Investigation of Potential Groundwater Intrusion into the Plainville Landfill

by

Emily Chen

S.B., Environmental Engineering Science
Massachusetts Institute of Technology, 1998

Submitted to the Department of Civil and Environmental Engineering
In Partial Fulfillment of the Requirement for the Degree of

MASTER OF ENGINEERING
In Civil and Environmental Engineering
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Abstract

The Plainville landfill, located in Plainville, Massachusetts, has been the subject of study for several groups in recent years. A contaminant plume is exiting the landfill, which may pollute drinking water wells located downgradient of the site. It is hypothesized that groundwater intrusion into the landfill may be hastening the production of the contaminated leachate that is leaking into the subsurface. This study addresses this possibility and investigates a solution to this problem.

Two methods used to ascertain whether groundwater intrusion into the landfill is occurring were to compare the landfill liner levels with the groundwater table elevation and to utilize a landfill water balance model. Both methods require knowledge of the construction of the landfill. The first method also used water level data from observation wells surrounding the landfill. The monthly amount of leachate collected over the years and precipitation data were used in the second method. The Hydrologic Evaluation for Landfill Performance (HELP) model predicted amounts of leachate expected for 1993 through 1998 and for five years after closure. These results were compared to actual leachate collection data for the site. This comparision demonstrated that about twice as much leachate is being collected than is predicted by the HELP model.

If groundwater is indeed entering the landfill, one method – as suggested by Prof. Patricia Culligan and Prof. Charles Harvey - to mitigate the plume formation is to decrease the amount of leachate produced by pumping upgradient of the landfill to lower the groundwater table. The feasibility of adopting this strategy was tested using a groundwater model of the area, developed with MODFLOW. Output from the groundwater model demonstrates that this solution is unrealistic; the pumping rates would be too high and the surrounding area would become dry.

Because few construction data were available, the results of this study may not be accurate. However, both methods strongly support the possibility of groundwater intrusion. In addition, pumping upgradient of the landfill was not shown to be a feasible solution. However, further study needs be done to fully support this theory.

Thesis Supervisor: Professor Patricia Culligan
Title: Professor of Civil and Environmental Engineering

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TABLE OF CONTENTS

FIGURES

TABLES

1. INTRODUCTION

Landfills have been a mainstay of American society throughout history. Municipal, industrial and sometimes hazardous wastes have, and continue to be, disposed of in such facilities. Only during the last twenty years have Americans begun to realize that while landfills consolidate and remove waste from the public view, they may also be a source of hidden danger to the surrounding water and air supplies. Landfills throughout the country have been leaking contaminants into their surrounding water and air. The United States Environmental Protection Agency (EPA)estimates that of 55,000 landfills, approximately 75% are polluting the groundwater (Westlake, 1995).

One such landfill is the Plainville landfill, the largest in the state of Massachusetts. The relationship between the landfill and the local groundwater table is the focus of this study.

1.1 DESCRIPTION

The Plainville landfill is located approximately seventy miles southwest of Boston, Massachusetts in the town of Plainville (Figure 1-1). The Plainville landfill covers close to one hundred thirty-nine acres in Plainville, forty acres in Wrentham and one acre in Foxborough. The actual landfill footprint occupies about ninety-two acres in Plainville. The remaining acreage consists of support buildings, sedimentation ponds, and an old quarry (Figure 1-2).

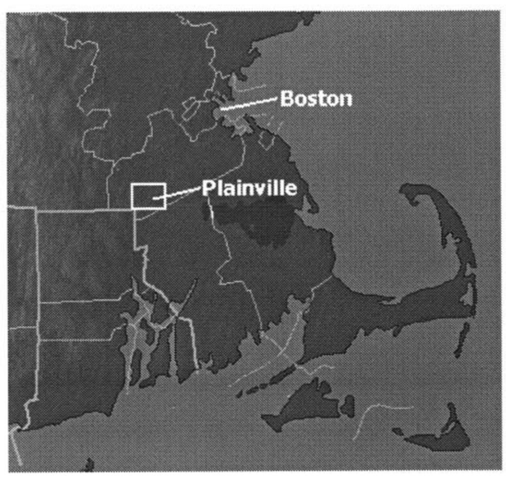

FIGURE 1-1: PLAINVILLE, MASSACHUSETTS

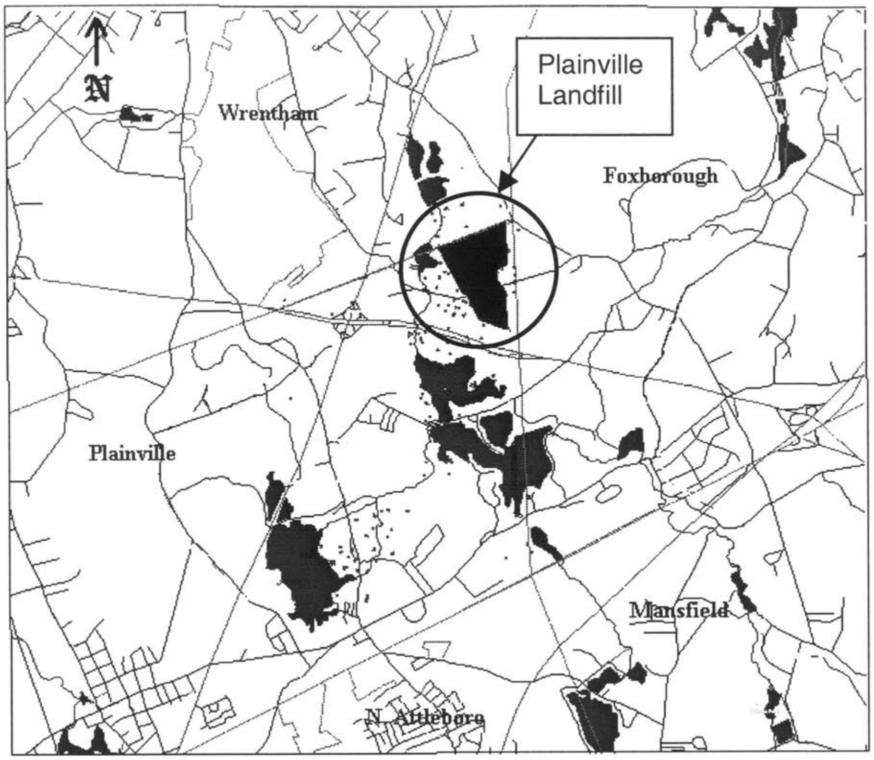

FIGURE 1-2: SITE LOCATION

It is hypothesized that groundwater intrusion into the landfill may be increasing leachate production, and consequently the amount of leachate contaminating the groundwater. Detected by quarterly testing of local monitoring wells, the contamination plume starts at the southwest corner of the landfill and extends downgradient, in a southwesterly direction (Figure 1-3). One reason why controlling the leachate is important is because the plume is heading towards public drinking water wells.

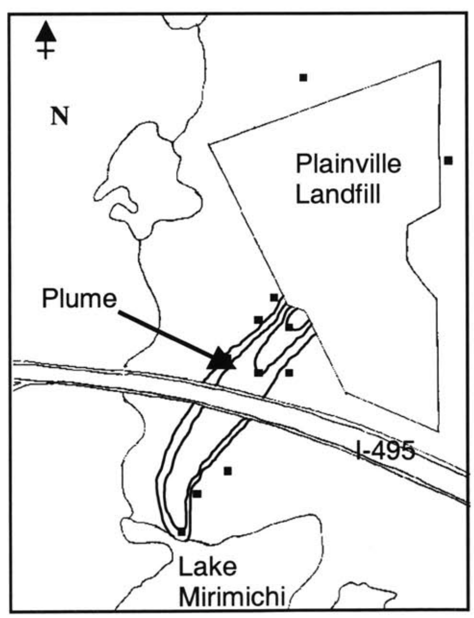

FIGURE 1-3: PLUME DIRECTION

This study investigates the possibility of groundwater intrusion into the landfill by utilizing two methods to determine how likely this theory is. In addition to this investigation, the study also tests and suggests appropriate measures to fix this problem in order to reduce the potential size of the contamination plume.

1.2 Methodology

A three stage approach was used for this study. First, the feasibility of the groundwater intrusion hypothesis was evaluated by comparing the liner elevation with water levels in observation wells surrounding the landfill. Next the predicted leachate production levels, computed using the HELP software package, were compared with those actually measured in the field. Finally, in order to investigate means to mitigate potential intrusion, and subsequently lessen the volume of the contamination plume, a groundwater model of the area created in MODFLOW was used to test different strategies for lowering the groundwater table.

1.3 Outline

The following chapters present the background information and the results of this study. In Chapter 2, general background information on landfills is provided. Chapter 3 describes background information on the Plainville landfill pertinent to this study. Chapter 4 focuses on the elevation of the landfill liner in relation to the local groundwater table. The use of, and results from, the HELP software package are presented in Chapter 5. Chapter 6 focuses on the feasibility of lowering the groundwater table upgradient of the landfill in order to prevent groundwater intrusion into the landfill. Finally, Chapter 7 summarizes conclusions and recommendations from this study.

2. BACKGROUND ON LANDFILLS

Landfills are specifically designed to hold certain types of waste. There are three types of landfills – namely, "dilute and attenuate," "containment," and "entombment". This chapter focuses on municipal solid waste containment landfills because this type describes the Plainville landfill.

2.1 WASTES

Municipal solid waste is generated by single family and multiple family households. It embodies food waste, yard waste, glass, metals, and others. The average percent composition of municipal refuse is shown in Table 2-1.

TABLE 2-1: AVERAGE PERCENT COMPOSITION OF MUNICIPAL REFUSE

Waste	% By Weight
Paper	40.0
Yard	17.6
Metal	8.5
Plastics	8.0
Food	7.4
Glass	7.0
Other	11.6

Source: Daniel, 1993

2.2 DESIGN

The objectives for the design of a landfill are:

- To contain waste to protect the environment and human health
- To minimize risk by at least using minimum technology
- To minimize leaks

In regard to the last point, no liner material known to mankind is forever impermeable to all chemicals (Daniel, 1993). Unless an inward hydraulic gradient exists, chemicals within a landfill will move via advection or diffusion through liner materials. Thus, for the third point, total prevention is not possible.

The objectives are upheld for landfill design by using an engineered lining system and cover system.

2.2.1 Liner Technology

Lining systems have two components – liners and drainage layers. Liners are designed to be low-permeability barriers that slow down liquid or gas flow. Drainage layers have a higher permeability and direct flow towards a collection point. The combination of a drainage layer and collection points is known as the leachate collection system (LCS).

Liner technology has improved over the past thirty years. Until the middle of this century, wastes were dumped openly on land and in water. In the 1940's, the concept of a sanitary landfill was developed that specified a disposal area and utilized daily cover, but still did not have a lining system to protect the local groundwater. Finally, in the 1970's, liner systems were implemented (Daniel, 1993). One of the first technologies that is still prevalent today is the compacted clay liner (CCL). This type of liner was used in the original cells of the Plainville landfill. As technology improved with time, the Plainville landfill expanded using geomembranes. Today, the Resource Conservation and Recovery Act (RCRA) requires that MSW landfills have the following liner configuration:

Drainage Layer	Height >= 0.3 m
Composite Liner	Geomembrane > 0.6 mm Compacted Clay Liner >= 0.6 m k <= 1 x 10^{-9} m/s

FIGURE 2-1: MSW LANDFILL REQUIREMENTS

2.2.1.1 Compacted Clay Liners

A typical system with a compacted clay liner is shown in Figure 2-2.

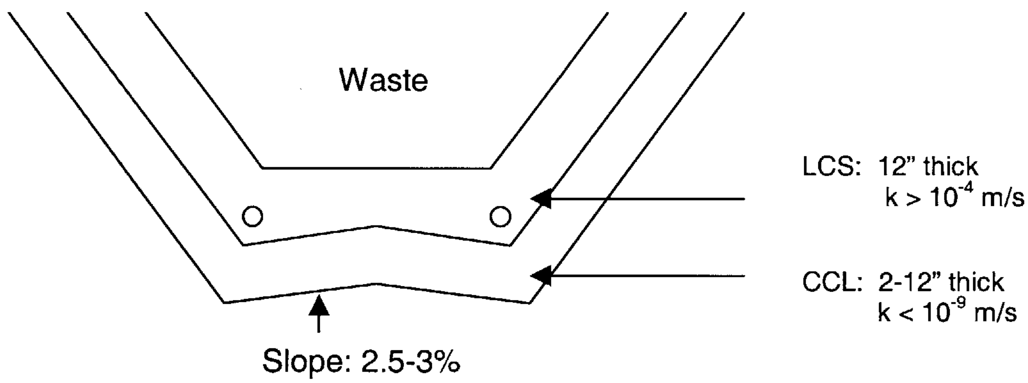

FIGURE 2-2: COMPACTED CLAY LINER SYSTEM

Construction of compacted clay liners occurs in six stages – processing, surface preparation, placement, compaction, protection, and quality control testing. In the first step, stones are removed, clumps of soil are broken down, and the material is wet or dried to achieve correct water content. During the next step of surface preparation, a stable base is created and each lift of soil liner is ensured to bond to neighboring lifts. Placement must maintain a 2% slope and the soil is prepared for compaction. Compaction is done with a number of passes of a roller. Compacted soil needs to be protected from freezing and drying out. Finally, quality control testing involves verifying materials and design (Culligan, 1999).

Among the disadvantages of using compacted clay liners are the difficulty of construction, susceptibility to chemical attack, and negative impacts from freezing and thawing. An alternative liner type that has been developed is the geomembrane (GM).

2.2.2.2 Geomembrane

Although geomembranes also have disadvantages - such as a high leakage rate if holes exist, difficulty in maintaining slope stability, and no sorptive capacity, geomembranes fill a very volume of the landfill, are flexible, and have a low permeability.

Care must be taken in choosing the type of geomembrane; common choices are butyl rubber, chlorinated polyethylene, chlorosulfonated polyethylene, ethylene-propylene rubber, high-density polyethylene, medium, low- and very low-density polyethylene, linear low-density polyethylene, and polyvinyl chloride (Bagchi, p. 162). The type of geomembrane should be chosen for its compatibility with the waste and its biological and thermal resistences.

Geomembranes must be installed carefully in order to be effective. Most important is the seaming of the sheets of synthetic membranes. Improper sealing of adjacent membranes would allow leachate to readily escape, no matter how low the permeability of the membrane material itself.

Combining a geomembrane with a compacted clay liner removes some of the disadvantages of both liner types. This is the type of system used in the later cells of the Plainville landfill. Figure 2-3 shows a typical combined system.

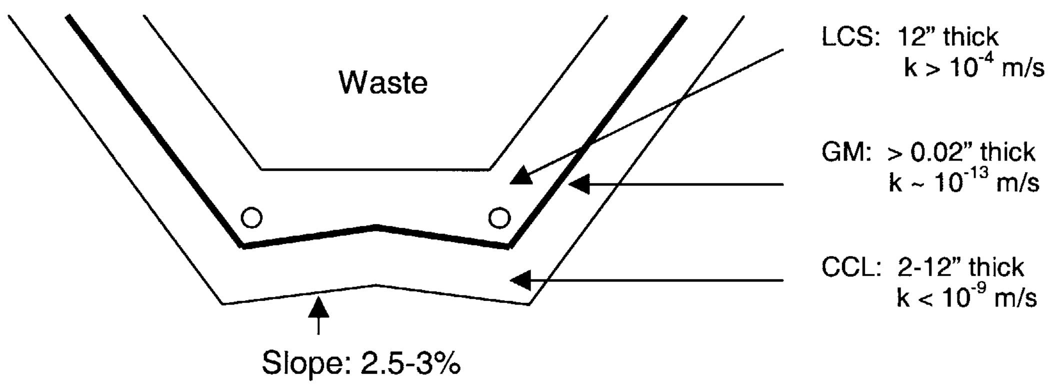

FIGURE 2-3: COMBINED GEOMEMBRANE AND CLAY LINER SYSTEM

2.2.2 Capping

The goals of landfill closure, according to the EPA, are to minimize the infiltration of water into the landfill and to maintain the integrity of the cover during the post-closure period by minimizing cover erosion (Westlake, 1995). Possessing a thirty year design life, cover systems usually have five components – surface, protection, drainage, barrier, and gas collection layers (Figure 2-4).

Surface Layer: 4-6" top soil
Protection Layer: 1-3.5 ft, silty-loam
Drainage Layer: sand/gravel, k >= 10^{-4} m/s, slope ~ 3%
Barrier Layer: 2 ft, k <= 10^{-9} m/s
Gas Collection Layer: sand/gravel/geotextiles

FIGURE 2-4: COMPONENTS OF COVER SYSTEM

The uppermost layer, the surface layer, has a number of functions. Typically, four to six inches deep, it promotes vegetative growth and evapotranspiration and thereby reduces surface erosion. The surface layer usually is made of top soil and may have some geosynthetic erosion control systems.

The underlying layer is the protection layer. It serves to store water for plant growth, protects the underlying layers from animals and plants, and prevents the barrier layer from drying out. Ranging from one to three-and-a-half feet deep, the layer is a silty-clay soil.

Next is the drainage layer. It functions to drain away the infiltrating water, dissipates seepage forces, and improves slope stability. Made of sand or gravel and possibly containing geotextiles, the layer typically has a hydraulic conductivity on the order of 10^{-4} m/s and a slope of around 3%.

Under the drainage layer is the barrier layer. The most critical part of the cover system, this layer minimizes infiltration to the underlying waste and reduces gas percolation. The minimum thickness is two feet and maximum hydraulic conductivity is 10^{-9} m/s. Although many options exist in terms of materials (i.e. geomembranes, geosynthetic clay liners, combinations), this study focuses on municipal solid waste landfills and subsequently, emphasis is on compacted clay liners and a combination of geomembrane with clay liner.

The final layer of the cover system is for gas collection. Made of sand, gravels, or thick geotextiles, this layer provides a stable base for the construction of the barrier layer and transmits gas to collection points (Culligan, 1999).

2.2 Leachate production

Leachate is defined as the soluble components of waste and soluble intermediates and the products of waste degradation which enter the water as it percolates through the waste (Westlake, 1995). It is produced in the following ways:

- Consolidation of fluid bearing waste
- Biodegradation of organic matter
- Leaching action and water movement through waste

The amount of leachate depends on water availability, landfill surface conditions, the state of the refuse, and the surrounding strata conditions. Water availability depends on precipitation, surface runoff, groundwater intrusion, irrigation, liquid waste disposal, and refuse decomposition. The surface conditions vary with vegetation, cover material, surface topography, and local weather. The maximum moisture content a soil can retain affects the refuse state. The surrounding strata depends on water levels (Westlake, 1995).

Leachate treatment can either be done on-site via recirculation or direct treatment, or off-site at a wastewater treatment plant via physical, chemical, and biological processes. The pre-closure generation can be described with the following:

$$L_v = P + S - E - FC$$

where: L_v = leachate volume
P = precipitation
S = pore-fluid "squeeze"
E = evaporation
FC = field capacity

After closure, the leachate generation can be described by:

$$L_v = P - R - ET - \Delta S$$

where: L_v = leachate volume
P = precipitation
R = runoff
ET = evapotranspiration
ΔS = change in soil moisture (Culligan, 1999)

The rate of leachate production depends on the rates of these variables. In addition, leachate percolation may be retarded by ion-exchange, precipitation and dissolution, generation of insoluble complexes, generation of colloids, flocculation and filtration (Westlake, 1995).

Water balance modeling is used to predict the amount of leachate produced at a landfill site. This method is good for designing liners, the leachate collection system, and the liner/cover slope. The two models most often used are Water Balance Modeling (WBM) and Hydrologic Evaluation of Landfill Performance (HELP). While the WBM can predict leachate generation rates, the HELP model accounts for more complex scenarios and subsequently, has become the "model of requirement". A description of this model can be found in Chapter 5, Section 1. In this study, HELP was chosen as the model to predict leachate generation at the Plainville site.

3. Plainville Landfill

The Plainville landfill may be generating the contamination plume in two ways - a leak in the landfill liner may be allowing leachate to escape from the landfill, and groundwater infiltration into the landfill may be hastening the production of this leachate (Figure 3-1). If these statements are true, lowering the groundwater table before it reaches the landfill may be a more effective means of alleviating contamination at the site than direct remediation. The following chapters will discuss the feasibility of groundwater intrusion into the landfill, and alternative strategies for eliminating contamination at the site using basic construction plans of the landfill, a landfill performance computer model, and a model of the area developed by the Master of Engineering Plainville Project group. In this chapter, the focus is on the landfill history.

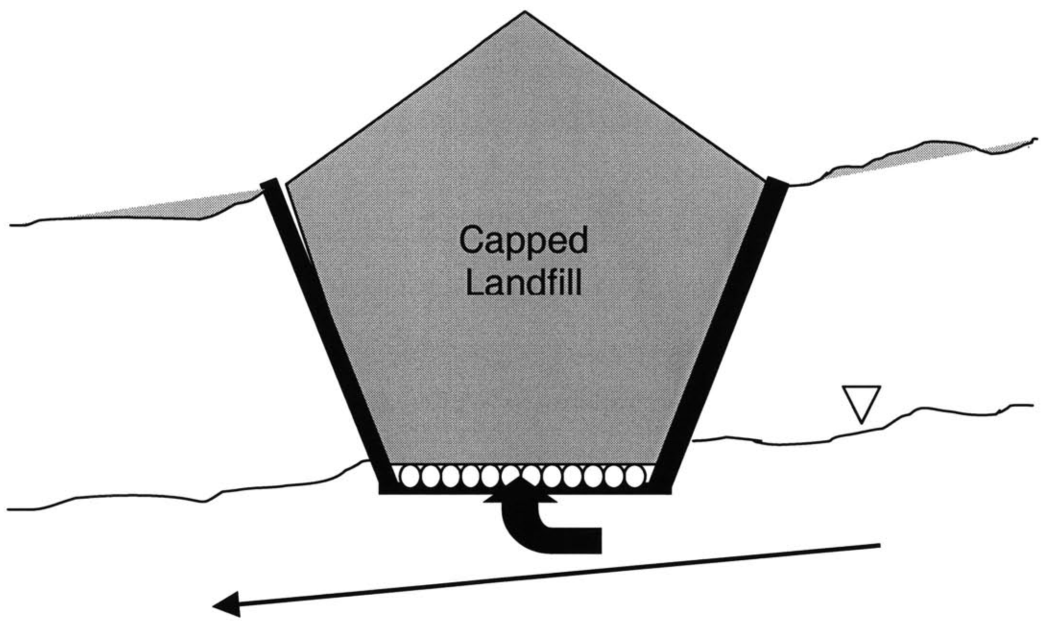

FIGURE 3-1: GROUNDWATER INFILTRATION SCHEMATIC

3.1 Changes to Liner and Leachate Collection System

Construction of the landfill was completed by Camp, Dresser and McKee, Inc. (CDM) on September 12, 1975. The design included a groundwater protection and leachate collection system that consisted of "18-inches of compacted silty clay material…to seal the ground surface and seal the leachate." On top of this clay liner, "an 18-inch layer of permeable material will be placed on the impermeable material to provide a channel for leachate flow and mechanical protection to the impermeable layer...Leachate collection piping consisting of 4-inch perforated PVC piping will be installed on the impermeable layer" (Roy F. Weston, 1997). The landfill was designed for disposal of 750 tons of refuse per day. As the landfill grew in size, expansion of the site was necessary.

A number of landfill expansions included new leachate and liner designs. In 1985, approximately 21.5 acres of the landfill

> ...was constructed with 1.5- to 2.0-foot thick silt liner and perimeter leachate collection system. Liner materials consisted of plant washings from the on-site quarrying operation. The permeability of this material was reported at less than 1 x 10^{-5} centimeters per second (cm/sec). Washings from the quarrying process were also used for daily and intermediate cover as well as secondary liner and base material for synthetic liners placed in expansion areas. New basal liner areas were constructed of imported clay that ranged from 1 x 10^{-5} to 1 x 10^{-7} cm/sec in permeability (Roy F. Weston, 1997).

In August 1987, while incorporating Belcher Street into the landfill, an additional sedimentation basin was added, existing underground concrete leachate collection tanks were replaced with a centrally located aboveground fiberglass tank, and a geomembrane was added (Roy F. Weston, 1997). About thirty-six acres of the landfill have this composite membrane-soil groundwater protection system. In the summer of 1989, because Golder Associates, Inc. (GAI) reported that the integrity of the old leachate system was suspect (Golder Associates, Inc., 1990), the old concrete underground storage tanks were replaced with 13,000-gallon fiberglass aboveground storage tanks in an improved leachate storage facility, and older concrete leachate lines were slip-lined with PVC pipe (Roy F. Weston, 1997). In March 1990, three 13,000-gallon aboveground storage tanks were installed and one 30,000-gallon underground storage tank was removed (Roy F. Weston, 1997). Also at this time, new leachate sewers were installed between the landfill and the storage facility (DeFeo, Wait & Pare, Inc., 1992). A final cover, consisting of a low permeability (1 x 10^{-7} cm/sec) barrier soil, a permeable drainage layer above the barrier soil and a vegetative/protective layer above the drainage layer, was installed as cells of the landfill were closed (DeFeo, Wait & Pare, Inc., 1992).

3.2 OPERATION

3.2.1 Refuse

The Plainville landfill is largely a municipal waste landfill. Examples of the sources of the waste are show in Table 3-1.

TABLE 3-1: SOURCES OF WASTE AT THE PLAINVILLE LANDFILL

Waste Disposal May 1993 - April 1994		
Material	Non-MSW & non-Combustibles (tons)	MSW (tons)
Ash	46643	----
Soil/Grit	29462	----
Industrial Residues	16853	----
C & D	9761	----
MSW from Municipal Contract	----	*122284
MSW from Brokers	----	*14584
Waste from Laidlaw Collection/Hauling Divisions	51819	72582
MSW from Other Collection/Hauling Companies	----	*190746
Incinerator By-Pass Waste	----	36983
MSW from Private Generators	----	*754
Total	154538	437933
Percentage of Total	26.10%	73.90%
*No effort has been made to separate non-combustibles from these categories.		

Source: DeFeo, Wait & Pare, Inc., 1994.

3.2.2 Leachate

3.2.2.1 Trend Over Years

Presently, leachate is collected and disposed off-site. Figure 3-2 shows the amounts of leachate collected from January 1992 until January 1999. Note that there is no strong correlation between precipitation and leachate. At best, a three-month lag can be discerned between July 1993 to January 1995. More recent measurements do not show any strong correlation. The amount of leachate may therefore be controlled by another source, such as groundwater infiltration.

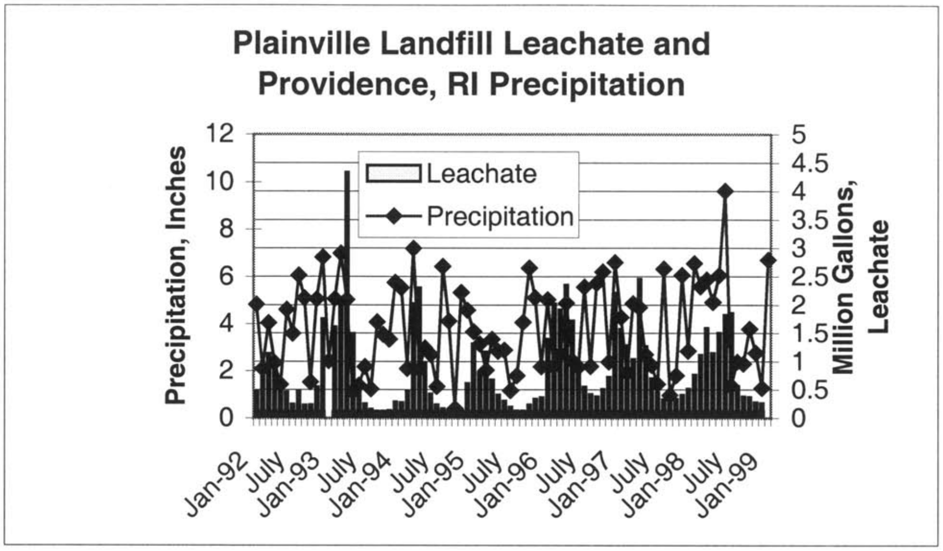

FIGURE 3-2: LEACHATE AND PRECIPITATION
Source: Cushing, Goins & Kirschner, Inc., 1999.

3.2.2.2 Leachate Monitoring

The Plainville leachate samples are tested for various compounds. Table 3-2 summarizes some of the substances detected in leachate samples, leachate composite samples, and leachate collection tanks. A number of these compounds also exist in the groundwater plume: 1,1-dichloroethane, 1,1-dicholorethlyene, 1,2-dichloroethane, 1,2-dichloropropane, benzene, chromium, ethylbenzene, iron, lead, tetrachloroethylene, toluene, zinc among other constituents (Foster Environmental, 1996).

TABLE 3-2: SUBSTANCES IN LEACHATE FROM PLAINVILLE

Analytical Summary: Plainville Sanitary Landfill Substances Reported by GAI as Detected in Leachate Samples, Leachate Composite Samples, and Leachate Collection Tanks From 26 June 1981 to 1990 (concluded)		
1,1-dichloroethane	Benzene	Iron
1,1-dichloroethylene	Chlorobenzene	Lead
1,2-dichloroethane	Chloroform	Manganese
1,2-dichloropropane	Chromium	Methylene Chloride
2-butanone	Cyanide	Tetrachloroethylene
4-methylphenol	Diethylphthalate	Toluene
Acetone	Ethylbenzene	Zinc

Source: Roy F. Weston, 1997.

3.3 CURRENT STATUS

Using eight years of quarterly monitoring results, comprehensive studies by CDM, Goldberg, Zoino, and Associates (GZA), and GAI document a plume of groundwater contamination in the southwest corner of the landfill (Golder Associates, Inc., 1990). In addition, the Massachusetts Department of Environmental Protection's 1984 Site Inspection report for the Plainville Sanitary Landfill for the Environmental Protection Agency concluded that trace organics have been detected in the landfill leachate and monitoring wells (Roy F. Weston, 1997).

> Analytical data from...the southwest corner of the main landfill have consistently shown anomalously high concentrations of several parameters, including alkalinity, ammonia, chloride, iron, manganese, total dissolved solids, and the presence of some organic compounds (Golder Associates, Inc., 1990).

According to Eckenfelder who also conducted a study at the site, the groundwater flows across the landfill in a southwesterly direction, starting as infiltration in highlands north and east of the property and travelling southwest through shallow fractured bedrock towards thicker outwash deposits (Roy F. Weston, 1997).

4. LINER LEVEL VERSUS GROUNDWATER TABLE

4.1 HYPOTHESIS

A major concern is that the groundwater table is within the landfill. Although some people have claimed that the area was dry while the landfill was constructed, others are skeptical. Resource Systems, Inc. claimed that "at no time has it been excavated below the water table" (Resource Systems, 1974). However, John C. Collins, director of the Environmental Health Division of the Massachusetts Department of Public Health, says that the "locus of the proposed landfill is a very difficult site with...groundwater and surface water problems" (Collins, 1974). It is hard to determine who is correct. However, the liner system is questionable. The following excerpt comes from a letter to Mr. George Crombie, the regional director of the EPA, from Mr. Jonathan I. Brucks:

> The existing Landfill liner cross section is based on design drawings, from the 1970's, in the DEP SERO file. I have never seen any documentation that this design is the actual liner system in place nor that is through out the Landfill. In fact there is documentation strongly suggesting that certain locations 'of the Landfill were constructed with substandard liners or no liners at all.' (Brucks, 1984)

This chapter will discuss the feasibility of groundwater intrusion into the landfill by using basic construction plans of the landfill and well data.

4.2 DETERMINATION OF LINER ELEVATION

No original construction reports were available at the company library of CDM in Cambridge, MA and few were found at the Department of Environmental Protection in Plainville, MA. To estimate the elevation of the liner, the best option was therefore to use a cross-section produced by Eckenfelder as seen in Figure 4-1. Figure 4-2 shows the area of the landfill where the cross-section has been drawn. The slice goes west to east through the middle part of the landfill; the bottom liner elevation ranges from about 162 to 181 feet.

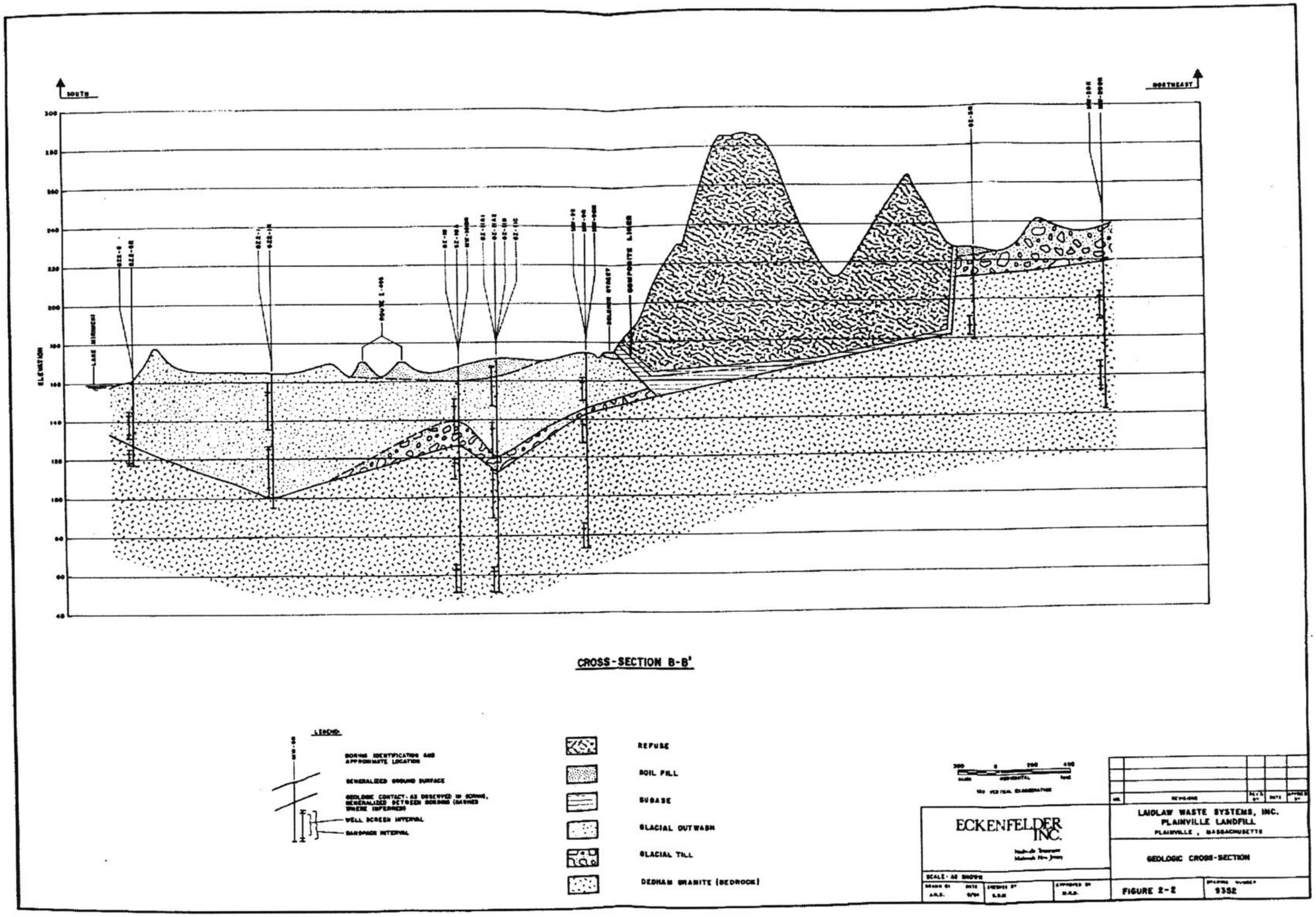

FIGURE 4-1: CROSS-SECTION OF LANDFILL
Source: Eckenfelder, 1994.

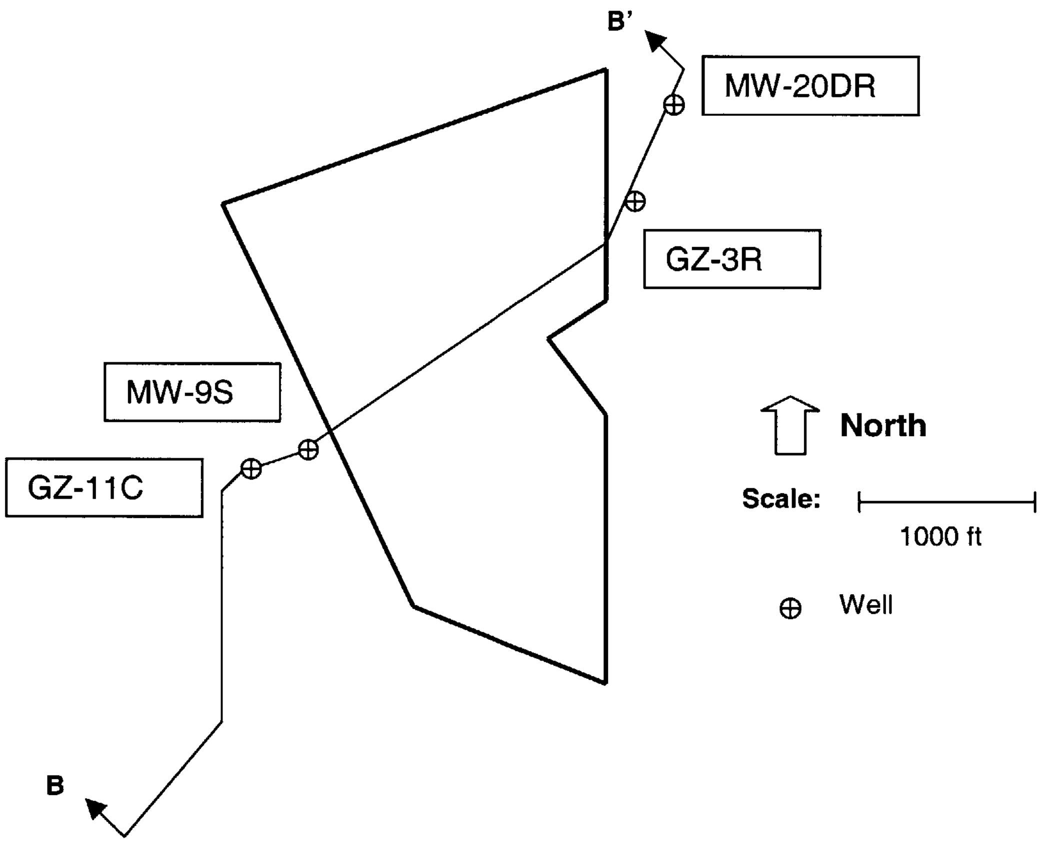

FIGURE 4-2: LOCATION OF CROSS-SECTION

4.3 DETERMINATION OF GROUNDWATER TABLE

A number of observation and monitoring wells exist around the landfill to enable good estimation of the water level below the landfill. The water elevation data from May 1996 were used as recent springtime data in order to incorporate the highest possible water elevations during the year (Eckenfelder, 1998).

Wells MW-20DR and GZ-3R, upgradient of the landfill, have a water level elevation higher than the bottom of the liner as do wells MW-9S and GZ-11C, downgradient of the landfill. Figure 4-3 shows a schematic representation of these data. One interpretation of these elevations is that the landfill liner is intact and that it is causing the underlying aquifer to be confined. However, the water levels also indicate that the groundwater intrusion is likely, given that there is at least one leak in the liner from which the plume must be escaping.

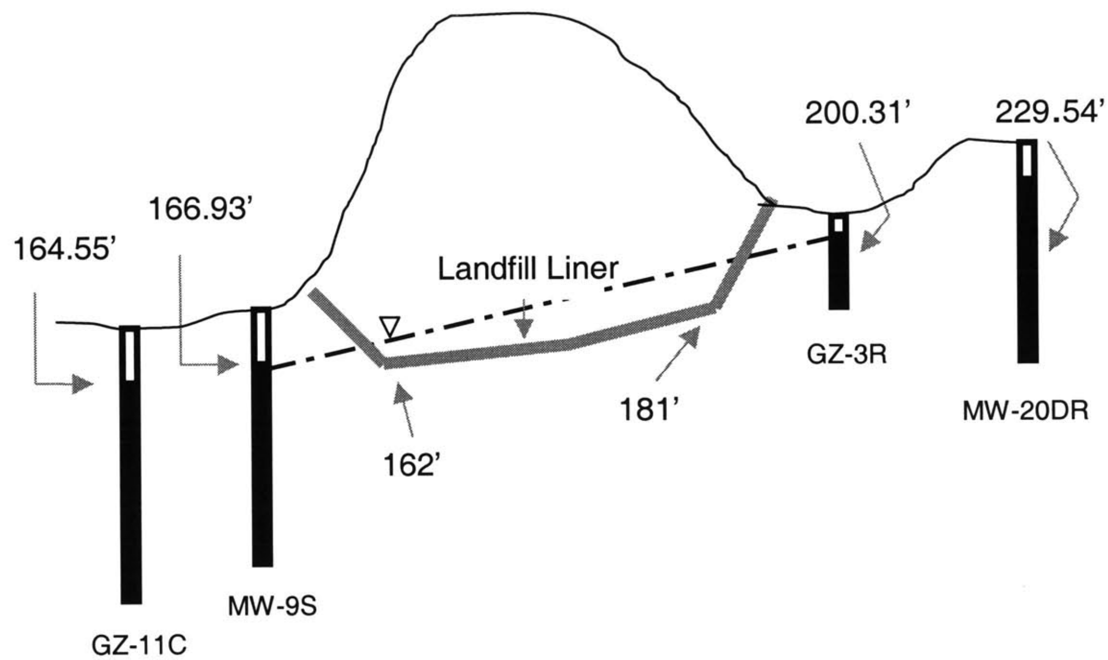

FIGURE 4-3: WATER LEVEL ELEVATION (MAY 1996)

4.4 CONCERNS

Because it is impossible to pinpoint physically the location of a leak(s) in the landfill base that may be permitting groundwater to enter the landfill, an indirect method for confirming its existence needs to be utilized. One such method is to compare the actual amount of leachate collected with the amount predicted by a landfill water balance model. If more leachate is exiting the landfill leachate collection system than is predicted, groundwater flow through the landfill probably occurs. This is discussed in Chapter 5.

5. Estimating leachate production using HELP

This chapter will discuss the feasibility of groundwater intrusion into the landfill using a landfill performance computer model. This model can estimate groundwater infiltration by doing a mass balance of the water going into and coming out of the landfill. The industry standard that was used to do this is Version 3 of the EPA's HELP model.

5.1 Description of program

Developed by the US Army Corps of Engineers Waterways Experimental Station for the US EPA, the HELP computer program is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills (Schroeder et al, 1994). The program accepts various input parameters including weather, soil and design data in order to account for processes such as surface storage, snowmelt, runoff, infiltration, evapotranspiration, soil storage, lateral drainage, vertical drainage, and leakage through a landfill liner. The model evaluates landfill systems that have different combinations of vegetation, cover soils, lateral drainage layers, low permeability barrier soils, and synthetic geomembrane liners. It provides a rapid, economical tool for screening landfill designs by estimating amounts of runoff, evapotranspiration, drainage, leachate collection and liner leakage for different landfill scenarios (Culligan, 1999).

5.2 Parameters

The HELP program contains an extensive database of weather data for about 100 cities. The default values for Providence, Rhode Island were selected for use at the Plainville site. Descriptions of the soil and design data used in this study follow.

5.2.1 Liner Systems

Due to the lack of available information on the construction of the landfill, a number of assumptions were made in setting up the model. One unknown was the type of liner, geomembrane, or soil barrier underlying parts of the landfill. Given that geomembrane liners decrease leakage into the subsurface, and therefore increase leachate collection more so than clay liners, modeling using geomembrane liners should predict the maximum amount of leachate that can be potentially collected from a leachate collection system. Therefore, comparing this information to the amount of leachate actually collected at the Plainville site should give the strongest case scenario for arguing the presence of groundwater infiltration into the landfill.

Figure 5-1 describes the configuration for the original liner system. Silt washings which had a maximum saturated hydraulic conductivity of 1 x 10^{-5} cm/sec formed the impermeable liner (Eckenfelder, 1997). Above this was placed an eighteen inch permeable layer (Eckenfelder, 1997). The drainage system has a two percent slope (CDM, 1979). From Figure 4-1, the landfill was estimated to be 100 feet high. The cover system includes an 18-inch thick, compacted, low-permeability soil layer which has a maximum conductivity of 1 x 10^{-7} cm/sec (DeFeo, Wait & Pare, Inc., 1993). The drainage layer is twelve inches thick and has a minimum conductivity of 1 x 10^{-3} cm/sec (DeFeo, Wait & Pare, 1993). Above this is the vegetative support layer that has a hydraulic conductivity no more than 7 x 10^{-4} cm/sec (Cushing, Goins & Kirschner, Inc., 1997).

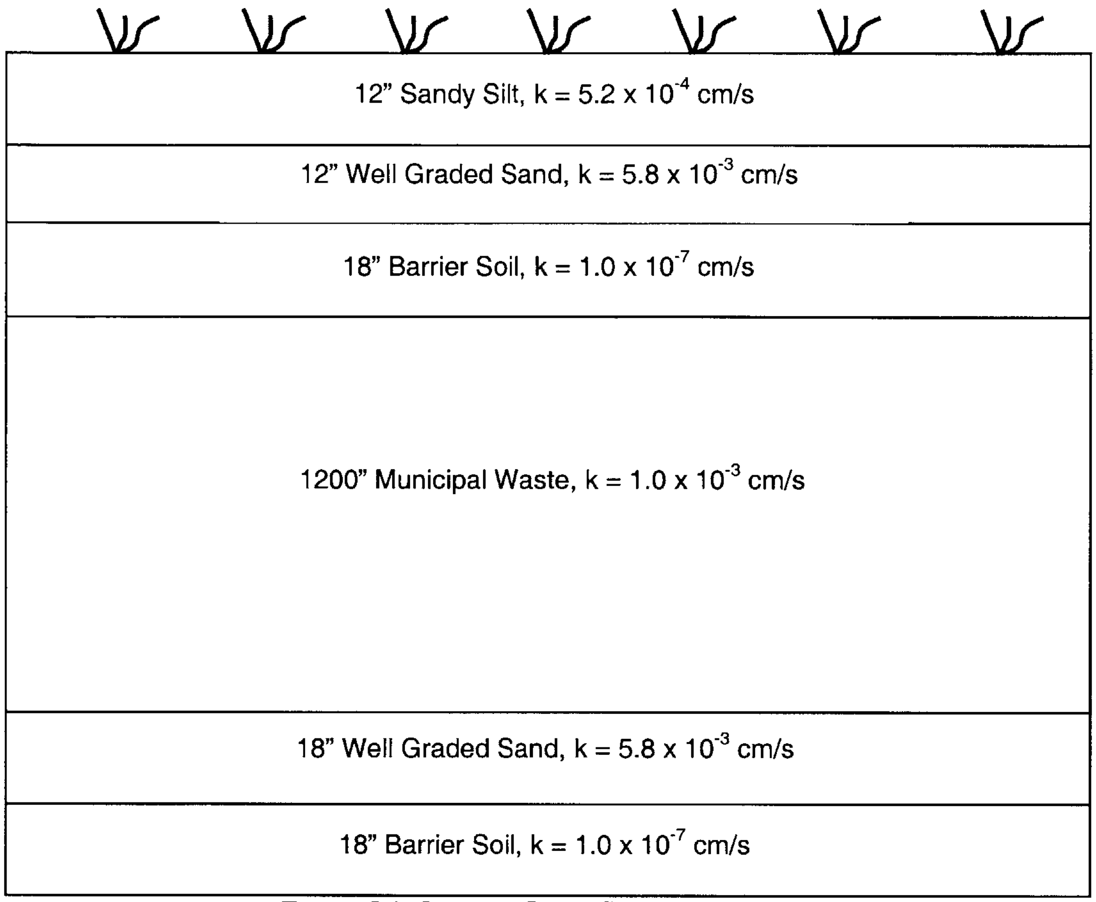

FIGURE 5-1: ORIGINAL LINER SIMULATION PROFILE

Figure 5-2 shows the configuration for the new liner system with the geomembrane. The only difference is that a synthetic flexible membrane (60-mil high density polyethylene) is incorporated in the liner (Eckenfelder, 1997). Running these scenarios for five years after capping produced the data listed in Table 5-1.

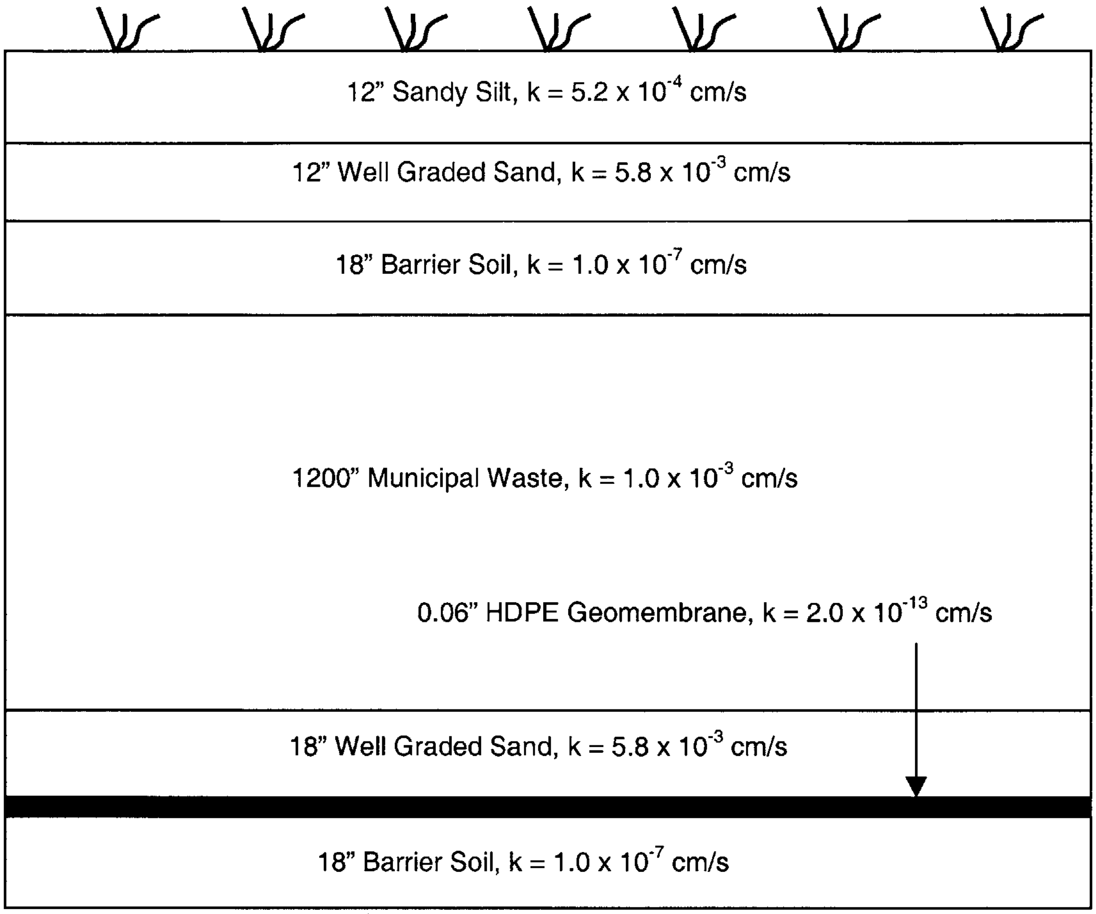

FIGURE 5-2: LINER SYSTEM WITH GEOMEMBRANE

TABLE 5-1: LEACHATE PREDICTED BY HELP FIVE YEARS AFTER CAPPING

Liner Type	Annual Predicted Leachate Per Inch Precipitation ($x10^4$ gallons)
Barrier Soil System	3.93
Geomembrane Liner	10.4

The predicted amounts of leachate for the original liner system and the later system with the geomembrane have a factor of 2.6 difference. Interest lies in the maximum amount of leachate that can be collected. Therefore, modeling the entire landfill with the geomembrane system is considered sufficient for this study.

Another use of this five-year prediction after capping is to determine how long it would take for the landfill to produce the amount of leachate predicted by the model. This was determined by fitting a curve to the last few months of leachate collection data in order to extrapolate to the amount predicted by HELP (Figure 5-3). Inserting the amount predicted with the geomembrane system – an average of 8,600 gallons of leachate per inch precipitation per month – into the exponential equation shows that it would take 18.5 months after the downward trend starts to reach the leachate amount predicted by the HELP model. This means that this amount will be reached in March 2000, about three years earlier than predicted. Because the landfill is producing more leachate than predicted, the possibility of groundwater intrusion is likely.

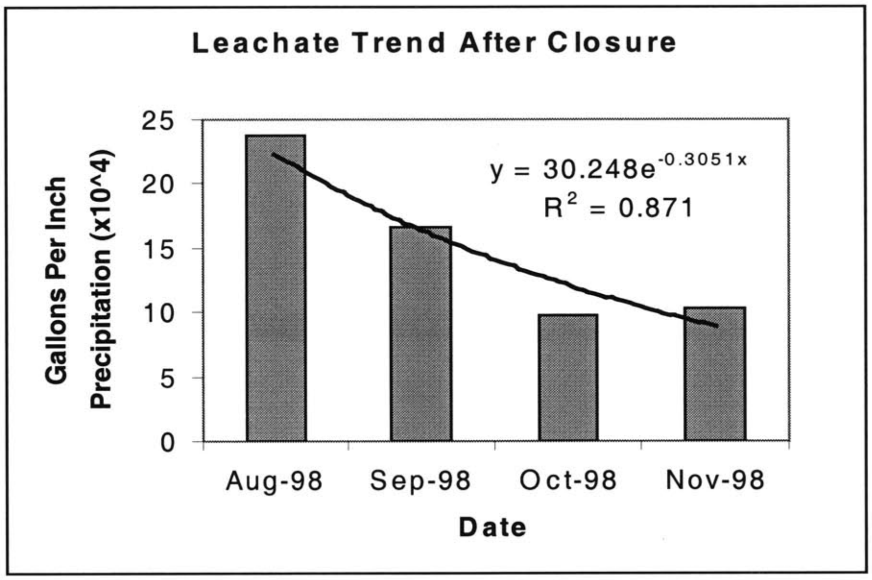

FIGURE 5-3: LEACHATE TREND AFTER CAPPING

5.2.2 Acreage Over Time

Another unknown in the construction of the landfill is the rate of landfill expansion. To estimate how the landfill acreage changed over time, a linear progression of expansion was assumed. In other words, the landfill is known to have covered sixty acres in 1987 and 88.5 acres in 1998 (Southeast Region web site); thus, for eleven years, the landfill acreage increased by about 2.6 acres per year. Figure 5-4 shows the assumed landfill acreage since 1987.

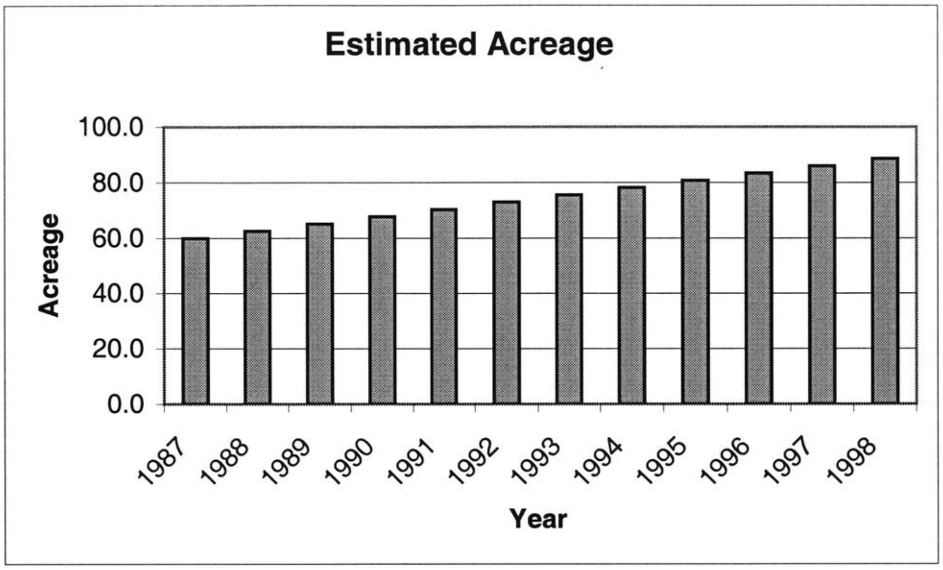

FIGURE 5-4: ESTIMATED ACREAGE

5.2.3 Coverage Over Time

Parts of the landfill were capped at different times. Figure 5-5 shows a capping schedule sketched by Roy F. Weston (1997). Based on a report describing the capping of the North Face (DeFeo, Wait & Pare, Inc., 1993), the cells at the north and south of the landfill are assumed to have been capped in 1993. Using this drawing, the areas of the cells were determined. These areas of coverage were combined with acreage at the time of capping in order to determine percentage of landfill capped in a particular year (Figure 5-6). These numbers served as inputs to the HELP program.

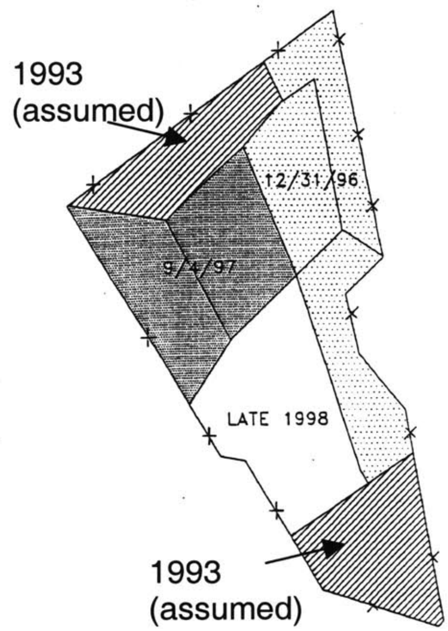

FIGURE 5-5: LANDFILL CAPPING SCHEDULE

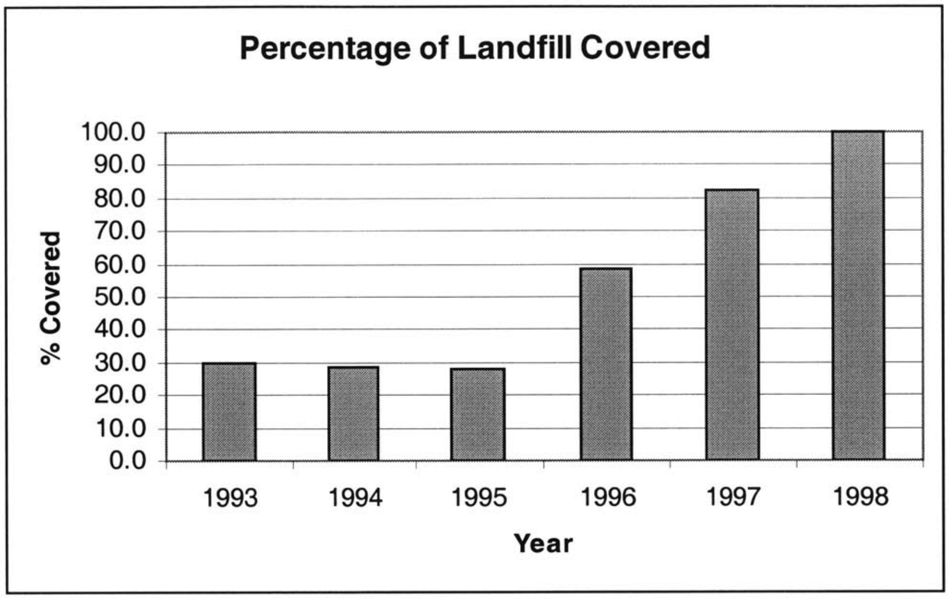

FIGURE 5-6: LANDFILL COVERAGE

5.3 RESULTS

The model was run for individual years 1993 through 1998 (Appendix A). Figure 5-7 shows the average annual amount of leachate predicted by the HELP model and the mean amount of leachate collected. Appendix B contains the calculations on a monthly basis. Because the amount of leachate predicted is only a fraction of that collected, groundwater infiltration into the landfill is considered a strong possibility (Table 5-2).

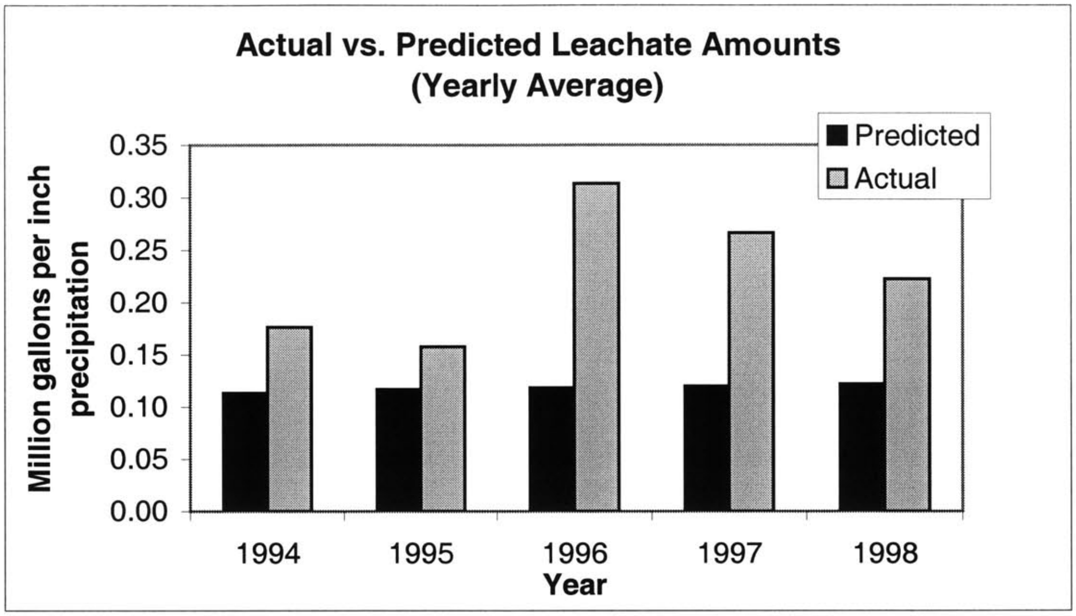

FIGURE 5-7: PREDICTED VS ACTUAL LEACHATE AMOUNTS

TABLE 5-2: COMPARISON OF PREDICTED AND ACTUAL LEACHATE AMOUNTS

Year	Predicted Leachate (per inch precipitation)/Actual Leachate (per inch precipitation)
1993	0.39
1994	0.64
1995	0.74
1996	0.38
1997	0.45
1998	0.55
average	0.53

5.4 OTHER POSSIBLE CAUSES OF LEACHATE DISCREPANCY

If groundwater infiltration cannot account for the leachate discrepancy, some other possible reasons lie in the model assumptions and program limitations. Because construction reports could not be obtained, gross assumptions about the landfill expansions and the capping schedule were made. This could make a difference in the predicted leachate amount; however, these variations did not affect the predicted amounts for 1993 – 1998 as seen in Figure 5-7. The other unknowns were the types of lining systems that exist. One type for the entire landfill was assumed here, but in reality many exist as the landfill base. These systems could greatly change the amount of leachate predicted. Also, the amount of leachate collected at the Plainville landfill may be from some parts of the landfill that were not filled at the time. This would result in a high leachate collection due to precipitation over an area where there is no waste to store water. Accurate construction reports would determine if any of these cases are true.

Although the majority of the discrepancy is probably due to the gross assumptions of the construction, these limitations of the HELP program are worth noting. In terms of the scope of this study, the following limitations apply:

- Underprediction of the surface runoff coefficient due to use of daily time increment. Averaging the rainfall rate from a short intense rainfall over the daily time increment causes the underprediction because the intensity is lowered.

- Uncertainty in synthetic liner leakage fraction. This assignment depends on hole size, depth of leachate ponding, and saturated hydraulic conductivity (Culligan, 1999).

6. FEASIBILITY OF LOWERING THE GROUNDWATER TABLE

Given that the liner may be below the groundwater table and that groundwater flow through the landfill may be likely, one possible solution to alleviating the spread of contamination from the landfill would be to lower the water table before it reaches the landfill by pumping water from the aquifer (Figure 6-1). This chapter will discuss the feasibility of implementing this solution and alternative strategies for eliminating contamination at the site using a MODFLOW model of the area developed by the author and other members of the Plainville Project group (Appendix C).

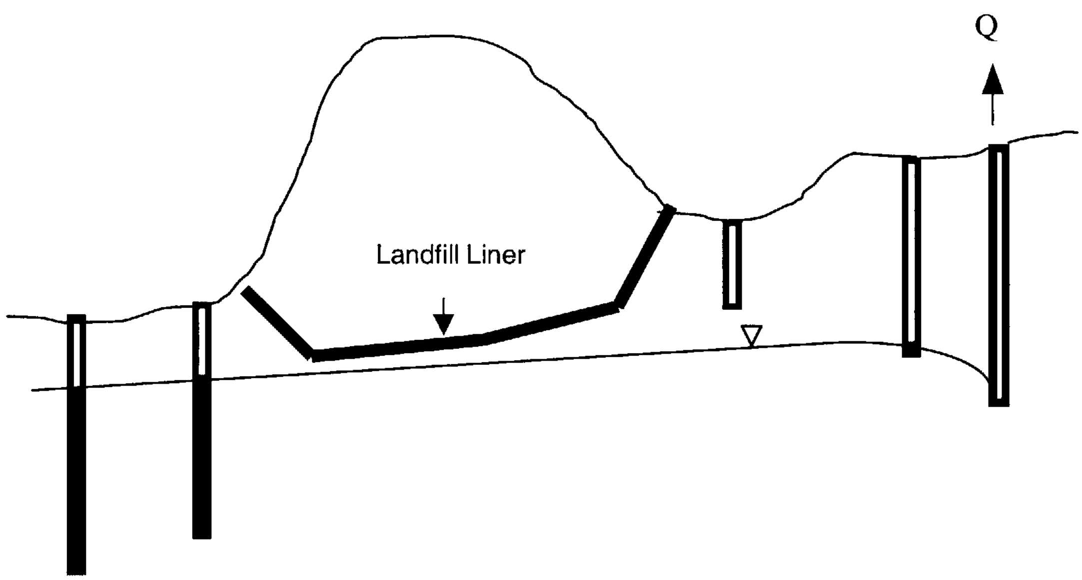

FIGURE 6-1: PUMPING GROUNDWATER UPGRADIENT

6.1 DIFFICULT ANALYTICAL SOLUTION

The complex groundwater system in the landfill vicinity prevents an analytical solution for determining hypothetical locations and extraction rates of pumping wells. Due to the steep slope of the groundwater table and the thinness of the aquifer under the landfill, the Theim equation for unconfined aquifers cannot be applied to this situation. The water elevation data presented in Section 4.3 indicates that the water level on the east side of the landfill is approximately thirty feet above that on the west side. This causes a large groundwater flow that is difficult to incorporate using mathematical techniques for determining necessary well drawdown and thus, pumping rate. In addition, superposition of drawdown due to the no flow till area to the east of the landfill would need to be quantified. Consequently, a groundwater model of the area was utilized to determine the locations and extraction rates of pumping wells.

6.2 USE OF MODFLOW MODEL

Because the groundwater enters the landfill at the northeast, a series of three pumping wells were simulated north of the landfill. Figure 6-2 indicates the locations of these extraction wells. The model shows that large amounts of pumping will not be enough to support the proposed solution. A pumping rate of 1,000 gallons per minute per well could not lower the groundwater table below the landfill liner.

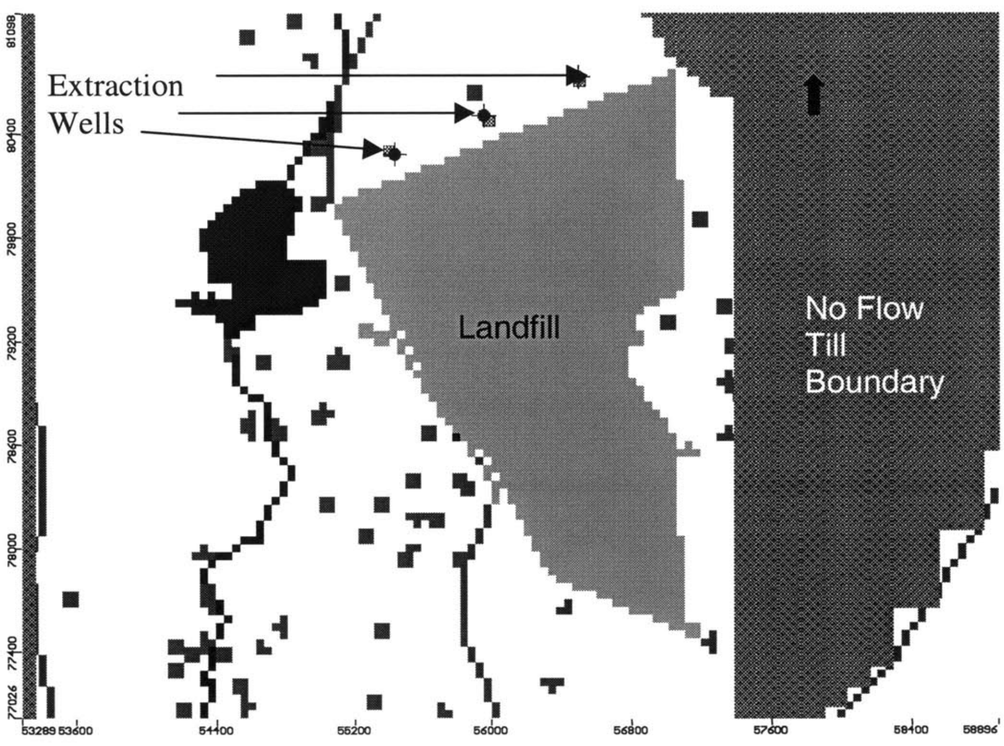

FIGURE 6-2: LOCATIONS OF EXTRACTION WELLS

6.3 EFFECTS ON AREA

According to the model, much of the surrounding area would go dry (Figure 6-3). This solution is undesirable because many people inhabit/utilize the immediate vicinity. For example, the cranberry bogs would go dry.

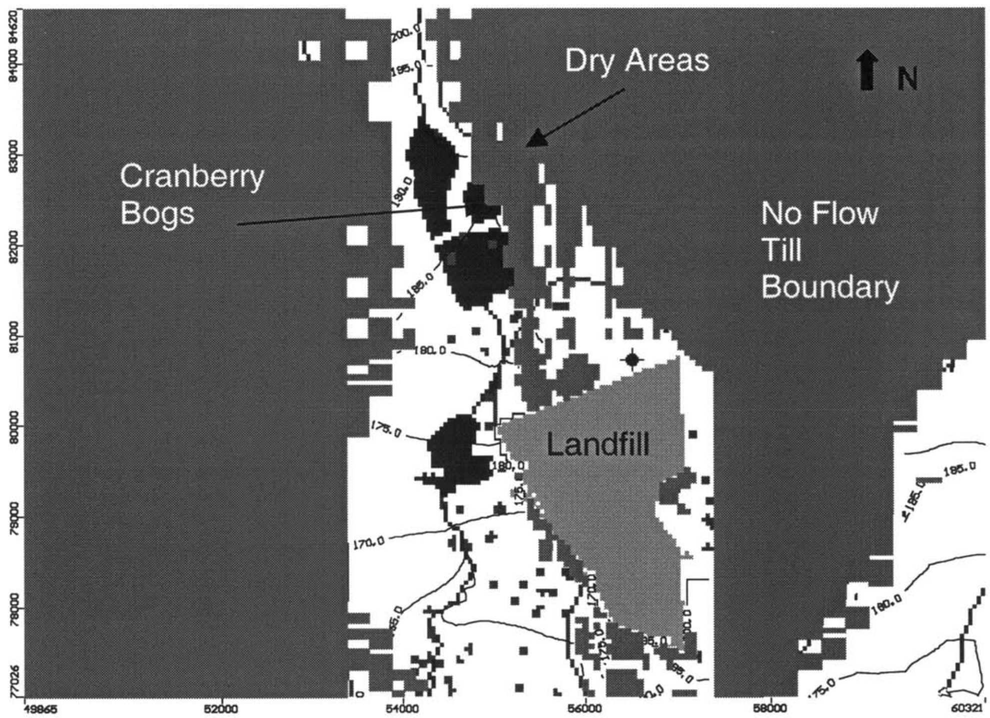

FIGURE 6-3: RESULTS ON OUTWASH LAYER FROM PUMPING UPGRADIENT

Not only would the normal water availability be disturbed, but also lowering the groundwater table may hasten leaching of contaminants from the landfill. Already, there have been contaminants detected in wells northeast of the landfill. Lowering the groundwater table would form a hydraulic gradient that would cause leachate to flow downgradient, away from the landfill. However, whether or not the contaminant spreading is worse than groundwater infiltration cannot be discerned from the results of this simulation.

6.4 OTHER SOLUTIONS

Pumping upgradient of the landfill will not only cause undesirable effects on the local area, but it is also a worse solution compared to extraction for the remediation system. The extraction rate of water to be pumped, treated, and reinjected is less than that necessary for lowering the groundwater table upgradient (Woodworth, 1999).

Another solution that was investigated was a french drain system which would divert groundwater away from the landfill. A french drain was installed in the northwest portion of the landfill in 1975, but it is presently closed (Connick, personal communication). The MODFLOW model was used to test this solution. A constant head boundary across the northern part of the landfill represented the french drain (Figure 6-4). Its height was at the elevation of the landfill liner. The simulation did not lower the groundwater table below the landfill liner due to the large change in landfill liner elevation from the north to the south (Figure 6-5).

Other solutions for lowering the groundwater table should be tested. One other suggestion would be to employ a vertical cutoff wall to surround the landfill and prevent further contaminant spreading.

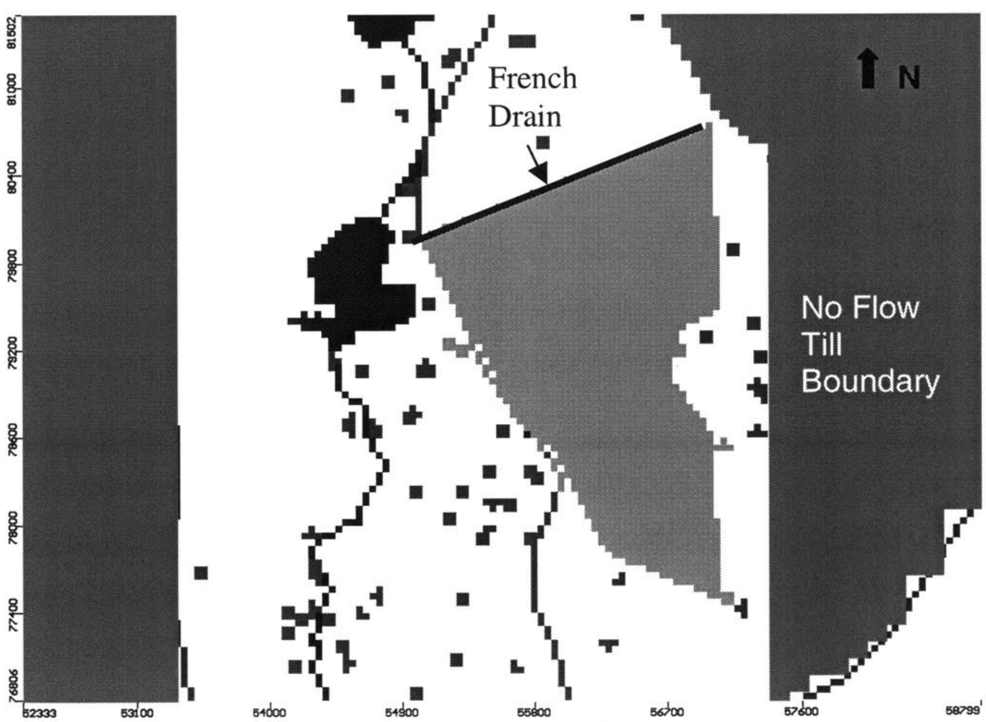

FIGURE 6-4: FRENCH DRAIN SCENARIO

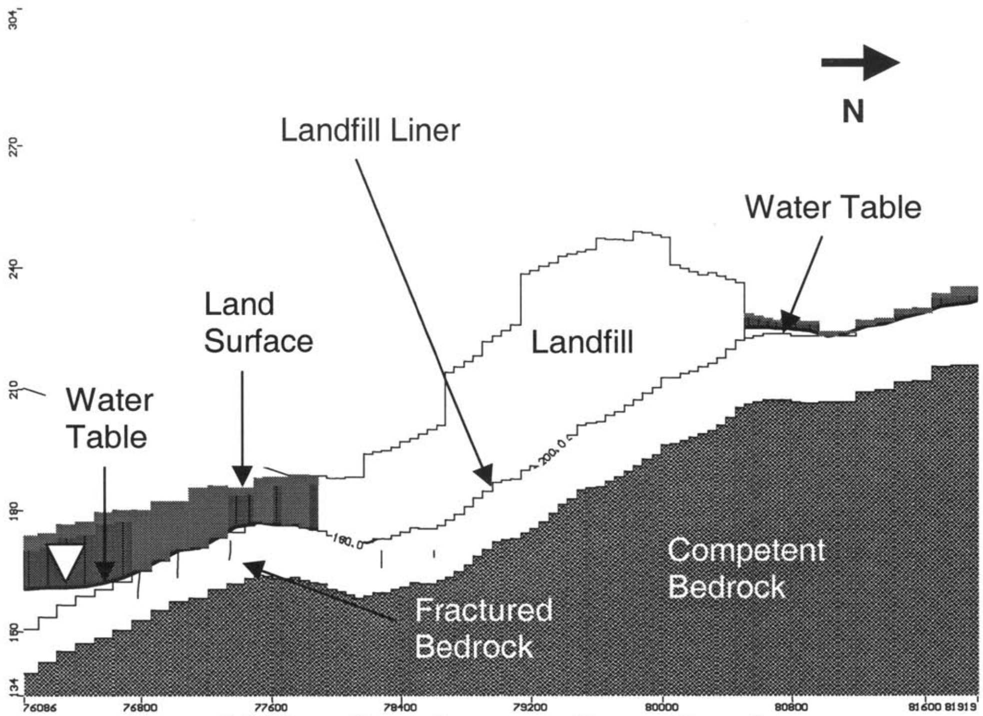

FIGURE 6-5: MODEL CROSS-SECTION FOR FRENCH DRAIN SYSTEM

7. CONCLUSIONS

7.1 RESULTS

Groundwater may be entering the Plainville landfill. When the water table was extrapolated through the landfill, the May 1996 water elevation data from observation wells on opposing sides of the landfill indicated that the water table is above the landfill liner. Although gross assumptions were made for the landfill configuration, data generated by the HELP model also demonstrated the possibility of groundwater intrusion. This conclusion was reached by comparing the difference between the actual amount of leachate collected at the site with that predicted by the water balance model. After normalizing the leachate collected by the amount of precipitation, it was noted that the HELP model predicted 47.5% less leachate collection than is being observed at the site.

Since the possibility of groundwater infiltration into the landfill was high, a couple of solutions to this problem were investigated using a groundwater model of the area. One solution involved installing a number of groundwater pumping wells upstream of the landfill to lower the groundwater table below the base of the landfill liner. The MODFLOW model predicted that lowering the groundwater table by pumping upgradient would cause parts of the surrounding area to go dry. It also demonstrated that the rate of water removal would have to be enormous in order to achieve the desired level of dewatering.

The second solution involved representing a french drain system at the northern part of the landfill to divert the groundwater before it reaches the landfill. Results from the model show that this system would not work because of the large change in landfill liner elevation from the north to the south. The drain system would have to be as deep as the lowest liner elevation of the landfill.

7.2 RECOMMENDATIONS

Because few construction data were available, the results of this study may not be accurate. Ideally, the elevation of the liner needs to be measured directly, as does the water level under/in the landfill. However, since it is not feasible to install wells within a filled landfill, detailed construction reports need to be resurrected and reviewed. Water level data from all around the landfill should be utilized to estimate the water elevation under/in the landfill area.

Detailed construction reports would also be useful in setting up and rerunning the HELP model to perform a more accurate water balance. The analysis should include the various phases of expansion and capping, in addition to a complete knowledge of the lining and capping systems over the years. Only then can a firm conclusion be made as to whether or not groundwater is entering the landfill.

If groundwater is entering the landfill, lowering the groundwater table by pumping upgradient of the landfill is not recommended due to the enormous quantity of water that would need to be extracted and reinjected under this scheme. In addition, the solution would result in negative drying effects on the surrounding area. The solution of employing a french drain system is not recommended either due to the small effect on the water table when the model was run. The current and proposed remediation systems could be a good alternative (Woodworth, 1999). Another suggestion for preventing groundwater from entering the landfill is implementing a vertical cutoff wall to prevent further contaminant spreading.

Additional work can be done with the groundwater model of the area. The MODFLOW model was developed with layers representing the landfill liner and cap in mind. This customization would allow the user to represent the landfill barrier system and alter its hydraulic conductivity. Flexibility in changing the properties of the lining system would facilitate testing of a number of different hypotheses. One suggestion would be putting a contaminant source in the landfill and rerunning the upgradient pumping to see how readily the contaminant would be drawn to the lower hydraulic gradient. Another scenario would be to determine what the conductivity of the liner would need to be in order for contaminants to begin escaping. Impacts on the groundwater of potential expansions of the landfill could be predicted. This model and the HELP program provide ample opportunity to support the groundwater intrusion hypothesis in addition to many other theories.

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9. APPENDICES

Appendix A: HELP Results

Original Liner System – Five Years After Capping:

```
******************************************************************************
******************************************************************************
**                                                                          **
**                                                                          **
**              HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE               **
**                HELP MODEL VERSION 3.05 (30 MARCH 1996)                   **
**               DEVELOPED BY ENVIRONMENTAL LABORATORY                      **
**                 USAE WATERWAYS EXPERIMENT STATION                        **
**             FOR USEPA RISK REDUCTION ENGINEERING LABORATORY              **
**                                                                          **
**                                                                          **
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PRECIPITATION DATA FILE:    U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE:      U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE:  U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA:    U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE:  U:\EMCHEN\PLAINV~1\HELP3\DATA10.D10
OUTPUT DATA FILE:           U:\EMCHEN\PLAINV~1\HELP3\OUTDATA.OUT

TIME: 17:12    DATE:  5/ 3/1999

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

   TITLE: Plainville Landfill - Original Liner System

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

   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 7
     THICKNESS              =   12.00  INCHES
     POROSITY               =   0.4730 VOL/VOL
     FIELD CAPACITY         =   0.2220 VOL/VOL
     WILTING POINT          =   0.1040 VOL/VOL
     INITIAL SOIL WATER CONTENT =   0.3322 VOL/VOL
     EFFECTIVE SAT. HYD. COND.  = 0.520000001000E-03 CM/SEC
   NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
         FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.
```

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0685 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 88.500 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.312 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 376.249 INCHES
TOTAL INITIAL WATER = 376.249 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	4.097	2.225	3.988	0.806	0.032	0.027
	0.314	0.289	0.109	0.237	0.663	1.091
STD. DEVIATIONS	2.895	1.590	2.361	0.798	0.061	0.033
	0.636	0.399	0.150	0.274	1.180	1.854
EVAPOTRANSPIRATION						
TOTALS	0.689	0.644	0.862	3.000	3.410	4.537
	2.701	2.727	3.026	2.358	1.309	0.757
STD. DEVIATIONS	0.175	0.093	0.335	0.339	1.089	1.631
	1.020	1.828	0.531	0.369	0.144	0.176
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.3357	0.2728	0.3315	0.4705	0.4624	0.3679
	0.2999	0.3182	0.3276	0.4049	0.4222	0.4594
STD. DEVIATIONS	0.0417	0.0610	0.0767	0.0484	0.0153	0.0476
	0.0138	0.0913	0.0891	0.0767	0.1320	0.0544
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1607	0.1403	0.1638	0.1977	0.1878	0.1615
	0.1511	0.1573	0.1535	0.1739	0.1841	0.1941
STD. DEVIATIONS	0.0109	0.0166	0.0188	0.0172	0.0100	0.0122
	0.0021	0.0210	0.0155	0.0199	0.0384	0.0208
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.0732	0.0556	0.0587	0.0649	0.0757	0.0711
	0.0635	0.0563	0.0523	0.0555	0.0626	0.0742
STD. DEVIATIONS	0.0103	0.0045	0.0106	0.0117	0.0116	0.0102
	0.0078	0.0045	0.0090	0.0067	0.0128	0.0210

PERCOLATION/LEAKAGE THROUGH LAYER 6

TOTALS	0.1082	0.0968	0.1071	0.1039	0.1076	0.1041
	0.1073	0.1071	0.1035	0.1070	0.1038	0.1076
STD. DEVIATIONS	0.0017	0.0001	0.0003	0.0003	0.0003	0.0003
	0.0002	0.0001	0.0003	0.0002	0.0004	0.0006

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	9.2594	8.5156	9.9680	16.8722	14.0595	10.4901
	7.7988	8.8553	9.0702	11.6856	14.4725	15.1255
STD. DEVIATIONS	1.9516	3.1355	3.2144	3.0337	1.7056	2.1569
	0.3583	3.5921	2.7289	3.3941	6.7788	3.5534

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.3564	0.3022	0.2883	0.3292	0.3717	0.3608
	0.3115	0.2765	0.2652	0.2725	0.3175	0.3640
STD. DEVIATIONS	0.0469	0.0246	0.0522	0.0594	0.0569	0.0517
	0.0381	0.0219	0.0456	0.0328	0.0647	0.1031

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.72 (3.815)	15009677.0	100.00
RUNOFF	13.879 (3.8014)	4458573.00	29.705
EVAPOTRANSPIRATION	26.021 (1.4874)	8359284.00	55.693
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.47294 (0.24822)	1436955.370	9.57353
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.02582 (0.06710)	650803.812	4.33589
AVERAGE HEAD ON TOP OF LAYER 3	11.348 (0.994)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	0.76378 (0.03792)	245367.219	1.63473
PERCOLATION/LEAKAGE THROUGH LAYER 6	1.26419 (0.00186)	406127.875	2.70577
AVERAGE HEAD ON TOP OF LAYER 6	0.318 (0.016)		
CHANGE IN WATER STORAGE	0.241 (3.0542)	77432.61	0.516

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)

PRECIPITATION 4.78 1535599.000
RUNOFF 3.524 1132030.0000
DRAINAGE COLLECTED FROM LAYER 2 0.01955 6279.10840
PERCOLATION/LEAKAGE THROUGH LAYER 3 0.007935 2549.00830
AVERAGE HEAD ON TOP OF LAYER 3 23.988
MAXIMUM HEAD ON TOP OF LAYER 3 32.77
LOCATION OF MAXIMUM HEAD IN LAYER 2
(DISTANCE FROM DRAIN) 167.8 FEET
DRAINAGE COLLECTED FROM LAYER 5 0.00332 1065.62231
PERCOLATION/LEAKAGE THROUGH LAYER 6 0.003497 1123.38892
AVERAGE HEAD ON TOP OF LAYER 6 0.505
MAXIMUM HEAD ON TOP OF LAYER 6 0.91
LOCATION OF MAXIMUM HEAD IN LAYER 5
(DISTANCE FROM DRAIN) 9.8 FEET
SNOW WATER 6.35 2041157.1200
MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4658
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0880

*** 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 1978

LAYER	(INCHES)	(VOL/VOL)
1	3.7882	0.315
2	5.2583	0.4382
3	7.6860	0.427
4	350.4000	0.292
5	1.2218	0.0679
6	7.6860	0.4270

SNOW WATER 1.414

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Geomembrane System – Five Years After Capping:

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** **
** **
** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE:   U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE:     U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA:   U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA12.D10
OUTPUT DATA FILE:          U:\EMCHEN\PLAINV~1\HELP3\OUTDAT12.OUT

TIME: 17:16    DATE:  5/ 3/1999

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  TITLE: Plainville Landfill - 1987 Liner System

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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  7
    THICKNESS                =    12.00   INCHES
    POROSITY                 =    0.4730 VOL/VOL
    FIELD CAPACITY           =    0.2220 VOL/VOL
    WILTING POINT            =    0.1040 VOL/VOL
    INITIAL SOIL WATER CONTENT =    0.3322 VOL/VOL
    EFFECTIVE SAT. HYD. COND.  = 0.520000001000E-03 CM/SEC
   NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
          FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                    LAYER  2
                    --------

          TYPE 2 - LATERAL DRAINAGE LAYER
           MATERIAL TEXTURE NUMBER  2
    THICKNESS                =    12.00   INCHES
    POROSITY                 =    0.4370 VOL/VOL
    FIELD CAPACITY           =    0.0620 VOL/VOL
    WILTING POINT            =    0.0240 VOL/VOL
    INITIAL SOIL WATER CONTENT =    0.4382 VOL/VOL
    EFFECTIVE SAT. HYD. COND.  = 0.579999993000E-02 CM/SEC
    SLOPE                    =     2.00   PERCENT
    DRAINAGE LENGTH          =    530.0   FEET

                    LAYER  3
                    --------

           TYPE 3 - BARRIER SOIL LINER
           MATERIAL TEXTURE NUMBER 16
    THICKNESS                =    18.00   INCHES
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POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0794 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL

INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 88.500 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.312 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 376.445 INCHES
TOTAL INITIAL WATER = 376.445 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1978

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	6.19	2.98	3.95	2.75	3.21	3.10
	3.56	4.08	4.37	4.82	2.78	4.93
STD. DEVIATIONS	2.07	0.30	1.11	0.52	1.25	1.31
	2.62	2.27	2.21	1.87	2.13	0.98
RUNOFF						
TOTALS	4.097	2.225	3.988	0.806	0.032	0.027
	0.314	0.289	0.109	0.237	0.663	1.091
STD. DEVIATIONS	2.895	1.590	2.361	0.798	0.061	0.033
	0.636	0.399	0.150	0.274	1.180	1.854
EVAPOTRANSPIRATION						
TOTALS	0.689	0.644	0.862	3.000	3.410	4.537
	2.701	2.727	3.026	2.358	1.309	0.757
STD. DEVIATIONS	0.175	0.093	0.335	0.339	1.089	1.631
	1.020	1.828	0.531	0.369	0.144	0.176
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.3357	0.2728	0.3315	0.4705	0.4624	0.3679
	0.2999	0.3182	0.3276	0.4049	0.4222	0.4594
STD. DEVIATIONS	0.0417	0.0610	0.0767	0.0484	0.0153	0.0476
	0.0138	0.0913	0.0891	0.0767	0.1320	0.0544
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1607	0.1403	0.1638	0.1977	0.1878	0.1615
	0.1511	0.1573	0.1535	0.1739	0.1841	0.1941
STD. DEVIATIONS	0.0109	0.0166	0.0188	0.0172	0.0100	0.0122
	0.0021	0.0210	0.0155	0.0199	0.0384	0.0208
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.1811	0.1525	0.1659	0.1686	0.1830	0.1751
	0.1709	0.1636	0.1560	0.1626	0.1662	0.1814
STD. DEVIATIONS	0.0117	0.0047	0.0106	0.0118	0.0118	0.0104
	0.0080	0.0046	0.0091	0.0068	0.0128	0.0212
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	9.2594	8.5156	9.9680	16.8722	14.0595	10.4901
	7.7988	8.8553	9.0702	11.6856	14.4725	15.1255
STD. DEVIATIONS	1.9516	3.1355	3.2144	3.0337	1.7056	2.1569
	0.3583	3.5921	2.7289	3.3941	6.7788	3.5534

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.8828	0.8286	0.8143	0.8551	0.8982	0.8878
	0.8384	0.8027	0.7909	0.7978	0.8429	0.8901
STD. DEVIATIONS	0.0484	0.0253	0.0519	0.0599	0.0579	0.0528
	0.0392	0.0225	0.0460	0.0334	0.0649	0.1041

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1978

	INCHES	CU. FEET	PERCENT
PRECIPITATION	46.72 (3.815)	15009677.0	100.00
RUNOFF	13.879 (3.8014)	4458573.00	29.705
EVAPOTRANSPIRATION	26.021 (1.4874)	8359284.00	55.693
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.47294 (0.24822)	1436955.370	9.57353
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.02582 (0.06710)	650803.812	4.33589
AVERAGE HEAD ON TOP OF LAYER 3	11.348 (0.994)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.02696 (0.03851)	651169.562	4.33833
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00087 (0.00001)	277.950	0.00185
AVERAGE HEAD ON TOP OF LAYER 6	0.844 (0.016)		
CHANGE IN WATER STORAGE	0.241 (3.0547)	77481.62	0.516

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1978

	(INCHES)	(CU. FT.)
PRECIPITATION	4.78	1535599.000
RUNOFF	3.524	1132030.0000
DRAINAGE COLLECTED FROM LAYER 2	0.01955	6279.10840
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007935	2549.00830
AVERAGE HEAD ON TOP OF LAYER 3	23.988	
MAXIMUM HEAD ON TOP OF LAYER 3	32.77	

LOCATION OF MAXIMUM HEAD IN LAYER 2
(DISTANCE FROM DRAIN) 167.8 FEET
DRAINAGE COLLECTED FROM LAYER 5 0.00678 2179.14380
PERCOLATION/LEAKAGE THROUGH LAYER 7 0.000003 0.91353
AVERAGE HEAD ON TOP OF LAYER 6 1.032
MAXIMUM HEAD ON TOP OF LAYER 6 1.75
LOCATION OF MAXIMUM HEAD IN LAYER 5
(DISTANCE FROM DRAIN) 15.1 FEET
SNOW WATER 6.35 2041157.120
MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4658
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0880

*** 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 1978

LAYER	(INCHES)	(VOL/VOL)
1	3.7882	0.3157
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4184	0.0788
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 1.414

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1993:

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** **
** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE:   U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE:     U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA:   U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA93.D10
OUTPUT DATA FILE:          U:\EMCHEN\PLAINV~1\HELP3\OUTDAT93.OUT

TIME: 17:27    DATE:  5/ 3/1999

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  TITLE: Plainville Landfill - 1993

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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  7
      THICKNESS                =    12.00   INCHES
      POROSITY                 =    0.4730 VOL/VOL
      FIELD CAPACITY           =    0.2220 VOL/VOL
      WILTING POINT            =    0.1040 VOL/VOL
      INITIAL SOIL WATER CONTENT =    0.3889 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.520000001000E-03 CM/SEC
    NOTE:  SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY  5.00
           FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

                           LAYER  2
                           --------

                      TYPE 2 - LATERAL DRAINAGE LAYER
                      MATERIAL TEXTURE NUMBER  2
      THICKNESS                =    12.00   INCHES
      POROSITY                 =    0.4370 VOL/VOL
      FIELD CAPACITY           =    0.0620 VOL/VOL
      WILTING POINT            =    0.0240 VOL/VOL
      INITIAL SOIL WATER CONTENT =    0.4382 VOL/VOL
      EFFECTIVE SAT. HYD. COND.  = 0.579999993000E-02 CM/SEC
      SLOPE                    =     2.00   PERCENT
      DRAINAGE LENGTH          =    530.0   FEET

                           LAYER  3
                           --------

                        TYPE 3 - BARRIER SOIL LINER
                      MATERIAL TEXTURE NUMBER 16
      THICKNESS                =    18.00   INCHES
      POROSITY                 =    0.4270 VOL/VOL
      FIELD CAPACITY           =    0.4180 VOL/VOL
      WILTING POINT            =    0.3670 VOL/VOL
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INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0807 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 29.9 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 75.600 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.992 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 377.150 INCHES
TOTAL INITIAL WATER = 377.150 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28
	1.64	3.10	6.15	2.79	1.56	4.54
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	1.646	1.113	1.995	1.341	0.000	0.003
	0.000	0.057	0.066	0.053	0.000	0.008
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.174	0.863	0.868	2.635	2.896	5.616
	1.665	0.818	3.916	2.683	1.502	1.010
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.4558	0.4476	0.4790	0.5266	0.4835	0.3751
	0.3040	0.2603	0.4104	0.4307	0.3815	0.4853
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1960	0.1889	0.2034	0.2178	0.2027	0.1620
	0.1518	0.1451	0.1716	0.1713	0.1602	0.2005
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.1854	0.1712	0.2025	0.1979	0.2085	0.1927
	0.1812	0.1673	0.1590	0.1691	0.1634	0.1728
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	15.4501	17.6981	16.7126	20.4185	16.5993	10.5788
	7.9074	6.7689	12.2751	11.2452	10.2534	16.2307
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.9096	0.9299	0.9939	1.0038	1.0233	0.9769
	0.8893	0.8209	0.8062	0.8298	0.8286	0.8482
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66 (0.000)	11158243.0	100.00
RUNOFF	6.281 (0.0000)	1723702.62	15.448
EVAPOTRANSPIRATION	25.645 (0.0000)	7037670.50	63.071
LATERAL DRAINAGE COLLECTED FROM LAYER 2	5.03979 (0.00000)	1383059.500	12.39496
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.17124 (0.00000)	595848.687	5.33999
AVERAGE HEAD ON TOP OF LAYER 3	13.512 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.17106 (0.00000)	595799.750	5.33955
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00092 (0.00000)	252.696	0.00226
AVERAGE HEAD ON TOP OF LAYER 6	0.905 (0.000)		
CHANGE IN WATER STORAGE	-0.094 (0.0000)	-25803.00	-0.231

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974

	(INCHES)	(CU. FT.)
PRECIPITATION	2.17	595508.750
RUNOFF	1.011	277422.0000
DRAINAGE COLLECTED FROM LAYER 2	0.01955	5365.71289
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007937	2178.09180
AVERAGE HEAD ON TOP OF LAYER 3	24.000	
MAXIMUM HEAD ON TOP OF LAYER 3	32.787	

LOCATION OF MAXIMUM HEAD IN LAYER 2
(DISTANCE FROM DRAIN) 167.8 FEET
DRAINAGE COLLECTED FROM LAYER 5 0.00676 1854.82056
PERCOLATION/LEAKAGE THROUGH LAYER 7 0.000003 0.77782
AVERAGE HEAD ON TOP OF LAYER 6 1.028
MAXIMUM HEAD ON TOP OF LAYER 6 1.74
LOCATION OF MAXIMUM HEAD IN LAYER 5
(DISTANCE FROM DRAIN) 15.1 FEET
SNOW WATER 1.63 446360.6560
MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4658
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0880

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.5734	0.3811
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4522	0.0807
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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1994:

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** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7

SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA: U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA94.D10
OUTPUT DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\OUTDAT94.OUT

TIME: 17:52 DATE: 5/ 3/1999
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TITLE: Plainville Landfill - 1994

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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 7
THICKNESS = 12.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3895 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0807 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT

SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 28.9 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 78.200 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.999 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 377.157 INCHES
TOTAL INITIAL WATER = 377.157 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28
	1.64	3.10	6.15	2.79	1.56	4.54
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	1.632	1.095	1.947	1.323	0.000	0.003
	0.000	0.055	0.064	0.051	0.000	0.008
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
EVAPOTRANSPIRATION						
TOTALS	1.194	0.869	0.848	2.635	2.896	5.627
	1.665	0.818	3.910	2.680	1.498	1.009
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000
LATERAL DRAINAGE COLLECTED FROM LAYER 2						
TOTALS	0.4559	0.4476	0.4791	0.5268	0.4838	0.3752
	0.3037	0.2600	0.4107	0.4313	0.3823	0.4861
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 3						
TOTALS	0.1960	0.1889	0.2034	0.2179	0.2028	0.1620
	0.1517	0.1451	0.1717	0.1715	0.1603	0.2009
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
LATERAL DRAINAGE COLLECTED FROM LAYER 5						
TOTALS	0.1854	0.1712	0.2026	0.1980	0.2086	0.1927
	0.1813	0.1673	0.1590	0.1692	0.1635	0.1730
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
PERCOLATION/LEAKAGE THROUGH LAYER 7						
TOTALS	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
	0.0001	0.0001	0.0001	0.0001	0.0001	0.0001
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

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DAILY AVERAGE HEAD ON TOP OF LAYER  3
-------------------------------------
 AVERAGES          15.4569  17.6986  16.7131  20.4291  16.6219  10.5786
              7.8994   6.7614  12.2883  11.2702  10.2738  16.2857
 STD. DEVIATIONS     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER  6
-------------------------------------
 AVERAGES           0.9099   0.9301   0.9941   1.0039   1.0236   0.9772
              0.8895   0.8209   0.8062   0.8301   0.8290   0.8489
 STD. DEVIATIONS     0.0000   0.0000   0.0000   0.0000   0.0000   0.0000
              0.0000   0.0000   0.0000   0.0000   0.0000   0.0000

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   AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974
------------------------------------------------------------------------------
                         INCHES          CU. FEET      PERCENT
                    -------------------  -------------  ---------
PRECIPITATION              40.66   (  0.000)  11541992.0    100.00
RUNOFF                  6.178   (  0.0000)   1753694.12    15.194
EVAPOTRANSPIRATION          25.649   (  0.0000)   7280982.00    63.083
LATERAL DRAINAGE COLLECTED    5.04248 (  0.00000)   1431387.500   12.40156
 FROM LAYER  2
PERCOLATION/LEAKAGE THROUGH    2.17204 (  0.00000)   616569.375    5.34197
 LAYER  3
AVERAGE HEAD ON TOP          13.523 (    0.000)
 OF LAYER  3
LATERAL DRAINAGE COLLECTED    2.17163 (  0.00000)   616450.750   5.34094
 FROM LAYER  5
PERCOLATION/LEAKAGE THROUGH    0.00092 (  0.00000)     261.448    0.00227
 LAYER  7
AVERAGE HEAD ON TOP           0.905 (    0.000)
 OF LAYER  6
CHANGE IN WATER STORAGE       -0.087   (  0.0000)    -24715.26    -0.214

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        PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974
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                           (INCHES)    (CU. FT.)
                           ----------   -------------
   PRECIPITATION                    2.17       615989.187
   RUNOFF                       0.983      279047.1250
   DRAINAGE COLLECTED FROM LAYER  2        0.01955       5550.24756
   PERCOLATION/LEAKAGE THROUGH LAYER  3     0.007937      2252.99976
   AVERAGE HEAD ON TOP OF LAYER  3          24.000
   MAXIMUM HEAD ON TOP OF LAYER  3          32.78
   LOCATION OF MAXIMUM HEAD IN LAYER  2
       (DISTANCE FROM DRAIN)           167.8 FEET
   DRAINAGE COLLECTED FROM LAYER  5        0.00676       1918.96143
   PERCOLATION/LEAKAGE THROUGH LAYER  7     0.000003        0.80470
   AVERAGE HEAD ON TOP OF LAYER  6           1.028
   MAXIMUM HEAD ON TOP OF LAYER  6           1.74
```

LOCATION OF MAXIMUM HEAD IN LAYER 5
(DISTANCE FROM DRAIN) 15.1 FEET
SNOW WATER 1.63 461711.6250
MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4658
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0880

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.5870	0.3823
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4525	0.0807
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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1995:

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** **
** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA: U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA95.D10
OUTPUT DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\OUTDAT95.OUT

TIME: 17:58 DATE: 5/ 3/1999

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TITLE: Plainville Landfill - 1995

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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 7
THICKNESS = 12.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3905 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18

THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0808 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 28.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 80.800 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 6.011 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 377.169 INCHES
TOTAL INITIAL WATER = 377.169 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28

```
           1.64    3.10    6.15    2.79    1.56    4.54
 STD. DEVIATIONS      0.00    0.00    0.00    0.00    0.00    0.00
           0.00    0.00    0.00    0.00    0.00    0.00

RUNOFF
------
 TOTALS          1.621   1.079   1.903   1.306   0.000   0.003
           0.000   0.053   0.062   0.049   0.000   0.007
 STD. DEVIATIONS      0.000   0.000   0.000   0.000   0.000   0.000
           0.000   0.000   0.000   0.000   0.000   0.000

EVAPOTRANSPIRATION
------------------
 TOTALS          1.215   0.874   0.848   2.635   2.896   5.660
           1.665   0.818   3.908   2.680   1.497   1.009
 STD. DEVIATIONS      0.000   0.000   0.000   0.000   0.000   0.000
           0.000   0.000   0.000   0.000   0.000   0.000

LATERAL DRAINAGE COLLECTED FROM LAYER  2
----------------------------------------
 TOTALS          0.4582  0.4476  0.4791  0.5271  0.4842  0.3751
           0.3014  0.2579  0.4100  0.4304  0.3814  0.4858
 STD. DEVIATIONS      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

PERCOLATION/LEAKAGE THROUGH LAYER  3
------------------------------------
 TOTALS          0.1968  0.1889  0.2034  0.2180  0.2030  0.1621
           0.1514  0.1447  0.1714  0.1713  0.1602  0.2007
 STD. DEVIATIONS      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
 TOTALS          0.1858  0.1715  0.2028  0.1981  0.2088  0.1929
           0.1813  0.1671  0.1588  0.1689  0.1633  0.1728
 STD. DEVIATIONS      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
 TOTALS          0.0001  0.0001  0.0001  0.0001  0.0001  0.0001
           0.0001  0.0001  0.0001  0.0001  0.0001  0.0001
 STD. DEVIATIONS      0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
           0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

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

DAILY AVERAGE HEAD ON TOP OF LAYER  3
-------------------------------------
 AVERAGES         15.5891  17.6990  16.7133  20.4463  16.6527  10.5872
           7.8398   6.7084  12.2390  11.2360  10.2507  16.2607

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

0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 6

```
 AVERAGES          0.9117  0.9320  0.9952  1.0046  1.0244  0.9780
                   0.8895  0.8202  0.8052  0.8290  0.8280  0.8481
 STD. DEVIATIONS   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                   0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
```

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974

```
---------------------------------------------------------------------------
                         INCHES          CU. FEET      PERCENT
                    -------------------  -------------  ---------
PRECIPITATION              40.66  (  0.000)  11925742.0    100.00
RUNOFF                     6.083  ( 0.0000)  1784149.25    14.960
EVAPOTRANSPIRATION        25.704  ( 0.0000)  7539194.00    63.218
LATERAL DRAINAGE COLLECTED   5.03825 ( 0.00000)  1477739.370  12.39117
  FROM LAYER 2
PERCOLATION/LEAKAGE THROUGH  2.17173 ( 0.00000)  636977.687   5.34120
  LAYER 3
AVERAGE HEAD ON TOP        13.519 (  0.000)
  OF LAYER 3
LATERAL DRAINAGE COLLECTED   2.17210 ( 0.00000)  637086.625   5.34211
  FROM LAYER 5
PERCOLATION/LEAKAGE THROUGH  0.00092 ( 0.00000)     270.193   0.00227
  LAYER 7
AVERAGE HEAD ON TOP         0.905 (  0.000)
  OF LAYER 6
CHANGE IN WATER STORAGE    -0.106  ( 0.0000)   -31095.52    -0.261
```

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974

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----------------------------------------------------------------------
                                      (INCHES)     (CU. FT.)
                                     ----------  -------------
  PRECIPITATION                          2.17      636469.750
  RUNOFF                                0.958     280861.0310
  DRAINAGE COLLECTED FROM LAYER 2     0.01955      5734.78320
  PERCOLATION/LEAKAGE THROUGH LAYER 3  0.007937    2327.90796
  AVERAGE HEAD ON TOP OF LAYER 3       24.000
  MAXIMUM HEAD ON TOP OF LAYER 3       32.78
  LOCATION OF MAXIMUM HEAD IN LAYER 2
    (DISTANCE FROM DRAIN)             167.8 FEET
  DRAINAGE COLLECTED FROM LAYER 5     0.00676      1984.17786
  PERCOLATION/LEAKAGE THROUGH LAYER 7  0.000003    0.83200
  AVERAGE HEAD ON TOP OF LAYER 6       1.029
  MAXIMUM HEAD ON TOP OF LAYER 6       1.74
  LOCATION OF MAXIMUM HEAD IN LAYER 5
    (DISTANCE FROM DRAIN)              15.1 FEET
  SNOW WATER                             1.63     477062.7190
```

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.4658
MINIMUM VEG. SOIL WATER (VOL/VOL) 0.0880

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.5808	0.3817
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4522	0.0807
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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1996:

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** **
** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
** **
** **
****
****

PRECIPITATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA: U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA96.D10
OUTPUT DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\OUTDAT96.OUT

TIME: 18: 7 DATE: 5/ 3/1999

****

TITLE: Plainville Landfill - 1996

****

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 7
THICKNESS = 12.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3690 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00 FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL

WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0802 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 58.6 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 83.400 ACRES

EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.753 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 376.902 INCHES
TOTAL INITIAL WATER = 376.902 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

****

AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28
	1.64	3.10	6.15	2.79	1.56	4.54
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00

RUNOFF

TOTALS	2.033	1.424	3.094	1.081	0.000	0.006
	0.000	0.112	0.129	0.102	0.000	0.014
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

EVAPOTRANSPIRATION

TOTALS	0.674	0.761	0.912	3.162	2.878	5.587
	1.665	0.818	3.933	2.684	1.504	1.011
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000
	0.000	0.000	0.000	0.000	0.000	0.000

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS	0.3846	0.4358	0.4673	0.5502	0.4816	0.3746
	0.3040	0.2602	0.4069	0.4167	0.3617	0.4748
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS	0.1727	0.1851	0.1995	0.2258	0.2018	0.1618
	0.1518	0.1451	0.1700	0.1689	0.1572	0.1969
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS	0.1787	0.1601	0.1942	0.1954	0.2069	0.1915
	0.1805	0.1669	0.1584	0.1679	0.1617	0.1703
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 7

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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES	11.4732	16.9785	16.0611	21.8209	16.4461	10.5445
	7.9066	6.7675	11.9871	10.8367	9.7219	15.6151
STD. DEVIATIONS	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000
	0.0000	0.0000	0.0000	0.0000	0.0000	0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES	0.8770	0.8700	0.9530	0.9908	1.0154	0.9712

0.8859 0.8189 0.8032 0.8238 0.8199 0.8355
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974

	INCHES	CU. FEET	PERCENT
PRECIPITATION	40.66 (0.000)	12309491.0	100.00
RUNOFF	7.995 (0.0000)	2420272.00	19.662
EVAPOTRANSPIRATION	25.590 (0.0000)	7747119.50	62.936
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.91846 (0.00000)	1489023.750	12.09655
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.13652 (0.00000)	646814.187	5.25460
AVERAGE HEAD ON TOP OF LAYER 3	13.013 (0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.13254 (0.00000)	645610.812	5.24482
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00091 (0.00000)	274.275	0.00223
AVERAGE HEAD ON TOP OF LAYER 6	0.889 (0.000)		
CHANGE IN WATER STORAGE	0.014 (0.0000)	4092.86	0.033

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974

	(INCHES)	(CU. FT.)
PRECIPITATION	2.17	656950.187
RUNOFF	1.608	486697.5310
DRAINAGE COLLECTED FROM LAYER 2	0.01955	5919.31836
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007937	2402.81567
AVERAGE HEAD ON TOP OF LAYER 3	24.000	
MAXIMUM HEAD ON TOP OF LAYER 3	32.78	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	167.8 FEET	
DRAINAGE COLLECTED FROM LAYER 5	0.00670	2028.82922
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000003	0.85145
AVERAGE HEAD ON TOP OF LAYER 6	1.019	
MAXIMUM HEAD ON TOP OF LAYER 6	1.73	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	15.0 FEET	
SNOW WATER	1.63	492413.719
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4658	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0880	

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.4380	0.3698
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4470	0.0804
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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1997:

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** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA: U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA97.D10
OUTPUT DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\OUTDAT97.OUT

TIME: 18:10 DATE: 5/ 3/1999

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TITLE: Plainville Landfill - 1997

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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 7
THICKNESS = 12.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3497 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0798 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 82.1 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 86.000 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.522 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 376.663 INCHES

TOTAL INITIAL WATER = 376.663 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28
	1.64	3.10	6.15	2.79	1.56	4.54
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	2.510	0.944	3.398	1.055	0.000	0.008
	0.000	0.157	0.180	0.142	0.000	0.018
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000

0.000 0.000 0.000 0.000 0.000 0.000

EVAPOTRANSPIRATION

TOTALS 0.620 0.708 0.703 3.150 2.879 5.533
1.665 0.817 3.940 2.687 1.508 1.012
STD. DEVIATIONS 0.000 0.000 0.000 0.000 0.000 0.000
0.000 0.000 0.000 0.000 0.000 0.000

LATERAL DRAINAGE COLLECTED FROM LAYER 2

TOTALS 0.3680 0.3956 0.4446 0.5445 0.4795 0.3733
0.3037 0.2600 0.4039 0.4058 0.3483 0.4670
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 3

TOTALS 0.1683 0.1751 0.1922 0.2238 0.2006 0.1614
0.1517 0.1451 0.1685 0.1673 0.1551 0.1941
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER 5

TOTALS 0.1748 0.1543 0.1881 0.1891 0.2026 0.1888
0.1788 0.1659 0.1575 0.1667 0.1602 0.1683
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

PERCOLATION/LEAKAGE THROUGH LAYER 7

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

AVERAGES OF MONTHLY AVERAGED DAILY HEADS (INCHES)

DAILY AVERAGE HEAD ON TOP OF LAYER 3

AVERAGES 10.7336 15.0864 14.8043 21.4771 16.2499 10.4727
7.8995 6.7614 11.7286 10.5542 9.3603 15.1316
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER 6

AVERAGES 0.8577 0.8385 0.9232 0.9591 0.9944 0.9574
0.8775 0.8140 0.7985 0.8182 0.8125 0.8261
STD. DEVIATIONS 0.0000 0.0000 0.0000 0.0000 0.0000 0.0000
0.0000 0.0000 0.0000 0.0000 0.0000 0.0000

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.66	(0.000)	12693240.0	100.00
RUNOFF	8.411	(0.0000)	2625888.25	20.687
EVAPOTRANSPIRATION	25.222	(0.0000)	7873744.50	62.031
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.79402	(0.00000)	1496596.500	11.79050
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.10323	(0.00000)	656585.000	5.17271
AVERAGE HEAD ON TOP OF LAYER 3	12.522	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.09535	(0.00000)	654126.750	5.15335
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00089	(0.00000)	278.350	0.00219
AVERAGE HEAD ON TOP OF LAYER 6	0.873	(0.000)		
CHANGE IN WATER STORAGE	0.134	(0.0000)	41832.96	0.330

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974

	(INCHES)	(CU. FT.)
PRECIPITATION	2.17	677430.625
RUNOFF	1.628	508197.6250
DRAINAGE COLLECTED FROM LAYER 2	0.01955	6103.85303
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007937	2477.72363
AVERAGE HEAD ON TOP OF LAYER 3	24.000	
MAXIMUM HEAD ON TOP OF LAYER 3	32.78	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	167.8 FEET	
DRAINAGE COLLECTED FROM LAYER 5	0.00655	2044.87817
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000003	0.85996
AVERAGE HEAD ON TOP OF LAYER 6	0.996	
MAXIMUM HEAD ON TOP OF LAYER 6	1.69	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	14.8 FEET	
SNOW WATER	1.63	507764.750
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4658	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0880	

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.3238	0.3603
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4431	0.0802
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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1998:

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** **
** HYDROLOGIC EVALUATION OF LANDFILL PERFORMANCE **
** HELP MODEL VERSION 3.05 (30 MARCH 1996) **
** DEVELOPED BY ENVIRONMENTAL LABORATORY **
** USAE WATERWAYS EXPERIMENT STATION **
** FOR USEPA RISK REDUCTION ENGINEERING LABORATORY **
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PRECIPITATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA4.D4
TEMPERATURE DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA7.D7
SOLAR RADIATION DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA13.D13
EVAPOTRANSPIRATION DATA: U:\EMCHEN\PLAINV~1\HELP3\DATA11.D11
SOIL AND DESIGN DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\DATA98.D10
OUTPUT DATA FILE: U:\EMCHEN\PLAINV~1\HELP3\OUTDAT98.OUT

TIME: 18:12 DATE: 5/ 3/1999

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TITLE: Plainville Landfill - 1998

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 7
THICKNESS = 12.00 INCHES
POROSITY = 0.4730 VOL/VOL
FIELD CAPACITY = 0.2220 VOL/VOL
WILTING POINT = 0.1040 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.3322 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.520000001000E-03 CM/SEC
NOTE: SATURATED HYDRAULIC CONDUCTIVITY IS MULTIPLIED BY 5.00
FOR ROOT CHANNELS IN TOP HALF OF EVAPORATIVE ZONE.

LAYER 2

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 12.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4382 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 530.0 FEET

LAYER 3

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SEC

LAYER 4

TYPE 1 - VERTICAL PERCOLATION LAYER
MATERIAL TEXTURE NUMBER 18
THICKNESS = 1200.00 INCHES
POROSITY = 0.6710 VOL/VOL
FIELD CAPACITY = 0.2920 VOL/VOL
WILTING POINT = 0.0770 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.2920 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000005000E-02 CM/SEC

LAYER 5

TYPE 2 - LATERAL DRAINAGE LAYER
MATERIAL TEXTURE NUMBER 2
THICKNESS = 18.00 INCHES
POROSITY = 0.4370 VOL/VOL
FIELD CAPACITY = 0.0620 VOL/VOL
WILTING POINT = 0.0240 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.0794 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.579999993000E-02 CM/SEC
SLOPE = 2.00 PERCENT
DRAINAGE LENGTH = 100.0 FEET

LAYER 6

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

LAYER 7

TYPE 3 - BARRIER SOIL LINER
MATERIAL TEXTURE NUMBER 16
THICKNESS = 18.00 INCHES
POROSITY = 0.4270 VOL/VOL
FIELD CAPACITY = 0.4180 VOL/VOL
WILTING POINT = 0.3670 VOL/VOL
INITIAL SOIL WATER CONTENT = 0.4270 VOL/VOL
EFFECTIVE SAT. HYD. COND. = 0.100000001000E-06 CM/SE

GENERAL DESIGN AND EVAPORATIVE ZONE DATA

NOTE: SCS RUNOFF CURVE NUMBER WAS COMPUTED FROM DEFAULT
SOIL DATA BASE USING SOIL TEXTURE # 7 WITH A
POOR STAND OF GRASS, A SURFACE SLOPE OF 2.%
AND A SLOPE LENGTH OF 530. FEET.

SCS RUNOFF CURVE NUMBER = 82.40
FRACTION OF AREA ALLOWING RUNOFF = 100.0 PERCENT
AREA PROJECTED ON HORIZONTAL PLANE = 88.500 ACRES
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
INITIAL WATER IN EVAPORATIVE ZONE = 5.312 INCHES
UPPER LIMIT OF EVAPORATIVE STORAGE = 6.987 INCHES
LOWER LIMIT OF EVAPORATIVE STORAGE = 1.320 INCHES
INITIAL SNOW WATER = 0.000 INCHES
INITIAL WATER IN LAYER MATERIALS = 376.445 INCHES

TOTAL INITIAL WATER = 376.445 INCHES
TOTAL SUBSURFACE INFLOW = 0.00 INCHES/YEAR

EVAPOTRANSPIRATION AND WEATHER DATA

NOTE: EVAPOTRANSPIRATION DATA WAS OBTAINED FROM
PROVIDENCE RHODE ISLAND

STATION LATITUDE = 41.73 DEGREES
MAXIMUM LEAF AREA INDEX = 4.50
START OF GROWING SEASON (JULIAN DATE) = 121
END OF GROWING SEASON (JULIAN DATE) = 290
EVAPORATIVE ZONE DEPTH = 15.0 INCHES
AVERAGE ANNUAL WIND SPEED = 10.60 MPH
AVERAGE 1ST QUARTER RELATIVE HUMIDITY = 64.00 %
AVERAGE 2ND QUARTER RELATIVE HUMIDITY = 65.00 %
AVERAGE 3RD QUARTER RELATIVE HUMIDITY = 72.00 %
AVERAGE 4TH QUARTER RELATIVE HUMIDITY = 70.00 %

NOTE: PRECIPITATION DATA FOR PROVIDENCE RHODE ISLAND
WAS ENTERED FROM THE DEFAULT DATA FILE.

NOTE: TEMPERATURE DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND

NORMAL MEAN MONTHLY TEMPERATURE (DEGREES FAHRENHEIT)

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
28.20	29.30	37.40	47.90	57.60	66.80
72.50	71.10	63.50	53.20	43.40	32.20

NOTE: SOLAR RADIATION DATA WAS SYNTHETICALLY GENERATED USING
COEFFICIENTS FOR PROVIDENCE RHODE ISLAND
AND STATION LATITUDE = 41.73 DEGREES

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 1974 THROUGH 1974

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	4.45	3.04	4.51	2.86	2.74	3.28
	1.64	3.10	6.15	2.79	1.56	4.54
STD. DEVIATIONS	0.00	0.00	0.00	0.00	0.00	0.00
	0.00	0.00	0.00	0.00	0.00	0.00
RUNOFF						
TOTALS	2.835	0.613	3.626	0.750	0.000	0.009
	0.000	0.192	0.219	0.172	0.000	0.021
STD. DEVIATIONS	0.000	0.000	0.000	0.000	0.000	0.000

```
                 0.000   0.000   0.000   0.000   0.000   0.000

EVAPOTRANSPIRATION
------------------
 TOTALS           0.619   0.708   0.699   3.145   2.677   5.695
                 1.662   0.815   3.946   2.691   1.512   1.013
 STD. DEVIATIONS     0.000   0.000   0.000   0.000   0.000   0.000
                 0.000   0.000   0.000   0.000   0.000   0.000

LATERAL DRAINAGE COLLECTED FROM LAYER  2
----------------------------------------
 TOTALS           0.3647  0.3802  0.4377  0.5338  0.4773  0.3688
                 0.3017  0.2583  0.4006  0.3959  0.3374  0.4597
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

PERCOLATION/LEAKAGE THROUGH LAYER  3
------------------------------------
 TOTALS           0.1672  0.1698  0.1907  0.2202  0.1993  0.1604
                 0.1514  0.1448  0.1671  0.1658  0.1535  0.1916
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

LATERAL DRAINAGE COLLECTED FROM LAYER  5
----------------------------------------
 TOTALS           0.1711  0.1518  0.1847  0.1856  0.1998  0.1867
                 0.1774  0.1649  0.1565  0.1656  0.1589  0.1667
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

PERCOLATION/LEAKAGE THROUGH LAYER  7
------------------------------------
 TOTALS           0.0001  0.0001  0.0001  0.0001  0.0001  0.0001
                 0.0001  0.0001  0.0001  0.0001  0.0001  0.0001
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000


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

DAILY AVERAGE HEAD ON TOP OF LAYER  3
-------------------------------------
 AVERAGES          10.5403  14.0990  14.5525  20.8451  16.0244  10.2982
                 7.8472   6.7171  11.4723  10.2963   9.0677  14.7106
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000

DAILY AVERAGE HEAD ON TOP OF LAYER  6
-------------------------------------
 AVERAGES          0.8398  0.8246  0.9062  0.9413  0.9807  0.9468
                 0.8703  0.8093  0.7938  0.8126  0.8056  0.8180
 STD. DEVIATIONS     0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
                 0.0000  0.0000  0.0000  0.0000  0.0000  0.0000
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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 1974 THROUGH 1974

	INCHES		CU. FEET	PERCENT
PRECIPITATION	40.66	(0.000)	13062229.0	100.00
RUNOFF	8.438	(0.0000)	2710742.50	20.753
EVAPOTRANSPIRATION	25.181	(0.0000)	8089603.00	61.931
LATERAL DRAINAGE COLLECTED FROM LAYER 2	4.71620	(0.00000)	1515102.620	11.59911
PERCOLATION/LEAKAGE THROUGH LAYER 3	2.08185	(0.00000)	668803.437	5.12013
AVERAGE HEAD ON TOP OF LAYER 3	12.206	(0.000)		
LATERAL DRAINAGE COLLECTED FROM LAYER 5	2.06976	(0.00000)	664920.312	5.09040
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.00088	(0.00000)	283.265	0.00217
AVERAGE HEAD ON TOP OF LAYER 6	0.862	(0.000)		
CHANGE IN WATER STORAGE	0.252	(0.0000)	80803.95	0.619

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PEAK DAILY VALUES FOR YEARS 1974 THROUGH 1974

	(INCHES)	(CU. FT.)
PRECIPITATION	2.17	697123.375
RUNOFF	1.898	609747.2500
DRAINAGE COLLECTED FROM LAYER 2	0.01953	6273.96143
PERCOLATION/LEAKAGE THROUGH LAYER 3	0.007929	2547.25854
AVERAGE HEAD ON TOP OF LAYER 3	23.959	
MAXIMUM HEAD ON TOP OF LAYER 3	32.74	
LOCATION OF MAXIMUM HEAD IN LAYER 2 (DISTANCE FROM DRAIN)	167.7 FEET	
DRAINAGE COLLECTED FROM LAYER 5	0.00646	2075.44727
PERCOLATION/LEAKAGE THROUGH LAYER 7	0.000003	0.87391
AVERAGE HEAD ON TOP OF LAYER 6	0.983	
MAXIMUM HEAD ON TOP OF LAYER 6	1.67	
LOCATION OF MAXIMUM HEAD IN LAYER 5 (DISTANCE FROM DRAIN)	14.7 FEET	
SNOW WATER	1.63	522525.344
MAXIMUM VEG. SOIL WATER (VOL/VOL)	0.4658	
MINIMUM VEG. SOIL WATER (VOL/VOL)	0.0880	

*** 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 1974

LAYER	(INCHES)	(VOL/VOL)
1	4.2266	0.3522
2	5.2583	0.4382
3	7.6860	0.4270
4	350.4000	0.2920
5	1.4397	0.0800
6	0.0000	0.0000
7	7.6860	0.4270

SNOW WATER 0.000

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Appendix B: Calculated Monthly Leachate Amounts

Year	Month	Area (acres)	Area (sq in)	Height (in)	Volume (cu in)	Volume (gal)	Actual (gal)	HELP precip (in)	pred/HELP precip (gal/in)	Real precip (in)	actual/real precip (gal/in)	pred/act (per in)
1993	Jan	75.6	474211584	0.1854	87918828	380601	unknown	4.45	85528	2.42	unknown	unknown
	Feb	75.6	474211584	0.1712	81185023	351450	1614638	3.04	115609	5.06	319098	0.36
	Mar	75.6	474211584	0.2025	96027846	415705	2015588	4.51	92174	6.99	288353	0.32
	Apr	75.6	474211584	0.1979	93846472	406262	4334103	2.86	142050	5.02	863367	0.16
	May	75.6	474211584	0.2085	98873115	428022	1496046	2.74	156212	1.12	1335755	0.12
	Jun	75.6	474211584	0.1927	91380572	395587	596681	3.28	120606	1.4	426201	0.28
	Jul	75.6	474211584	0.1812	85927139	371979	255402	1.64	226816	2.18	117157	1.94
	Aug	75.6	474211584	0.1673	79335598	343444	156429	3.1	110788	1.23	127178	0.87
	Sept	75.6	474211584	0.159	75399642	326405	125482	6.15	53074	4.08	30755	1.73
	Oct	75.6	474211584	0.1691	80189179	347139	126813	2.79	124423	3.55	35722	3.48
	Nov	75.6	474211584	0.1634	77486173	335438	137211	1.56	215024	3.35	40959	5.25
	Dec	75.6	474211584	0.1728	81943762	354735	286269	4.54	78135	5.76	49699	1.57
total						4076167	11144662	36.21	1434912	39.74	3634245	0.39
1994	Jan	78.2	490520448	0.1854	90942491	393690	275974	4.45	88470	5.53	49905	1.77
	Feb	78.2	490520448	0.1712	83977101	363537	471933	3.04	119585	2.1	224730	0.53
	Mar	78.2	490520448	0.2026	99379443	430214	2028213	4.51	95391	7.19	282088	0.34
	Apr	78.2	490520448	0.198	97123049	420446	2302847	2.86	147009	2.07	1112486	0.13
	May	78.2	490520448	0.2086	102322565	442955	988952	2.74	161662	2.98	331863	0.49
	Jun	78.2	490520448	0.1927	94523290	409192	429866	3.28	124754	2.7	159210	0.78
	Jul	78.2	490520448	0.1813	88931357	384984	235496	1.64	234746	1.34	175743	1.34
	Aug	78.2	490520448	0.1673	82064071	355256	169053	3.1	114599	6.43	26291	4.36
	Sept	78.2	490520448	0.159	77992751	337631	153192	6.15	54899	4.12	37183	1.48
	Oct	78.2	490520448	0.1692	82996060	359290	112717	2.79	128778	0.4	281793	0.46
	Nov	78.2	490520448	0.1635	80200093	347187	134748	1.56	222555	5.34	25234	8.82
	Dec	78.2	490520448	0.173	84860038	367359	612391	4.54	80916	4.58	133710	0.61
total						4611742	7915382	40.66	113422	44.78	176762	0.64

Year	Month	Area (acres)	Area (sq in)	Height (in)	Volume (cu in)	Volume (gal)	Actual (gal)	HELP precip (in)	pred/HELP precip (gal/in)	Real precip (in)	actual/real precip (gal/in)	pred/act (per in)
1995	Jan	80.8	506829312	0.1858	94168886	407658	1313727	4.45	91608	3.67	357964	0.26
	Feb	80.8	506829312	0.1715	86921227	376282	808324	3.04	123777	3.14	257428	0.48
	Mar	80.8	506829312	0.2028	102784984	444957	1175847	4.51	98660	2.03	579235	0.17
	Apr	80.8	506829312	0.1981	100402887	434645	674693	2.86	151974	3.34	202004	0.75
	May	80.8	506829312	0.2088	105825960	458121	410396	2.74	167197	2.83	145016	1.15
	Jun	80.8	506829312	0.1929	97767374	423235	303918	3.28	129035	2.89	105162	1.23
	Jul	80.8	506829312	0.1813	91888154	397784	194945	1.64	242551	1.17	166620	1.46
	Aug	80.8	506829312	0.1671	84691178	366628	132290	3.1	118267	1.8	73494	1.61
	Sept	80.8	506829312	0.1588	80484495	348418	132405	6.15	56653	4.06	32612	1.74
	Oct	80.8	506829312	0.1689	85603471	370578	238617	2.79	132824	6.37	37459	3.55
	Nov	80.8	506829312	0.1633	82765227	358291	337360	1.56	229674	5.1	66149	3.47
	Dec	80.8	506829312	0.1728	87580105	379135	369530	4.54	83510	2.18	169509	0.49
total						4765731	6092052	40.66	117209	38.58	157907	0.74
1996	Jan	83.4	523138176	0.1787	93484792	404696	1399226	4.45	90943	5.02	278730	0.33
	Feb	83.4	523138176	0.1601	83754422	362573	2024788	3.04	119268	2.19	924561	0.13
	Mar	83.4	523138176	0.1942	101593434	439798	1920993	4.51	97516	2.71	708854	0.14
	Apr	83.4	523138176	0.1954	102221200	442516	2356062	2.86	154726	4.88	482800	0.32
	May	83.4	523138176	0.2069	108237289	468560	1719187	2.74	171007	2.44	704585	0.24
	Jun	83.4	523138176	0.1915	100180961	433684	822981	3.28	132221	2.17	379254	0.35
	Jul	83.4	523138176	0.1805	94426441	408772	553650	1.64	249252	5.57	99399	2.51
	Aug	83.4	523138176	0.1669	87311762	377973	424218	3.1	121927	2.19	193707	0.63
	Sept	83.4	523138176	0.1584	82865087	358723	385110	6.15	58329	5.72	67327	0.87
	Oct	83.4	523138176	0.1679	87834900	380238	516149	2.79	136286	6.2	83250	1.64
	Nov	83.4	523138176	0.1617	84591443	366197	730765	1.56	234741	2.38	307044	0.76
	Dec	83.4	523138176	0.1703	89090431	385673	2213719	4.54	84950	6.59	335921	0.25
total						4829403	15066848	40.66	118775	48.06	313501	0.38

Year	Month	Area (acres)	Area (sq in)	Height (in)	Volume (cu in)	Volume (gal)	Actual (gal)	HELP precip (in)	pred/HELP precip (gal/in)	Real precip (in)	actual/real precip (gal/in)	pred/act (per in)
1997	Jan	86	539447040	0.1748	94295343	408205	1575134	4.45	91731	4.27	368884	0.25
	Feb	86	539447040	0.1543	83236678	360332	1285576	3.04	118530	1.93	666102	0.18
	Mar	86	539447040	0.1881	101469988	439264	1044860	4.51	97398	4.86	214992	0.45
	Apr	86	539447040	0.1891	102009435	441599	2455569	2.86	154405	4.69	523575	0.29
	May	86	539447040	0.2026	109291970	473125	1272208	2.74	172674	2.69	472940	0.37
	Jun	86	539447040	0.1888	101847601	440899	703729	3.28	134420	2.24	314165	0.43
	Jul	86	539447040	0.1788	96453131	417546	452283	1.64	254601	1.44	314085	0.81
	Aug	86	539447040	0.1659	89494264	387421	332364	3.1	124975	6.32	52589	2.38
	Sept	86	539447040	0.1575	84962909	367805	306379	6.15	59806	0.97	315855	0.19
	Oct	86	539447040	0.1667	89925822	389289	339278	2.79	139530	1.8	188488	0.74
	Nov	86	539447040	0.1602	86419416	374110	411651	1.56	239814	6.06	67929	3.53
	Dec	86	539447040	0.1683	90788937	393026	519017	4.54	86570	2.84	182752	0.47
total						4892621	10698048	40.66	120330	40.11	266718	0.45
1998	Jan	88.5	555128640	0.1711	94982510	411180	767303	4.45	92400	6.55	117145	0.79
	Feb	88.5	555128640	0.1518	84268528	364799	1115516	3.04	120000	5.58	199913	0.60
	Mar	88.5	555128640	0.1847	102532260	443863	1589453	4.51	98417	5.86	271238	0.36
	Apr	88.5	555128640	0.1856	103031876	446025	1153145	2.86	155953	4.91	234856	0.66
	May	88.5	555128640	0.1998	110914702	480150	1508622	2.74	175237	6.05	249359	0.70
	Jun	88.5	555128640	0.1867	103642517	448669	1823523	3.28	136789	9.62	189555	0.72
	Jul	88.5	555128640	0.1774	98479821	426320	1855220	1.64	259951	1.37	1354175	0.19
	Aug	88.5	555128640	0.1649	91540713	396280	567000	3.1	127832	2.39	237238	0.54
	Sept	88.5	555128640	0.1565	86877632	376094	383246	6.15	61153	2.3	166629	0.37
	Oct	88.5	555128640	0.1656	91929303	397962	369653	2.79	142639	3.78	97792	1.46
	Nov	88.5	555128640	0.1589	88209941	381861	282902	1.56	244783	2.76	102501	2.39
	Dec	88.5	555128640	0.1667	92539944	400606	262772	4.54	88239	1.27	206907	0.43
total						4973808	11678355	40.66	122327	52.44	222699	0.55

Appendix C: Groundwater Modeling

This appendix describes the development of a computer groundwater model using the United States Geological Survey (USGS) Modular Finite-Difference Ground-Water Flow Model (MODFLOW) (McDonald and Harbaugh, 1988). This method of analysis was chosen so that quantitative groundwater predictions could be made in the Master of Engineering Plainville Landfill Project's three areas of study. Three other groundwater models have been developed previously for portions of the area of concern. One of the models was developed by Eckenfelder Inc. (1998), one by Dufresne-Henry Inc. (1997), and another by Whitman and Howard (1996). These models were reviewed in detail during the development and construction of the model reported here.

C.1 PURPOSE

The purpose of this model is to provide a tool for the three areas of study for the Master of Engineering Plainville Landfill project. Using this model, local effects of lowering the groundwater table, via pumping upgradient of the landfill, will be determined. Radiuses of influence of the extraction wells of the remediation system will be established. Furthermore, the possibility of contamination reaching proposed drinking water wells will be examined.

C.2 CONCEPTUAL MODEL

The model area embodies typical New England geology. The stratified-drift aquifer consists of outwash that has been deposited by glacial meltwaters when glaciers retreated from New England (USGS, 1984). These depositions created small, permeable valley-filled aquifers in most of Massachusetts.

Plainville, Massachusetts is located within the Taunton River Watershed. The regional topography in the vicinity of Plainville is characterized by numerous north to south trending buried glacial outwash valleys that are underlain by bedrock. These outwash valleys constitute highly productive aquifers that provide groundwater resources in the region. The elevations in this area range from 450 feet above sea level at the top of the landfill to approximately 125 feet above sea level in the outwash valley.

The glacial outwash valley consists of glacial outwash that overlies fractured bedrock beginning north of the cranberry bogs and trending southward from Rabbit Hill Pond towards Lake Mirimichi. The glacial outwash consists of fine to coarse sand, some gravel, and little to trace amounts of silt and clay. These outwash deposits increase from as little as eight feet thick to approximately fifty feet thick in the vicinity of Lake Mirimichi. The outwash conductivity ranges from 150 ft/d to 290 ft/d (Eckenfelder, 1998). The bedrock, which underlies the outwash valley, consists primarily of Dedham Granite with a small area to the east of the landfill underlain by Wamsutta Formation sandstone and conglomerate (Eckenfelder, 1994). Approximately the top ten feet of the bedrock is fractured and provides groundwater resources to the Plainville area. The hydraulic conductivity within the fractured bedrock ranges from virtually no flow at 0.00003 ft/d, to 148 ft/d (Eckenfelder, 1998). Glacial till borders the outwash valley on both the west and east. The glacial till is virtually nonconductive - hydraulic conductivity ranges from 3.1 ft/d to 45 ft/d - and consequently fences in this valley channeling the groundwater flow through the outwash layer (Eckenfelder, 1998). There are also several lenses of relatively coarse-grained glacial till within and beneath the glacial outwash of this valley. A typical cross-section is shown in Figure C-1.

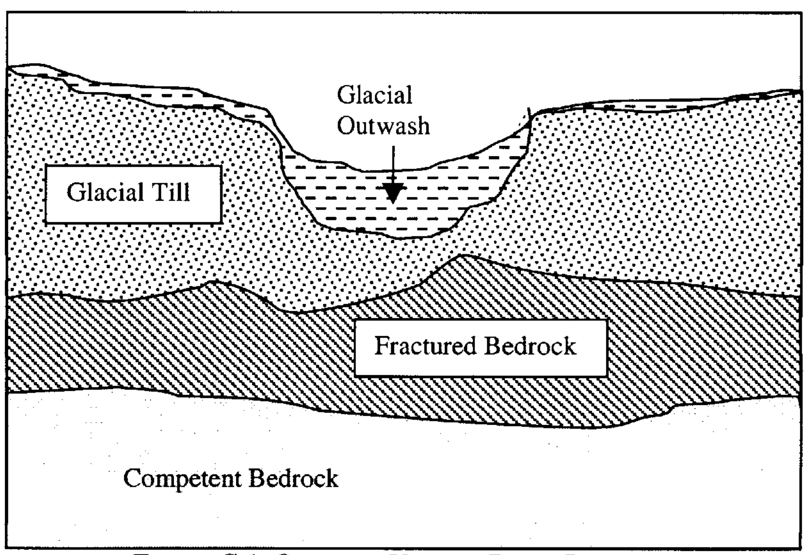


FIGURE C-1: OUTWASH VALLEY CROSS SECTION

C.3 Data Collection

In addition to visiting the site, the group members gathered data from previous studies performed in the area. These data included quarterly reports on chemicals detected in observation wells and ground and surface water elevation measurements, borehole data providing information about the site geology, previous studies done by various consulting companies, and background information on the history of the site. USGS maps of the area were also utilized (Williams & Willey, 1973; Williams & Willey, 1987).

C.4 Model Description

The USGS MODFLOW, an industry standard for groundwater flow modeling, was used in conjunction with the user-friendly interface developed by Waterloo Hydrogeologic, Inc. MODFLOW determines the distribution of hydraulic head and groundwater flow field over time and space.

MODFLOW is described by its authors as a modular computer program for three-dimensional groundwater flow modeling (McDonald and Harbaugh, 1988). The code is structured into independent subprograms or modules. One or more modules together make a "package". These packages address specific aspects of the groundwater system. The MODFLOW packages used for the Plainville project include:

- Basic package – establishes basic model structure and computer code bookkeeping and output instructions.
- Block-centered flow package – establishes geometry and hydraulic properties of model grid.
- River package – represents river underlain by variable permeability bottom.
- Recharge package – specifies the rate of rainfall recharge into the surface of the modeled area.
- Well package – represents pumping/injection or observation wells.
- Preconditioned Conjugate-Gradient Package (PCG2) – solves simultaneous equations produced by the model using a two tier approach.

The code provides computational options. MODFLOW can be used for steady state or transient simulations; for this study, the model was run in steady-state mode to evaluate long-term average behavior of the groundwater system. In vertical geometry, MODFLOW allows representations as three-dimensional, quasi-three-dimensional, or two-dimensional. This study utilized the three-dimensional capability.

C.5 Model Development

Steps were followed in order to transform the conceptual model into input for the MODFLOW computer program. Preparation for the three-dimensional numerical model included the following:

- Subdividing the horizontal area into a grid of computational elements
- Representing the underlying geology
- Specifying boundary conditions
- Assigning physical properties to the model cells

C.5.1 Horizontal Model Area

The model area and finite-difference grid is shown in Figure C-2. Natural boundaries were chosen to define the model. To the east and west, no-flow boundaries were delineated by the low conductivity till deposits. The outline of these boundaries was determined from subsurface geology USGS map (Williams & Willey, 1973) and a USGS topographic map of the area (USGS, 1987).

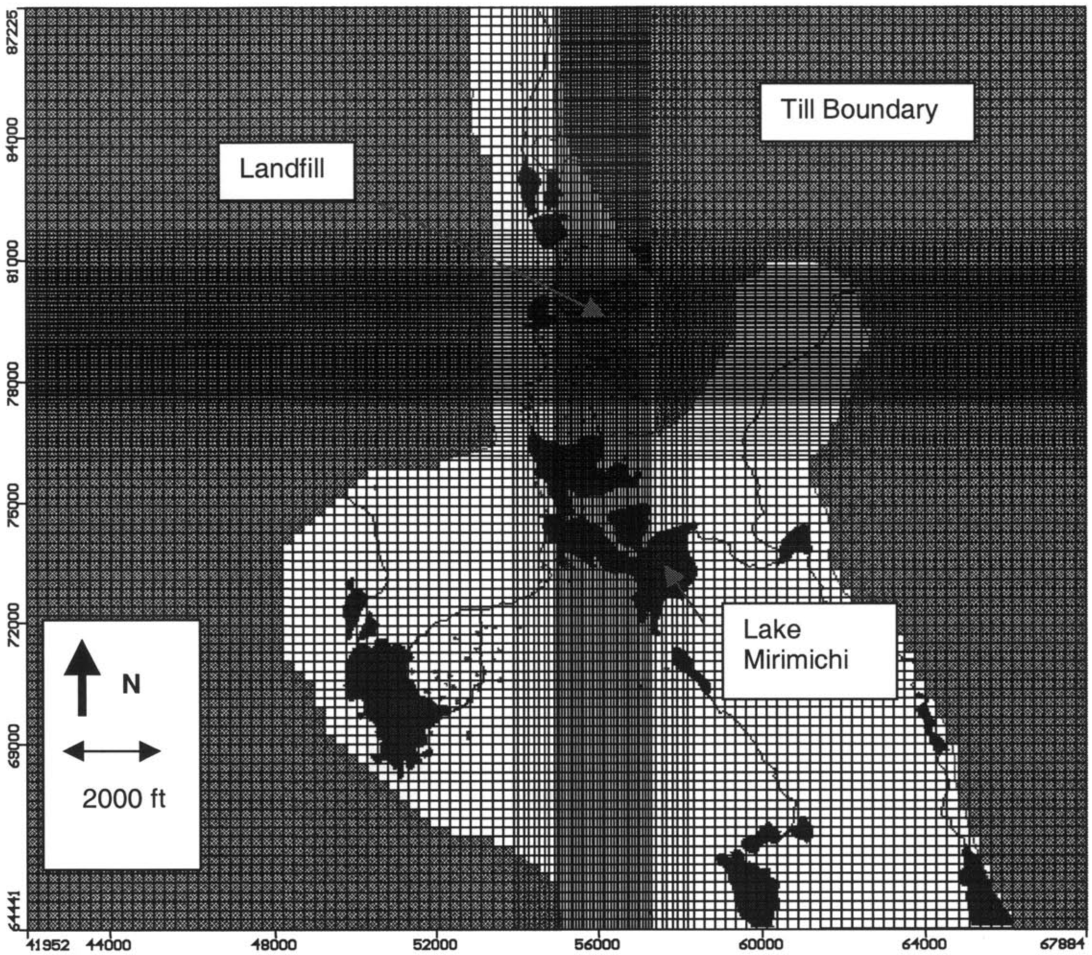


FIGURE C-2: MODEL AREA AND FINITE DIFFERENCE GRID

The northern boundary and southern boundaries were set at a sufficient distance so that the heads specified at these edges would not affect any evaluation in this study.

The numerical grid consisted of 155 rows and 135 columns. The grid was further refined over the areas of interest – namely, the landfill, remediation site, and drinking water wells by Lake Mirimichi. The resolution of these cells ranged from about 3,700 square feet to 60,000 square feet. For proper solution convergence, the requirement that the difference in area between adjacent cells must not exceed 50% was followed.

C.5.2 Vertical Model Area

A cross-section of the model is shown in Figure C-3. This is a close-up of the area from west to east through the landfill. Locations of wells and the elevations of the bottom of the outwash layer were input into Surfer, a program used to interpolate surfaces. Surfer does grid-based contouring and three-dimensional surface plotting of graphics; in this project, Kriging was used for interpolation. In addition to the bottom of the outwash layer, another interpolated surface was the ground-surface elevation; these data came from both borehole data and USGS maps (Williams & Willey, 1967; Williams & Willey, 1970). These two grid files were imported as layers in the MODFLOW model.

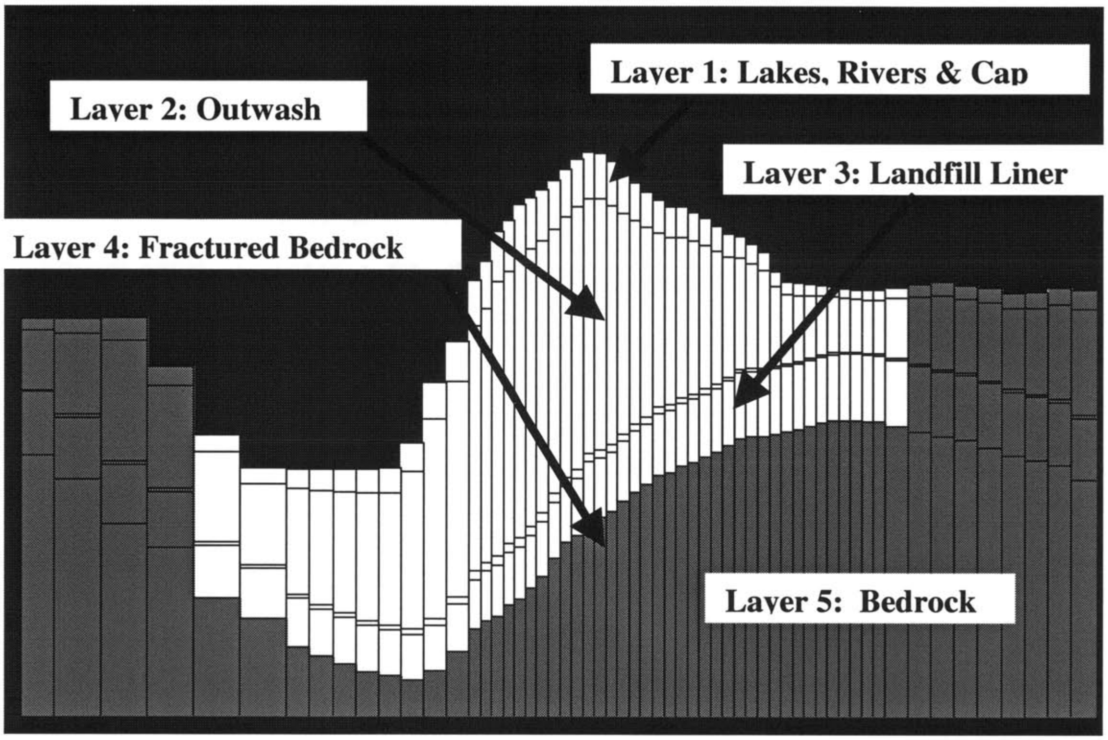


FIGURE C-3: MODEL LAYERS

Other layers were added to the model, keeping in mind what adjustable parameters or boundaries would be needed in the future. A ten foot fractured bedrock layer was added below the outwash layer because the site of the landfill used to be a rock quarry. Within the outwash layer, a thin layer was added to allow for a landfill liner. In addition, a thin layer over the entire region was allotted for a landfill cap and the river cells. These provided flexibility for analysis on problems of the landfill. Figures C-4 is a plan view of the model. Figures C-5A and C-5B show additional cross-sections through the model.

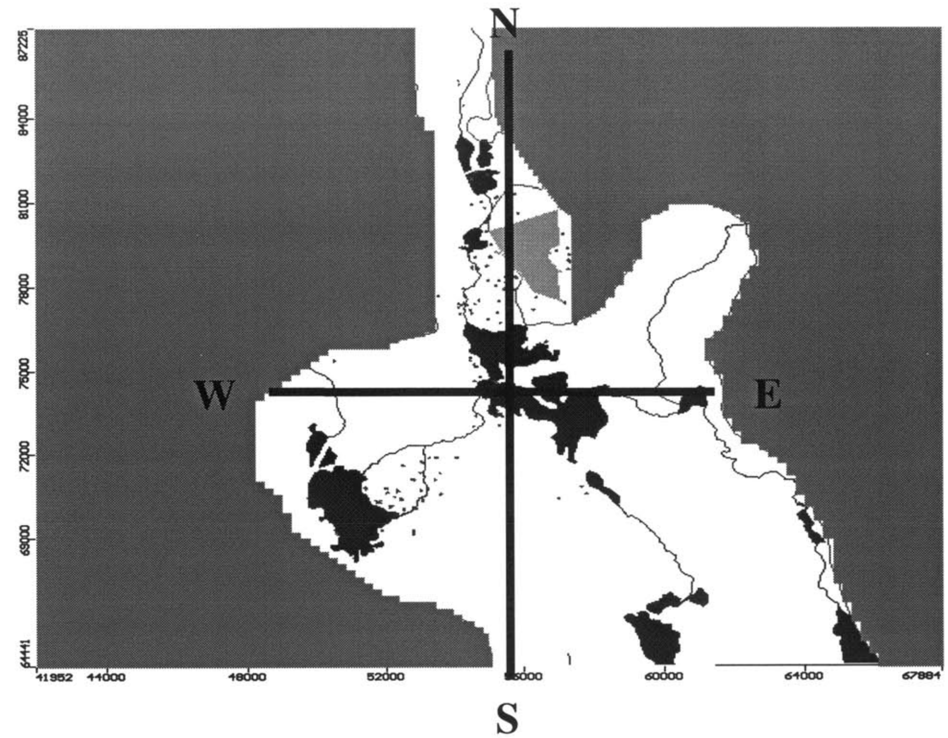


FIGURE C-4: PLAN VIEW WITH CROSS SECTION LOCATIONS

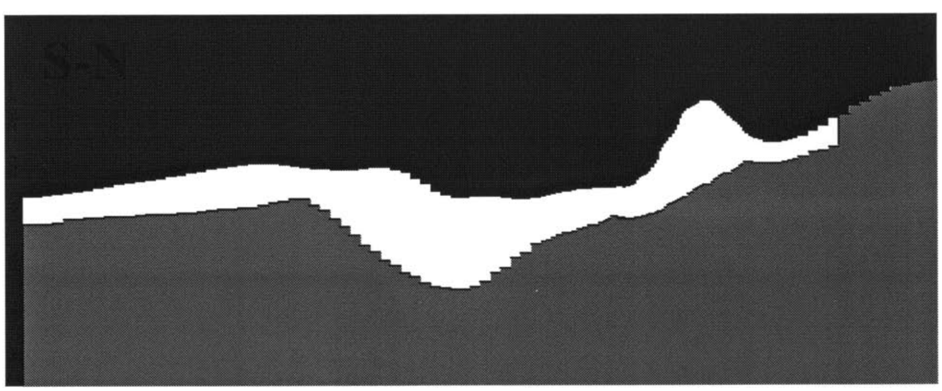


FIGURE C-5A: N-S CROSS SECTION OF MODEL

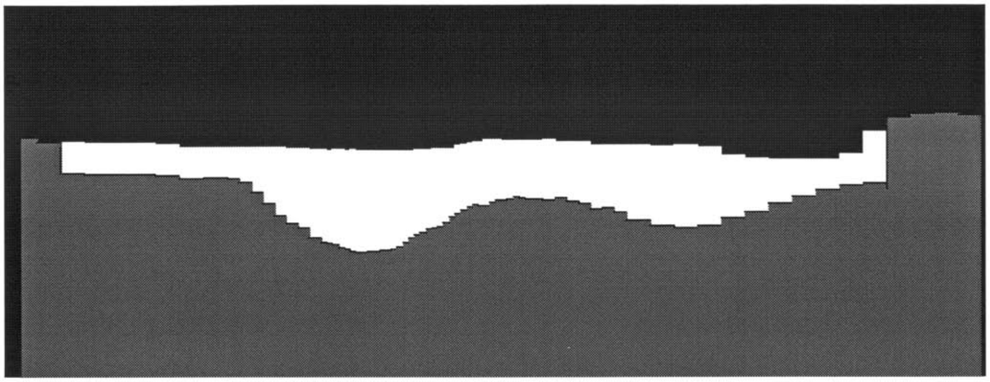


FIGURE C-5B: W-E CROSS SECTION OF MODEL

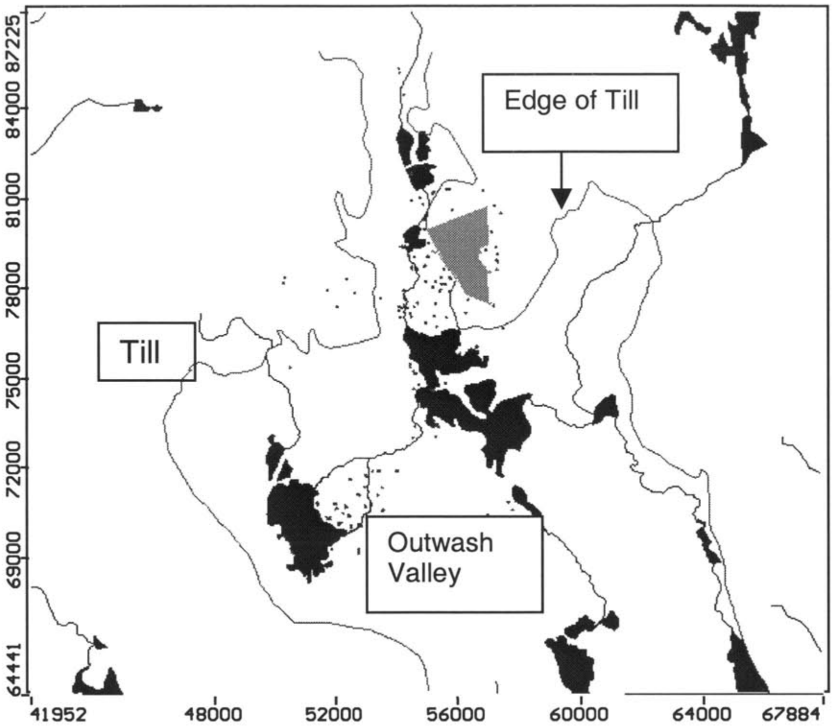
C.5.3 Model Boundary Conditions

No flow zones were identified which followed the till outlines (Figure C-6). Although the landfill area sits on till according to the USGS report (Williams and Willey, 1973), that boundary was not assigned as no flow because the plume exits from the landfill, and because the underlying rock is fractured due to rock quarry operations.

Lake Mirimichi, Turnpike Lake, Rabbit Hill Pond, Rabbit Hill Stream, the cranberry bogs, and Witch Pond as well as other tributaries were represented using the MODFLOW river package (Figure C-7). River stage elevation was defined as the surface elevation. As required by the river package, conductances of the streambed were assigned to individual cells using the following formula:

$$C = \frac{KLW}{M}$$

where C = conductance
K = conductivity of the river bed material (2 ft/d for rivers, 0.5 ft/d for lakes)
L = length of reach through cell
W = width of river in cell
M = thickness of river bed (1ft for rivers, 5ft for lakes) (Dufresne-Henry, Inc. 1997)



Edge of Till
Till
Outwash
Valley
87225
84000
81000
78000
75000
72000
69000
64441
41952
48000
52000
56000
60000
64000
67884

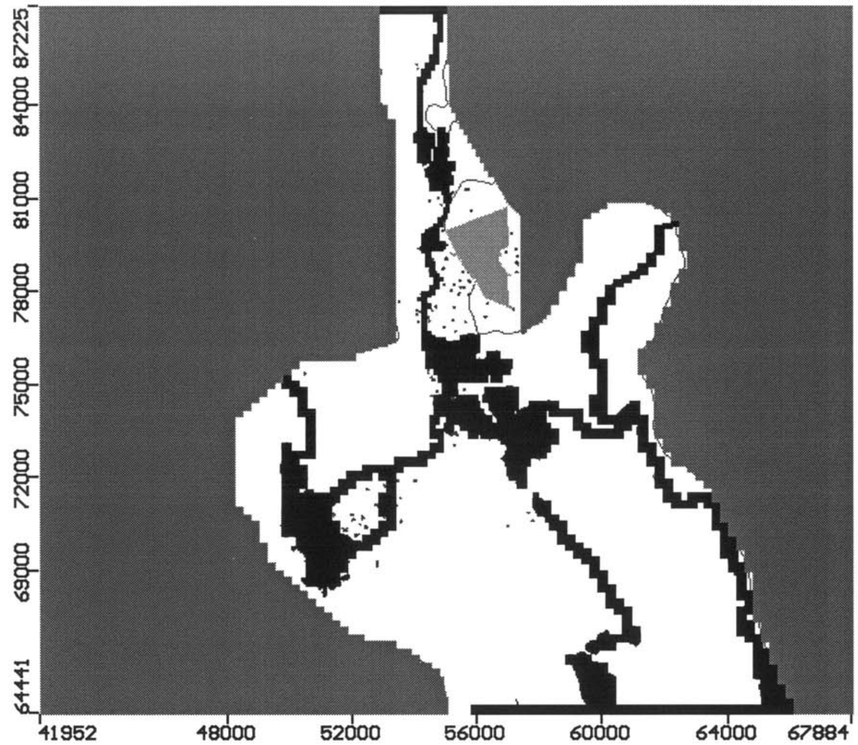


FIGURE C-6: TILL BOUNDARIES

FIGURE C-7: RIVER, LAKE, AND CONSTANT HEAD BOUNDARIES

C.5.4 Hydraulic Parameters

Preliminary values for aquifer parameters, such as hydraulic conductivity and recharge, were assigned according to accepted values for the geology and the area. These values are summarized in Table C-1.

TABLE C-1: INITIAL PARAMETERS

Layer	$K_x = K_y$ (ft/d)	K_z (ft/d)
1	250	25
2	250	25
3	250	25
4	0.5	0.05
5	0	0

C.5.5 Precipitation Recharge

Groundwater recharge initially was assigned as twenty-one inches per year, half of the average annual rate of precipitation over Massachusetts (USGS, 1984).

C.6 MODEL CALIBRATION

After creating a running model, calibration is done to ensure that the model is representative of the site. Adjustments of the parameters are usually made until head level reproduction is acceptable. Of the quarterly reports, the date chosen for calibration purposes was June 1996. The month of June was chosen because it is between the wet and dry seasons. The 1996 data was the latest available. Observation wells were placed in the model and these data were entered as observed elevations of the water table (Figure C-8). The model was rerun and the output provided an option to graph program-predicted groundwater levels in these wells versus observed values. A one to one correlation is desired. After adjustment of certain parameters, the final correlation is shown in Figure (C-9). The mean error was 1.45 feet; mean absolute error was 1.92 feet; RMS error was 2.05 feet. The end values for model parameters are given in Table C-2:

TABLE C-2: PARAMETERS FOR CALIBRATION

Layer	Kx = Ky (ft/d)	Kz (ft/d)
1	250	25
2	250	25
3	250	25
4	1	0.1
5	0	0
Landfill	25	2.5
At landfill, recharge = 1"/yr		
Elsewhere, recharge = 21"/yr		

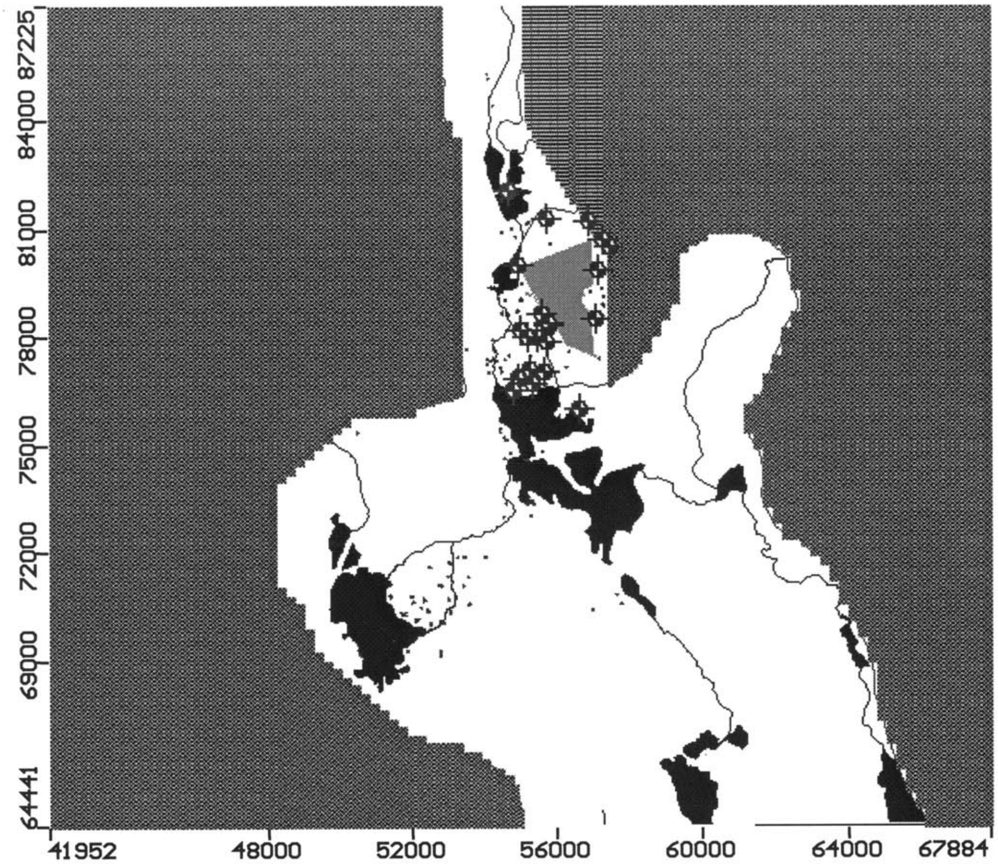


FIGURE C-8: OBSERVATION WELL LOCATIONS

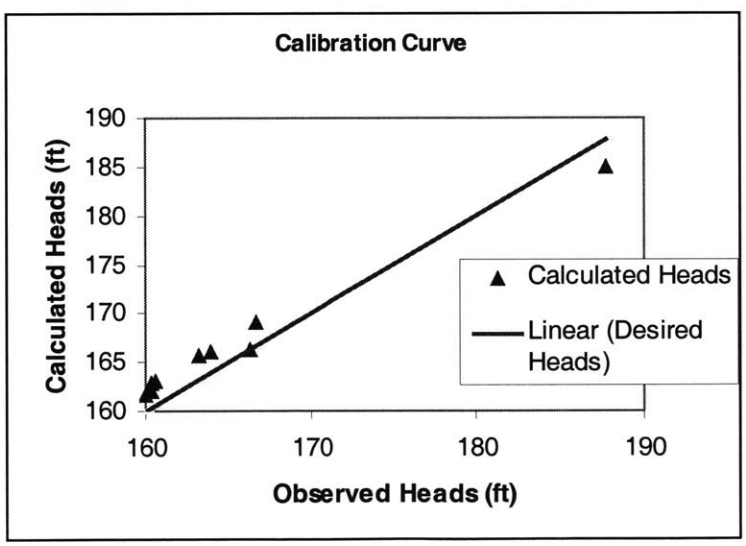


FIGURE C-9: CALIBRATION CURVE

Calibration was reached when the recharge rate over the landfill was set to one in/yr and the hydraulic conductivities K_x and K_z for layers 1, 2, and 3 at the landfill were 25 ft/d and 2.5 ft/d, respectively. The groundwater flow output can be seen in Figure C-10.

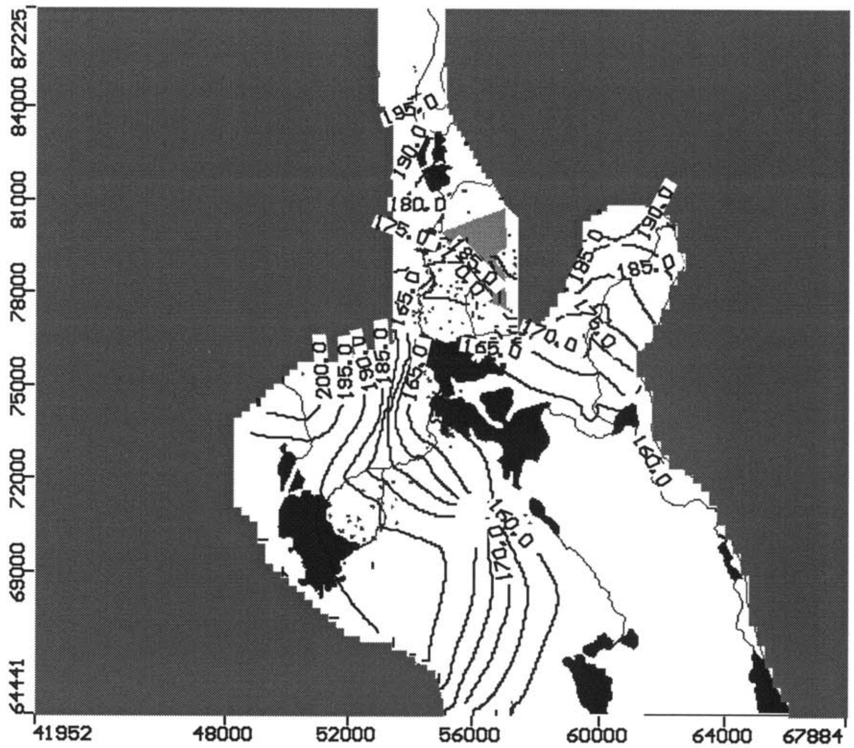


FIGURE C-10: MODEL OUTPUT

C.7 SENSITIVITY ANALYSIS

A sensitivity analysis was performed to evaluate the degree to which the base case values represent a unique solution. Various input parameters were changed to assess their impact on the model. If changing one parameter does not change the base case output, then the model is not sensitive to that particular parameter. Conversely, if the model is sensitive to a given parameter in this analysis, then that parameter needs to be close to the base case value for the model to remain in calibration. Sensitivity analysis was performed under steady-state conditions.

The sensitivity analysis was conducted by varying one input parameter at a time and comparing the predicted heads with those of the calibrated 'base-case' simulation.

Parameters such as the recharge through landfill, the areal recharge, and each of the hydraulic conductivities of layers 2, 3 and 4 were varied by values between ten and a thousand percent of the base case. The results are tabulated in Table C-3.

Of the five parameters evaluated, the least sensitive was the recharge through the landfill, the areal recharge, and the hydraulic conductivities in layer 4. The most sensitive parameter was the hydraulic conductivity of layer 2.

TABLE C-3: RESULTS OF STEADY-STATE SENSITIVITY ANALYSIS

		Decreasing		Base	Increasing	
Recharge Through Landfill (in/yr)		**0.1**	**0.5**	**1**	**2**	**10**
	Change Factor	0.10	0.50	1.00	2.00	10.00
	Mean Error	1.40	1.41	1.45	1.43	1.51
	Mean Absolute Error	1.90	1.90	1.92	1.91	1.97
	RMS Error	2.01	2.02	2.05	2.03	2.11
Areal Recharge (in/yr)		**4.2**	**10.5**	**21**	**31.5**	**42**
	Change Factor	0.20	0.50	1.00	1.50	2.00
	Mean Error	1.07	1.20	1.45	1.62	1.83
	Mean Absolute Error	1.66	1.75	1.92	2.07	2.26
	RMS Error	1.76	1.86	2.05	2.19	2.37
Hydraulic Conductivity in Layer 2 (ft/day)		**25**	**125**	**250**	**500**	**2500**
	Change Factor	0.10	0.50	1.00	2.00	10.00
	Mean Error	4.57	2.83	1.45	2.37	Error
	Mean Absolute Error	5.09	3.29	1.92	2.77	Error
	RMS Error	5.59	3.67	2.05	3.16	Error
Hydraulic Conductivity in Layer 3 (ft/day)		**25**	**125**	**250**	**500**	**2500**
	Change Factor	0.10	0.50	1.00	2.00	10.00
	Mean Error	1.46	1.52	1.45	1.88	Error
	Mean Absolute Error	1.94	1.98	1.92	2.30	Error
	RMS Error	2.07	2.12	2.05	2.50	Error
Hydraulic Conductivity in Layer 3 (ft/day)		**0.1**	**0.5**	**1**	**2**	**10**
	Change Factor	0.10	0.50	1.00	2.00	10.00
	Mean Error	1.42	1.41	1.45	1.43	1.58
	Mean Absolute Error	1.90	1.90	1.92	1.91	2.04
	RMS Error	2.02	2.01	2.05	2.04	2.18

C.8 Limitations

In evaluating model results, the following simplifications should be noted:

1. Homogeneity of subsurface geology. The model simplifies the actual region and geologic parameters. Not only can the hydraulic conductivity vary within sediment type, but also it is not homogeneous throughout a particular layer. A few patches of till lenses have been detected in boreholes.

2. Steady-state simulation. The model is calibrated for a steady state simulation; it does not take into consideration the seasonal effects of precipitation and groundwater recharge.

3. Fixed properties for lakes and rivers. All river cells were assigned the same conductivities for riverbed. Also, same conductivities were given to the lake cells.

4. Assumed till boundaries and fractured bedrock extent at the landfill. Where the till ends around the landfill and how thick and extensive the fractured bedrock layer is was up to the discretion of the modeler. Historical knowledge and current plume situation were taken into account in developing this simple, yet representative model of the area.