WATER	3.87	463700.5000

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4860

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1466

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FINAL WATER STORAGE AT END OF YEAR 100

LAYER	(INCHES)	(VOL/VOL)
1	2.2429	0.2804
2	27.1133	0.2259
3	2.9611	0.3701
4	26.9668	0.2247
5	3.0274	0.3784
6	26.0096	0.2167
7	3.1875	0.3984
8	26.7660	0.2230
9	3.1366	0.3921
10	28.1747	0.2348
11	3.2218	0.4027
12	28.9419	0.2412
13	13.8158	0.2878
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:\DATA\WMM\HELP34\MSSRAIN.D4
TEMPERATURE DATA FILE:        c:\data\wmm\help34\MSSTEMP.D7
SOLAR RADIATION DATA FILE:    c:\data\wmm\help34\MSSRAD.D13
EVAPOTRANSPIRATION DATA:      c:\data\wmm\help34\MSSEVAP.D11
SOIL AND DESIGN DATA FILE:    c:\data\wmm\help34\MSSCLOSE.D10
OUTPUT DATA FILE:             c:\data\wmm\help34\ms1out.OUT


TIME:  15:33     DATE:  11/ 8/2004


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     TITLE:  MSS FGD LF- Full Height w/Final Cover

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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 57

THICKNESS	=	9.00	INCHES
POROSITY	=	0.4400	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2772	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 2

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 56

THICKNESS	=	15.00	INCHES
POROSITY	=	0.4400	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.3870	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.739999996000E-05	CM/SEC

LAYER 3

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 0

THICKNESS	=	0.20	INCHES
POROSITY	=	0.8500	VOL/VOL
FIELD CAPACITY	=	0.0100	VOL/VOL
WILTING POINT	=	0.0050	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2086	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	1.00000000000	CM/SEC
SLOPE	=	12.50	PERCENT
DRAINAGE LENGTH	=	300.0	FEET

LAYER 4

TYPE 4 - FLEXIBLE MEMBRANE LINER

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                MATERIAL TEXTURE NUMBER  36
THICKNESS                    =      0.04    INCHES
POROSITY                     =      0.0000 VOL/VOL
FIELD CAPACITY               =      0.0000 VOL/VOL
WILTING POINT                =      0.0000 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.0000 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.399999993000E-12 CM/SEC
FML PINHOLE DENSITY          =      1.00    HOLES/ACRE
FML INSTALLATION DEFECTS     =      7.00    HOLES/ACRE
FML PLACEMENT QUALITY        =  3 - GOOD


                      LAYER  5
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           TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  55
THICKNESS                    =     18.00    INCHES
POROSITY                     =      0.4400 VOL/VOL
FIELD CAPACITY               =      0.2420 VOL/VOL
WILTING POINT                =      0.1220 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2420 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.739999996000E-05 CM/SEC


                      LAYER  6
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           TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  44
THICKNESS                    =    120.00    INCHES
POROSITY                     =      0.4700 VOL/VOL
FIELD CAPACITY               =      0.1800 VOL/VOL
WILTING POINT                =      0.0550 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.1800 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.508999976000E-03 CM/SEC


                      LAYER  7
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           TYPE 1 - VERTICAL PERCOLATION LAYER
                MATERIAL TEXTURE NUMBER  52
THICKNESS                    =      8.00    INCHES
POROSITY                     =      0.4900 VOL/VOL
FIELD CAPACITY               =      0.2420 VOL/VOL
WILTING POINT                =      0.1220 VOL/VOL
INITIAL SOIL WATER CONTENT   =      0.2420 VOL/VOL
EFFECTIVE SAT. HYD. COND.    =  0.220000002000E-04 CM/SEC
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LAYER 8

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 9

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 10

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 11

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 12

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 13

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 14

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 15

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 16

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 17

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 18

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

LAYER 19

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 52

THICKNESS	=	8.00	INCHES
POROSITY	=	0.4900	VOL/VOL
FIELD CAPACITY	=	0.2420	VOL/VOL
WILTING POINT	=	0.1220	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2420	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.220000002000E-04	CM/SEC

LAYER 20

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 44

THICKNESS	=	120.00	INCHES
POROSITY	=	0.4700	VOL/VOL
FIELD CAPACITY	=	0.1800	VOL/VOL
WILTING POINT	=	0.0550	VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1800	VOL/VOL
EFFECTIVE SAT. HYD. COND.	=	0.508999976000E-03	CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM A USER-SPECIFIED CURVE NUMBER OF 61.0, A SURFACE SLOPE OF 12.% AND A SLOPE LENGTH OF 300. FEET.

SCS RUNOFF CURVE NUMBER	=	63.80	
FRACTION OF AREA ALLOWING RUNOFF	=	100.0	PERCENT
AREA PROJECTED ON HORIZONTAL PLANE	=	33.000	ACRES
EVAPORATIVE ZONE DEPTH	=	13.0	INCHES
INITIAL WATER IN EVAPORATIVE ZONE	=	3.942	INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE	=	5.720	INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE	=	1.586	INCHES
INITIAL SNOW WATER	=	0.000	INCHES
INITIAL WATER IN LAYER MATERIALS	=	199.044	INCHES
TOTAL INITIAL WATER	=	199.044	INCHES
TOTAL SUBSURFACE INFLOW	=	0.00	INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
CHARLOTTE NORTH CAROLINA

STATION LATITUDE	=	35.60	DEGREES
MAXIMUM LEAF AREA INDEX	=	2.00	
START OF GROWING SEASON (JULIAN DATE)	=	83	
END OF GROWING SEASON (JULIAN DATE)	=	312	
EVAPORATIVE ZONE DEPTH	=	13.0	INCHES
AVERAGE ANNUAL WIND SPEED	=	7.50	MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY	=	64.00	%
AVERAGE 2ND QUARTER RELATIVE HUMIDITY	=	67.00	%
AVERAGE 3RD QUARTER RELATIVE HUMIDITY	=	74.00	%
AVERAGE 4TH QUARTER RELATIVE HUMIDITY	=	70.00	%

NOTE: PRECIPITATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY PRECIPITATION (INCHES)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
4.10	4.10	4.70	3.80	3.60	3.90
5.00	5.60	3.80	3.40	3.10	4.10

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
41.00	42.00	49.00	59.00	67.00	75.00
77.00	76.00	70.50	60.50	49.00	41.50

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR CHARLOTTE NORTH CAROLINA
AND STATION LATITUDE = 35.60 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1 THROUGH 100

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.00	4.06	4.67	4.27	3.64	4.31
	5.01	5.15	3.58	3.23	3.08	4.25
STD. DEVIATIONS	1.99	1.84	2.23	1.97	1.79	2.10
	2.36	3.06	2.62	2.06	1.67	1.89
RUNOFF						
TOTALS	0.816	0.792	0.907	0.851	0.565	0.843
	0.927	1.461	1.173	0.875	0.577	1.000
STD. DEVIATIONS	0.893	0.910	1.030	0.823	0.743	0.807
	1.113	1.463	1.424	0.983	0.692	1.018
EVAPOTRANSPIRATION						
TOTALS	1.394	1.685	2.520	2.873	3.717	3.912
	3.919	3.373	2.313	1.298	1.076	1.059
STD. DEVIATIONS	0.237	0.309	0.443	0.784	0.812	1.419
	1.398	1.403	1.041	0.422	0.248	0.179
LATERAL DRAINAGE COLLECTED FROM LAYER 3						
TOTALS	1.8113	1.7317	1.5538	0.9534	0.6359	0.3383
	0.1810	0.1276	0.1468	0.1605	0.4092	1.2680
STD. DEVIATIONS	1.1311	1.1107	0.8897	0.6631	0.5101	0.1948
	0.1427	0.1134	0.2023	0.3471	0.6752	1.1428
PERCOLATION/LEAKAGE THROUGH LAYER 4						
TOTALS	0.0001	0.0001	0.0001	0.0001	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
STD. DEVIATIONS	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0001
PERCOLATION/LEAKAGE THROUGH LAYER 20						
TOTALS	0.0001	0.0001	0.0001	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0001	0.0000	0.0001
STD. DEVIATIONS	0.0006	0.0004	0.0005	0.0003	0.0003	0.0000
	0.0003	0.0000	0.0003	0.0004	0.0003	0.0004

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 4

AVERAGES	0.0251	0.0264	0.0216	0.0137	0.0088	0.0048
	0.0025	0.0018	0.0021	0.0022	0.0059	0.0176
STD. DEVIATIONS	0.0157	0.0169	0.0123	0.0095	0.0071	0.0028
	0.0020	0.0016	0.0029	0.0048	0.0097	0.0159

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

	INCHES		CU. FEET	PERCENT
PRECIPITATION	49.24	(7.134)	5898304.5	100.00
RUNOFF	10.785	(3.5727)	1291904.62	21.903
EVAPOTRANSPIRATION	29.138	(3.1938)	3490395.25	59.176
LATERAL DRAINAGE COLLECTED FROM LAYER 3	9.31758	(2.74914)	1116153.250	18.92329
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.00061	(0.00016)	73.196	0.00124
AVERAGE HEAD ON TOP OF LAYER 4	0.011	(0.003)		
PERCOLATION/LEAKAGE THROUGH LAYER 20	0.00057	(0.00123)	68.526	0.00116
CHANGE IN WATER STORAGE	-0.002	(1.1464)	-218.25	-0.004

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PEAK DAILY VALUES FOR YEARS 1 THROUGH 100

	(INCHES)	(CU. FT.)
PRECIPITATION	5.58	668428.187
RUNOFF	4.651	557161.3120
DRAINAGE COLLECTED FROM LAYER 3	0.25170	30150.92970
PERCOLATION/LEAKAGE THROUGH LAYER 4	0.000014	1.70696
AVERAGE HEAD ON TOP OF LAYER 4	0.108	
MAXIMUM HEAD ON TOP OF LAYER 4	0.222	
LOCATION OF MAXIMUM HEAD IN LAYER 3 (DISTANCE FROM DRAIN)	0.0 FEET	
PERCOLATION/LEAKAGE THROUGH LAYER 20	0.003179	380.79507
SNOW WATER	3.87	463700.5000

MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4400
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.1220

*** 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	2.4968	0.2774
2	5.6322	0.3755
3	0.0266	0.1330
4	0.0000	0.0000
5	4.3560	0.2420
6	21.5997	0.1800
7	1.9360	0.2420
8	21.5997	0.1800
9	1.9360	0.2420
10	21.5997	0.1800
11	1.9360	0.2420
12	21.5997	0.1800
13	1.9360	0.2420
14	21.5997	0.1800
15	1.9360	0.2420
16	21.5997	0.1800
17	1.9360	0.2420
18	21.5998	0.1800
19	1.9360	0.2420
20	21.5999	0.1800
SNOW WATER	0.000	

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Attachment 5

Input Data for MYGRT Model Runs

Marshall Steam Station
FGD Residue Landfill
Properties Used in MYGRT

Cross Section 2-2

(Reference Figures 1 and 2)

(All elevations and thickness values in feet)

Volumetric Moisture Content of Soil:

Estimated from Table 6, Ref. 4 25%

Thickness of Unsaturated Zone:

	Source	MS-10	B-2	B-1
Approximate Elevation of Excavation	-	Outside of Footprint	834	Outside of Footprint
Estimated Seasonal High Groundwater Elevation (NAVD 88)	Figure 3 of 7, Ref. 4	836.07	819.5	802.52
Thickness of Unsaturated Zone	-		14.5	

Hydraulic Gradient for Section:

Approximate Seasonal High GW elevation:	
at MS-10	836.1
at 2L Compliance Boundary	805
Hydraulic Gradient (ft/ft)	0.03

Attachment 6

MYGRT Model
Input Data and Results

MYGRT Analysis
Input and Results

Cross Section 1-1
Sulfate

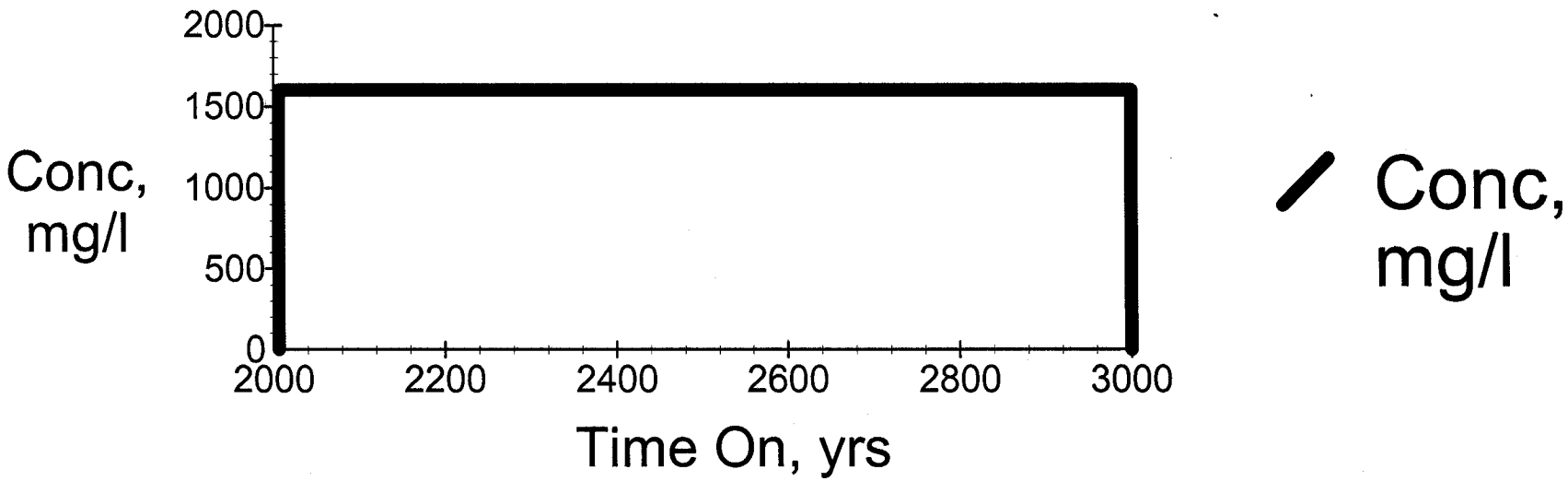
Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 1	
Description		X Sect 1-1 Cap @End of Year 5	
Notes			
Solute Name		SO4	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	2.48	Calc'd
Depth to water table	ft	4	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	1300	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	196	
Dispersion along Y	ft2/yr	19.6	
Dispersion along Z	ft2/yr	1.96	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	27.8	
Seepage Velocity	ft/yr	7.84	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.28	
Hydraulic Gradient	ft/ft	0.01	
Hydraulic Conductivity	ft/yr	219.4	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	27.8	Calc'd
Source Penetration Depth After Switch	ft	25.8	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

Input Parameters

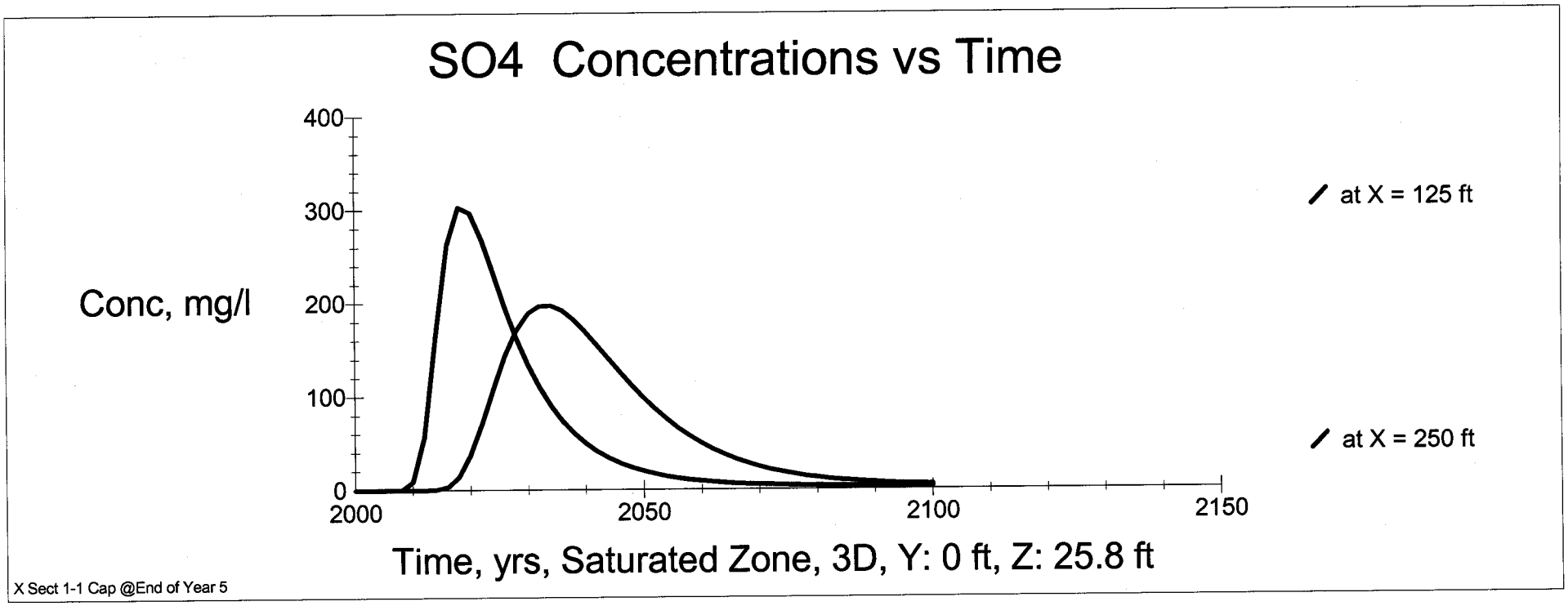
Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration



Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	1600.000
2	2007.000	1600.000
3	2008.000	1600.000
4	2009.000	1600.000
5	2010.000	1600.000
6	3000.000	0.000


SO4 Concentrations vs Time
Conc, mg/l
400
300
200
100
0
2000
2050
2100
2150
at X = 125 ft
at X = 250 ft
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 25.8 ft
X Sect 1-1 Cap @End of Year 5

SO4 Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	0.00539223	0
6	2010	9.25679	3.75838E-6
7	2012	57.3216	0.00641813
8	2014	164.68	0.334785
9	2016	263.102	3.2946
10	2018	302.507	14.1674
11	2020	296.698	37.2733
12	2022	267.834	70.9081
13	2024	231.65	108.698
14	2026	195.195	143.38
15	2028	162.355	170.609
16	2030	133.879	188.291
17	2032	109.961	196.762
18	2034	90.1504	197.311
19	2036	73.8641	191.64
20	2038	60.5893	181.678
21	2040	49.7752	168.866
22	2042	41.0077	154.609
23	2044	33.9328	139.979
24	2046	28.1691	125.376
25	2048	23.4907	111.382
26	2050	19.6861	98.2637
27	2052	16.6135	86.3378
28	2054	14.1073	75.4975
29	2056	12.0681	65.8042
30	2058	10.4063	57.2097
31	2060	9.04954	49.6367
32	2062	7.94194	43.0168
33	2064	7.04209	37.3024
34	2066	6.30236	32.3236
35	2068	5.69632	28.0255
36	2070	5.19936	24.3267
37	2072	4.79156	21.1534
38	2074	4.45592	18.4305
39	2076	4.18141	16.1185
40	2078	3.95516	14.1429
41	2080	3.76867	12.4588
42	2082	3.61502	11.0272

X Sect 1-1 Cap @End of Year 5

SO4 Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	3.48852	9.81378
44	2086	3.38386	8.7813
45	2088	3.29741	7.90586
46	2090	3.22594	7.16413
47	2092	3.16673	6.53501
48	2094	3.11786	6.00434
49	2096	3.07736	5.55519
50	2098	3.0438	5.17556
51	2100	3.01596	4.85467

MYGRT Analysis
Input and Results

Cross Section 2-2
Sulfate

Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 2-2	
Description		X Sect 2-2 Cap @End of Year 5	
Notes			
Solute Name		Sulfate	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	8.99	Calc'd
Depth to water table	ft	14.5	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	760	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	510	
Dispersion along Y	ft2/yr	51	
Dispersion along Z	ft2/yr	5.1	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	24.3	
Seepage Velocity	ft/yr	20.4	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.27	
Hydraulic Gradient	ft/ft	0.03	
Hydraulic Conductivity	ft/yr	183.9	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	24.3	Calc'd
Source Penetration Depth After Switch	ft	19.9	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

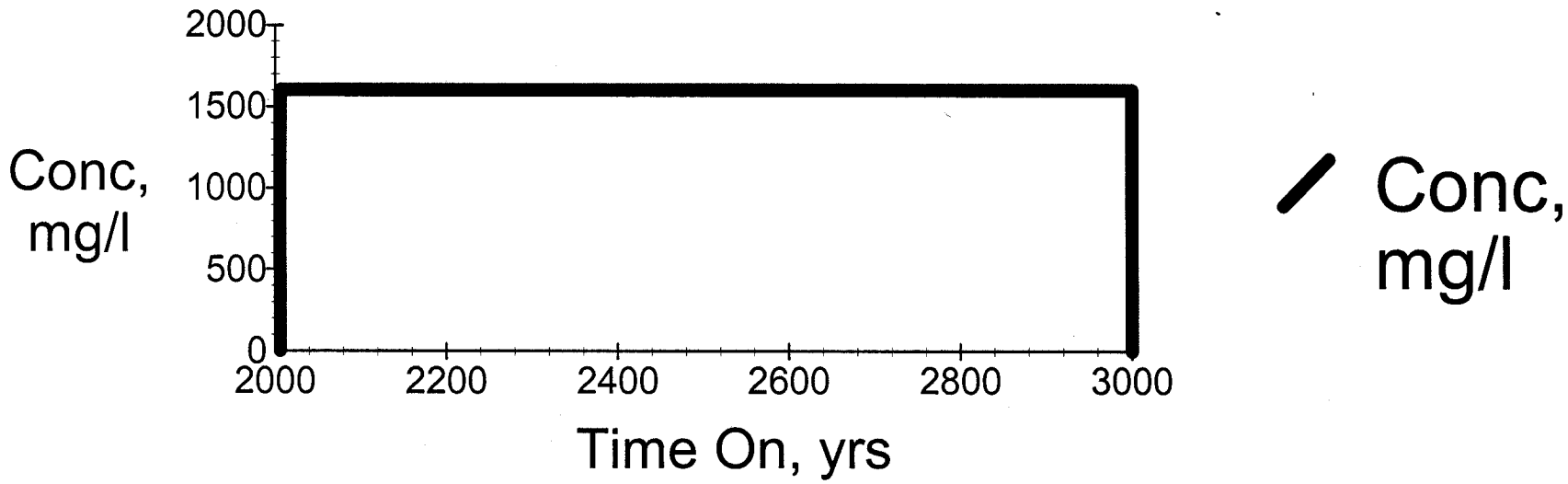
Input Parameters

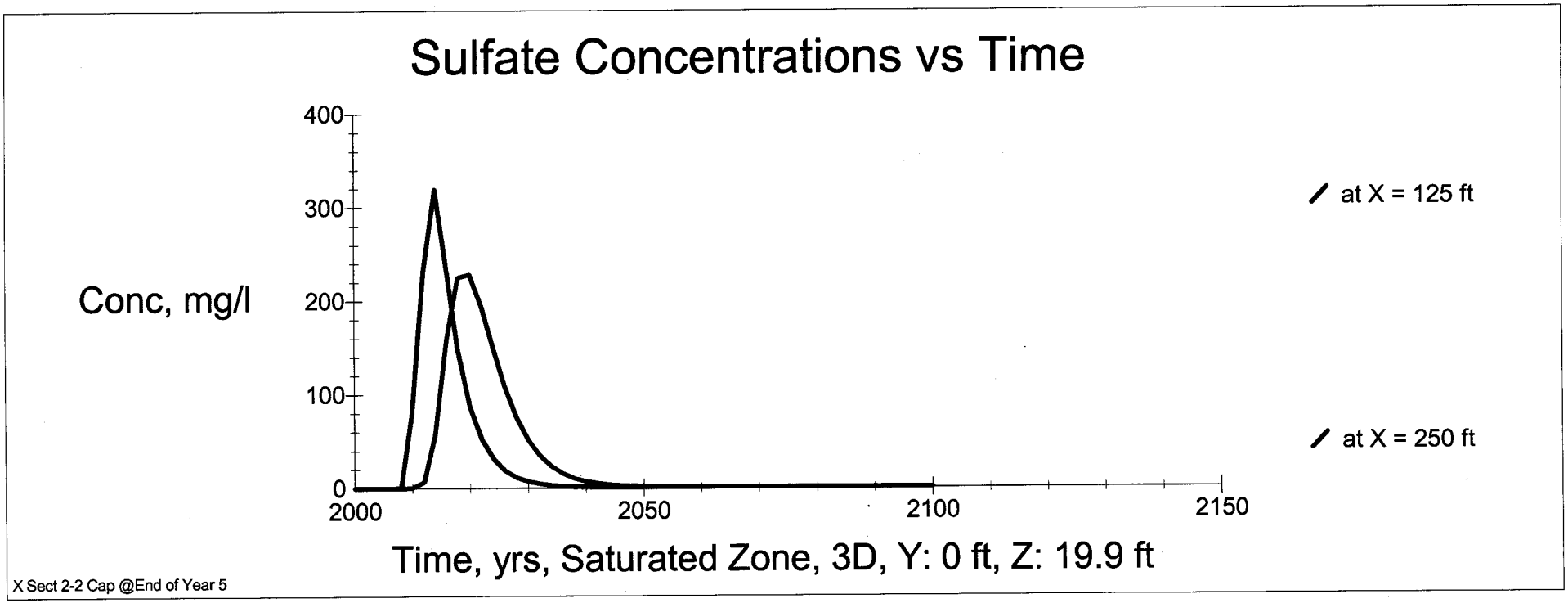
Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	1600.000
2	2007.000	1600.000
3	2008.000	1600.000
4	2009.000	1600.000
5	2010.000	1600.000
6	3000.000	0.000

Source Concentration




Sulfate Concentrations vs Time
Conc, mg/l
400
300
200
100
0
2000
2050
2100
2150
at X = 125 ft
at X = 250 ft
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 19.9 ft
X Sect 2-2 Cap @End of Year 5

Sulfate Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	0.182063	0
6	2010	80.7221	0.105003
7	2012	232.317	6.80978
8	2014	319.275	58.2183
9	2016	233.203	158.4
10	2018	146.083	224.881
11	2020	87.7905	228.255
12	2022	52.2885	194.219
13	2024	31.2685	149.719
14	2026	18.8643	108.695
15	2028	11.5436	76.0413
16	2030	7.20303	51.9509
17	2032	4.6176	34.9868
18	2034	3.06776	23.3688
19	2036	2.13395	15.5667
20	2038	1.56937	10.4041
21	2040	1.22581	7.01323
22	2042	1.01596	4.8025
23	2044	0.887643	3.36984
24	2046	0.808749	2.44425
25	2048	0.760079	1.84699
26	2050	0.729997	1.46245
27	2052	0.711401	1.2156
28	2054	0.699879	1.05709
29	2056	0.692747	0.955452
30	2058	0.688332	0.890216
31	2060	0.685612	0.848423
32	2062	0.683921	0.821608
33	2064	0.682943	0.804553
34	2066	0.682349	0.793626
35	2068	0.68201	0.786664
36	2070	0.68183	0.78224
37	2072	0.681748	0.779444
38	2074	0.681726	0.777694
39	2076	0.681741	0.776614
40	2078	0.681778	0.775961
41	2080	0.681827	0.77558
42	2082	0.681882	0.775373

X Sect 2-2 Cap @End of Year 5

Sulfate Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	0.68194	0.775276
44	2086	0.681999	0.775248
45	2088	0.682058	0.775263
46	2090	0.682115	0.775304
47	2092	0.68217	0.775361
48	2094	0.6822	0.775377
49	2096	0.682275	0.775495
50	2098	0.682324	0.775567
51	2100	0.682371	0.775638

MYGRT Analysis
Input and Results

Cross Section 1-1
Arsenic

Input Parameters

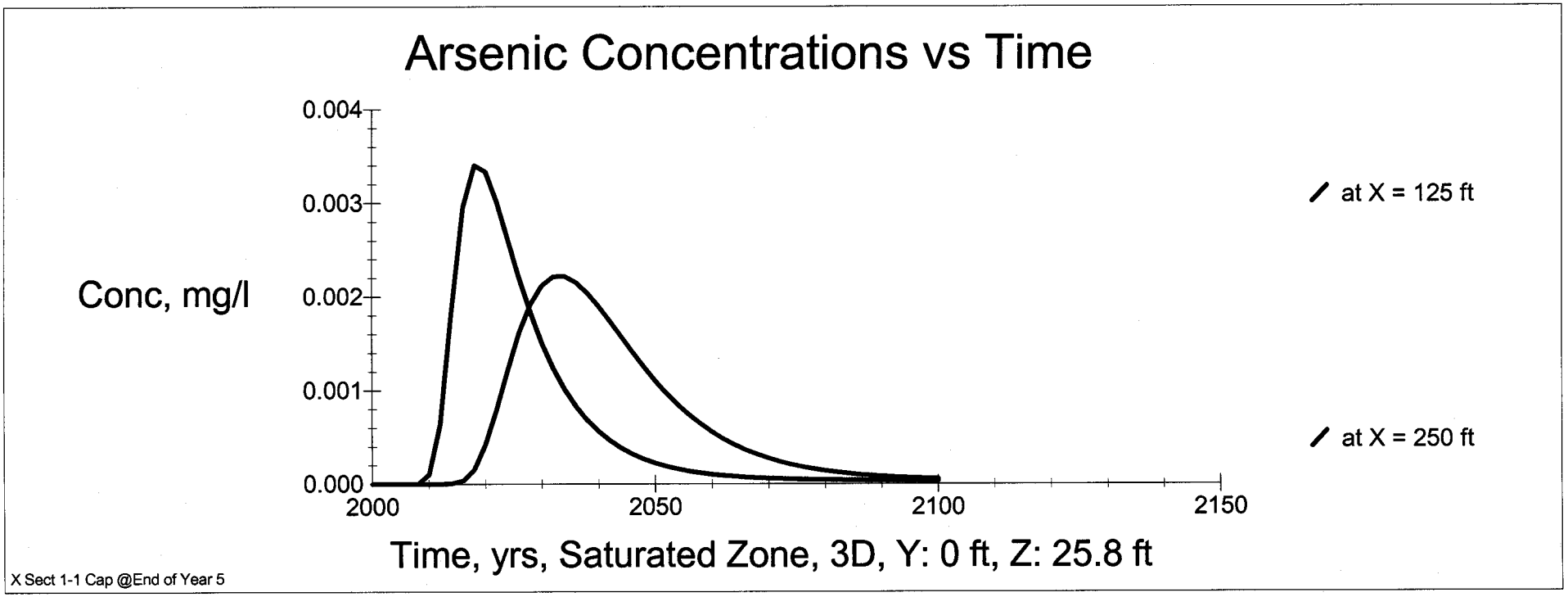
Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 1-1	
Description		X Sect 1-1 Cap @End of Year 5	
Notes			
Solute Name		Arsenic	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	2.48	Calc'd
Depth to water table	ft	4	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	1300	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	196	
Dispersion along Y	ft2/yr	1.96	
Dispersion along Z	ft2/yr	1.96	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	27.8	
Seepage Velocity	ft/yr	7.84	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.28	
Hydraulic Gradient	ft/ft	0.01	
Hydraulic Conductivity	ft/yr	219.4	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	27.8	Calc'd
Source Penetration Depth After Switch	ft	25.8	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

Input Parameters

Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	0.018
2	2007.000	0.018
3	2008.000	0.018
4	2009.000	0.018
5	2010.000	0.018
6	3000.000	0.000


Arsenic Concentrations vs Time
Conc, mg/l
0.004
0.003
0.002
0.001
0.000
2000
2050
2100
2150
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 25.8 ft
at X = 125 ft
at X = 250 ft
X Sect 1-1 Cap @End of Year 5

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	6.06621E-8	0
6	2010	0.000104139	4.22817E-11
7	2012	0.000644868	7.22039E-8
8	2014	0.00185264	3.76634E-6
9	2016	0.0029599	3.70643E-5
10	2018	0.00340321	0.000159383
11	2020	0.00333785	0.000419325
12	2022	0.00301313	0.000797716
13	2024	0.00260598	0.00122282
14	2026	0.00219543	0.00161271
15	2028	0.00182643	0.00191929
16	2030	0.00150613	0.00211827
17	2032	0.00123693	0.00221333
18	2034	0.00101419	0.00221975
19	2036	0.000830971	0.00215595
20	2038	0.000681526	0.00204354
21	2040	0.000559969	0.00189973
22	2042	0.000461219	0.0017389
23	2044	0.000381743	0.00157476
24	2046	0.000316895	0.00141044
25	2048	0.000264266	0.00125302
26	2050	0.00022144	0.0011053
27	2052	0.000186901	0.000971296
28	2054	0.000158707	0.000849346
29	2056	0.00013575	0.000740183
30	2058	0.000117058	0.000643516
31	2060	0.000101807	0.000558411
32	2062	8.93309E-5	0.000483815
33	2064	7.92235E-5	0.000419652
34	2066	7.09015E-5	0.00036364
35	2068	6.40829E-5	0.00031528
36	2070	5.84922E-5	0.00027367
37	2072	5.39045E-5	0.000237971
38	2074	5.01263E-5	0.000207315
39	2076	4.70408E-5	0.000181333
40	2078	4.44955E-5	0.000159107
41	2080	4.23975E-5	0.000140161
42	2082	4.06689E-5	0.000124056

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	3.92459E-5	0.000110405
44	2086	3.80683E-5	9.87878E-5
45	2088	3.70957E-5	8.89397E-5
46	2090	3.62918E-5	8.05954E-5
47	2092	3.56257E-5	7.3518E-5
48	2094	3.50759E-5	6.7548E-5
49	2096	3.46202E-5	6.24953E-5
50	2098	3.42427E-5	5.82245E-5
51	2100	3.39296E-5	5.46146E-5

MYGRT Analysis
Input and Results

Cross Section 2-2
Arsenic

Input Parameters

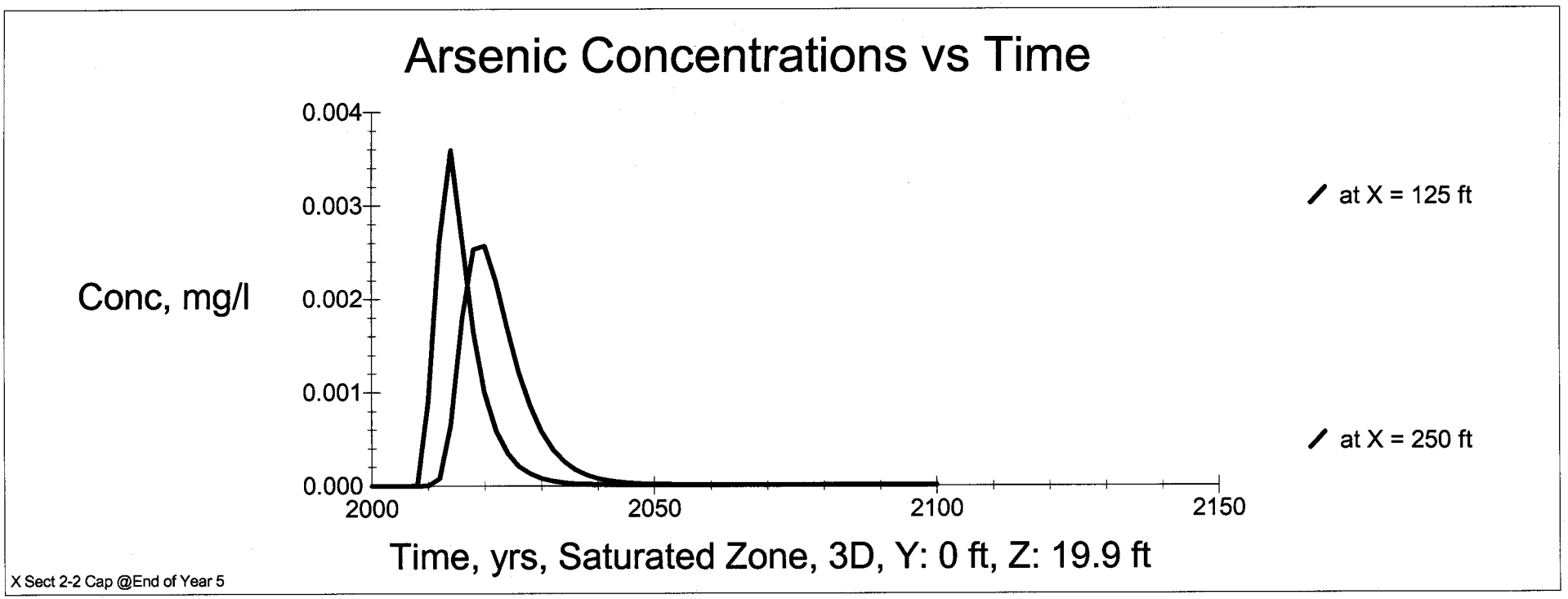
Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 2-2	
Description		X Sect 2-2 Cap @End of Year 5	
Notes			
Solute Name		Arsenic	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	8.99	Calc'd
Depth to water table	ft	14.5	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	760	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	510	
Dispersion along Y	ft2/yr	5.1	
Dispersion along Z	ft2/yr	5.1	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	24.3	
Seepage Velocity	ft/yr	20.4	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.27	
Hydraulic Gradient	ft/ft	0.03	
Hydraulic Conductivity	ft/yr	183.9	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	24.3	Calc'd
Source Penetration Depth After Switch	ft	19.9	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

Input Parameters

Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	0.018
2	2007.000	0.018
3	2008.000	0.018
4	2009.000	0.018
5	2010.000	0.018
6	3000.000	0.000


Arsenic Concentrations vs Time
Conc, mg/l
0.004
0.003
0.002
0.001
0.000
2000
2050
2100
2150
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 19.9 ft
at X = 125 ft
at X = 250 ft
X Sect 2-2 Cap @End of Year 5

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	2.04823E-6	0
6	2010	0.000908123	1.18129E-6
7	2012	0.00261356	7.661E-5
8	2014	0.00359184	0.000654955
9	2016	0.00262352	0.00178199
10	2018	0.00164343	0.00252991
11	2020	0.000987603	0.00256777
12	2022	0.000588241	0.00218496
13	2024	0.000351767	0.00168433
14	2026	0.000212221	0.00122282
15	2028	0.000129863	0.000855458
16	2030	8.10308E-5	0.000584438
17	2032	5.19455E-5	0.000393596
18	2034	3.45099E-5	0.000262894
19	2036	2.40053E-5	0.000175122
20	2038	1.76533E-5	0.000117042
21	2040	1.37885E-5	7.88948E-5
22	2042	1.14289E-5	5.40267E-5
23	2044	9.9843E-6	3.79071E-5
24	2046	9.09682E-6	2.74944E-5
25	2048	8.54938E-6	2.07754E-5
26	2050	8.21101E-6	1.64494E-5
27	2052	8.00188E-6	1.36726E-5
28	2054	7.87233E-6	1.18894E-5
29	2056	7.79215E-6	1.07462E-5
30	2058	7.74253E-6	1.00124E-5
31	2060	7.71198E-6	9.54229E-6
32	2062	7.69327E-6	9.24132E-6
33	2064	7.68203E-6	9.04893E-6
34	2066	7.67538E-6	8.92608E-6
35	2068	7.67161E-6	8.84784E-6
36	2070	7.66961E-6	8.79814E-6
37	2072	7.66872E-6	8.76675E-6
38	2074	7.6685E-6	8.7471E-6
39	2076	7.6687E-6	8.73503E-6
40	2078	7.66914E-6	8.72773E-6
41	2080	7.66972E-6	8.7235E-6
42	2082	7.67036E-6	8.72122E-6

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	7.67104E-6	8.72018E-6
44	2086	7.67172E-6	8.71991E-6
45	2088	7.6724E-6	8.72011E-6
46	2090	7.67306E-6	8.72061E-6
47	2092	7.6737E-6	8.72129E-6
48	2094	7.67429E-6	8.72203E-6
49	2096	7.67491E-6	8.72287E-6
50	2098	7.67548E-6	8.72371E-6
51	2100	7.67602E-6	8.72454E-6

MYGRT Analysis
Input and Results

Cross Section 1-1
Fluoride

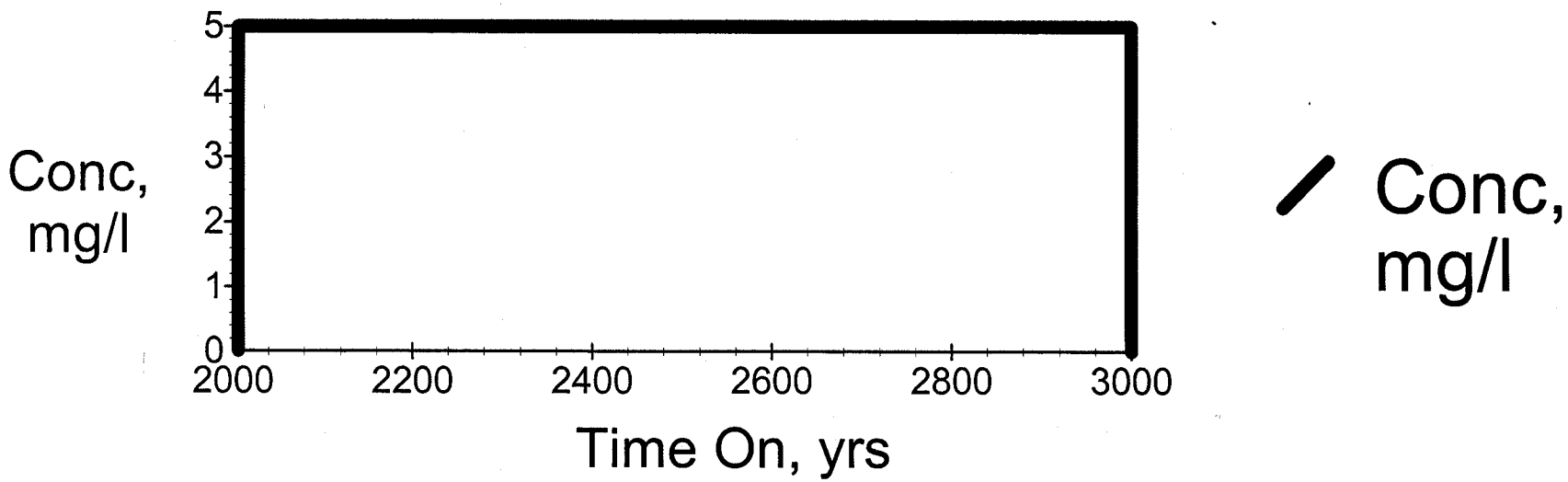
Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 1-1	
Description		X Sect 1-1 Cap @End of Year 5	
Notes			
Solute Name		Fluoride	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	2.48	Calc'd
Depth to water table	ft	4	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	1300	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	196	
Dispersion along Y	ft2/yr	19.6	
Dispersion along Z	ft2/yr	1.96	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	27.8	
Seepage Velocity	ft/yr	7.84	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.28	
Hydraulic Gradient	ft/ft	0.01	
Hydraulic Conductivity	ft/yr	219.4	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	27.8	Calc'd
Source Penetration Depth After :	ft	25.8	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

Input Parameters

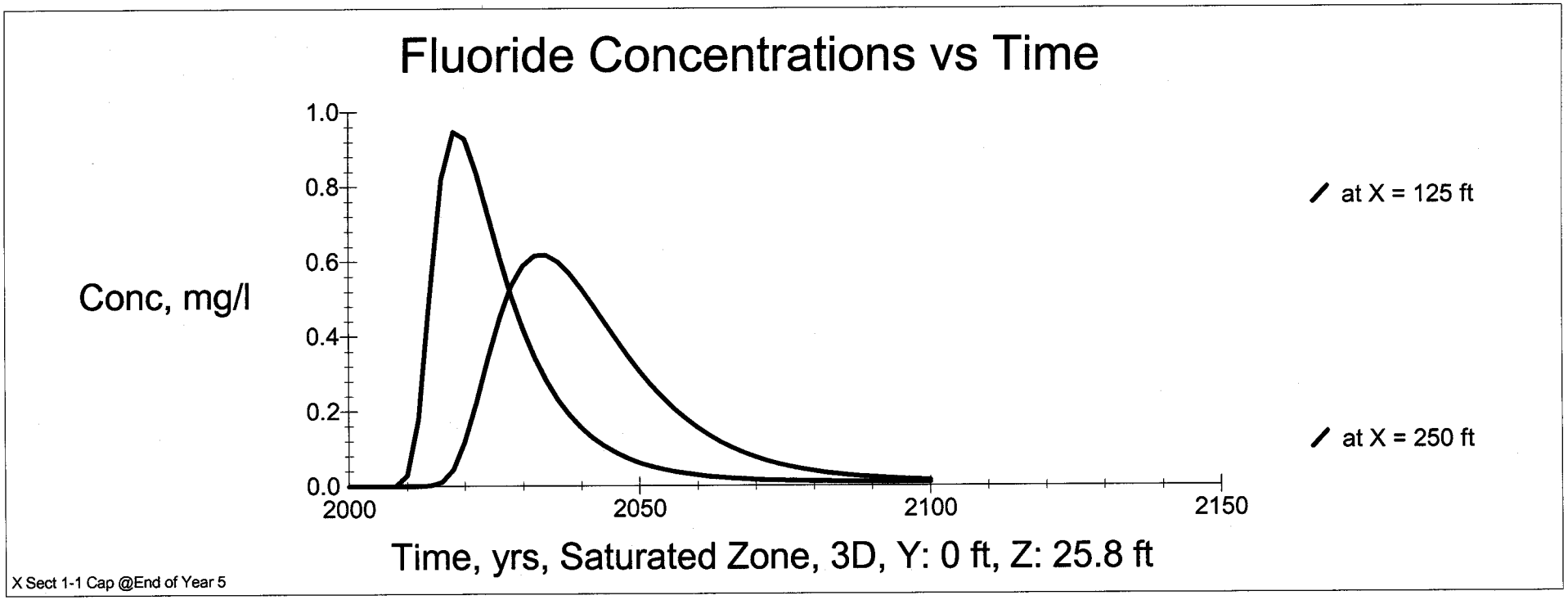
Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration



Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	5.000
2	2007.000	5.000
3	2008.000	5.000
4	2009.000	5.000
5	2010.000	5.000
6	3000.000	0.000


Fluoride Concentrations vs Time
Conc, mg/l
1.0
0.8
0.6
0.4
0.2
0.0
2000
2050
2100
2150
at X = 125 ft
at X = 250 ft
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 25.8 ft
X Sect 1-1 Cap @End of Year 5

Fluoride Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	1.68507E-5	0
6	2010	0.0289275	1.17449E-8
7	2012	0.179132	2.00566E-5
8	2014	0.514624	0.0010462
9	2016	0.822193	0.0102956
10	2018	0.945335	0.044273
11	2020	0.92718	0.116479
12	2022	0.836981	0.221588
13	2024	0.723905	0.339681
14	2026	0.609983	0.448063
15	2028	0.50736	0.533154
16	2030	0.418371	0.58841
17	2032	0.343628	0.614882
18	2034	0.28172	0.616596
19	2036	0.230825	0.598874
20	2038	0.189341	0.567743
21	2040	0.155547	0.527705
22	2042	0.128149	0.483154
23	2044	0.10604	0.437435
24	2046	0.0880284	0.391799
25	2048	0.0734085	0.348069
26	2050	0.061519	0.307074
27	2052	0.051917	0.269805
28	2054	0.0440854	0.23593
29	2056	0.0377128	0.205638
30	2058	0.0325198	0.17878
31	2060	0.0282798	0.155115
32	2062	0.0248185	0.134427
33	2064	0.0220065	0.11657
34	2066	0.0196949	0.101011
35	2068	0.017801	0.0875795
36	2070	0.016248	0.0760211
37	2072	0.0149736	0.0661044
38	2074	0.0139248	0.0575952
39	2076	0.0130669	0.0503704
40	2078	0.0123599	0.0441965
41	2080	0.0117771	0.0389337
42	2082	0.0112969	0.03446

X Sect 1-1 Cap @End of Year 5

Fluoride Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	0.0109016	0.0306681
44	2086	0.0105746	0.0274416
45	2088	0.0103044	0.0247058
46	2090	0.0100811	0.0223879
47	2092	0.00989604	0.0204219
48	2094	0.00974332	0.0187635
49	2096	0.00961675	0.01736
50	2098	0.00951187	0.0161736
51	2100	0.00942489	0.0151709

MYGRT Analysis
Input and Results

Cross Section 2-2
Fluoride

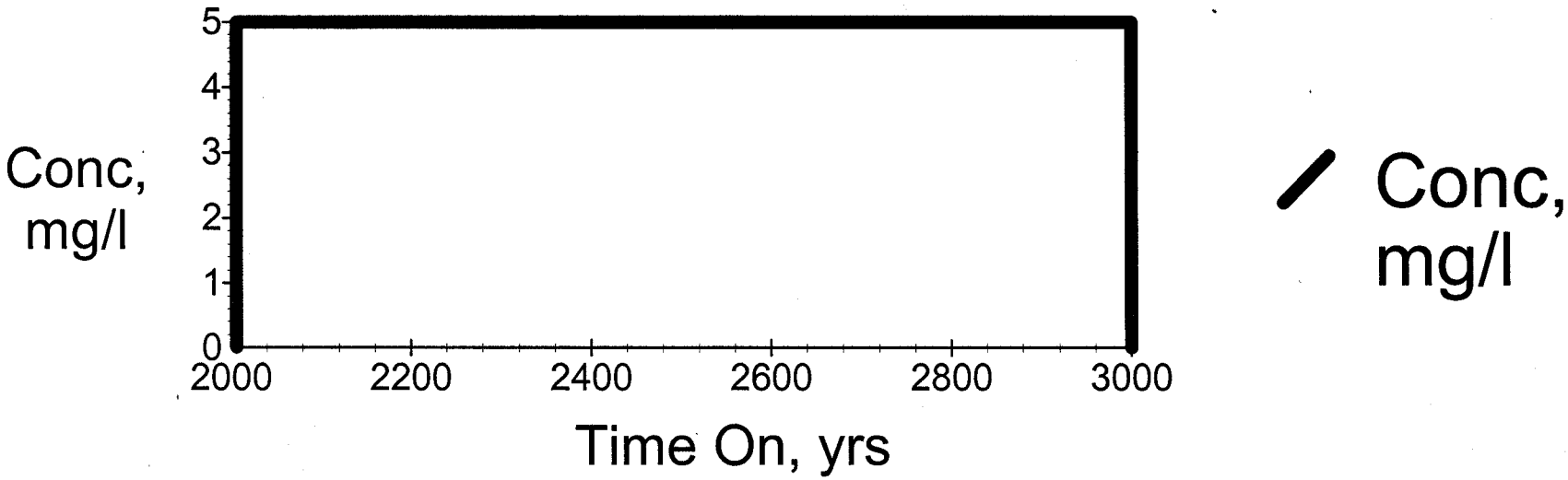
Input Parameters

Description	Units	Value	Note
General Parameters			
Site		MSS FGD Landfill - Cross Section 2-2	
Description		X Sect 2-2 Cap @End of Year 5	
Notes			
Solute Name		Flouride	
Organic		No	
Zones Simulated		Unsat/Sat	
Source Location		Unsat	
Saturated Zone Dimension		Sat_3d	
Point or Depth Averaged		Point	
Aquifer Thickness		Finite	
Number of Sat Down Gradient Zones		One	
Unsaturated Zone Parameters			
Unsat Infiltration Rate used in Sat		Yes	
Unsat Infiltration Rate	ft/yr	1.55	
Infiltration Switching		Yes	
Time to Switch Infiltration	yr	2011	
Unsat Infiltration After Switch	ft/yr	0.0001	
Unsat Moisture Content	ft3/ft3	0.25	
Unsat Dispersion Coeff in Z	ft2/yr	8.99	Calc'd
Depth to water table	ft	14.5	
Unsat Retardation Coeff		1	
Dispersion Calculated		Yes	
Source Parameters			
Width of Source	ft	1440	
Source Length	ft	760	
Saturated Zone Properties			
Zone Length	ft	32.8084	
Dispersion along X	ft2/yr	510	
Dispersion along Y	ft2/yr	5.1	
Dispersion along Z	ft2/yr	5.1	
Distance for Dispersion	ft	250	
Dispersion calculated		Yes	
Aquifer Thickness	ft	24.3	
Seepage Velocity	ft/yr	20.4	Calc'd
Sat Volumetric Porosity	ft3/ft3	0.27	
Hydraulic Gradient	ft/ft	0.03	
Hydraulic Conductivity	ft/yr	183.9	
Horozontal Velocity calculated		Yes	
Source Penetration Depth	ft	24.3	Calc'd
Source Penetration Depth After Switch	ft	19.9	Calc'd
Mixing Depth Calculated		Yes	
Mixing Depth (2) Calculated		Yes	
Solute Plume Description			

Input Parameters

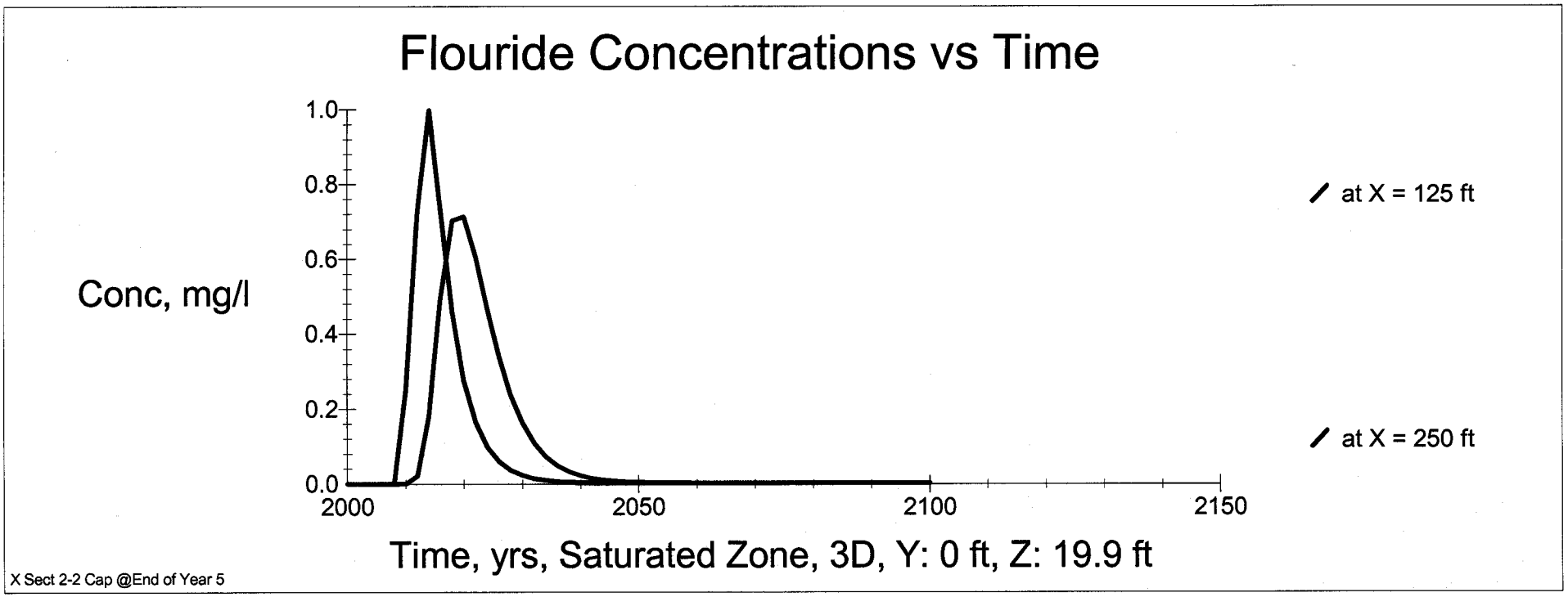
Description	Units	Value	Note
Background Concentration	mg/l	0	
Bulk Density	g/ml	1.6	
pH		7	
Rd (inorganic)		1	Calc'd
Partition Coeff, Kd	ml/g	0	
Rd calculated		Yes	
Distance to Top of Source	ft	0	
Distance to Bottom of Source	ft	16.4042	

Source Concentration



Source Concentration

	Time On, yrs	Conc, mg/l
1	2006.000	5.000
2	2007.000	5.000
3	2008.000	5.000
4	2009.000	5.000
5	2010.000	5.000
6	3000.000	0.000


Flouride Concentrations vs Time
Conc, mg/l
1.0
0.8
0.6
0.4
0.2
0.0
2000
2050
2100
2150
Time, yrs, Saturated Zone, 3D, Y: 0 ft, Z: 19.9 ft
at X = 125 ft
at X = 250 ft
X Sect 2-2 Cap @End of Year 5

Flouride Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
1	2000	0	0
2	2002	0	0
3	2004	0	0
4	2006	0	0
5	2008	.000568948	0
6	2010	0.252257	.000328136
7	2012	0.725991	0.0212806
8	2014	0.997736	0.181932
9	2016	0.728759	0.495001
10	2018	0.45651	0.702754
11	2020	0.274345	0.713297
12	2022	0.163401	0.606934
13	2024	0.097714	0.467872
14	2026	0.058951	0.339673
15	2028	0.0360739	0.237629
16	2030	0.0225095	0.162347
17	2032	0.01443	0.109334
18	2034	.00958675	0.0730275
19	2036	.00666859	0.048646
20	2038	.00490427	0.0325127
21	2040	.00383067	0.0219163
22	2042	.00317487	0.0150078
23	2044	.00277389	0.0105308
24	2046	.00252734	.00763827
25	2048	.00237525	.00577184
26	2050	.00228124	.00457015
27	2052	.00222313	.00379876
28	2054	.00218712	0.0033034
29	2056	.00216483	.00298579
30	2058	.00215104	.00278193
31	2060	.00214254	.00265132
32	2062	.00213725	.00256752
33	2064	0.0021342	.00251423
34	2066	.00213234	.00248008
35	2068	.00213128	.00245833
36	2070	.00213072	0.0024445
37	2072	.00213046	.00243576
38	2074	.00213039	0.0024303
39	2076	.00213044	.00242692
40	2078	.00213056	.00242488
41	2080	.00213071	.00242369
42	2082	.00213088	.00242304

X Sect 2-2 Cap @End of Year 5

Flouride Concentrations vs Time

	Time, yrs	Conc, mg/l at X = 125 ft	Conc, mg/l at X = 250 ft
43	2084	0.00213106	0.00242274
44	2086	0.00213125	0.00242265
45	2088	0.00213143	0.0024227
46	2090	0.00213161	0.00242283
47	2092	0.00213178	0.002423
48	2094	0.00213187	0.00242305
49	2096	0.00213211	0.00242342
50	2098	0.00213226	0.00242365
51	2100	0.00213241	0.00242387

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PROCUREMENT, CONSTRUCTION AND EH&S

Duke Power
EC11E / P.O. Box 1006
Charlotte, NC 28201-1006

November 17, 2004

North Carolina Department of Environment
and Natural Resources
Division of Waste Management
Solid Waste Section
401 Oberlin Road, Suite 150
Raleigh, NC 27605-1350

ATTENTION: Ms. Ellen Lorscheider
Hydrogeologist
Solid Waste Permitting Branch

SUBJECT: Marshall Steam Station
FGD Industrial Landfill
Construction Plan Application

After review of your September 20, 2004 letter, we have hopefully included a response to the concerns you have cited. These concerns are cross referenced with the number sequence used in your letter. For each concern expressed, a Duke Power response is given below.

Construction Plan Application

1.0 Phase 1 is cited as 33 acres. The Site Suitability document only referenced 20.64 acres.

The Phase 1 footprint is 33 acres. An addendum to applicable portions of the Site Suitability document is included under separate cover.report have been revised to reflect the 33 acre landfill footprint for Phase 1. These revised portions are found in the Site Suitability Report, Addendum 1, dated November 12, 2004.

2.2 "Closure of cells will commence once final elevations are reached." This statement is contrary to the 5-year cap being placed regardless of the quantity of FGD material disposed of.

The closure of the landfill will commence following the 5-year permit period. An addendum to Section 2.2 is attached.

2.3 8" soil/10 feet. Compaction level and lift depth of FGD is not included. S&ME document cites that FGD will "typically" be compacted to 95%. Compaction as indicated in the modeling should also be reflected in the construction and operation plans.

The intermediate soil layer will be compacted to 92 percent of standard Proctor maximum dry density. The modeling has been revised to reflect the compaction criteria.

3.0 "The FGD gypsum landfill at Marshall will receive FGD residue generated at Marshall and potentially from other Duke Power plants located within North Carolina." This is contrary to the zoning letter from Catawba County.

The Catawba County Planning Department has approved a Duke Power request to receive FGD residue generated by other Duke Power facilities at Marshall Steam Station. Please refer to the attached letter.

5.4 The intermittent stream and wetland area of 0.56 acres that are located within the landfill footprint area for Cell 2 may need to be further evaluated. Is it possible to break this out into another phase? Further evaluation of the hydrogeology may be necessary after stream is relocated and wetland mitigation is complete.

The wetland area within the Cell 2 footprint is currently being permitted to be filled. The groundwater observation wells within the Cell 2 footprint will remain during operation of Cell 1 so that additional groundwater level data can be obtained prior to construction of Cell 2.

<u>Landfill Operations and Maintenance</u>

1.5 Areas not filled for 12 months or more shall be seeded with temporary seeding. Long period of infiltration with no evapotranspiration.

Temporary seeding of the FGD residue will not be done during operations. An addendum to Section 1.5 is attached. The HELP analyses used a LAI (Leaf Area Index) equal to zero for the upper layer in the model (this is the intermediate soil cover layer). This LAI is associated with bare ground and would provide no transpiration. Evaporation would still occur with the actual rate dependent on soil and evaporative conditions. These conditions are modeled in HELP.

1.6 "will allow the facility to accept...FGD residue that is removed from settling or clarifer stages of the associated waste treatment facility." What are the specific waste characteristics of this material? In particular the increased surface area of this waste due to it being a finer material than the FGD residue may cause the leaching of contaminants to be increased. The moisture level of the material may be greater than the FGD residue. Comment

FGD residue from utilities that utilize analogous scrubber technology and coal types was analyzed and characterized. Once the Marshall scrubber is operational, Duke Power will fully analyze the FGD residue.

2.1 Compaction levels are only indicated for the berms. Subgrades of landfills, even if insitu, are usually disked and recompacted to eliminate conduits for contamination to enter the groundwater. Subgrade preparation is not addressed. It looks from the cross sections that Silty Sand (SM) material will make up the (4 foot sepration to groundwater) subgrade material of the landfill. SM materials are not desirable materials for unlined landfills.

Compaction criteria for the FGD residue and intermediate cover has been added to the attached addendum to Sections 1.3 and 1.5.

Sign posted shall read "No Hazardous or Liquid Waste Permitted" it would be pertinent to limit the waste on this sign to FGD residue etc.

The sign information has been revised per the attached addendum .

Compliance Demonstration

5.1.1 The SPLP was run on FGD residue typical of the material produced by the scrubber system. The FGD residue material that does not meet specifications (CaSO4 is generally >94% for use in wallboard) for the end use (probably wallboard) will be lower in the amount of gypsum, higher in the contaminant.

The material from the clarifier stage will be placed in the landfill. This material will be "the same composition as the FGD residue, but will consist of smaller particles." Due to the increased surface area would this not increase potential leachate from this material?

Once the wastewater treatment system becomes operational, samples of the clarifier stage material will be collected. The physical, chemical, and leaching characteristics of these samples will be determined and presented to NCDENR.

FGD residue from utilities that utilize analogous scrubber technology and coal types was analyzed and characterized. Once the Marshall scrubber is operational, Duke Power will fully analyze the FGD residue.

8.4 Two cases were modeled with HELP. Operational at 40 feet filled, and Closed with 80.5 feet of waste in the landfill. More runs of HELP are needed. At a minimum yearly runs are needed. Also runs of HELP are needed for smaller fill areas. For example what if only one lift of 10 feet was needed in a year due to reuse of material. A worst case scenario, generated by HELP, needs to be used in MYGRT. This may require a number of HELP runs evaluating various scenarios.

The comments appeared to be addressed to two areas; comments concerning the quantity of leachate and comments concerning the concentration of constituents in leachate. The responses are addressed to these two areas.

Quantity of Infiltration (Leachate)
Two periods were modeled with HELP. These periods are:

- *Operational Period – models the infiltration that occurs during the period of gypsum placement.*
- *Closed Period – models the infiltration that occurs after placement of the engineered cover.*

The landfill was modeled during the operational period (the 5 year period of gypsum placement) to determine the quantity of infiltration that would pass through the gypsum, becoming leachate. The properties described in the Compliance Demonstration Addendum, Section 8.3, were used, along with a 100 year period of simulated weather conditions to determine the amount of infiltration that would occur.

Since the thickness of the gypsum will increase during the operational period. Separate HELP runs were made to at the thicknesses listed below to evaluate the infiltration at different thicknesses of material. As described in the Construction Plan Application, after 10 feet of gypsum are placed, an 8" layer of site soil will be placed. The HELP runs for the Operational Period include an 8" layer of site soil placed over each 10' layer of gypsum. The thicknesses listed below are nominal thicknesses representing only the thickness of the gypsum layer. A nominal elevation of 740' was selected as the base grade for the landfill. Conservative assumptions were used to characterize conditions and properties of site soils and FGD residue.

The infiltration values calculated by HELP using these conservative conditions and properties should envelope worst case conditions for infiltration.

HELP Run Thickness	*Upper Elevation*	*HELP Calculated Infiltration During Operational Period (in/yr)*
10 feet	*750 feet*	*18.64*
20 feet	*760 feet*	*18.64*
40 feet	*780 feet*	*18.53*
60 feet	*800 feet*	*18.36*

The HELP model removes surface water run-off from further calculations for evapotranspiration and infiltration. In these analyses the entire landfill was considered to have a runoff characteristics based on a 2% slope, with soils having site properties for wilting point and field capacity, and having a good grass cover. These characteristics reduce run-off, increasing the

water available for infiltration. The value for LAI was chosen to be zero (0) for the entire landfill, reducing evapotranspiration. As the landfill height reaches and goes above the surrounding grade, the outer side slopes will receive grassing (increasing evapotranspiration) and will be sloped at the final side slope grade around 12%). These actual conditions will produce more run-off than the modeled conditions and therefore will generate less infiltration. Regular inspections and good surface water control practices will prevent the concerns noted about preferential pathways of flow developing.

Concentration of Constituents in Leachate
Refer to the Figure on page 3 of 5 with pathways labeled as "A" and "B." There would be no significant difference in the concentrations of leachate at either point. The concentrations of the constituents in the infiltration are controlled more by solubility, and conditions expressed by eH and pH, than by the thickness or available mass of material.

If any difference were to be found, it likely would be that lower constituent concentrations would be found under the thinner material (pathway "B") since the infiltration might pass through the thinner material (depending on the thermodynamics of the reactions) before the reactions could occur.

8.4.2 The assumed number of holes in the LDPE cover used by HELP should be 8 per acre instead of 5.

The number of holes in the HELP analysis for the LDPE cover was increased to 8 per acre.

8.5 Properties for the Gypsum Layer from the S&ME FGD Scrubber Sludge Testing (Revision 1).

Total Porosity – value used is for 8 ksf loading at 92% compaction. This indicates moderately compacted FGD with close to optimum moisture. The field conditions of no compaction and 11.8% moisture should be used to determine porosity at least in the upper portion of a HELP run.

The value for porosity for the FGD material in the HELP analyses was changed to the porosity for 90% maximum dry density. The value for the porosity of the FGD residue used in the HELP analyses is 0.47.

Additional SPLP testing needs to be performed on FGD residue from the pilot plant.

Additional testing of the FGD residue will be performed once the Marshall scrubber is operational.

The material generated by the FGD system to be installed at Marshall will be washed with water to remove chlorides. In addition to the reduction of chlorides, we anticipate that the concentrations of other constituents will be reduced by removal or exchange of water from the pore spaces. The material generated by the pilot scrubber plant was not washed, so we do not believe that it represents the material that the actual FGD system will generate. Therefore, we

do not plan on using this material in an evaluation of the material to be produced by the actual FGD system at Marshall.

8.5 Properties for Soil layer Beneath the Landfill

Cover material: An evaluation of the type of material used as cover is necessary. Because of the large quantity of sand that will be cut from the footprint of landfill, stockpiled and presumably used for cover, the 8 inches of cover per 10 feet may increase the infiltration during operation.

As described in the Compliance Demonstration Report – Addendum 1, the HELP model runs for the operational conditions model an 8" thick layer of soil placed after placement of 10 feet of gypsum. The properties used for these soil layers were determined by reviewing the soil boring information and by considering the range of soils that could be used. Section 8.0 of the Compliance Demonstration Report – Addendum 1 presents these values and the results of the HELP runs.

Appendix B

USGS Seismic Maps showing Peak Acceleration were updated in 2002. Map, if required, should be updated.

The USGS Seismic Maps referred to are contained in Appendix B of a document (S&ME Project 12264-03-057 - February 2004) prepared by S&ME on properties of FGD Scrubber Sludge testing. This document was included in the Compliance Demonstration Report since selected geotehcnical properties of FDG residue were used in the modeling.

As described on page 8 of this S&ME report, the stability analyses performed were on various conceptual designs for FGD residue landfills with final slopes (2:1, 3:1, 4:1) and a fill height (100 ft) selected to illustrate stability of slopes only at the conceptual level. Because these maps were used in analyses at the conceptual level, there is no need to update these maps.

Other HELP questions

It is necessary that the porosity and hydraulic conductivity which is used in HELP is the same as would occur during actual operation. For example a figure of 0.41 is currently used but if the material is compacted to only 90% this may produce a porosity of 0.47. It is our understanding that a new proctor test will be performed, which should stimulate operating conditions.

A second proctor test was performed on the gypsum material to verify that 90% maximum dry density could be achieved at 12% moisture conditions. This additional testing found that 90% maximum dry density could be achieved at 12% moisture conditions. The value for porosity of the FGD material in the HELP analyses was changed to the porosity for 90% maximum dry density. The value for porosity used in the HELP analyses is 0.47. A copy results of this proctor test is included.

Other MYGRT questions:
Are the Input values – Width of Source and Source Length, reversed in all analyses?

The values input for Width of Source and Source Length are correct as presented in the analyses. As the MYGRT manual states (page 7-10), the Source Length is the length of the source parallel to the direction of flow. The Width of Source is the width of the source perpendicular to the groundwater flow.

There are two cross sections used in the MYGRT analyses to represent the conditions at the landfill. These two cross sections represent the two major groundwater drainage areas. The dimensions used for width and length for both of these areas are larger than the actual dimensions for these two areas. This results in MYGRT providing constituent loading over a larger area than will actually occur.

Is the Input – Dispersion along the Y supposed to be 19.6 in the Sulfate analysis?

The definitions and methods for calculating the coefficients for dispersion in the saturated material are found on page 7-17 and 7-18 of the MYGRT manual. The user enters a value for the Scale Distance for Dispersion. This is normally taken to be the furthest down gradient distance of interest. In this case a distance of 250', was used. The values for horizontal, transverse, and vertical dispersion were calculated by the program using the horizontal seepage velocity and the factors presented in the definitions found on page 7-18 of the MYGRT manual.

Please include the soil type on the cross sections used for MYGRT.

The cross sections used for the MYGRT analyses are the same as two of the cross sections provided in the Hydrogeological report report. The soil boring information is provided on the cross sections in the Hydrogeological report. Please refer to the cross sections on the hydro-geological report.

An additional run of MYGRT analyzing a worst case scenario (0.018 mg/l) of Arsenic is needed.

As described in the Compliance Demonstration Report and the Addendum to the Compliance Demonstration Report, arsenic did not leach at concentrations greater than the 2L standard in the initial SPLP leaches. As described in Section 9.1 of the Addendum to the Compliance Demonstration Report, the period of time associated with these initial leaches is longer than the period of time that the landfill will be operational and exposed to infiltration. However, to address the issue, additional MYGRT analyses were performed for arsenic at a concentration of 0.018 mg/l.

Other questions:
The coal ash landfill at Belews showed that water tended to wick up in the waste. In the absence of a liner or a capillary break, how do we know a similar situation is not to occur here. The FHA recommends 5 feet separation of flyash structural fills from groundwater and a capillary break. Water has been proven to move up in the ash. FGD material because of its particle size and porosity would be expected to act similarly.

An investigation of the water levels near well OB-1 is being performed at the Belews Creek ash landfill. This investigation consists of field work installing piezometers, performing filed permeability's, and lab work. The field work is complete and the lab work will be completed in 1-2 weeks. The preliminary findings are that the water observed in the ash near and around well OB-1 is from a perched condition, where a clay-rich layer of soil exists under a portion of the landfill. Duke will submit a report on this matter at some future date. No evidence of capillary action causing water to be present in the ash was observed.

Please contact me at (704) 382-4309 if additional information is needed to ensure that a Permit to Construct is issued by December 15, 2004.

Sincerely,

Allen Stowe

Allen Stowe, Scientist
Environmental Support

Attachments

Allen Stowe/ncdenr112004final

bc wo attachments: R.E. Baker
D. L. Burrell
T.D. Ervine
W.M. Miller
M.A. Ruhe
D. T. Shuping

File Number: 403.080.01 (Marshall Steam Station – NC)
UPS

NCDENR

North Carolina Department of Environment and Natural Resources

Dexter R. Matthews, Director | Division of Waste Management | Michael F. Easley, Governor
William G. Ross Jr., Secretary

September 20, 2004

RECEIVED
SEP 29 2004
EH & S

Mr. Allen Stowe
Duke Power
EC11E / 526 South Church Street
Charlotte, NC 28202-1802

Subject: Review Application for Permit to Construct
Duke Energy Marshall Steam Station FGD Residue Landfill
Catawba County, North Carolina

Dear Mr. Stowe,

I have reviewed the Site Study for the proposed landfill in Catawba County. The materials, which were reviewed for this letter, include the Compliance Demonstation Report dated March 31, 2004 and received April 6, 2004, and the Construction Plan Application for Phase 1 dated March 2004 and received April 2, 2004. This review is according to and is referenced to the *15A NCAC 13B Solid Waste Management Rules* Section .0503 and .0504. I have the following comments regarding the application.

Construction Plan Application

1.0 Phase 1 is cited as being 33 acres. The Site Suitability document only evaluated 20.64 acres.

2.2 "Closure of cells will commence once final elevations are reached". This statement is contrary to the 5-year cap being placed regardless of the quantity of FGD material disposed of.

2.3 8" soil / 10 feet. Compaction level and lift depth of FGD is not included. S&ME document cites that FGD will "typically" be compacted to 95% (page 5). Compaction as indicated in the modeling should also be reflected in the construction and operation plans.

3.3 "The FGD gypsum landfill at Marshall will receive FGD residue generated at Marshall and potentially from other Duke Power plants located within North Carolina." This is contrary to the zoning letter from Catawba County.

5.4 The intermittent stream and wetland area of .56 acres that are located within the landfill footprint area for Cell 2 may need to be further evaluated. Is it possible to break this out into another Phase? Further evaluation of the hydrogeology may be necessary after stream is relocated and wetland mitigation is complete.

Landfill Operations and Maintenance

1.5 Areas not filled for 12 months or more shall be seeded with temporary seeding. Long period of infiltration with no evapotranspiration.

1.6 " will allow the facility to accept....FGD residue that is removed from settling or clarifier stages of the associated waste treatment facility." What are the specific waste characteristics of this material? In particular the increased surface area of this waste due to it being a finer material than the FGD residue may cause the leaching of contaminants to be increased. The moisture level of the material may be greater than FGD residue. Comment

2.1 Compaction levels are only indicated for the berms. Subgrades of landfills, even if insitu, are usually disked and recompacted to eliminate conduits for contamination to enter the groundwater. Subgrade preparation is not addressed. It looks from the cross sections that Silty Sand (SM) material will make up the (4 foot separation to groundwater) subgrade material of the landfill. SM materials are not desirable materials for unlined landfills.

2.1 Sign posted shall read "No Hazardous or Liquid Waste Permitted" it would be pertinent to limit the waste on this sign to FGD residue etc.

Compliance Demonstration

5.1.1 The SPLP was run on FGD residue typical of the material produced by the scrubber system. The FGD residue material that does not meet the specifications ($CaSO4$ is generally $>94\%$ for use in wallboard) for the end use (probably wallboard) will be lower in the amount of gypsum, higher in the contaminant.

5.1.1 The material from the clarifier stage will be placed in the landfill. This material will be " the same composition as the FGD residue, but will consist of smaller particles". Due to increased surface area would this not increase potential leachate from this material?

8.4 Two cases were modeled with HELP. *Operational* at 40 feet filled, and *Closed* with 80.5 feet of waste in the landfill. More runs of HELP are needed. At a minimum yearly runs are needed. Also runs of HELP are needed for smaller fill areas. For example what if only one lift of 10 feet was needed in a year due to reuse of material. A worst case

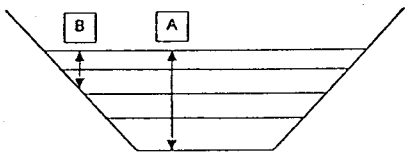
scenario, generated by HELP, needs to be used in MYGRT. This may require a number of HELP runs evaluating various scenarios.

The following is taken from a memo from Geof Little, SWS engineer, and is in relation to Belews Proposed coal ash landfill. The scenario is identical to Marshall:

"The thickness of ash used in HELP modeling, as summarized in Table 18 and restated below.

Year of Operation	Thickness of Ash (ft)	Predicted Infitration (in/year)
1	11.6	7.15
2	23.1	7.15
3	34.7	7.15
4	46.2	7.15
5	57.8	7.15

The HELP model idealizes infiltration at the point identified by Label A in the schematic below and assumes a rectangular shaped facility. For facilities with a barrier liner system, this approach is not an issue since (i) a barrier system exists to minimize infiltration into the underlying soils, and (ii) the regulations establish a maximum head of leachate above the liner.



In the case of the above facility, we have concerns about the quantity and quality of leachate that passes through the waste material through the idealized pathway labeled B in the schematic above.

Of further concern is during initial operations when the waste material is substantially less than the thicknesses analyzed. The potential for loading contaminants into the underlying soil would be greatest during the initial year of operation due to the comparatively thin veneer of the leading edge of the waste mass over unlined soil. The potential for contamination would be greatly aggravated by higher than average rainfall during the initial phases of operation.

The HELP model predicts 7.15 inches of infiltration each year across the surface of the facility, including the surface area above the side slopes. Depending on the grade, the quantity of infiltration above the side slopes would be considerable, particularly at the edges of the waste mass.

Another area of concern is the potential for preferential pathways to develop at the interface of the waste mass and the in-situ soils beneath the waste mass along the side slopes. The presence of erosion rills, desiccation, cobbles and tire ruts from operating equipment at the site either singularly or together, would allow or create direct pathways to groundwater."

8.4.2 The assumed number of holes in the LDPE cover used by HELP should be 8 per acre instead of 5.

8.5 Properties for the Gypsum Layer from the S&ME *FGD Scrubber Sludge Testing (Revision 1)*

Total Porosity – value used is for 8ksf loading at 92% compaction. This indicates moderately compacted FGD with close to optimum moisture. The field conditions of no compaction and 11.8% moisture should be used to determine porosity at least in the upper portion of a HELP run

Additional SPLP testing needs to be performed on FGD residue from the pilot plant.

8.5 Properties for Soil Layer Beneath the Landfill

Cover material: An evaluation of the type of material used as cover is necessary. Because of the large quantity of sand that will be cut from the footprint of landfill, stockpiled and presumably used for cover, the 8 inches of cover per 10 feet may increase the infiltration during operation.

Appendix B
USGS Seismic Maps showing Peak Acceleration were updated in 2002. Map, if required, should be updated.

Other HELP questions:

It is necessary that the porosity and hydraulic conductivity which is used in HELP is the same as would occur during actual operation. For example a figure of 0.41 is currently used but if the material is compacted to only 90% this may produce a porosity of 0.47. It is our understanding that a new proctor test will be performed, which should simulate operating conditions.

Other MYGRT questions:

Are the Input values – *Width of Source* and *Source Length*, reversed in all analyses?

Is the Input – *Dispersion along Y* supposed to be 19.6 in the Sulfate analysis?

Please include the soil type on the cross sections used for MYGRT.

An additional run of MYGRT analyzing a worst case scenario (0.018 mg/l) of Arsenic is needed.

Other questions:

The coal ash landfill at Belews showed that water tended to wick up in the waste. In the absence of a liner or a capillary break, how do we know a similar situation is not to occur here. The FHA recommends 5 feet separation of flyash structural fills from groundwater and a capillary break. Water has been proven to move up in the ash. FGD material because of its particle size and porosity would be expected to act similarly.

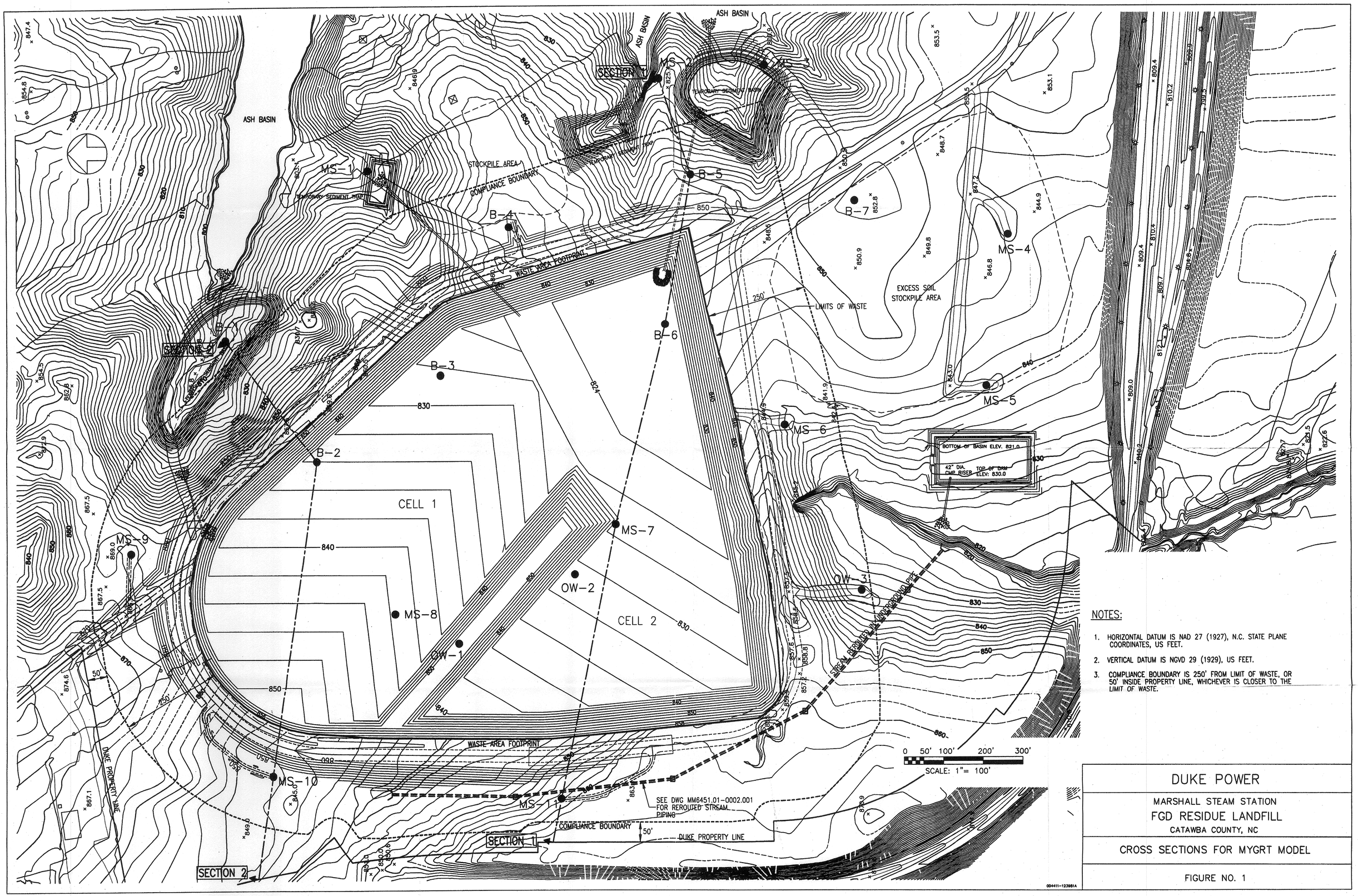
Please contact me regarding questions or to schedule a meeting to discuss this letter. I can be contacted at 919-733-0692 extension 345, or by email at Ellen.Lorscheider@ncmail.net

Sincerely,

Ellen Lorscheider

Ellen Lorscheider
Hydrogeologist
Solid Waste Section

Cc: Bill Miller, Duke Energy
Dan Brewer, Chas. H. Sells, Inc.
John Murray, SWS
Jim Barber, SWS
Teresa Bradford, SWS



NOTES:

1. HORIZONTAL DATUM IS NAD 27 (1927), N.C. STATE PLANE COORDINATES, US FEET.
2. VERTICAL DATUM IS NGVD 29 (1929), US FEET.
3. COMPLIANCE BOUNDARY IS 250' FROM LIMIT OF WASTE, OR 50' INSIDE PROPERTY LINE, WHICHEVER IS CLOSER TO THE LIMIT OF WASTE.

DUKE POWER

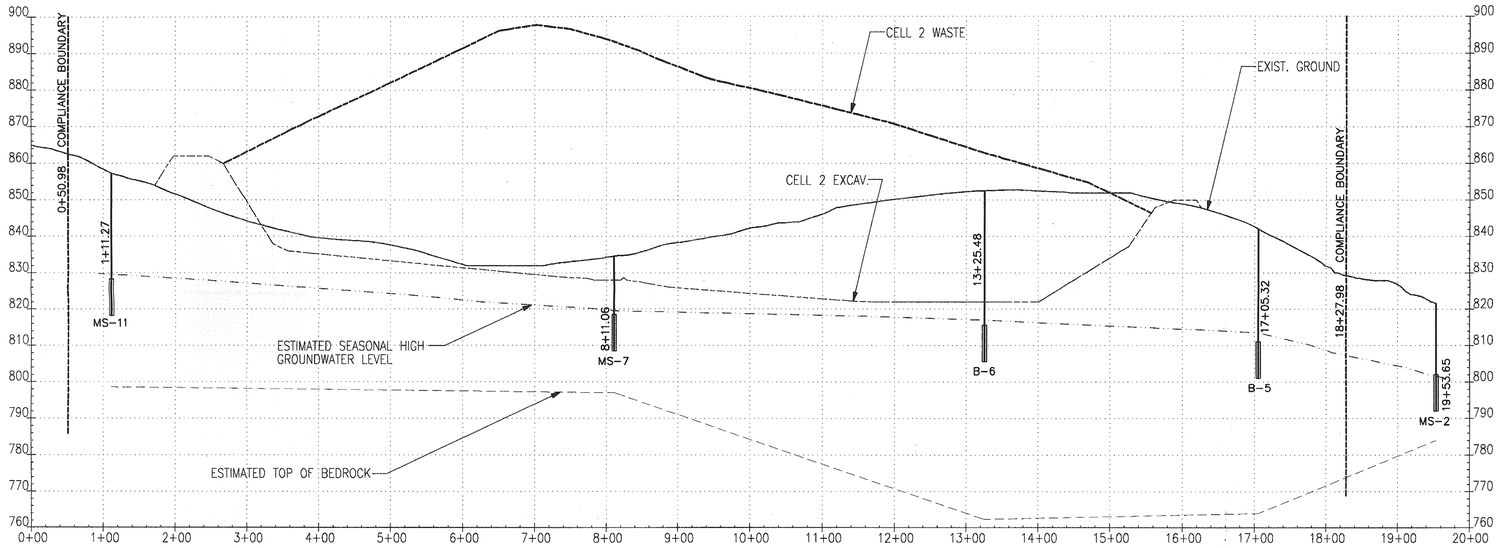
MARSHALL STEAM STATION

FGD RESIDUE LANDFILL

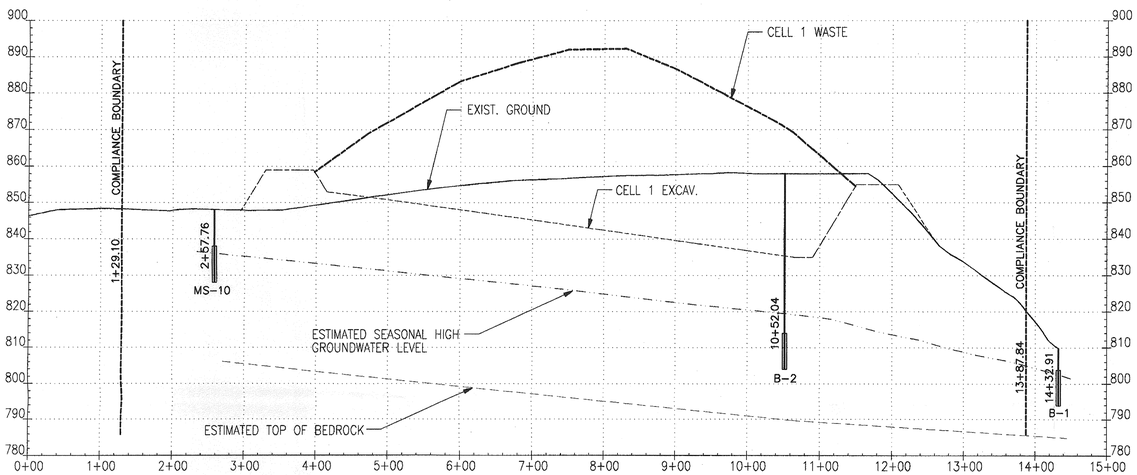
CATAWBA COUNTY, NC

CROSS SECTIONS FOR MYGRT MODEL

FIGURE NO. 1



SECTION 1-1



SECTION 2-2

VERTICAL
0 10' 20' 40' 60'
SCALE: 1"= 20'

HORIZONTAL
0 50' 100' 200' 300'
SCALE: 1"= 100'

NOTES:

1. HORIZONTAL DATUM IS NAD 27 (1927), N.C. STATE PLANE COORDINATES, US FEET.
2. VERTICAL DATUM IS NGVD 29 (1929), US FEET.
3. ESTIMATED SEASONAL HIGH GROUNDWATER LEVEL AND TOP OF BEDROCK FROM REFERENCE 4.
4. REVISION 1 CORRECTED ESTIMATED SEASONAL GROUNDWATER PROFILE |

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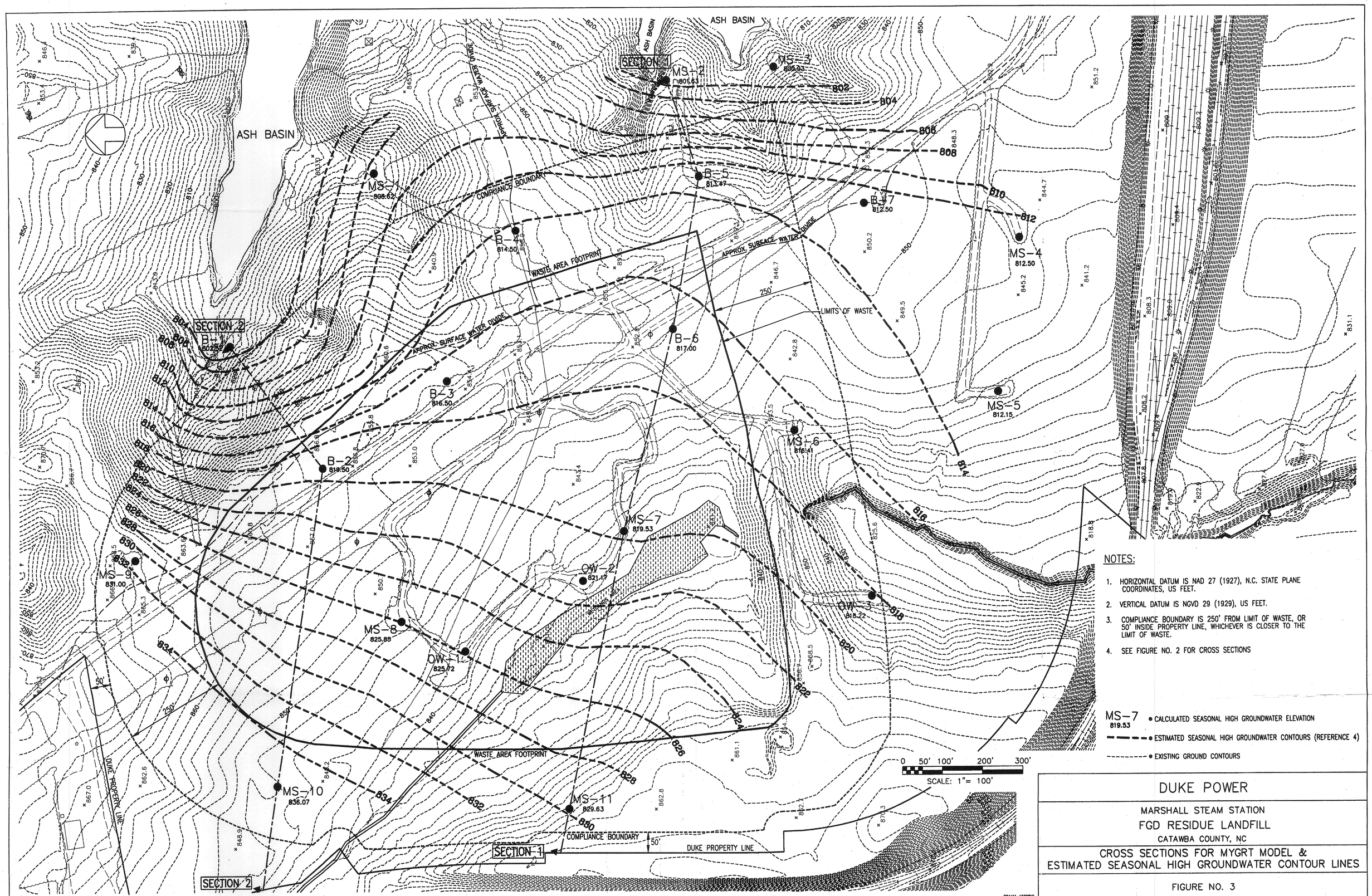
CATAWBA COUNTY, NC

CROSS SECTIONS FOR MYGRT MODEL

FIGURE NO. 2 (REVISION NO. 1)

004411-123981B



NOTES:

1. HORIZONTAL DATUM IS NAD 27 (1927), N.C. STATE PLANE COORDINATES, US FEET.
2. VERTICAL DATUM IS NGVD 29 (1929), US FEET.
3. COMPLIANCE BOUNDARY IS 250' FROM LIMIT OF WASTE, OR 50' INSIDE PROPERTY LINE, WHICHEVER IS CLOSER TO THE LIMIT OF WASTE.
4. SEE FIGURE NO. 2 FOR CROSS SECTIONS

MS-7 819.53 • CALCULATED SEASONAL HIGH GROUNDWATER ELEVATION

• ESTIMATED SEASONAL HIGH GROUNDWATER CONTOURS (REFERENCE 4)

• EXISTING GROUND CONTOURS

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CROSS SECTIONS FOR MYGRT MODEL & ESTIMATED SEASONAL HIGH GROUNDWATER CONTOUR LINES

FIGURE NO. 3