FINAL

REMEDIAL INVESTIGATION REPORT

HIDDEN VALLEY LANDFILL

VOLUME I

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Submitted to

Washington State Department of Ecology

Submitted by

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PREFACE

This report documents a Remedial Investigation conducted at Hidden Valley Landfill in Pierce County, Washington, under Washington Department of Ecology Consent Order DE-86-S173, between August 1987 and September 1990. This report was submitted in draft form on September 15, 1990. A final draft, reflecting agency comments, was submitted on February 1, 1991. This revised submittal reflects a second set of agency comments. Only Volume I was revised for this submittal. The report is contained in four volumes:

- Volume I contains the report text
- Volumes II through IV contain Appendices A through M

References in this document to Sweet-Edwards/EMCON, Inc. and Sweet-Edwards and Associates are synonymous with EMCON Northwest, Inc.

EXECUTIVE SUMMARY

Project Background

Hidden Valley Landfill is located in Pierce County, Washington. The landfill has been in operation since the mid-1960s, when it was operated by the Pierce County Department of Public Works. Land Recovery, Inc., a privately owned solid waste disposal company, purchased the landfill in 1977. The site has accepted over 8 million cubic yards of solid waste from private and municipal collection and transfer vehicles. Prior to 1985, small quantities of bulk liquids, sludges, and larger volumes of industrial waste were reported to have been accepted at the landfill.

The results of environmental studies conducted from 1981 through 1985 were used by USEPA to prepare a preliminary assessment (PA) and a hazard ranking scoring (HRS) of the site. As a result of the HRS, Hidden Valley Landfill was placed on the National Priority List in April 1989. The Washington Department of Ecology is the lead agency for the remedial investigation/feasibility study (RI/FS) at the site. The remedial investigation was conducted under Washington Department of Ecology Consent Order DE-86-S173.

Site Hydrogeology

Six hydrogeologic units comprise the uppermost 275 feet beneath the Hidden Valley Landfill site. They consist of a vadose zone; three water-bearing zones, referred to as the Shallow Perched, Upper Regional, and Lower Regional Aquifers; and two aquitards, referred to as the Lower Vashon Till Aquitard and the Salmon Springs Aquitard. The aquitards separate the aquifers.

The vadose (unsaturated) zone is composed of Vashon recessional outwash deposits of silty fine sand and gravelly sand. Northwest of the landfill, a Vashon till deposit (Upper Vashon Till) is also present. The vadose zone varies in thickness from not present beneath portions of the landfill during seasonal high water table conditions to 145 feet northwest of the landfill.

The Shallow Perched Aquifer is present within the Recessional Outwash deposits in the vicinity of the landfill. These deposits consist of permeable sands and gravel that contain a varying percentage of silt. Ground water flow in this unconfined aquifer is generally to the northwest, with local components to the north and west. The aquifer is recharged from infiltration of precipitation both on-site and off-site. Seasonal fluctuations of the water table elevation have exceeded 15 feet during the study period. Within about 800 feet northwest of the landfill, the Shallow Perched Aquifer is not present.

The Lower Vashon Till Aquitard separates the Shallow Perched Aquifer and Upper Regional Aquifer in the vicinity of the landfill. Northwest of the landfill, this deposit forms the uppermost zone of saturation. The Lower Vashon Till Aquitard is about 10- to 30-feet thick and composed of a dense mixture of gravel, sand, and silt. A downward vertical hydraulic gradient exists across the aquitard in the area of the landfill. Some downward movement of ground water through the aquitard in the vicinity of the landfill is suggested from water quality data and rapid response of the Upper Regional Aquifer to recharge from precipitation.

The Upper Regional Aquifer is present within Vashon Advance Outwash deposits of sand and gravel. This aquifer is confined beneath the Lower Vashon Till Aquitard and is continuous across the site. Ground water flow is similar to flow in the Shallow Perched Aquifer; generally to the northwest, with local components to the north and west. The aquifer is recharged primarily from infiltration of precipitation off-site. On-site recharge occurs to the Upper Regional Aquifer via "leakage" through the Lower Vashon Till Aquitard. Seasonal fluctuations in the potentiometric surface elevation exceeded 12 feet during the study period.

The Salmon Springs Aquitard hydraulically separates the Upper Regional Aquifer and Lower Regional Aquifer. The deposit is about 55 to 138 feet thick and composed of Salmon Springs Till and Salmon Springs Interglacial deposits. A downward vertical hydraulic gradient exists across the aquitard.

The Lower Regional Aquifer is located in Salmon Springs Advance Outwash deposits. The aquifer is confined and appears to be continuous beneath the site. Ground water flow direction has not been determined because of the influence of ground water extraction from the Corliss Sand & Gravel well. The recharge area for this aquifer is primarily off-site. Little to no recharge occurs to the Lower Regional Aquifer from on-site sources.

Ground Water Quality

Water quality in the Shallow Perched Aquifer, and to a lesser degree, the Upper Regional Aquifer, has been impacted by the landfill. Contaminants include compounds typical of municipal solid waste: dissolved iron and manganese, chloride, ammonia, nitrate, sulfate, specific conductance, and total dissolved solids. Low levels of volatile organic compounds (VOCs), including benzene, chlorobenzene, 1,1-dichloroethane, and 1,4-dichlorobenzene, have also been reported in both aquifers.

Nitrate levels in the Shallow Perched Aquifer have sporadically exceeded the federal primary drinking water standard of 10 milligrams per liter (mg/L). These exceedances occur concurrent with periods of ground water recharge, with the highest nitrate concentrations recorded when water levels were increasing rapidly.

Fluctuations in ammonia-nitrogen and nitrate-nitrogen concentrations in the Shallow Perched Aquifer are interpreted as follows. During periods of aquifer recharge (typically winter and early spring), the aquifer receives oxygenated water, and the water table rises. Under these conditions, nitrogen is present primarily in the oxidized form as nitrate. During non-recharge periods, nitrate in the ground water is reduced to ammonia due to anaerobic conditions in the vicinity of the landfill.

No impacts to the water quality of the Lower Regional Aquifer from landfilling operations have been identified.

Source Evaluation

Landfill leachate includes liquids that are produced during decomposition of wastes as well as liquid that passes through the refuse. Ammonia-rich leachate present within the solid waste is considered the likely source of ammonia and nitrate in the Shallow Perched and Upper Regional Aquifers.

Three wells installed in the refuse found minimal leachate to be present. Temporary and final closure of the landfill using low permeability membrane capping materials will minimize the infiltration of precipitation into the refuse and limit future leachate production. However, whenever ground water elevations in the Shallow Perched Aquifer exceed approximately 430 feet (typically in late winter and early spring), the base of the solid waste is interpreted to become locally saturated. Under these conditions, leachate may be generated and released into the ground water. Seasonal saturation of the refuse may be the primary mechanism by which leachate-derived constituents have migrated into the ground water beneath the site.

1 INTRODUCTION

1.1 Objectives

The objective of this remedial investigation report is to present the findings of investigations performed by Sweet-Edwards/EMCON, Inc. (SE/E) on behalf of Land Recovery, Inc. at Hidden Valley Landfill under Consent Order DE-86-S173. These findings supplement existing information collected in previous studies that have been performed at the site since 1981.

The scope of work was negotiated by the Washington State Department of Ecology (Ecology), the Tacoma-Pierce County Health Department (TPCHD), and Land Recovery Inc. (LRI), the owner of the landfill. Negotiations focused on evaluating existing data, identifying remedial investigation objectives, and implementing a study to meet these objectives. The work that was agreed upon, and implemented at the landfill site, was developed in consideration of these requirements and the Washington State Department of Ecology Minimum Functional Standards for Solid Waste Handling (WAC 173-304).

1.2 Site Background

1.2.1 Site Description

The Hidden Valley Landfill, also known as the Thun Field Landfill and the Pierce County Landfill, is located at 17925 S. Meridian St., approximately 5 miles south of Puyallup in Pierce County, Washington (see Figure 1-1). The site lies in the north half of the northwest one-quarter of Section 34, T 19 N, R 4 E. It is bordered on the west by S. Meridian Street (State Route 161), on the north by two undeveloped parcels and the Thun Field/Pierce County Airport, and on the east by undeveloped wooded property (see Figure 1-2). Puyallup Sand and Gravel Company owns and operates a gravel processing operation to the south of the site.

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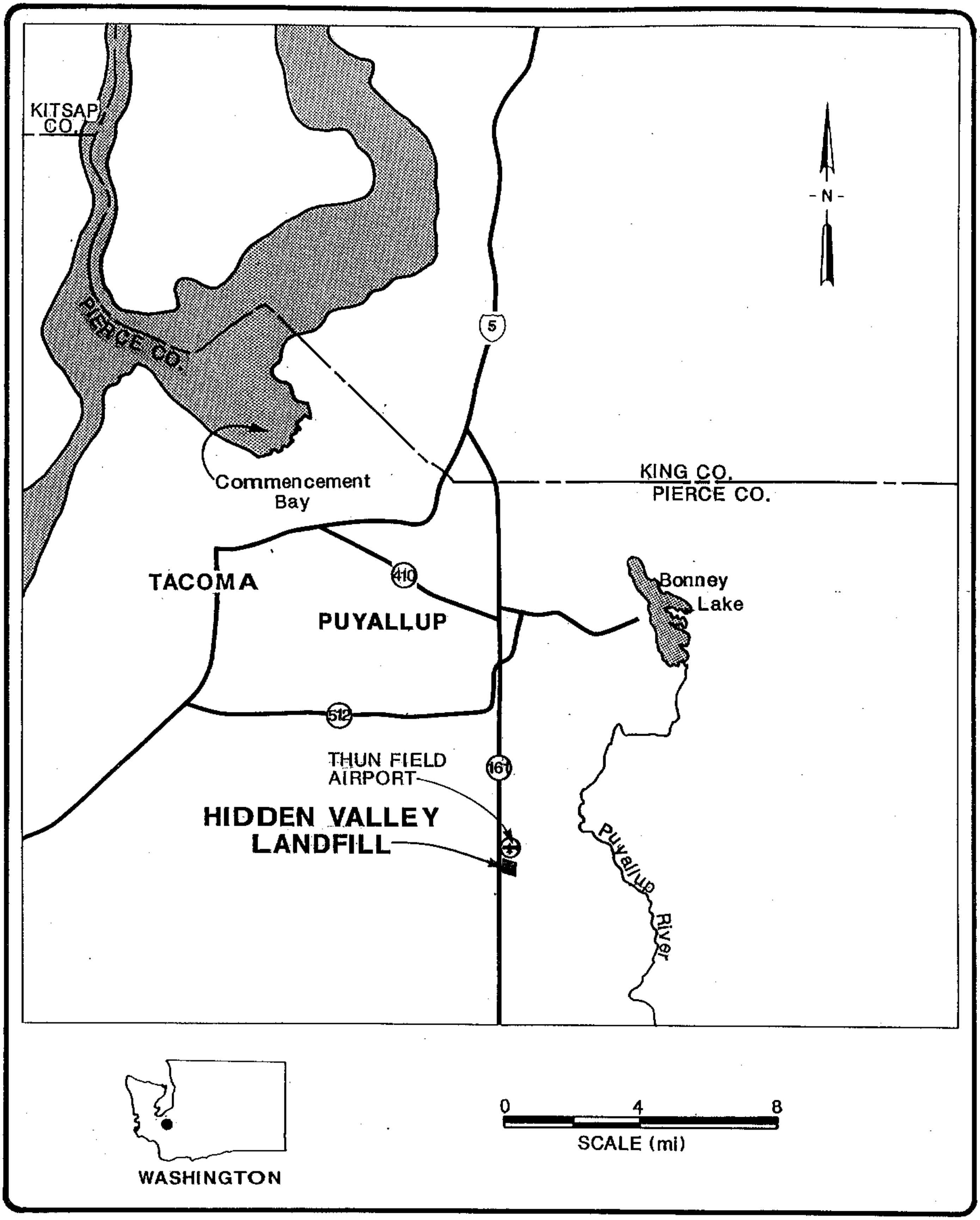

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Figure 1-1
HIDDEN VALLEY LANDFILL

SITE VICINITY MAP

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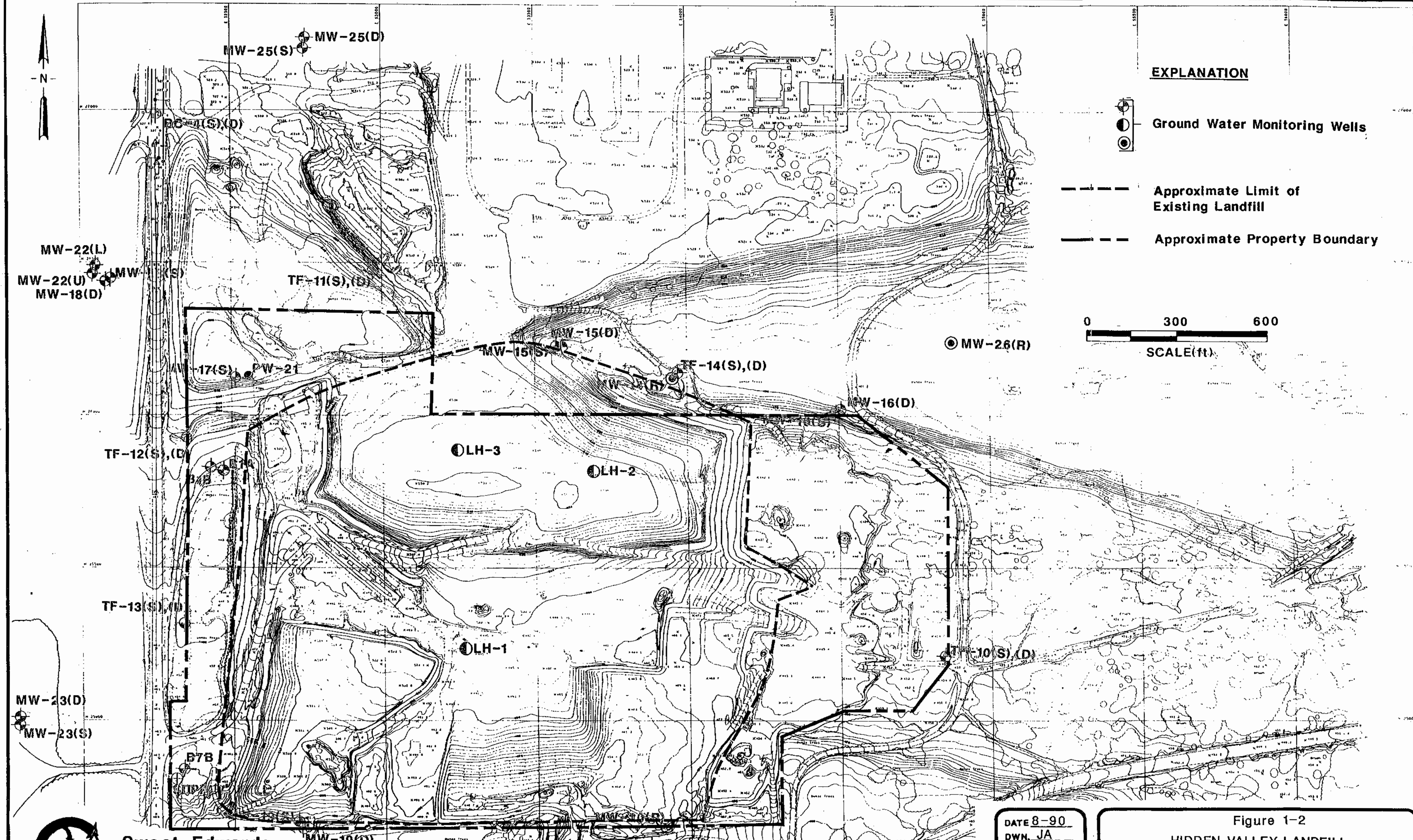

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Figure 1-2
HIDDEN VALLEY LANDFILL
PROPERTY AND LANDFILL BOUNDARIES

The Hidden Valley Landfill property is approximately 77 acres and is irregularly shaped as shown on Figure 1-2. LRI is currently in the process of acquiring an additional 5 acres northeast of the landfill to install a storm water retention basin. The existing landfill footprint area is approximately 52 acres. The landfill footprint area had extended up to 200 feet beyond a portion of the northern property boundary, on property currently owned by the Pierce County airport. Approximately 14 additional acres remain undeveloped on the easternmost portion of the site. This area is currently used for storage of organic debris and yard waste (see Figure 1-2).

The main portion of the landfill is located in an east-west trending glacial meltwater channel. The elevation of the ancient channel is typically 50 to 100 feet lower than the adjacent uplands to the north and south of the site. Some changes to the natural topography have resulted from gravel mining operations that have been continuing both to the north and south of the landfill.

1.2.2 Site History

Hidden Valley Landfill began accepting solid waste in the mid-1960s when it was operated by the Pierce County Department of Public Works. Little information is available regarding the method of landfilling. Following about 12 years of operation by Pierce County, the landfill was sold to the current owner and operator, LRI, a privately owned solid waste disposal company.

Historically, waste received at the landfill has consisted of compacted and loose residential waste from private and municipal collection vehicles and transfer vehicles; loose, mixed waste from private cars, vans, and pick-ups; loose and compacted commercial and industrial waste from private haulers; bulk liquids; and demolition wastes. Bulk liquids, sludges, and large volumes of industrial waste have not been accepted at the Hidden Valley Landfill since 1985.

The landfilling method originally used appears to have been the trench method. Since LRI acquired the site in 1977, they have operated the landfill using the area fill method. This method can best be described as placing and compacting solid waste in small lifts daily to minimize daily cover requirements. The landfill currently accepts approximately 800-950 tons of solid waste per day. The landfill has accepted over 8 million cubic yards of solid waste and the fill thickness exceeds 100 feet in places.

Relatively small volumes of industrial waste, jet fuel treater clay, heavy metals treatment residue, and digested municipal sewage plant sludges have been accepted at the landfill under the approval of Tacoma Pierce

County Health Department and/or the Washington State Department of Ecology.

This remedial investigation has substantiated findings of previous studies and has shown that the landfill has impacted the subsurface environment. A review of ground water quality data shows that the landfill is largely in compliance with federal primary drinking water standards (maximum contaminant levels (MCLs)). Since early 1986 nitrate has sporadically exceeded the primary drinking water standard in ground water samples collected from monitoring wells completed in the Shallow Perched Aquifer. Prior to implementation of the Phase II work, the seasonal detection of nitrate in the Shallow Perched Aquifer had been difficult to interpret due to its sporadic and irregular occurrence. Additional studies have been conducted to clarify the significance of these nitrate detections. Elevated levels relative to background of other constituents such as iron, manganese, chloride, and other non-toxic constituents in both the Shallow Perched and Upper Regional Aquifers also reflect the impact of the landfill on the ground water quality. A detailed discussion of ground water quality is included in Section 6 of this report.

1.3 Previous Work

1.3.1 Consultant Reports

Published information regarding subsurface conditions at the site prior to 1981 is not available. Information on pre-1981 conditions was obtained only by interviews with LRI and Pierce County personnel.

In 1981, Hart-Crowser, Inc. initiated the first ground water study at the landfill site on behalf of the Tacoma-Pierce County Health Department. This investigation included installing monitoring wells and laboratory testing of ground water samples collected from these wells. Findings were published in the Thun Field Landfill Hydrogeological Study (1982).

In 1985, Ecology and Environment, Inc. (E&E) prepared a preliminary assessment (PA) of the site for the Environmental Protection Agency under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA). This PA was used to prepare the site Hazard Ranking Scoring (HRS), which resulted in the facility being placed on the National Priority List (Superfund) in April 1989.

The regional geologic setting of the facility is probably best described in the Clover/Chambers Creek Basin study completed by Brown and Caldwell for the TPCHD (1985). This report specifically discussed the Hidden Valley Landfill and includes a description of the off-site monitoring wells designated "BC-4(S)" and "BC-4(D)", which were installed to evaluate the hydrogeology and ground water quality in the area to the northwest of the landfill site (see Figure 2-1).

In 1985, LRI retained SE/E (formerly Sweet, Edwards and Associates) to perform additional environmental investigations at the site. These include the Hydrogeologic Data Update (1985); the Current Situation Report (1987); the Hidden Valley Master Plan (1988); and the Draft Phase I Remedial Investigation Report (1989).

Quarterly monitoring of ground water has been ongoing since 1985 for a wide range of parameters, including heavy metals, volatile organics, and indicator parameters. Monthly ground water monitoring of selected wells for nitrate and indicator parameters was continued from April 1986 through September 1990 (see Section 2.3, Ground Water Sampling).

1.3.2 Landfill Gas Monitoring

Prior to October 1987, management of the landfill gas system was conducted by CH2M HILL/Mandeville. No written documentation of combustible gas concentrations was found for this period. SE/E assumed responsibility for the gas system in October 1987 and quarterly readings in the probes were performed from October 1987 to December 1988. Monthly readings have been obtained from January 1989 to December 1989 (see Section 7, Landfill Gas Investigation and Appendix I).

1.4 Phase I - Scope of Work

Field investigations for the Phase I Remedial Investigation were performed between October 1987 and March 1989. The scope of work was as described in the consent order and included the following tasks:

<u>Monitoring Well Construction</u>

- Drill and install a well designated MW-15(S) and a well designated MW-15(D) in the Shallow Perched and Upper Regional Aquifers.

- Drill and install a well designated MW-16(S) and a well designated MW-16(D) near the northeastern corner of the site.

- Drill and install a well designated MW-17(S), a well designated MW-18(S), and a well designated MW-18(D) northwest of the landfill.

- Drill and install a well designated MW-19(S) and a well designated MW-19(D) along the southern boundary of the landfill site.

- Install two additional deep wells, designated ,MW-14(R) and MW-20(R) in the Lower Regional Aquifer.

- Drill and install a pumping well designated PW-21 adjacent to MW-17(S).

Determination of Aquifer Parameters

- Perform a drawdown/recovery test in a new well designated PW-21.

- Perform a drawdown/recovery test in the on-site water supply well.

- Perform single-well hydraulic conductivity tests in all monitoring wells at the site to determine aquifer properties.

1.4.1 Ground Water Sampling

Perform four quarterly rounds of ground water sampling in April 1988, July 1988, October 1988, and January 1989.

1.4.2 Soils Attenuation

If possible, sample the gravelly soils and perform sieve analysis as well as cation exchange capacity and organic carbon content on a minimum of four samples.

1.4.3 Leachate Head Wells

Install three leachate head wells in the solid waste to determine if leachate occurs in the waste. Conduct a single round of leachate sampling to test for full scan priority pollutants, temperature, conductivity, pH, chloride, nitrate, nitrite, ammonia, sulfate, total iron, total zinc, total manganese, COD, and BOD.

1.4.4 Surface Water Investigation

A surface water investigation is required only if leachate movement into surface water is a concern. No surface water, except for ponded water in the event of heavy rain, exists in the site area.

1.4.5 Soils Investigation

Excavate three backhoe pits in each of four areas surrounding the solid waste area. Soils are to be visually inspected for staining. Three soil samples per pit are to be screened using an OVA, then compared to background soil conditions. A maximum of eight discrete soil samples (maximum of three from any area) are to be analyzed for EPA's priority pollutant list of contaminants.

1.4.6 Air Investigation

Conduct an air investigation to characterize and define expected air emissions from the landfill after completion of the landfill gas migration and control systems. This investigation was limited per discussions with Ecology and TPCHD (see Section 7.4.2).

1.4.7 Landfill Gas Subsurface Migration

Define the existing concentrations of subsurface landfill gas. Install and monitor additional multiple-completion gas monitoring probes. Ensure safety conditions are monitored in on-site structures.

1.4.8 Survey Monitoring Wells and Gas Probes

Survey all newly installed monitoring wells and gas probes to establish vertical and horizontal control.

1.5 Phase II - Scope of Work

Field investigations for the Phase II Remedial Investigation were performed between October 1989 and June 1990. The scope of work was performed as proposed in the Phase II remedial investigation work plan. Where there are deviations to the proposed work plan per discussions with Ecology, the changes and amendments have been addressed in their respective sections of this report. The investigation included the following tasks:

- Drill and install two additional monitoring wells designated MW-22(U) and MW-22(L) in the Shallow Perched Aquifer.

- Drill and install four additional monitoring wells designated [MW-23(S), MW-23(D), MW-25(S), and MW-25(D)] at two locations in the Shallow Perched and Upper Regional Aquifers.

- Drill and install one additional monitoring well [designated MW-26(R)] in the Lower Regional Aquifer.

- Perform continuous monitoring of water level and conductivity in selected wells beginning November 1989 through June 1990.

- Sample selected wells bi-weekly for nitrate, ammonia, and total nitrogen from December 1989 through June 1990.

- Perform slug testing in all new monitoring wells.

- Enter ground water quality data into database, perform data validation, and evaluate data.

- Survey new wells to establish vertical and horizontal control.

- Prepare monthly progress reports.

- Conduct progress meetings, initiate quality control, implement corrective action as necessary.

- Prepare draft remedial investigation report.

2 FIELD INVESTIGATIONS

2.1 Phase I Field Investigations

This section describes the field investigations completed for the Phase I Remedial Investigation. Locations of monitoring wells, leachate wells, and the pump test well which were installed as part of the Phase I work are shown on Figure 2-1.

2.1.1 Monitoring Well Designation

Monitoring wells were installed using either air rotary or cable tool drilling techniques. Wells completed in the Shallow Perched Aquifer are designated shallow (S); wells in the Upper Regional Aquifer as deep (D); and wells in the Lower Regional Aquifer as regional (R).

2.1.1.1 Air Rotary Drilling Technique

A Speedstar SS-15, owned and operated by Hayes Well Drilling Company, Bow, Washington, was used to install monitoring wells MW-15(S), MW-16(S), MW-16(D), MW-17(S), MW-18(S), MW-19(S), and MW-19(D).

Each boring was advanced using a 6-inch-diameter tri-cone bit. Six-inch steel casing was driven concurrent with the boring. Drill cuttings were collected at 5-foot intervals or at any change in lithology and were logged in terms of color, grain size, moisture content, and any other pertinent descriptors (see Appendix A, Boring Logs).

2.1.1.2 Cable Tool Drilling Techniques

Cable tool drilling rigs owned and operated by Tacoma Pump and Drilling Company, Graham, Washington, were used to drill and install wells MW-15(D), MW-18(D), MW-14(R) and MW-20(R). Borings were advanced by driving 6-inch-diameter steel casing using percussion techniques. Samples were collected at approximately 5-foot intervals from the bailer used to remove drill cuttings from the borehole.

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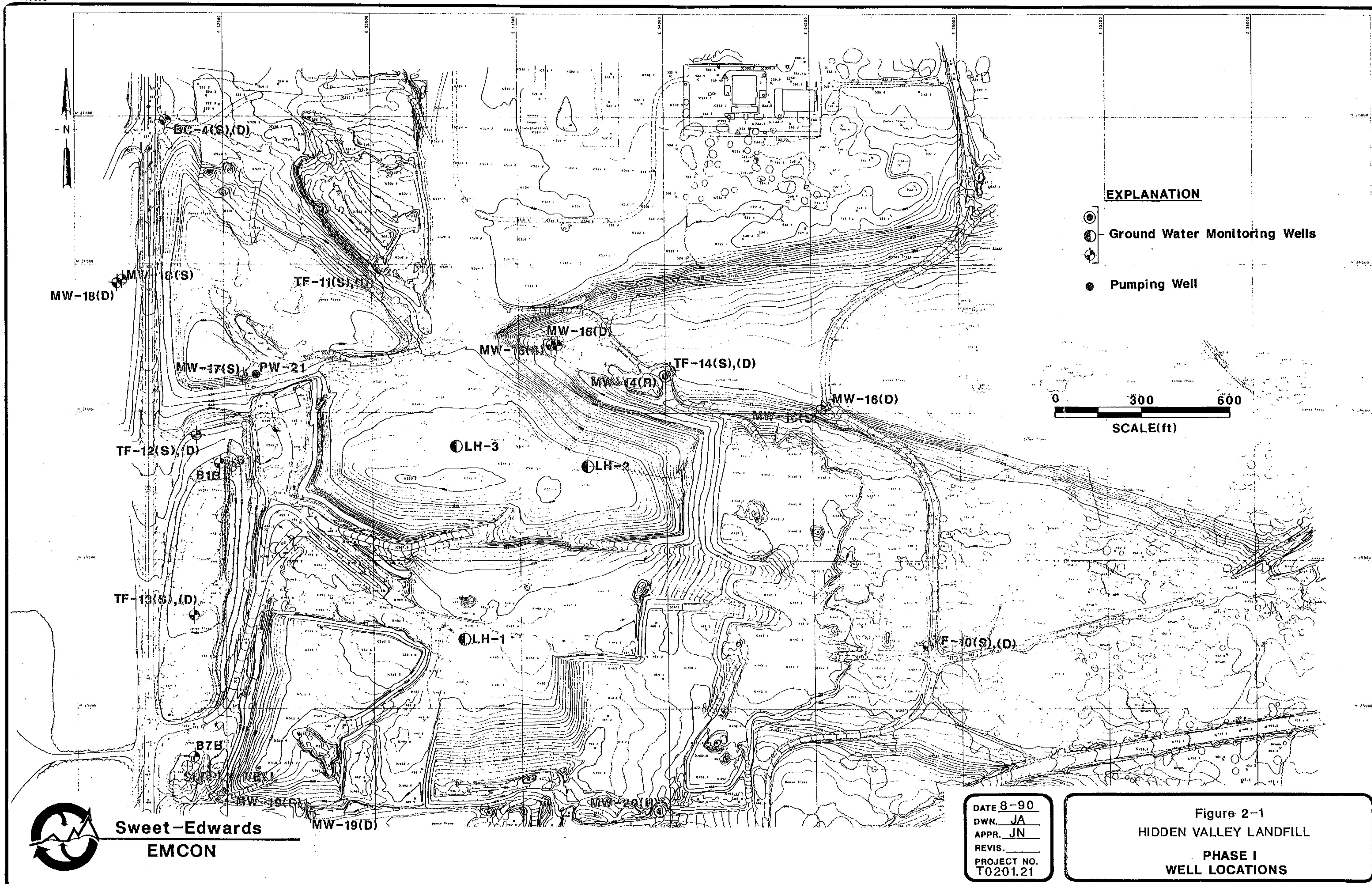

Figure 2-1
HIDDEN VALLEY LANDFILL
PHASE I
WELL LOCATIONS

2.1.2 Installation of Monitoring Wells

Each monitoring well consists of 2-inch-diameter PVC well screen (.020-inch slot) and 2-inch-diameter riser pipe. Typically, 10 feet of screen was used for each well. Stainless steel centralizers were placed immediately above the screened interval and at several positions on the riser pipe, depending on depth. Either silica sand or washed pea gravel was used as filter pack material around each well screen interval. Bentonite seals were placed above the filter pack and filled to the ground surface. Protective lockable steel casings were placed over the top of each riser pipe. All soil cuttings and waste water that were produced during the drilling operation were controlled as specified in the work plan. Well completion details are shown on the boring logs presented in Appendix A.

2.1.3 Monitoring Well Development

Monitoring wells installed using air rotary techniques were developed using an air-lift method. Wells installed with the cable tool rig were developed using the bailing method. Development continued until discharge water was sediment-free or showed no further improvement, and field measurements of pH, temperature, and conductivity had stabilized.

2.1.4 Determination of Aquifer Parameters

This section discusses the aquifer testing procedures for the pump tests performed in PW-21 and the on-site supply well, and single well hydraulic conductivity testing in all on-site monitoring wells. Results of these tests have been used to evaluate the hydraulic characteristics of each aquifer beneath the site (see Section 5, Hydrogeology).

2.1.4.1 Drawdown/Recovery Test in PW-21

PW-21 was installed in March 1988 for the purpose of performing an aquifer test in the Upper Regional Aquifer. The well was installed using a cable tool drilling rig owned and operated by Tacoma Pump and Drilling Company. Twelve-inch-diameter steel casing was advanced to 186 feet below ground surface (bgs). Continuous geologic samples were collected from 150 to 180 feet bgs for sieve analysis and were used to determine the screen interval and design. Based on the sieve analysis, 30 feet of 8-inch-diameter screen was placed from 150 to 180 feet bgs. The screen design consisted of four slot-size variations, which consisted of 0.50-inch slot from 150 feet to 160 feet, 0.15-inch slot from 160 feet to 174 feet, 0.30-inch slot from

174 feet to 177 feet, and 0.60-inch slot from 177 feet to 180 feet. A 3-foot basement or sump was installed below the bottom of the well screen (refer to Appendix A for well details).

On June 1, 1988, a 72-hour drawdown/recovery test was performed in PW-21 to: 1) evaluate the hydraulic characteristics of the Upper Regional Aquifer, and 2) further investigate the degree and extent of hydraulic connection, if any, between the Shallow Perched and Upper Regional Aquifers beneath the northwest area of the landfill site.

2.1.4.2 Test Set-Up

Tacoma Pump and Drilling Company performed the test between June 1 and 4, 1988. A Berkeley-Franklin 30 horse power, 4-stage submersible pump was installed in PW-21 and the pump intake set at 165.5 feet bgs. Discharge water was directed via 1,400 feet of 6-inch-diameter pipe to an infiltration area along the south property line of the landfill site (see Figure 2-2).

Based on pre-testing on June 1, 1988, the pump test was performed at a discharge rate of 150 gallons per minute (gpm). Water level measurements were recorded automatically throughout the test using a TERRA 8 data logger with transducers set in PW-21 and monitoring wells B1-A, B1-B, TF-11(D), TF-12(S), TF-12(D), and MW-17(S).

2.1.4.3 Test Procedures

Analytical solutions developed by Theis (1935), Hantush and Jacob (1955), and Hantush (1964) were used to determine aquifer characteristics in the Upper Regional Aquifer and the vertical leakage rate through the Lower Vashon Till from the Shallow Perched Aquifer. A spike on the drawdown vs. time plots between t = 1000 and 2000 minutes is thought to have resulted from a temporary fluctuation in the discharge rate at PW-21. Estimated values of transmissivity, storativity, and hydraulic conductivity are shown in Table 2-1 (see also Appendix B, Drawdown/Recovery Data in PW-21). The aquifer thickness was not determined at observation well locations TF-12(D) and B1-B, therefore, the aquifer thickness at PW-21 (35 feet) was used to calculate hydraulic conductivity.

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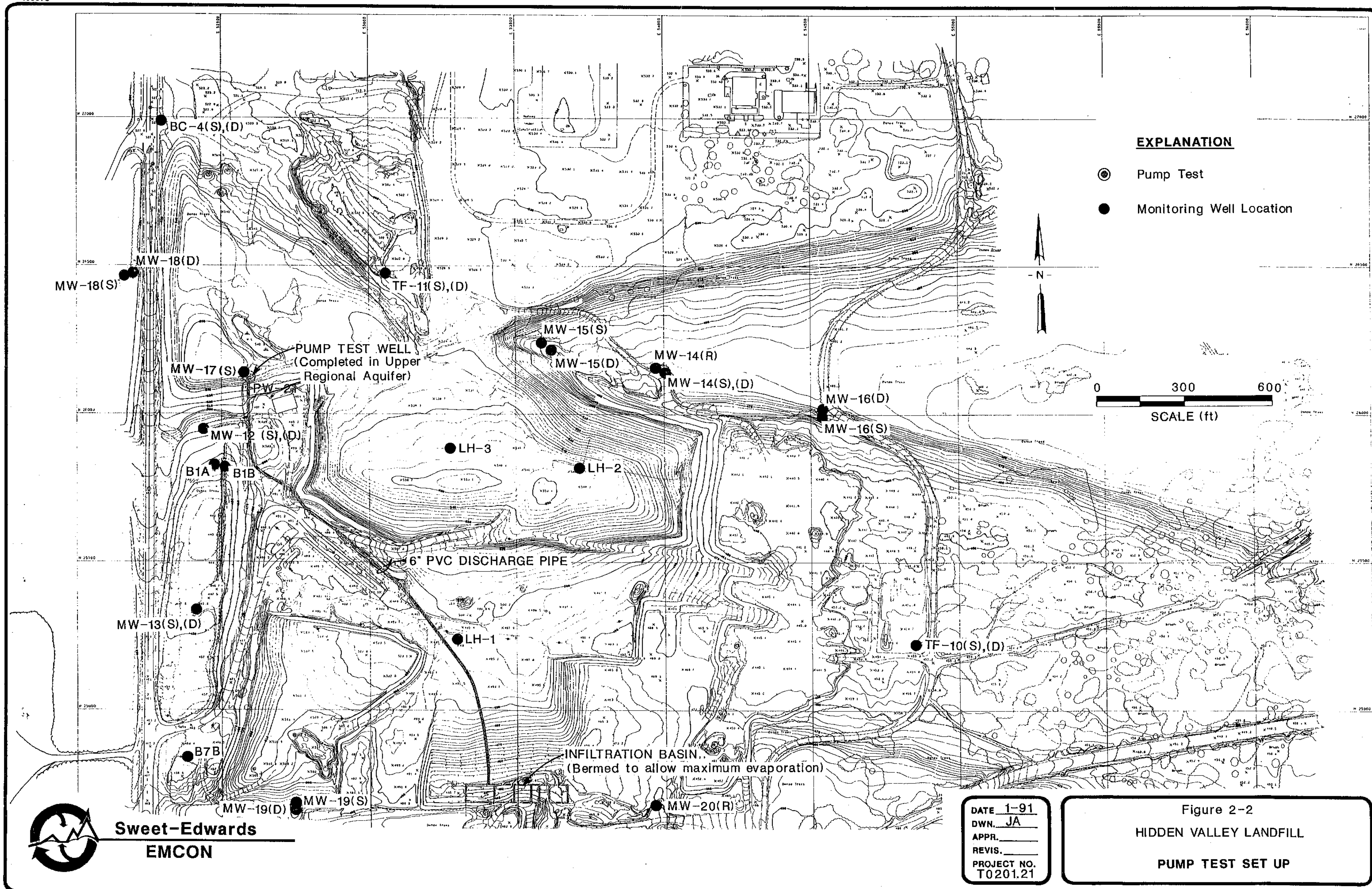

Figure 2-2
HIDDEN VALLEY LANDFILL
PUMP TEST SET UP

Table 2-1

Summary of Aquifer Characteristics
PW-21 Pump Test

Well	Aquifer Transmissivities	Aquifer Storativity (dimensionless)	Hydraulic Conductivity[a]
Upper Regional Aquifer (UNIT D)			
B-1B[b]	2,710 ft^2/day 20,300 gpd/ft	1.7×10^{-4}	5.4×10^{-2} ft/min 2.7×10^{-2} cm/sec
B-1B[c]	2,710 ft^2/day 20,300 gpd/ft	1.7×10^{-4}	5.4×10^{-2} ft/min 2.7×10^{-2} cm/sec
TF-12(D)[b]	2,880 ft^2/day 21,500 gpd/ft	2.2×10^{-4}	5.7×10^{-2} ft/min 2.9×10^{-2} cm/sec
TF-12(D)[c]	3,290 ft^2/day 24,600 gpd/ft	2.1×10^{-4}	6.5×10^{-2} ft/min 3.3×10^{-2} cm/sec

Notes: [a] Hydraulic conductivity calculated assuming an aquifer thickness of 35 feet.
[b] Values calculated using the Hantush-Jacob Method.
[c] Values calculated using the Hantush Method.

Water level data collected in the Shallow Perched Aquifer during the pump test indicated minimal drawdown (less than 0.5 foot) in TF-12(S), MW-17(S), and B-1A, which are located approximately 250 feet, 30 feet, and 325 feet from PW-21, respectively. The downward leakage rate (v) through the lower till during the pumping period was estimated at 0.006 ft/day. Under non-pumping conditions the leakage would be lower than this estimated value because the hydraulic gradient between the two aquifers is less than the gradient developed under pumping conditions.

Drawdown response in TF-11(S) and TF-11(D) was not consistent with drawdowns measured in other nested sets of monitoring wells completed in the Shallow Perched and Upper Regional Aquifers. Extrapolated drawdown in TF-11(D) after 1,000 minutes of continuous pumping at 150 gpm was estimated at 3.1 feet using distance drawdown information collected in PW-21, TF-12(D), and B-1B. Actual drawdown after 1,000 minutes was measured at less than 0.23 foot in TF-11(S) and 0.29 foot in TF-11(D). This implies that either 1) the Lower Vashon Till aquitard is considerably more permeable in the vicinity of TF-11(S),(D), or 2) there is hydraulic connection between TF-11(S) and TF-11(D) and the integrity of the annular seal is doubtful.

2.1.4.4Ground Water Quality

Water samples were collected three times during the pump test to provide information on time-variant chemistry. Samples were collected from a sampling port at the well head after 20 minutes, 45 hours, and 71 hours of pumping and submitted for analysis of dissolved metals; non-metals; volatile organic compounds; base, neutral, and acid extractables; and pesticides and PCBs. Water quality results are presented in Table 2-2 (see also Appendix B).

Table 2-2

Time-Variant Water Chemistry In PW-21
(for parameters detected above the method reporting limit)

Parameter	Pumping Time 20 min	45 hours	71 hours
chloride (mg/L)	137	78	74
ammonia (mg/L)	27	5.8	4.7
nitrate (mg/L)	< 0.01	0.01	0.02
dissolved solids (mg/L)	814	566	598
methylene chloride (μg/L)	1.6 B	2.0 B	1.3 B
cis-1,2-dichloroethene (μg/L)	0.4 J	0.7	0.6 J
benzene (μg/L)	1.1	ND	ND
toluene (μg/L)	0.5 M	ND	0.5 M
chloroform (μg/L)	ND	ND	1.3

Notes:
- B - Indicates analyte found in blank as well as in sample. Indicates probable blank contamination.
- J - Indicates an estimated value when result is less than specified detection limit.
- M - Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.
- ND - Indicates none detected.

2.1.4.5 Drawdown/Recovery in On-Site Supply Well

In October 1988, a drawdown/recovery test was performed in the supply well to determine the characteristics of the Upper Regional Aquifer beneath the southwest part of the landfill site. The supply well is completed at 60 feet bgs and adjacent to B-7B, which is a 1.5-inch-diameter monitoring well installed by Hart, Crowser in 1981. The discharge rate was determined by the water supply distribution system and measured in a 5-gallon bucket at approximately 12 gpm. Discharge was directed from a faucet adjacent to the maintenance shop and allowed to infiltrate in the vicinity of B-1A and B-1B.

Water level measurements were recorded automatically using a Hermit environmental data logger in the supply well. Estimated transmissivity values for the Upper Regional Aquifer are summarized in Table 2-3 (see also Appendix C). It is our opinion that the aquifer properties determined in this test do not reflect conditions in this aquifer beneath the site. Insufficient discharge rates at which the test was performed, and the well construction consisting of an open ended drill pipe, may account for the much lower transmissivity valves for this test than calculated for the pump test performed in PW-21 (see Table 2-3). No water samples were collected during the pump test.

Table 2-3

Upper Regional Aquifer Characteristics
(based on data collected during pump test in supply well)

Test	Method	Transmissivities
Drawdown Pump Test	Jacob	633 gpd/ft
Recovery Period	Jacob	301 gpd/ft

2.1.4.6 Single Well Hydraulic Testing

Permeability values were estimated in each monitoring well using single-well hydraulic testing. Generally, rate-of-rise (rising head) tests were performed in wells not equipped with Well Wizard pumps and rate-of-fall (falling head) tests in wells equipped with pumps.

Permeability is estimated from rate-of-rise tests after the water level has been abruptly lowered by the removal of a "slug" of water using a PVC bailer. Rate-of-fall tests are initiated by the sudden injection of a slug of water into the well. In both methods, the water level recovery to the pre-test level was measured either by transducers or an Actat electric well probe. Permeabilities were calculated using Hvorslev's (1951) method of analysis.

A summary of estimated permeabilities for the Shallow Perched, Upper Regional, and Lower Regional Aquifers is shown in Table 2-4 (see also Appendix D).

2.1.5 Ground Water Sampling

Four rounds of ground water sampling required under the consent order were performed in April, July, and October 1988, and January 1989. Additional ground water quality data collected since 1982 are discussed in Section 6, Ground Water Quality and presented in Appendix G.

2.1.5.1 Sampling Procedures

Sampling procedures used were as documented in the Consent Order sampling and analysis plan submitted to Ecology on September 29, 1987. Sampling protocol is summarized in Appendix E.

2.1.5.2 Sampling Parameters

Sampling parameters were as specified in the Consent Order and included the following:

Round 1.

For all wells except B-7A and B-7B:
- Full EPA Priority Pollutant Scan.
- State of Washington Minimum Functional Standards (omitting total coliform)

For wells B-7A and B-7B:
- State of Washington Minimum Functional Standards (omitting total coliform)

Round 2.

For all wells except B-7A and B-7B:
- Volatile Organic Compounds
- State of Washington Minimum Functional Standards (omitting total coliform)

For wells B-7A and B-7B:
- State of Washington Minimum Functional Standards (omitting total coliform)

Table 2-4

Summary of Single Well Hydraulic Conductivity Results

Well	Hydraulic Conductivity cm/sec	Type of Slug Test[a]	Comments
Shallow Perched Aquifer			
TF-10(S)		--	Not tested
TF-11(S)	$\geq 1.0 \times 10^{-1}$	--	Recovery < 3 seconds
TF-12(S)	2.3×10^{-2}	Rising Head	
TF-13(S)	2.5×10^{-3}	Rising Head	
TF-14(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 4 seconds
MW-15(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 6 seconds
MW-16(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 6 seconds
MW-17(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 2 seconds
MW-19(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 3 seconds
MW-23(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 3 seconds
Lower Vashon Till Aquitard			
MW-18(S)	$\geq 1.0 \times 10^{-1}$	Rising Head	Recovery < 2 seconds
MW-22(U)		--	Insufficient H_2O for test
MW-22(L)	4.4×10^{-4}	Rising Head	
MW-25(S)	2.2×10^{-1}	Rising Head	Recovery < 5 seconds
Upper Regional Aquifer			
TF-10(D)	9.2×10^{-3}	Rising Head	
TF-11(D)	2.3×10^{-2}	Falling Head	
TF-12(D)	1.2×10^{-2}	Rising Head	
TF-13(D)	9.0×10^{-3}	Rising Head	
TF-14(D)	5.4×10^{-2}	Falling Head	
MW-15(D)	2.5×10^{-2}	Rising Head	
MW-16(D)	3.8×10^{-3}	Rising Head	
MW-18(D)	1.9×10^{-3}	Falling Head	
MW-19(D)	4.6×10^{-3}	Rising Head	
MW-23(D)	3.5×10^{-2}	Rising Head	
MW-25(D)	3.8×10^{-3}	Rising Head	
Lower Regional Aquifer			
MW-14(R)	1.5×10^{-3}	Falling Head	
MW-20(R)	3.3×10^{-4}	Falling Head	
MW-26(R)	8.6×10^{-5}	Rising Head	

Notes:
[a] Values calculated using the Hvorslev Method
The dedicated pump in TF-10(S) could not be easily removed.
The well screen for well TF-13(S) is open to the Shallow Perched Aquifer and the Lower Vashon Till.
The well screen for well MW-25(S) is open to the Lower Vashon Till Aquitard and the Upper Regional Aquifer.

Round 3.

For all wells except B-7A and B-7B:
- Volatile Organic Compounds
- State of Washington Minimum Functional Standards (omitting total coliform)

Round 4.

For all wells except B-7A and B-7B:
- Volatile Organic Compounds
- State of Washington Minimum Functional Standards (omitting total coliform)

Priority Pollutant Metals were analyzed for in 12 wells, including all wells where they were detected above background in Round 1. All other priority pollutants were analyzed for only where Round 1 detections were above 5 μg/l, except for acetone and phthalates, which were analyzed for if detected above 50 μg/l.

2.1.6 Soils Testing In MW-14(R)

Two soil samples were collected and analyzed for total organic carbon, cation exchange capacity, and grain size distribution from 65 feet bgs (Lower Vashon Till) and 90 feet bgs (Vashon Outwash Deposits) in MW-14(R). A soil sample was also collected at 45 feet bgs, but the sample size was not sufficient for laboratory analysis. All samples were collected using a Dames and Moore split barrel sampler. The analytical results are shown in Table 2-5.

Table 2-5
Soil Attenuation Data

Well Number	Depth (ft bgs)	Geologic Unit	Total Organic Carbon (%)	Cation Exchange Capacity (mg/Kg)
MW-14(R)	65	Lower Vashon Till	0.26	18
	90	Advance Outwash	0.16	15

2.1.7 Installation And Sampling Of Leachate Head Wells

Three leachate head wells designated LH-1, LH-2 and LH-3, were installed in the solid waste between October and November 1987. Each well was drilled and installed using a cable tool drilling rig owned and operated by Tacoma Pump and Drilling Company.

LH-1 was drilled to a depth of 43 feet; the bottom of the solid waste was encountered at approximately 37 feet bgs. Leachate was found only in the bottom 5 feet of the solid waste during drilling. Ten feet of 2-inch-diameter schedule 80 PVC, 0.025-inch slot screen was placed from 25 to 35 feet bgs and 2-inch-diameter PVC riser pipe was taken to above ground surface.

LH-2 was drilled to a depth of 117 feet bgs. The bottom of the solid waste was encountered at approximately 115 feet bgs. Refuse at the bottom of the solid waste pile was wet but not saturated during drilling. Ten feet of 2-inch-diameter schedule 80 PVC, 0.025-inch slot screen was placed from 103 to 113 feet bgs and 2-inch-diameter PVC riser pipe was taken to ground surface.

LH-3 was drilled to a depth of 104 feet bgs. The bottom of the solid waste was encountered at approximately 98 feet bgs. Refuse at the bottom of the solid waste was wet but not saturated while drilling. Ten feet of 2-inch-diameter schedule 80 PVC, 0.025-inch slot screen was placed from 85 to 95 feet bgs and 2-inch-diameter PVC riser pipe was taken to ground surface.

Leachate head wells LH-1 through LH-3 were sampled on April 29, 1988. Samples were collected in LH-2 for full EPA priority pollutants scan and State of Washington Minimum Functional Standards, omitting total coliform. A volatile organic sample was collected in LH-3. No other samples were collected in LH-3 and LH-1 on April 29, 1988, due to an insufficient amount of leachate.

At Ecology's request, LH-1 through LH-3 were sampled on October 27, 1988, in an attempt to collect sufficient samples for full priority pollutant scan analysis. Samples were collected for only volatile organic compounds in each well, again, due to an insufficient amount of leachate. Leachate chemistry is discussed in greater detail in Section 8.2 and is summarized in Table 2-6 (see also Appendix G). Field measurements of specific conductance, pH, and temperature from each sampling round are shown in Table 2-7.

Table 2-6

Leachate Chemistry

Parameter	LH-1 10/28/88	LH-2 04/29/88	LH-2 11/07/88	LH-3 04/29/88	LH-3 10/28/88
Organics (μg/L)					
Benzene	12	3.8	5	13	11
Chlorobenzene	106	0.6L	1L	4.7	6
1,2-dichlorobenzene	4	n/a	3	n/a	3
1,4-dichlorobenzene	25	n/a	18	n/a	12
Cis-1,2-dichloroethene	n/a	30	n/a	3.1	n/a
Trans-1,2-dichloroethene	1L	1.1	1L	1.1	1L
Ethylbenzene	8L	32	41	210	97
Toluene	1L	54	50	23	5
Vinyl chloride	2	4.2	7	18	4
Total xylenes	6	77	93	200	128
Naphthalene	n/s	150	n/s	n/s	n/s
2-methylnaphthalene	n/s	260	n/s	n/s	n/s
Phenanthrene	n/s	44	n/s	n/s	n/s
2,4-dimethylphenol	n/s	20	n/s	n/s	n/s
4-methylphenol	n/s	27	n/s	n/s	n/s
Di-n-octyl phthalate	n/s	14	n/s	n/s	n/s
Bis(2-ethylhexyl)phthalate	n/s	220	n/s	n/s	n/s
Non Metals and Total Metals (mg/L)					
Chloride	n/s	4,255	n/s	n/s	n/s
Fluoride	n/s	0.28	n/s	n/s	n/s
Ammonia	n/s	1,168	n/s	n/s	n/s
Sulfate	n/s	8	n/s	n/s	n/s
Cyanide	n/s	0.2	n/s	n/s	n/s
Phenol	n/s	0.29	n/s	n/s	n/s
TDS	n/s	9,270	n/s	n/s	n/s
MBAS	n/s	0.92	n/s	n/s	n/s
Arsenic	n/s	0.03	n/s	n/s	n/s
Beryllium	n/s	0.006	n/s	n/s	n/s
Cadmium	n/s	0.015	n/s	n/s	n/s
Chromium	n/s	0.22	n/s	n/s	n/s
Copper	n/s	0.59	n/s	n/s	n/s
Lead	n/s	0.03	n/s	n/s	n/s
Silver	n/s	0.0048	n/s	n/s	n/s
Nickel	n/s	0.3	n/s	n/s	n/s
Zinc	n/s	4.1	n/s	n/s	n/s

Notes:
L = less than detection limit
n/a = not analyzed
n/s = insufficient leachate to sample

Table 2-7
Leachate Head Wells — Field Measurements
(pH, temp, specific conductance)

Well #	Date	Specific Conductance (µmhos)	Temp (°C)	pH	Depth To Leachate (ft)	Leachate Elevation (amsl)
LH-1	04/29/88	5,595	20	6.63	35.71	453.63
	10/27/88	5,030	19	6.67	35.66	456.68
LH-2	04/29/88	22,500	33	7.40	112.79	438.89
	10/27/88	18,480	28	7.50	108.01	442.07
LH-3	04/29/88	8,900	--	7.40	100.35	449.29
	10/27/88	7,780	26	7.73	100.35	449.29

2.1.8 Surface Water

No surface water investigations were required at the landfill site due to the absence of on-site or adjacent drainage systems such as rivers, streams, creeks, ponds, or lakes. Surface water is not found on-site due to the free-draining surficial gravelly soils. Seasonal ponded water can occur in the area east of the solid waste footprint as a result of runoff from the temporary plastic cover after heavy rainfall events, or whenever water table elevations exceed 440 feet amsl, which typically occurs in late winter.

2.1.9 Soils Investigation

Three test pit excavations were completed in each of the four areas designated A, B, C, and D surrounding the landfill site (see Figure 2-3).

Test pits, using a backhoe, were excavated to depths ranging from 3 feet in D-2 to 9 feet in B-2 (see Appendix H, Test Pit Exploration Logs). Representative soil samples were collected from two test pits in each area and submitted to Columbia Analytical Services (CAS), Longview, Washington, for the laboratory analysis of EPA's priority pollutant list of contaminants. Soils from each test were field-screened for volatile organic compounds using an organic vapor analyzer (OVA) in a head space sampling method. The maximum level of organic vapor detected was 34 ppm in test pit excavation A-2 (see Table 2-8). Soil quality data are presented in Appendix H.

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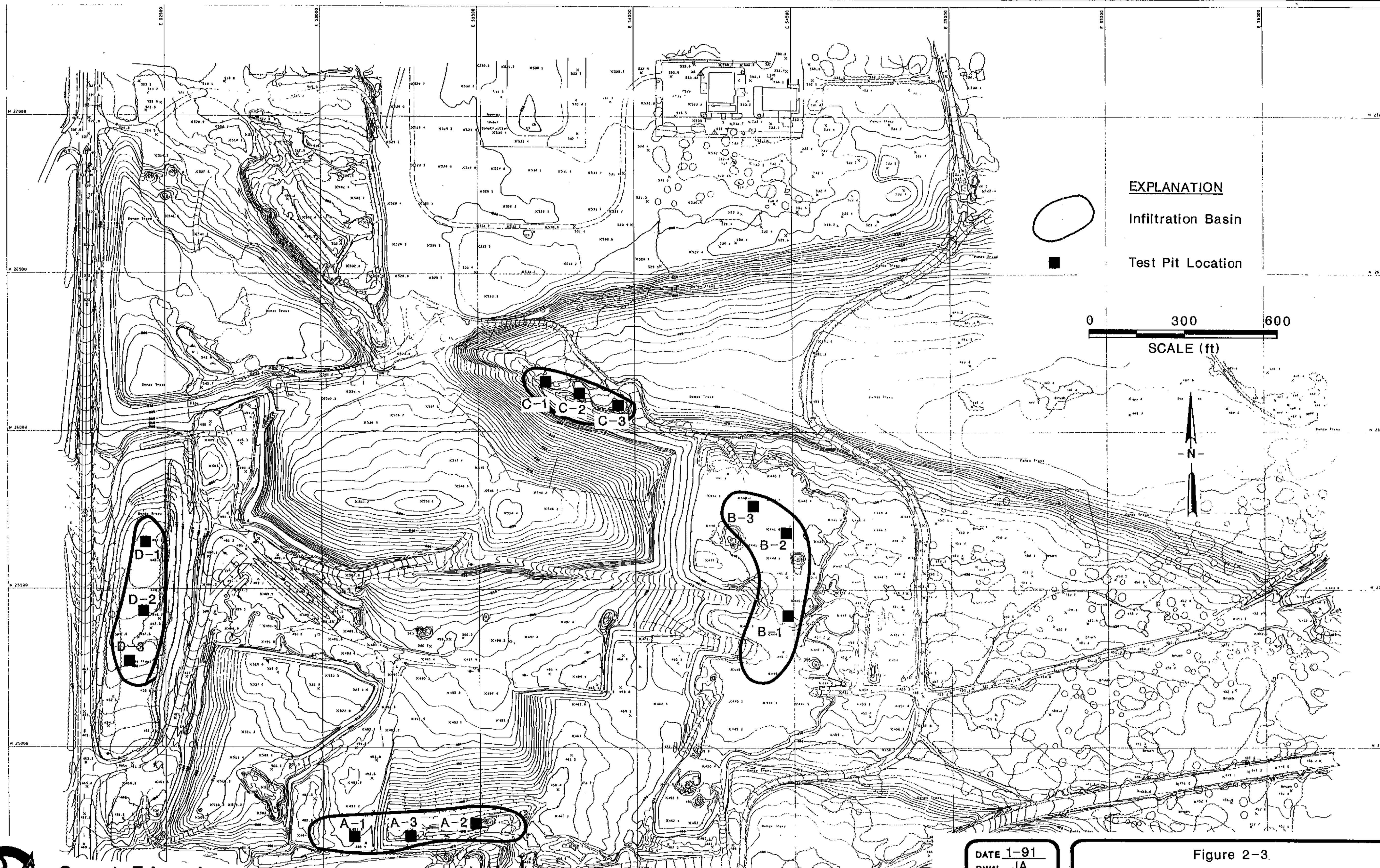

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Figure 2-3
HIDDEN VALLEY LANDFILL

TEST PIT LOCATIONS

Table 2-8

Test Pit Excavations — Summary of Soil Sampling Intervals and OVA Readings

Test Pit	Sample Depth (inches bgs)	OVA Reading (ppm)	Sampling Interval (inches)
A-1	24	3	24 - 30
	48	7	
	72	5	
A-2	24	30	36 - 40
	60	21	
	84	34	
A-3	30	1	- not sampled -
	50	4	
	72	4	
B-1	36	trace	32 - 38
	70	trace	
	105	trace	
B-2	24	trace	48 - 54
	38	trace	
	70	trace	
B-3	20	2	- not sampled -
	34	trace	
	48	trace	
C-1	30	15	34 -37
	60	5	
	98	1	
C-2	24	2	25 - 36
	60	3	
	74	2	
C-3	20	14	- not sampled -
	40	32	
	72	18	
D-1	24	trace	24 - 30
	36	trace	
	68	trace	
D-2	12	trace	30 - 36
	18	trace	
D-3	30	trace	- not sampled -

Notes: No refuse was encountered in any of the four areas.
OVA = Organic Vapor Analyzer field measurements.
Trace = 1 ppm or less than 1 ppm

2.1.10 Ambient Air Investigations

Initial air investigations were conducted to evaluate landfill gas emissions. Air investigations performed at the landfill site are described in Section 7.4 and Appendix I.

2.1.11 Landfill Gas Investigations

A subsurface landfill gas investigation was conducted to monitor landfill gas concentrations. Landfill gas investigations performed at the landfill site are described in Section 7.2 and Appendix I.

2.1.12 Survey of Monitoring Wells and Gas Probes

D. A. Berg Engineers of Tacoma, Washington, surveyed the horizontal and vertical elevations of each gas probe and monitoring well. Elevations were measured to the nearest 0.01 foot above mean sea level using Pierce County data (see Appendix J, Monitoring Well and Gas Probe Survey Data).

2.2 Phase II Field Investigations

Installation of Monitoring Wells

Monitoring wells were installed under the Phase II scope of work using air-rotary drilling techniques. Monitoring wells were designated using the (S), (D), and (R) notation as used in the Phase I investigation. Monitoring wells MW-22(U) and MW-22(L) were screened at different depths in the Lower Vashon Till Aquitard.

Air Rotary Drilling

A Speedstar SS-15 TH, owned and operated by Tacoma Pump and Drilling of Graham, Washington, was used to install monitoring wells MW-22(U), MW-22(L), MW-23(S), and MW-23(D). Each boring was advanced using a 6-5/8-inch-diameter tri-cone bit. Eight-inch steel casing was driven concurrent with the boring. Drill cuttings were collected at 10-foot intervals or at any change in lithology and were logged in terms of color, grain size, moisture content, and any other pertinent descriptors (see Appendix A, Boring Logs).

A Speedstar SS-15 TH, owned and operated by Hayes Well Drilling of Bow, Washington, was used to install monitoring wells MW-25(S), MW-25(D), and MW-26(R). Each boring was advanced using a 6-5/8-inch-diameter tri-cone bit. Eight-inch steel casing was driven concurrent with the boring. Drill cuttings were collected at 10-foot intervals and were logged in terms of color, grain size, moisture content, and any other pertinent descriptors (see Appendix A, Boring Logs).

2.2.1 Additional Rate and Extent Investigations

In order to better characterize horizontal and vertical distribution of nitrate within the Shallow Perched and Upper Regional Aquifers, the installation of a series of eight nested well pairs was proposed as part of the Phase II Remedial Investigation. This was agreed upon by Ecology, TPCHD, LRI, and SE/E and included in the Phase II RI work plan. One of the nested well pairs [designated MW-24(S) and MW-24(D)] was not installed because of difficulties in acquiring site access from the property owner (see Appendix L, Correspondence With Property Owner). The other six wells [designated MW-22(U), MW-22(L), MW-23(S), MW-23(D), MW-25(S), and MW-25(D)] were installed at the agreed upon locations (see Figure 2-4).

2.2.1.1 Installation of Nested Wells

Monitoring wells MW-23(S), MW-23(D), MW-25(S), and MW-25(D) were installed as nested pairs, with each pair consisting of a well completed in the uppermost zone of saturation and a well completed in the Upper Regional Aquifer. The locations for these wells were selected to provide additional data on ground water quality downgradient of the landfill. The wells were installed at locations slightly lateral to the predominant flow direction in order to better clarify seasonal variations in ground water flow direction.

2.2.1.2 Installation of Additional Monitoring Wells at MW-18

Two monitoring wells, MW-22(U) and MW-22(L), were installed in the Lower Vashon Till aquitard near MW-18. The wells were installed to provide information on the vertical distribution of nitrate ammonia and total nitrogen within the uppermost zone of saturation. Each well was constructed using a 5-foot screened interval. MW-22(U) was screened above MW-18(S), and MW-22(L) was screened below MW-18(S), as shown in Figure 4-2, Cross Section A-A.

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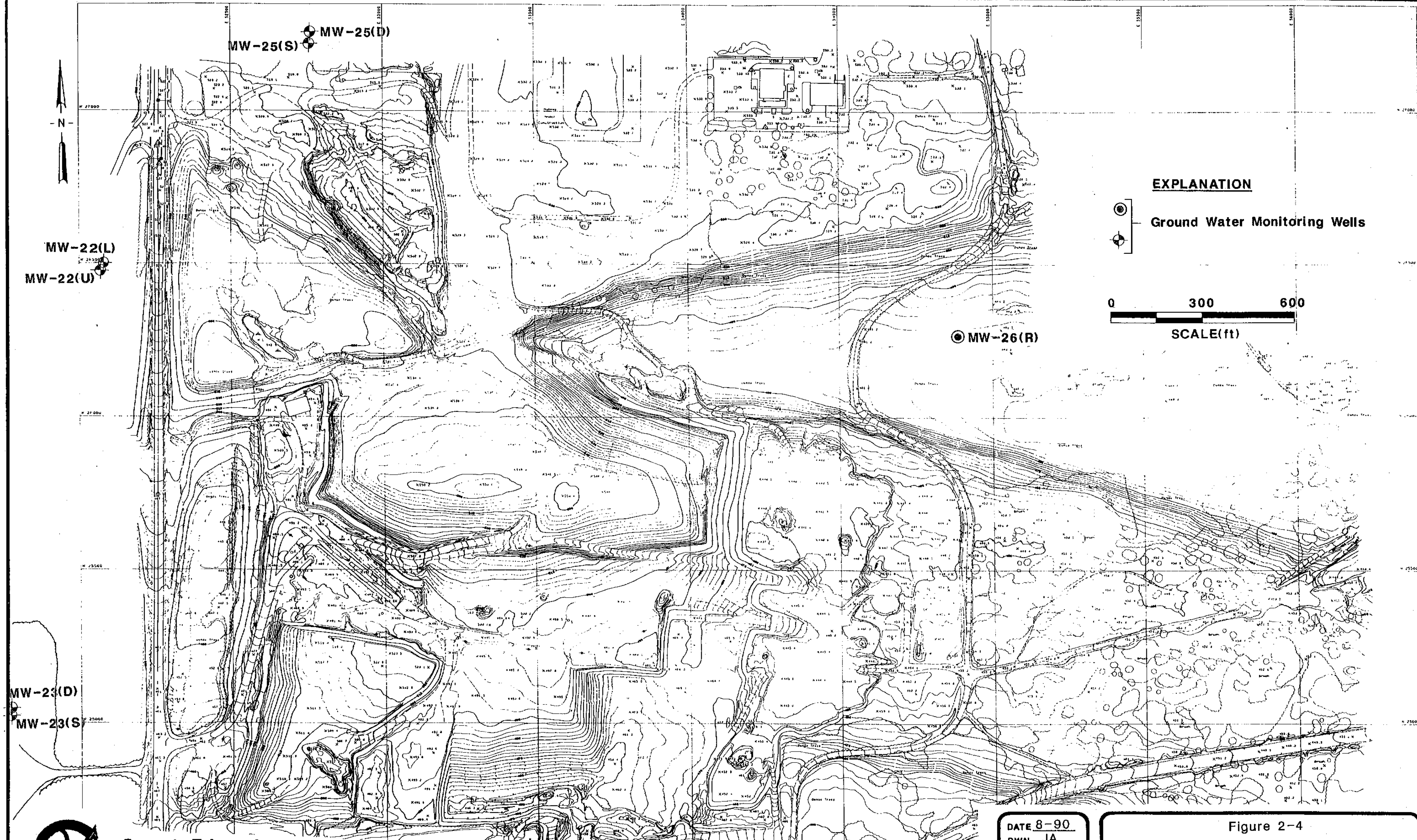

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Figure 2-4
HIDDEN VALLEY LANDFILL
PHASE II
WELL LOCATIONS

2.2.2 Installation of Monitoring Well in Lower Regional Aquifer

One well, MW-26(R), was installed in the Lower Regional Aquifer. The well is located northeast of the landfill site on property that LRI is in the process of acquiring. The location was selected in order to monitor ground water quality in this aquifer which is inferred to be downgradient of the solid waste. The well was completed at 196 ft bgs following penetration of a silty clay aquitard between 165 and 174 ft bgs.

2.2.3 Slug Testing of Newly Installed Wells

A rising head hydraulic conductivity test was performed in each of the newly installed wells. The test was performed by removing a slug of water from the well and measuring the rate of water level rise to the original static level. Water level measurements were obtained during the test using a Hermit environmental data logger and transducer. The test results were analyzed using the Hvorslev method (1951). Hydraulic conductivity values obtained from the tests are included in Table 2-4.

2.2.4 Ground Water Sampling

The ground water sampling program consisting of monthly and quarterly sample collection continued throughout Phase II field activities. Additional bi-weekly sampling of monitoring wells TF-10(S), TF-11(S), TF-12(S), TF-13(S), TF-14(S), MW-15(S), MW-17(S), and MW-18(S) was conducted between November 1989 and June 1990. Samples were collected in accordance with the sampling and analysis plan and were analyzed for nitrate, ammonia, and total nitrogen. Ground water quality results are included in Appendix F, Ground Water Quality.

2.2.5 Continuous Water Level and Conductivity Monitoring

The seasonal fluctuation in ground water elevation in the Shallow Perched Aquifer can be greater than 10 feet between the seasonal high (occurring in early spring) and the seasonal low (occurring in late fall). In an effort to better understand the correlation between increasing water levels and nitrate occurrence, a program of continuous water level and conductivity monitoring was implemented in monitoring wells TF-10(S), TF-11(S), TF-12(S), TF-13(S), TF-14(S), MW-17(S), and MW-18(S).

Using Terra data loggers and transducers, measurements were collected every six hours. The data loggers were downloaded to a laptop computer approximately every two weeks and graphical plots generated. The data are discussed more thoroughly in Section 6.

2.2.6 Survey of Newly Installed Wells

The seven newly installed wells were surveyed for horizontal and vertical location by D. A. Berg Engineers of Tacoma, Washington. Elevations were measured at the top of the PVC well casing to the nearest 0.01-foot amsl using the Pierce County data (see Appendix J, Monitoring Well and Gas Probe Survey Data).

3 PHYSICAL SETTING

3.1 Physiography and Topography

Hidden Valley Landfill is located on the southeast edge of the Puget Sound Lowlands within the Clover/Chambers Creek Basin. The lowlands are bounded to the east by the Cascade Mountains and to the west by the Olympic Mountains. The physiography is the result of a complex geologic history that has taken place over several million years.

Topographically, the site is located within an undulating, well drained area approximately two miles west of the Puyallup River Valley. The landfill site is located in a former glacial melt water channel which trends in an east-west direction across the site. Ground elevation varies from 440 feet amsl in the central part of the channel to more than 500 feet amsl on upland areas bordering the channel to the north and south. Past sand and gravel extraction operations have modified the surface topography within the area of the landfill site.

The nearest surface water bodies to the landfill site are the Puyallup River, approximately two miles to the northeast (approximate elevation 150 feet amsl), and the upper tributaries of Clover/Chambers Creeks approximately 1.5 miles to the west. Commencement Bay in Tacoma is located approximately 10 miles northwest of the site.

3.2 Climatology

The site is located in a part of Pierce County that has a moderate climate with temperatures normally above freezing in the winter (range 30-45°F) and below 80°F in the summer (range 45-75°F) (Puyallup experiment station 1930-86 climatological records). Annual precipitation ranged from 25 to 55 inches (average 41 inches) between 1930 and 1986. Evaporation rates over a 5-year period (1975 through 1980) averaged 25 inches between April and November (Washington State University, 1968 and ongoing).

3.3 Land Use

Land use within a one-mile radius of the site is largely mixed: rural and semi-rural residential, commercial, industrial, and wooded undeveloped land. Much of the area surrounding the site is zoned General Use (G), which permits a variety of uses from agriculture and forestry to single- and multi-family housing and all facilities that accompany residential developments (schools, churches, and shops) to light industry.

Immediately south of the landfill is a sand and gravel extraction operation. Gravel mining operations both north and south of the landfill have resulted in changes to the natural topography. The eastern portion of the landfill site was mined for gravel prior to its current use.

Southwest of the site, west of Meridian Street, is the Paul Bunyan Sportsman Club. This is a privately owned gun club, rifle range, archery range, and campground. It has approximately 500 members, of which several hundred use the facilities daily.

Immediately north of the landfill is the Thun Field or Pierce County airport. The airport began operations in 1944 and was purchased by Pierce County in 1979. Approximately 125 aircraft have been based at the airport since 1979. Fifty new hangars are currently under construction, with another 30 to 40 proposed for future construction. Airport traffic averages between 160,000 and 170,000 takeoffs and landings each year.

East of the site a residential development, Sunrise (formerly named Rainier Terrace), began development in 1990; it will have 140 single-family homes. Development of single-family housing in this area is anticipated to increase by 6 percent per year, resulting in an additional 2,500 persons (2.6 persons per household) in this area. The Rainier Terrace development also includes plans for construction of multi-family units; commercial, industrial and office space; an elementary school; and park space within its boundaries. An extension of 176th Street East in progress along the northern boundary of the landfill as access to the development from Meridian Street (SR-161).

West of the site, across Meridian Street and north of the gun club, another residential development, Rainier Vista, is being planned. The Draft Environmental Impact Statement (EIS) (May 1989) specifies that the land use will include development of 480 acres including single-family, multi-family, residential developments and community commercial facilities. Single-family dwellings will occupy 48 percent of the site or 147.5 acres, while multi-family dwellings will occupy 30 percent of the site or 97 acres. The Draft EIS states that the development will be limited to 493 single-family homes and 509 multi-family units. The developer has applied for a well installation permit for water supply to the development, but the capacity of the well is not known at this time. The area is also slated for sewerage.

Another residential development is planned for the area north of 176th Street East and west of Meridian Street. No information is available on this development at this time.

Good Samaritan Hospital owns a 6.5 acre site adjacent to the Thun Field Airport. Development plans for this parcel of land are not known at this time.

4 REGIONAL AND SITE GEOLOGY

4.1 Geologic History and Regional Stratigraphy

Thick sequences of glacial sediments were deposited in the Puget Sound Lowlands during the Pleistocene Ice Age. Four major glacial episodes have resulted in the deposition of sediment sequences that are estimated in thicknesses from greater than 2,000 feet to less than 100 feet (Crandell et al, 1958). The glacial history that occurred throughout most parts of central and western Pierce County includes the following chronology (from youngest to oldest):

- Non-glacial recent deposits
- Vashon Glaciation
- Kitsap Nonglacial Interval
- Salmon Springs Glaciation (a non-glacial sequence suspected within the unit)
- Puyallup Interglaciation
- Stuck Glaciation
- Alderton Interglaciation
- Orting Glaciation

Glacial deposits typically include outwash deposits, glacial till, and interglacial lacustrine sediments. Outwash deposits are composed of sands and gravels, which were deposited as the glacial ice front advanced (advance outwash) or receded (recessional outwash). Glacial till is a compact concrete-like mixture of gravel, sand, and fines (silt and clay). It is formed by glaciers overriding, grinding, and compacting outwash material. Lacustrine (lake) sediments typically include finer-grained materials such as clay, silt, and fine sands, and often contain organic debris.

4.2 Site Geology

Based on the field investigations, eight distinct geologic units have been identified beneath the site. The units from youngest to oldest are as follows:

- Vashon Age Deposits
  - Upper Vashon Till (Unit A)
  - Recessional Outwash (Unit B)
  - Lower Vashon Till (Unit C)
  - Advance Outwash (Unit D)
- Salmon Springs Age Deposits
  - Upper Salmon Springs Till (Unit E)
  - Interglacial Sequence (Unit F)
  - Lower Salmon Springs Till (Unit G)
  - Salmon Springs Advance Outwash (Unit H)

4.2.1 Vashon Age Deposits

Vashon Age deposits are divided into four distinct sedimentary units, which have been designated Units A through D in this report.

4.2.1.1 Upper Vashon Till (Unit A)

The Upper Vashon Till was encountered in surficial deposits at borings MW-17(S), MW-18(S), (D), MW-25(S), (D), and PW-21 at elevations ranging from 550 to 480 feet above mean sea level (Figures 4-1, 4-2, and 4-3). These deposits consist of dense mixtures of gravel, sand, and silt. The unit is light olive brown grading into a brownish gray with depth. Surficial till is exposed in cuts and excavations in the northwest corner of the site. This unit is unsaturated, has low permeability, and appears to be restrictive to the vertical and horizontal movement of moisture.

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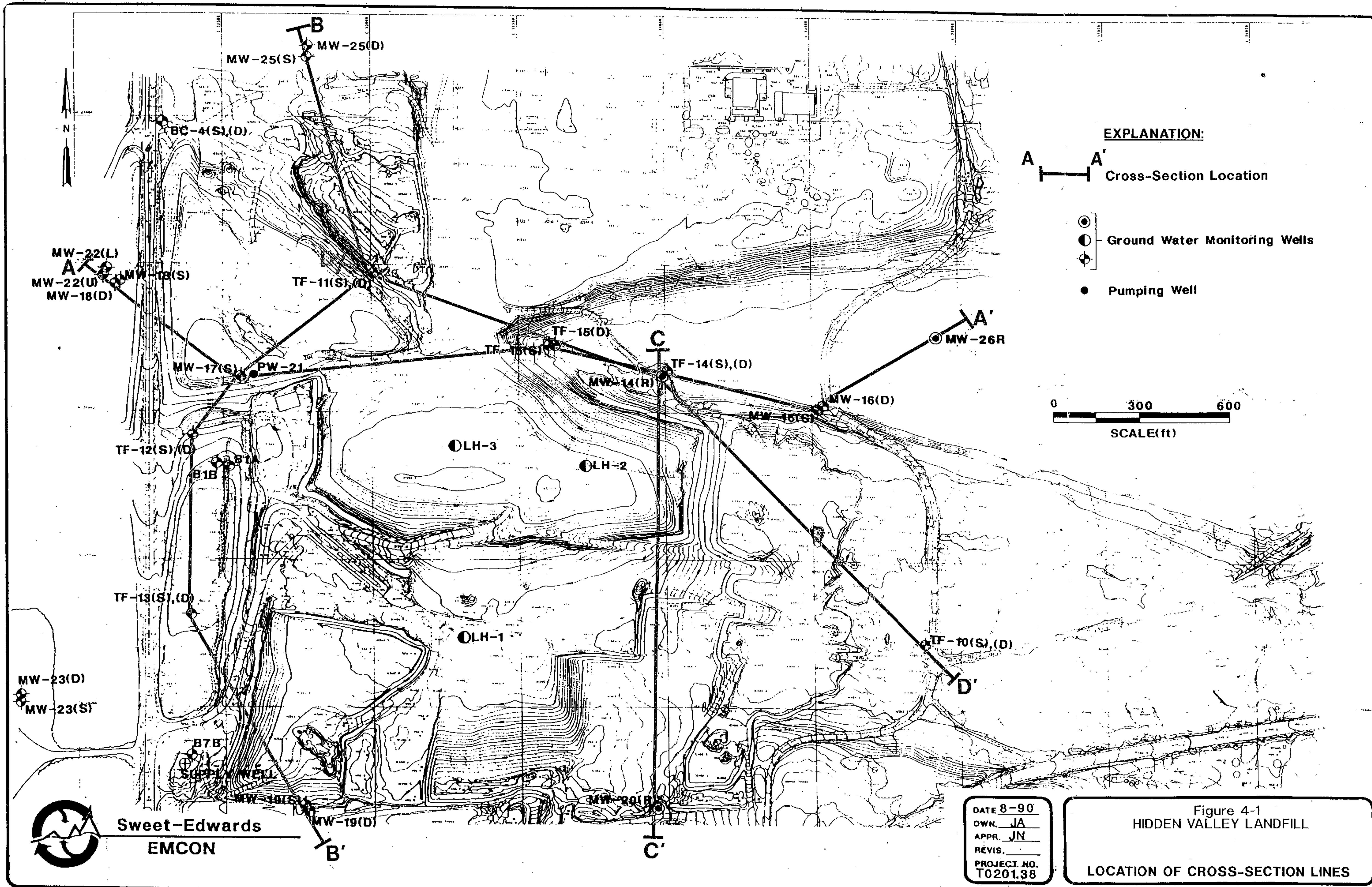

Figure 4-1
HIDDEN VALLEY LANDFILL

LOCATION OF CROSS-SECTION LINES

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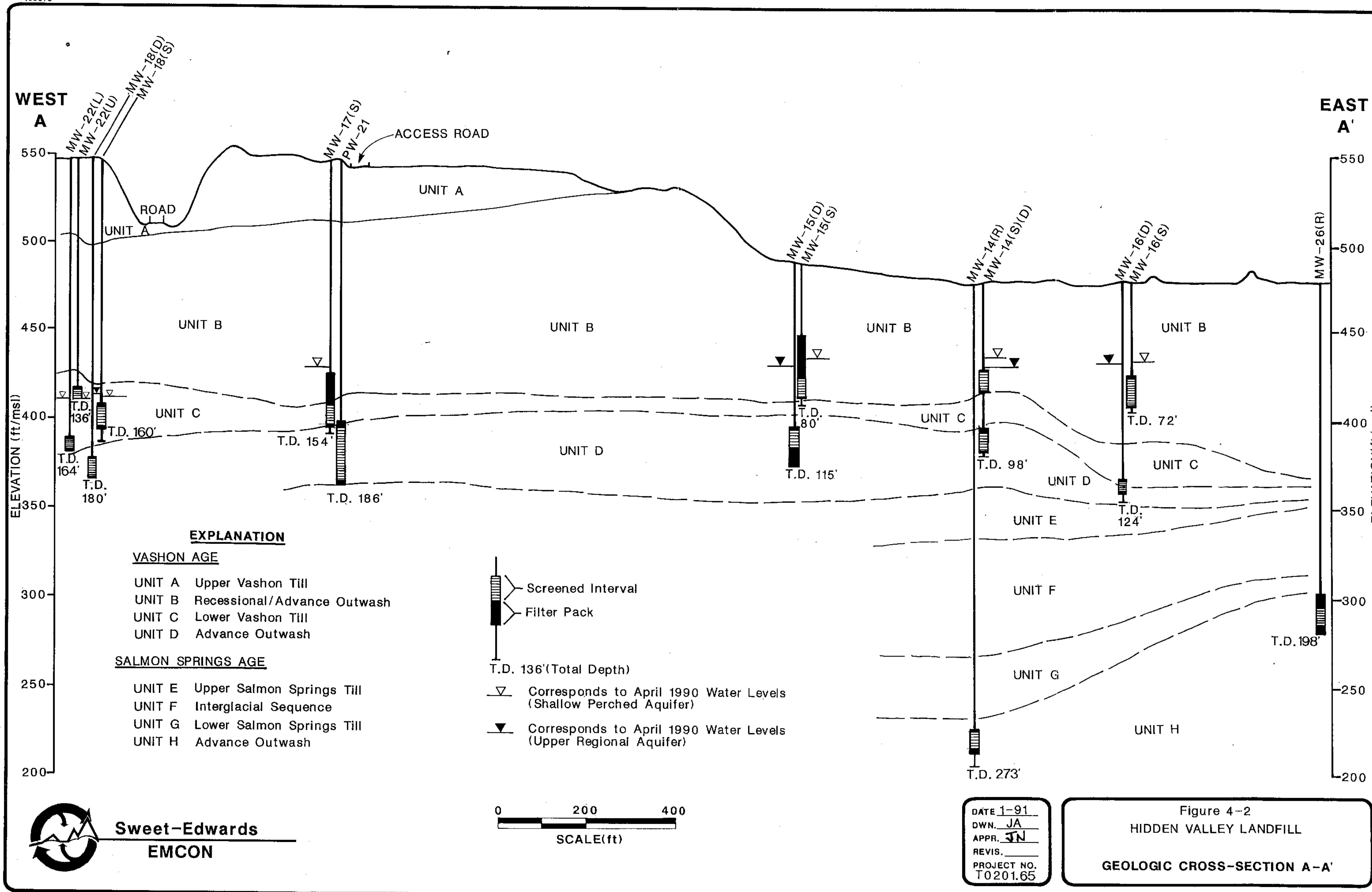

Figure 4-2
HIDDEN VALLEY LANDFILL
GEOLOGIC CROSS-SECTION A-A'

4.2.1.2 Recessional Outwash (Unit B)

Recessional outwash deposits (Unit B) consist primarily of silty, fine sand to gravelly sand, which is typically olive brown and medium dense to loose. Recessional outwash deposits were encountered at elevations ranging from 480 to 425 feet amsl. The average thickness of the unit is approximately 70 feet with the maximum thickness of 120 feet occurring in MW-17(S) (refer to Geologic Cross-sections, Figures 4-2 through 4-5).

4.2.1.3 Lower Vashon Till (Unit C)

The Lower Vashon Till (Unit C) underlies the Vashon Recessional Outwash deposits and ranges in thickness from 9 feet (MW-15(S)) to 32 feet (B-7B). Elevations range from 430 feet to 370 feet amsl. The average thickness is 18 feet beneath the site. Deposits are composed of dense, silty sand, gravelly sandy silt, and silty sandy gravel typically light olive gray in color. The upper surface of the unit is irregular and reflects the complex depositional and erosional history of glaciation in the site area (see Figure 4-3, Geologic Cross Section B-B'). Depth to the upper surface of the till ranges from 45 to 150 feet bgs. SE/E identified the Lower Vashon Till unit in all borings that penetrated the Vashon Outwash deposits. Hart, Crowser (1982) reported that this unit was absent in borings designated B-3A and B-9A.

4.2.1.4 Vashon Advance Outwash Deposits (Unit D)

Vashon Advance Outwash deposits (Unit D) consisting of sands and gravels underlie the Lower Vashon Till and overlie the Upper Salmon Springs Till. Advance outwash deposits were encountered in all borings at the site from elevations ranging from 400 to 350 feet amsl. The unit consists of well-graded, medium-dense to dense, fine-grained sand and gravels. The thickness of the unit varies from 11 to 50 feet, thinning toward the northwest in the vicinity of TF-12(D), MW-18(D), and PW-21. The average thickness is 30 feet.

4.2.2 Pre-Vashon Deposits

4.2.2.1 Upper Salmon Springs Till (Unit E)

The Upper Salmon Springs Till (Unit E) was encountered in borings MW-13(D) and PW-21 and was fully penetrated in MW-14(R), MW-20(R), and MW-26(R). Elevations range from 360 to 340 feet amsl. The unit is typically a brown, dense to very dense, gravelly silty sand to silty sandy

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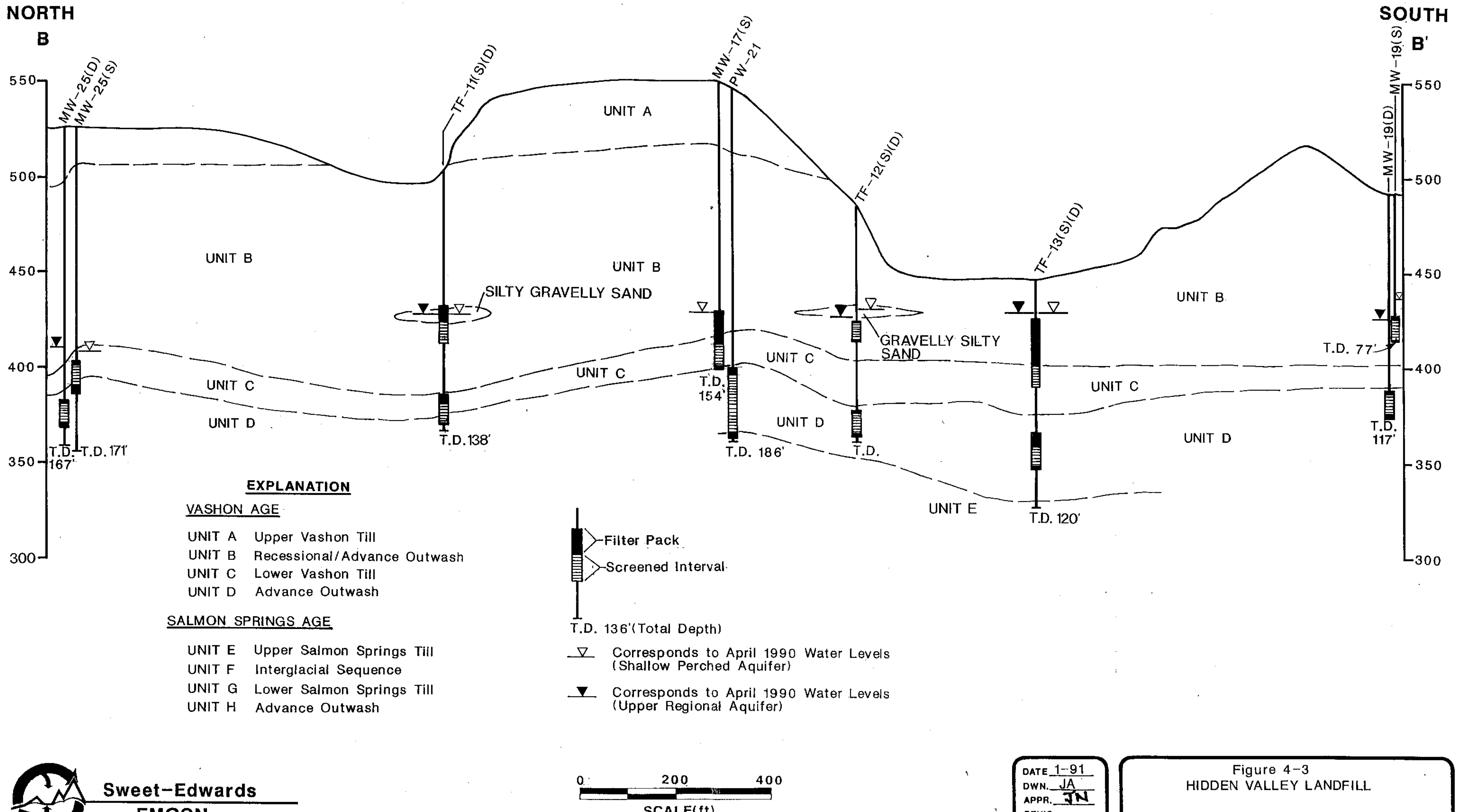

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Figure 4-3
HIDDEN VALLEY LANDFILL

GEOLOGIC CROSS-SECTION B-B'

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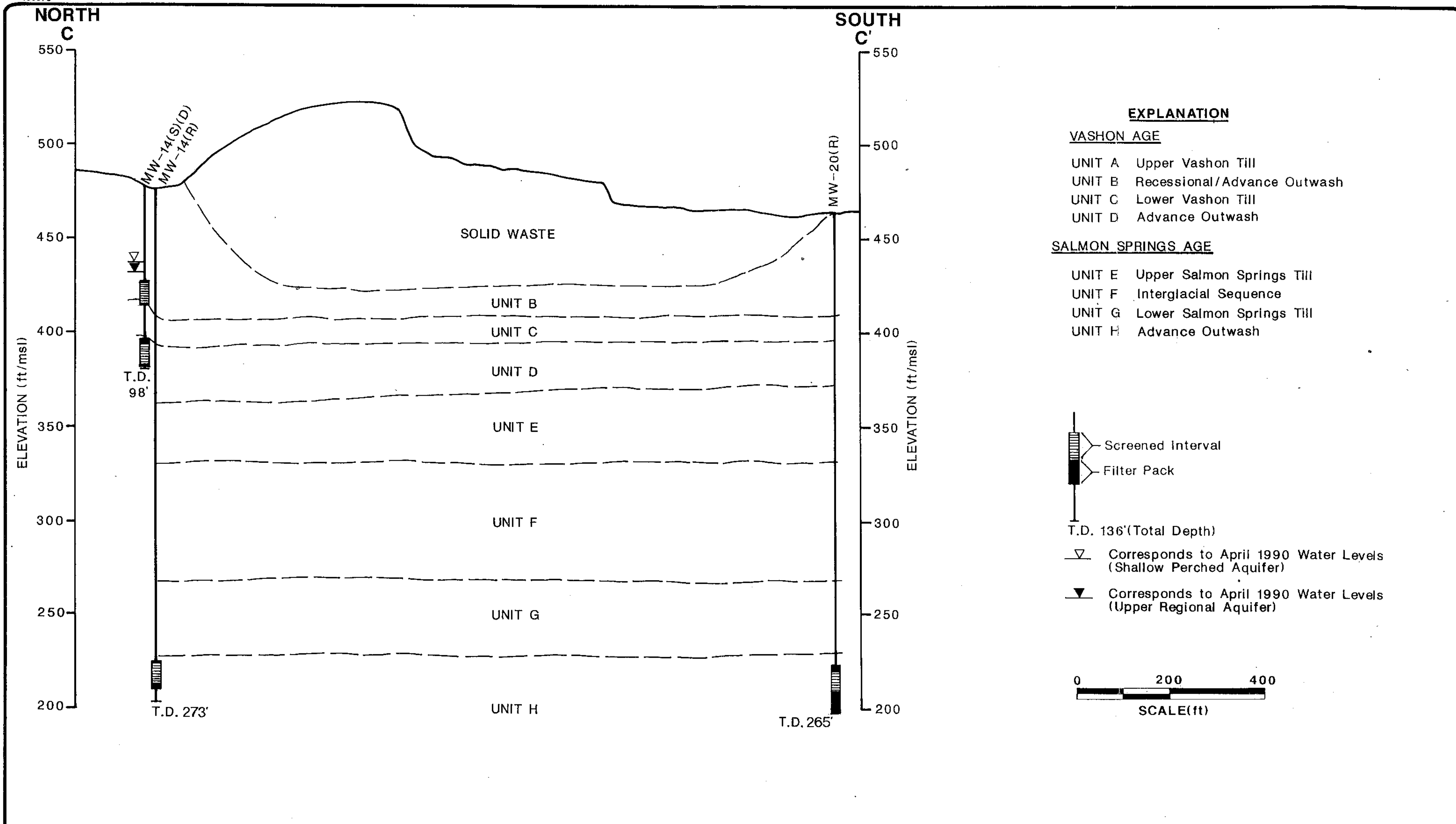

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Figure 4-4
HIDDEN VALLEY LANDFILL
GEOLOGIC CROSS-SECTION C-C'

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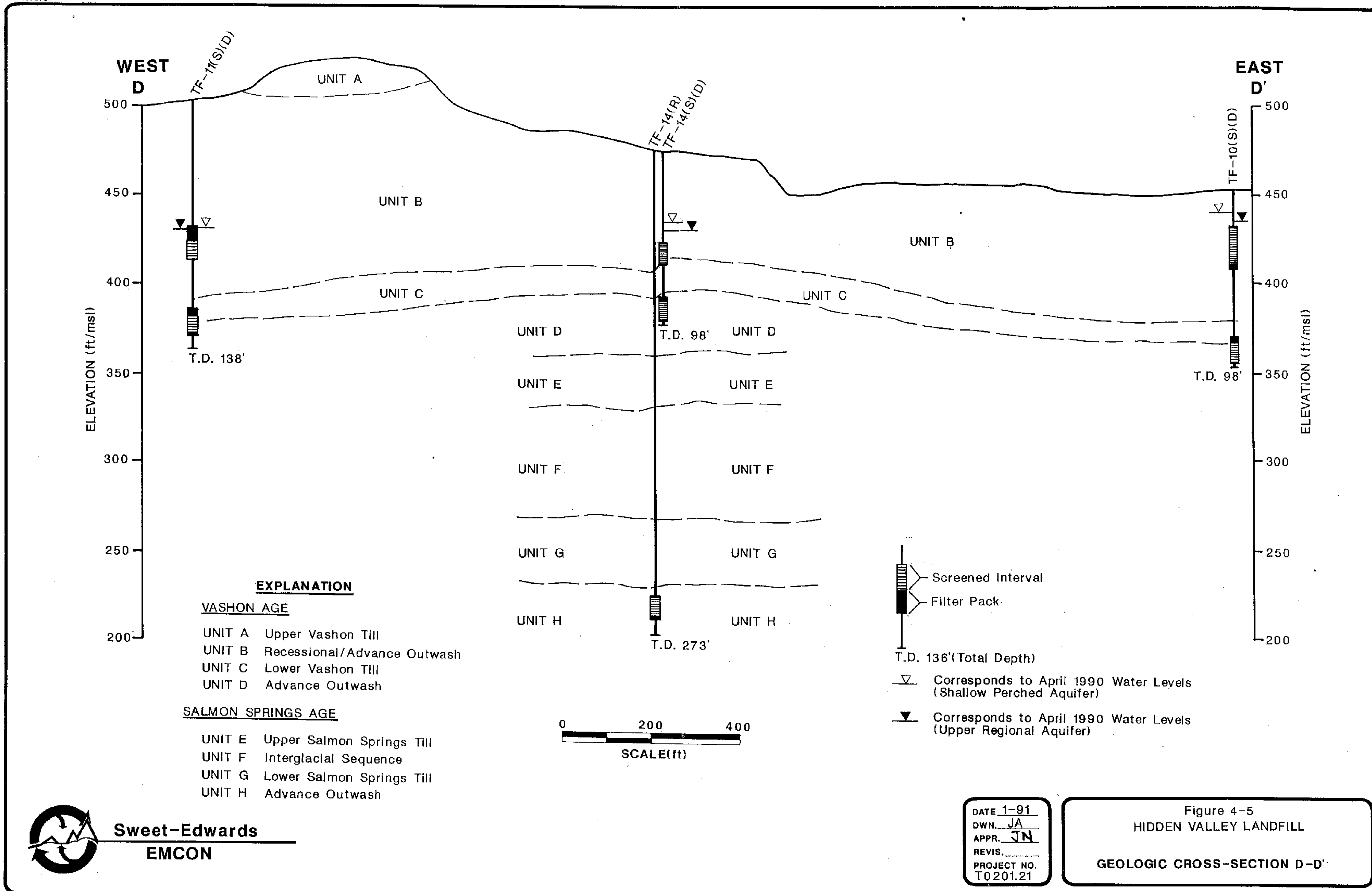


Figure 4-5
HIDDEN VALLEY LANDFILL

GEOLOGIC CROSS-SECTION D-D'

gravel. Till thickness averages 25 feet and the upper surface appears to be relatively flat beneath the site (see Geologic Cross Section C-C', Figure 4-4).

4.2.2.2 Salmon Springs Interglacial (Unit F)

Salmon Springs Interglacial Deposits (Unit F) were encountered from an elevation of approximately 340 feet to 265 feet amsl and are comprised of interbedded sandy gravels, gravelly sands, and silty sands (see Figure 4-4, Geologic Cross Section C-C'). Deposit thicknesses are 48 feet and 65 feet in MW-14(R) and MW-20(R), respectively. Drill cuttings indicate that the unit is loose to dense and includes scattered wood debris and other organic material.

4.2.2.3 Lower Salmon Springs Till (Unit G)

The Lower Salmon Springs Till (Unit G) was encountered at 280 feet amsl (210 feet bgs) in MW-20(R). It consists of dark brownish gray, dense, silty sandy gravel and silty gravelly sand. The unit was approximately 45 feet thick (see Figure 4-4).

4.2.2.4 Salmon Springs Advance Outwash (Unit H)

The Salmon Springs Advance Outwash consists primarily of dark gray, fine to medium-fine, gravelly sands to silty sands. Deposits are loose, permeable, and support the productive use of the Lower Regional Aquifer. The top of this unit was encountered at a depth of approximately 225 feet amsl (240 feet bgs). The base of the outwash deposits was not encountered in either MW-20(R) or MW-14(R).

5 HYDROGEOLOGY

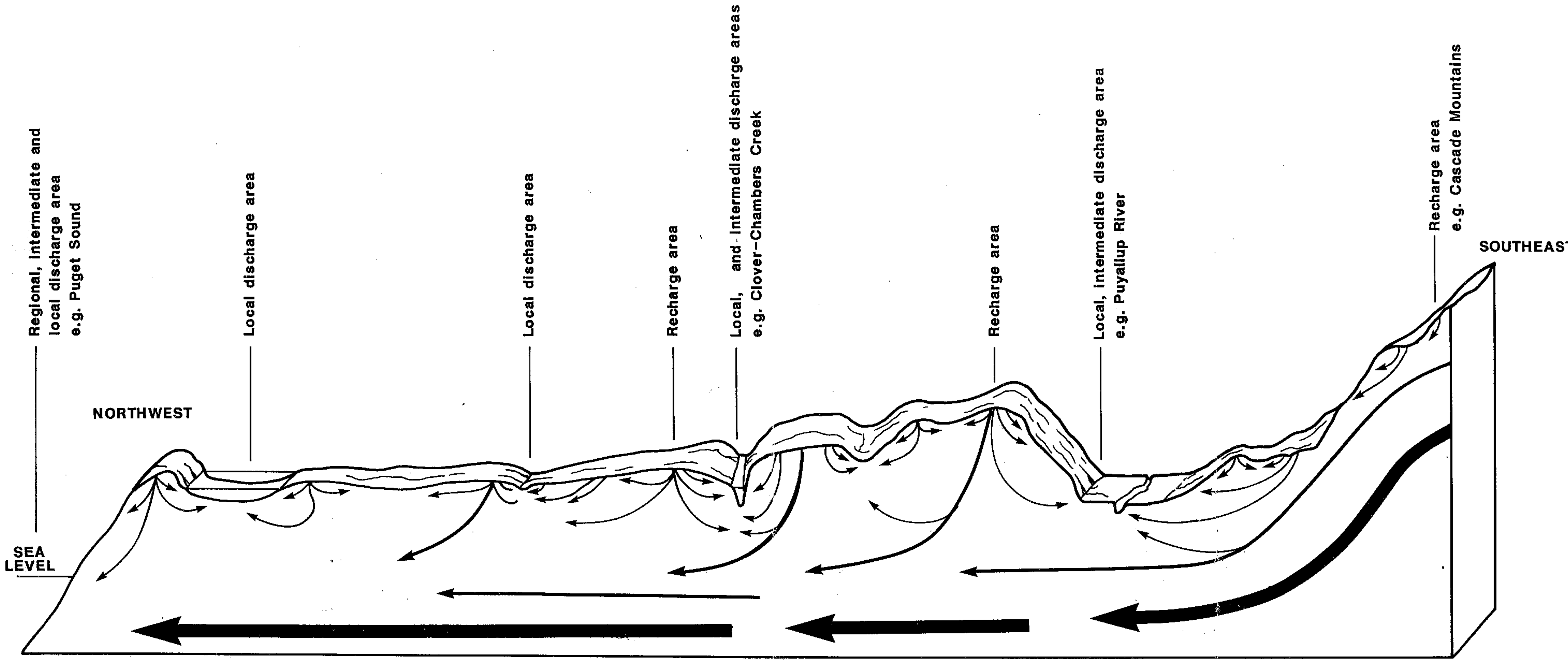
5.1 Regional Hydrogeologic Framework

An understanding of regional ground water flow systems in Pierce County helps simplify the explanation of ground water movement beneath the landfill site.

The first published work on basin-wide ground water flow that considered steady state phenomena was published by Hubbert (1940). Toth (1962, 1963) developed Hubbert's work and developed a model to express regional flow patterns. This model showed that local changes in topography control upper zones of local ground water flow systems while regional flow regimes are controlled by major regional topographic features. Toth identified three different types of flow system that occur within a sedimentary basin: local, intermediate, and regional. A local system has a recharge area at a topographic high and a discharge area at a topographic low, and these two areas are adjacent to each other. Intermediate systems do not receive recharge from the highest elevation in the basin, and the discharge area does not occupy the lowest discharge area in the basin. A regional system occupies the basin ground water divide and the discharge area is at the bottom of the basin.

In Pierce County, the Cascade mountain range is the major topographic high and recharge area, and is the ground water basin divide. Puget Sound, as the lowest area of the basin, is the regional discharge area. Intermediate and local systems are superimposed on the "deeper seated" regional system(s) and are influenced by the basin's topography, geology and surface drainage (see Figure 5-1).

The landfill site is located in the Clover/Chambers Creek (CCC) sub-basin within which local and intermediate ground water flow systems dominate (Brown and Caldwell, 1985). Regional recharge occurs east of the CCC sub-basin and regional discharge occurs to Puget Sound and the Puyallup and Nisqually River valleys. Local and intermediate systems occur in smaller basins within the CCC area.



* NOT TO SCALE *

EXPLANATION
Local flow
Intermediate flow
Regional flow

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Figure 5-1
HIDDEN VALLEY LANDFILL

SCHEMATIC OF GROUND WATER FLOW SYSTEM FOR PIERCE COUNTY

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5.2 Site Hydrogeology

The hydrogeologic setting of the landfill site is interpreted as an intermediate recharge area for the Shallow Perched and Upper Regional Aquifers, superimposed on the Lower Regional Aquifer, a "deeper" intermediate system. Primary recharge to all three ground water regimes occurs off-site from infiltration of precipitation, surface runoff, and snow melt, particularly in spring and early summer.

Recharge also occurs to the Shallow Perched and Upper Regional Aquifers on-site via precipitation and infiltration of runoff from the landfill's temporary plastic liner. Minimal, if any, recharge to the Lower Regional Aquifer occurs at the landfill site. There is no discharge to surface water from any of the three aquifers beneath the site in the vicinity of the landfill. The Shallow Perched and Upper Regional Aquifers discharge to Puget Sound via the Clover Creek and Chambers Creek drainage basins; the Lower Regional Aquifer discharges to Puget Sound via the Puyallup and Nisqually River drainage systems.

Based on information collected while drilling and sampling monitoring wells and PW-21, six distinct hydrogeologic units have been identified below the landfill site:

- Vadose Zone (Upper Vashon Till and Vashon Recessional Outwash)
- Shallow Perched Aquifer (Vashon Recessional Outwash)
- Vashon Till Aquitard (Lower Vashon Till)
- Upper Regional Aquifer (Vashon Advance Outwash)
- Salmon Springs Aquitard (Upper Salmon Springs Till, Salmon Springs Interglacial, and Lower Salmon Springs Till)
- Lower Regional Aquifer (Salmon Springs Advance Outwash)

5.2.1 Vadose Zone

The vadose zone performs a complex role in ground water recharge beneath the site and possibly influences the chemistry of the uppermost aquifer. The vadose zone exists between the ground surface and water table. This zone still contains water, but the water is held to the soil particles by capillary forces. Seasonal variations in the vadose zone thickness have ranged from zero feet beneath the solid waste area (beneath the landfill) during high water table elevations in winter and early spring to approximately 145 feet in the upland area at MW-18.

5.2.2 Shallow Perched Aquifer

5.2.2.1 Ground Water Occurrence

The Shallow Perched Aquifer is the uppermost saturated zone beneath the landfill site and consists of the saturated Vashon Recessional Outwash deposits. Northwest of the landfill, in the vicinity of MW-18, MW-22, and MW-25, the Shallow Perched Aquifer is not present, and the uppermost saturated zone is the Lower Vashon Till unit.

The Shallow Perched Aquifer is unconfined and under water table conditions. It is recharged from infiltration of precipitation and surface runoff both on-site and off-site. Seasonal fluctuations of the ground water table can exceed 15 feet within the Shallow Perched Aquifer (see Table 5-1). Depth to ground water ranges from less than 20 feet bgs [TF-10(S)] to greater than 120 feet [MW-18(S)].

5.2.2.2 Ground Water Movement

The general ground water flow direction in the Shallow Perched Aquifer is to the northwest with local components of flow towards the north and west (see Figures 5-2 and 5-3). Increased runoff due to the temporary capping of the north hill before the summer of 1990, resulted in a 'rapid' recharge condition to the Shallow Perched Aquifer in the vicinity of TF-14 and MW-15. The increased recharge locally steepened water level gradients, particularly in the winter and spring. Under these conditions, ground water flow was towards the north and northwest with a northeast component in the vicinity of MW-14 and MW-16 (see Figure 5-3). Final capping of the landfill using geotextile fabric together with runoff control will minimize the recharge to ground water in the immediate vicinity of the solid waste and prevent the steepening of gradients in winter and spring.

5.2.2.3 Ground Water Velocities

Permeability data obtained from the single-well hydraulic tests performed in ten wells screened in the Shallow Perched Aquifer indicate that the horizontal hydraulic conductivity (K_h) is typically $\geq$ 1.0 x 10^{-1} cm/sec. Moderately high hydraulic conductivity within the Shallow Perched Aquifer

Table 5-1

Summary of Ground Water Elevation Data
October 1989 and April 1990

Well #	Top of PVC Elevation (amsl)	October 1989 Depth to Ground Water (feet)	Ground Water Elevation (amsl)	April 1990 Depth to Ground Water (feet)	Ground Water Elevation (amsl)
TF-10(S)	455.45	28.75	426.70	15.01	440.44
TF-10(D)	456.19	33.04	423.15	20.65	435.54
TF-11(S)	501.48	DRY	---	72.14	429.34
TF-11(D)	501.45	84.33	417.12	72.25	429.20
TF-12(S)	489.94	DRY	---	58.72	431.22
TF-12(D)	489.97	73.30	416.67	61.73	428.24
TF-13(S)	448.81	28.29	420.52	18.30	430.51
TF-13(D)	448.94	30.72	418.22	18.52	430.42
TF-14(S)	477.95	DRY	---	41.53	436.42
TF-14(D)	477.98	58.51	419.47	46.30	431.68
MW-14(R)	476.84	115.54	361.30	109.42	367.42
MW-15(S)	490.53	68.68	421.85	55.21	435.32
MW-15(D)	490.61	72.14	418.47	60.05	430.56
MW-16(S)	480.27	57.92	422.35	47.22	433.05
MW-16(D)	480.73	60.07	420.66	48.30	432.43
MW-17(S)	552.44	134.87	417.57	122.77	429.67
MW-18(S)	546.88	143.19	403.69	134.98	411.90
MW-18(D)	546.01	142.28	403.73	133.53	412.48
MW-19(S)	492.49	65.71	426.78	55.78	436.71
MW-19(D)	492.52	74.58	417.94	63.95	428.57
MW-20(R)	465.68	96.18	369.50	90.46	357.22
MW-22(U)	545.92	*	*	136.45	409.47
MW-22(L)	546.07	*	*	136.82	409.25
MW-23(S)	449.92	*	*	17.45	432.47
MW-23(D)	449.96	*	*	21.35	428.61
MW-25(S)	526.54	*	*	118.85	407.69
MW-25(D)	526.66	*	*	116.39	410.27
MW-26(R)	481.81	*	*	77.42	404.39
BC-4(S)	524.35	125.23	399.12	117.65	406.70
BC-4(D)	524.26	156.86	367.40	149.27	374.99

Note: "DRY" measurements for wells TF-11(S), TF-12(S), and TF-14(S) indicates below top of dedicated pumping equipment.
* Indicates well was not installed at this time

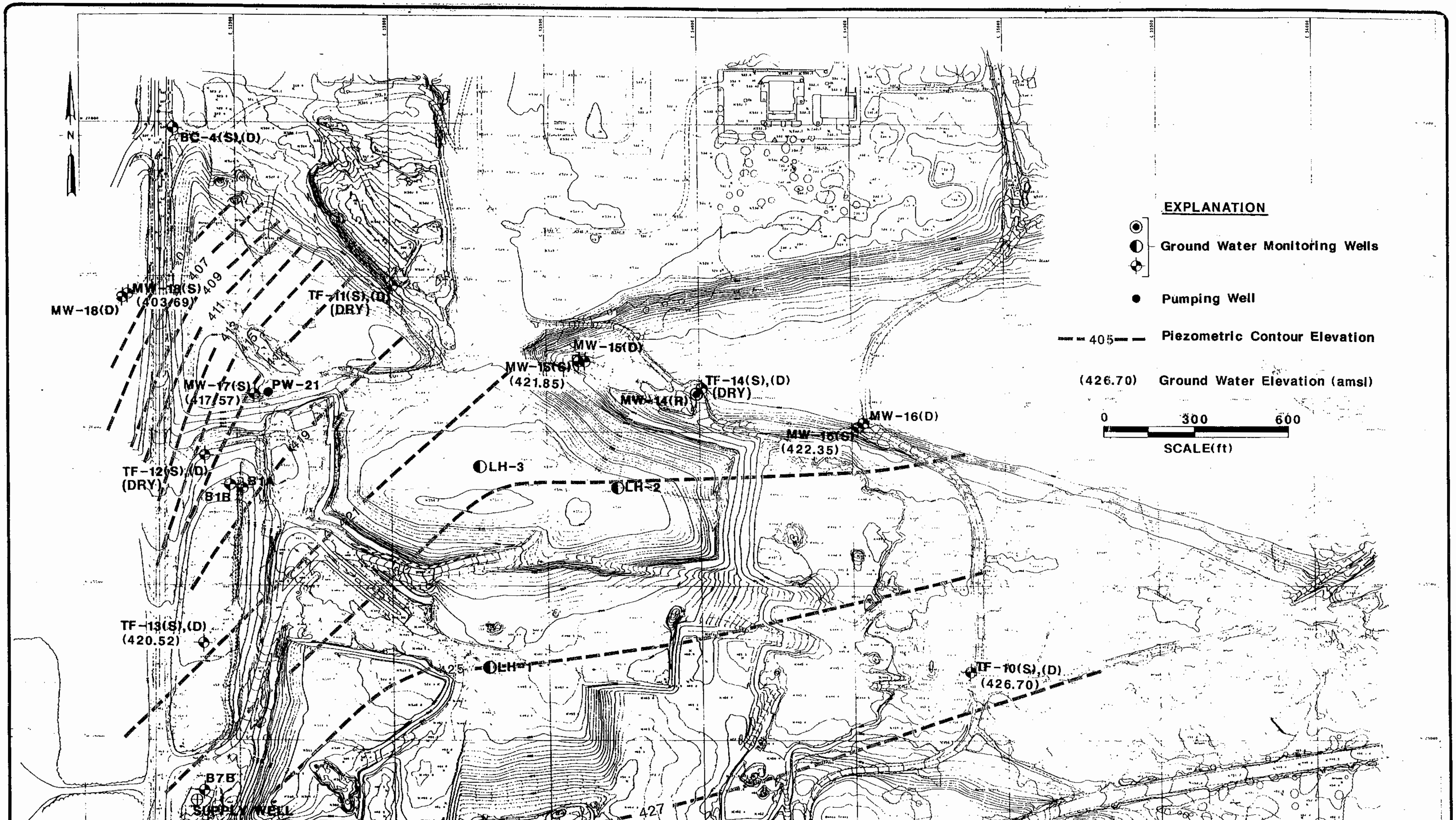

Figure 5-2
HIDDEN VALLEY LANDFILL
PIEZOMETRIC SURFACE IN SHALLOW PERCHED AQUIFER (OCT. 1989)

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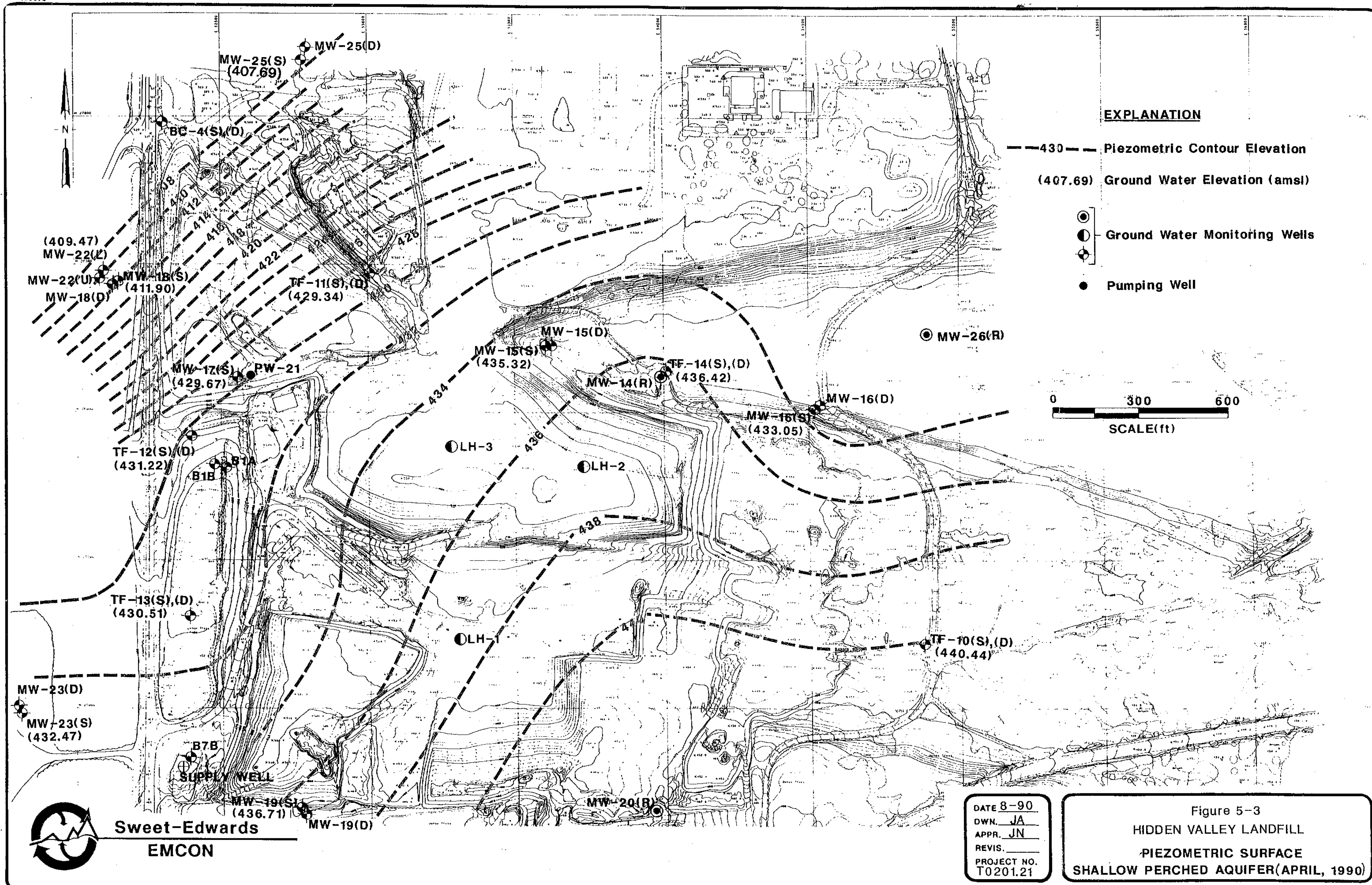

Figure 5-3
HIDDEN VALLEY LANDFILL
PIEZOMETRIC SURFACE
SHALLOW PERCHED AQUIFER(APRIL, 1990)

at Hidden Valley Landfill is consistent with observations of ground water discharge and soil grain size during drilling, and with published values for sand and gravel (Freeze and Cherry, 1979).

Horizontal hydraulic gradients are about .004 north of the landfill, .006 west of the landfill, and about .008 to .01 northwest of the landfill.

The following equation was used to estimate the velocity of ground water movement in the Shallow Perched Aquifer beneath the site.

$$v = \frac{Ki}{n}$$

where v = Velocity of ground water (length/time)
K = Hydraulic conductivity (1.0×10^{-1} cm/sec)
i = Hydraulic gradient (.004 to .008 dimensionless)
n = Porosity (assume 0.35, see Table 5-2)

Ground water flow velocities are estimated to be about 3.2 ft/day to 6.5 ft/day based on the above assumptions.

Porosity was estimated from published ranges for the type of lithology found in the aquifer (Fetter, 1988).

Table 5-2

Porosity Ranges for Sediments

Description	Percent
Well sorted sand or gravel	25-50
Sand and gravel, mixed	20-35
Glacial till	10-20
Silt	35-50
Clay	33-60

Notes:
From Fetter, C.W., 1988, Applied Hydrogeology, pg. 68

5.2.3 Lower Vashon Till Aquitard

The Lower Vashon Till Aquitard restricts the vertical movement of ground water. Vertical permeability of the till is estimated at 9.2 x 10^{-3} cm/sec in the vicinity of B-1B and 3.7 x 10^{-4} cm/sec in the vicinity of TF-12(D), based on data collected during the aquifer test performed in PW-21.

Vertical hydraulic gradients across the Lower Vashon Till Aquitard were calculated by dividing the difference in water level elevations (feet) by the distance between the mid-point of well screen saturation (feet) of adjacent wells screened in the Shallow Perched Aquifer (overlying the till) and the Upper Regional Aquifer (underlying the till), respectively. Downward vertical hydraulic gradients exist between the Shallow Perched Aquifer and the Upper Regional Aquifer the area of the landfill (Table 5-3).

Northwest of the landfill, wells MW-18(S) and MW-25(S) appear to be screened within the Lower Vashon Till Aquitard. At these locations, vertical hydraulic gradients between the Lower Vashon Till Aquitard and the Upper Regional Aquifer are upward, possibly reflecting the confining nature of the aquitard and a lack of direct recharge from precipitation.

Table 5-3

Vertical Hydraulic Gradient Measurements

Well Cluster	October 1989 $\Delta h(ft)$	October 1989 i_v	April 1990 $\Delta h(ft)$	April 1990 i_v	July 1990 $\Delta h(ft)$	July 1990 i_v
Shallow Perched Aquifer/Upper Regional Aquifer						
TF-10(S)/(D)	3.55	.06	4.90	.09	4.09	.07
TF-11(S)/(D)	0.20	.005	0.14	.003	0.27	.006
TF-12(S)/(D)	4.20	.09	2.98	.06	2.35	.05
TF-13(S)/(D)	2.30	.06	0.09	.002	1.42	.03
TF-14(S)/(D)	3.65	.11	4.74	.15	3.54	.11
TF-15(S)/(D)	3.38	.12	4.76	.17	4.30	.15
MW-16(S)/(D)	1.69	.03	0.62	.01	-1.03	-.02
MW-19(S)/(D)	8.84	.22	8.14	.20	8.41	.21
MW-23(S)/(D)	--	--	3.86	.08	4.65	.10
Lower Vashon Till/Upper Regional Aquifer						
MW-18(S)/(D)	-0.04	-.001	-0.58	-.02	-.26	-.009
MW-25(S)/(D)	--	--	-2.58	-.13	-3.69	-.18

Note: (--) indicates measurement not obtained
Vertical gradients for TF-12(S)/(D) and TF-14(S)/(D) are from July 1989 rather than October 1989 due to "dry" conditions in TF-12(S) and TF-14(S) in October

5.2.4 Upper Regional Aquifer

5.2.4.1 Ground Water Occurrence

The Upper Regional Aquifer occurs in the Vashon Advance Outwash deposits and is continuous beneath the landfill site. The aquifer is confined beneath the Lower Vashon Till aquitard. Saturated thickness varies from 11 feet [MW-16(D)] to 50 feet [TF-13(D)]. Depth to water measurements ranged from 18.9 feet in TF-13(D) to 133 feet in MW-18(D) in April 1990. Ground water levels in monitoring wells completed in the Upper Regional Aquifer displayed a seasonal variation of up to 12 feet between October 1989 and April 1990 in TF-14(D).

Infiltration of precipitation via the Shallow Perched Aquifer and Lower Vashon Till Aquitard is believed to be the primary source of recharge to the Upper Regional Aquifer both on-site and off-site. A short time lag of approximately one to three days between peaks in precipitation and ground water elevation suggests that recharge to the Upper Regional Aquifer is rapid.

5.2.4.2 Ground Water Movement

The flow direction in the Upper Regional Aquifer is to the northwest with local components to the north and west beneath the site (see Figures 5-4 and 5-5). Elevation of the potentiometric surface amsl ranged from 435.35 feet in TF-10(D) to 412.53 feet in MW-18(D) in April 1990.

5.2.4.3 Ground Water Velocities

Analysis of the pump test conducted on PW-21 indicates transmissivity values of 20,300 gpd/ft to 24,600 gpd/ft with corresponding hydraulic conductivity values of 2.7×10^{-2} cm/sec to 3.3×10^{-2} cm/sec, assuming an aquifer thickness of 35 feet (see Section 2.1.4.3). Single-well hydraulic conductivity tests performed in 11 wells screened in the Upper Regional Aquifer indicate a horizontal hydraulic conductivity range of 5.4×10^{-2} cm/sec [TF-14(D)], to 1.9×10^{-3} cm/sec [MW-18(D)]. Hydraulic gradients range from .03 [between MW-18(D) and TF-12(D)] to .003 [between TF-12(D) and TF-10(D)]. Estimated porosity of the aquifer material is 35 percent. Based on this information, the ground water velocity in the Upper Regional Aquifer is estimated to be .05 to 1.3 ft/day beneath and immediately adjacent to the landfill, and .5 to 13 ft/day northwest of the landfill.

5.2.5 Interglacial Aquitard

The Salmon Spring Aquitard is comprised of the Upper Salmon Springs Till, the Salmon Springs Interglacial deposits and the Lower Salmon Springs Till. Vertical thickness of the aquitard ranges from 130 feet in MW-14(R) to 138 feet in MW-20(R). Geologic information indicates that thin sand and gravel layers exist within the Salmon Springs Interglacial unit, which may contain minimal quantities of ground water. Insufficient moisture was encountered in the aquitard during drilling to warrant placement of a well screen. Permeability of the aquitard appears to be low and restrictive to the downward vertical movement of ground water from the Upper Regional Aquifer.

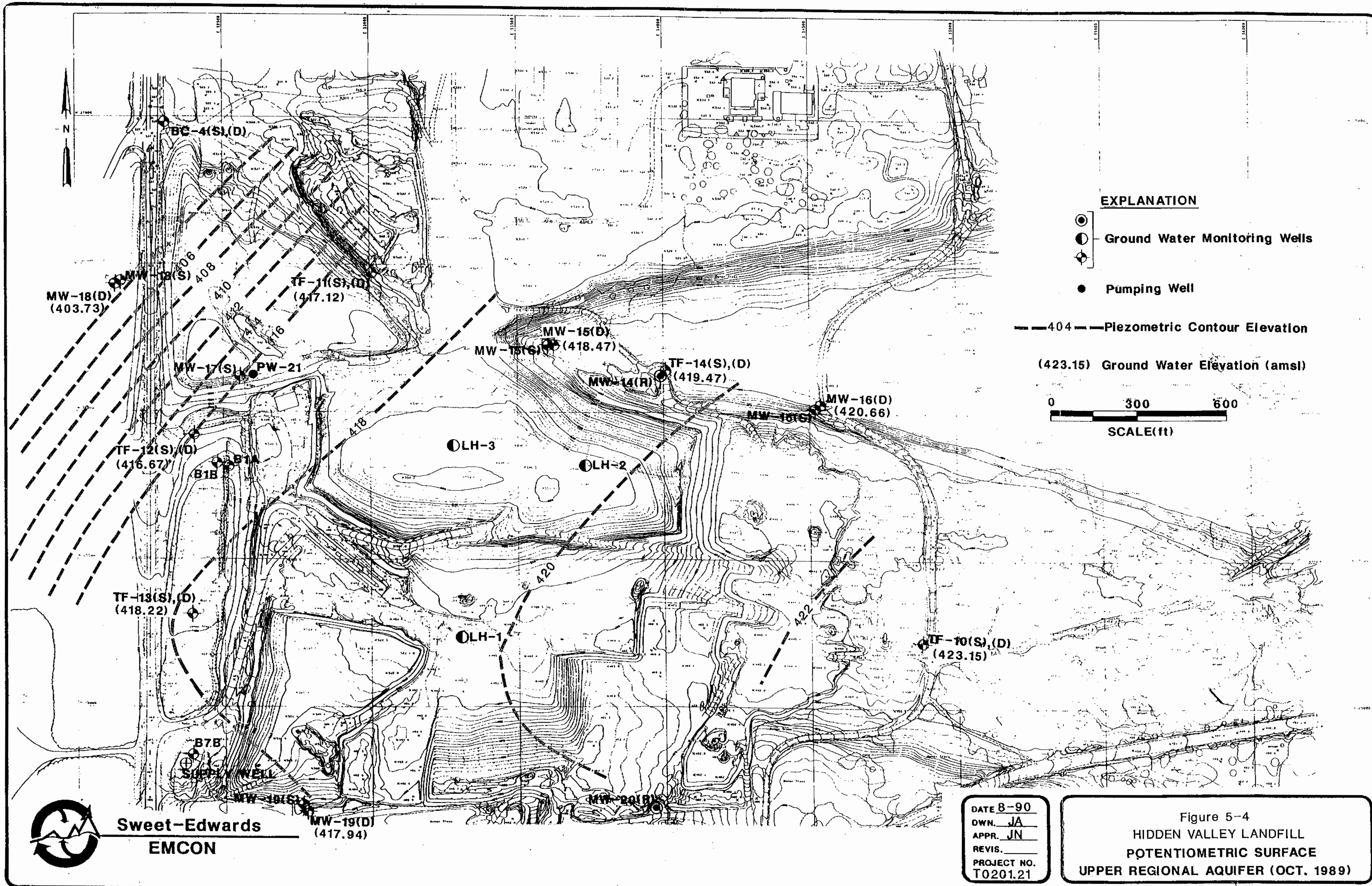

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Figure 5-4
HIDDEN VALLEY LANDFILL
POTENTIOMETRIC SURFACE
UPPER REGIONAL AQUIFER (OCT. 1989)

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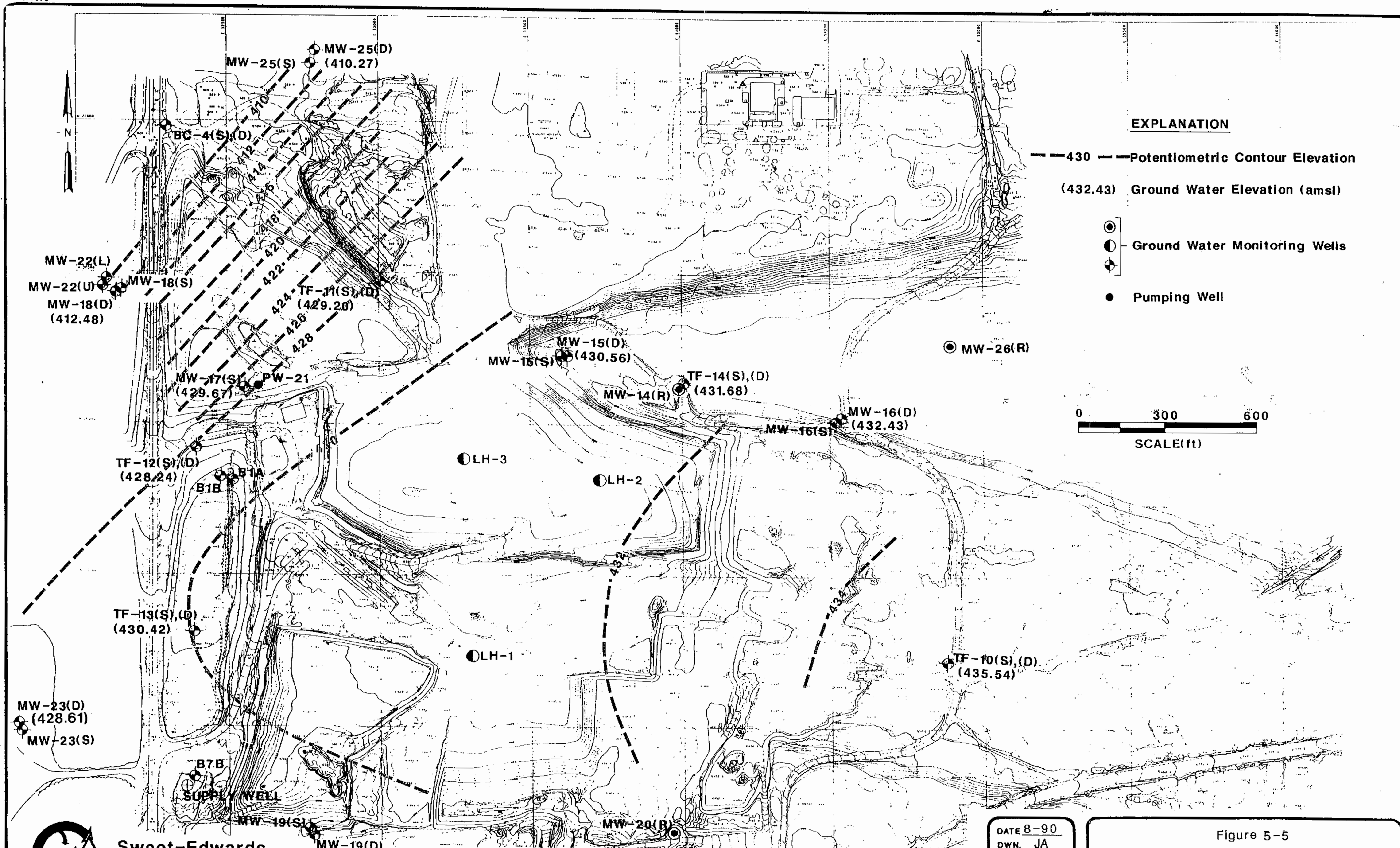

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Figure 5-5
HIDDEN VALLEY LANDFILL
POTENTIOMETRIC SURFACE
UPPER REGIONAL AQUIFER (APRIL, 1990)

5.2.6 Lower Regional Aquifer

5.2.6.1 Ground Water Occurrence

The Lower Regional Aquifer exists in the Salmon Springs Advance Outwash deposits. The aquifer was encountered at approximately 240 feet bgs at an elevation of 230 feet amsl. Ground water elevation data indicate that the aquifer is confined and the potentiometric surface occurs approximately 120 feet above the top of the aquifer. Recharge to the aquifer is from off-site sources.

5.2.6.2 Ground Water Movement

A comparison of boring logs completed for MW-14(R), MW-20(R), and MW-26(R), and the well log prepared for the Corliss supply well located south of the landfill, suggests that all of these wells are screened in the Lower Regional Aquifer. Depth to water measurements and ground water elevation data for the on-site monitoring wells cannot be used to evaluate ground water flow direction in the Lower Regional Aquifer due to the frequent and irregular quantities of ground water used at Corliss Sand and Gravel. Periodic pumping at varying extraction rates is creating drawdown in the potentiometric surface beneath the landfill site, i.e., the radius of influence extends from the Corliss supply well to at least beyond MW-26(R). Available data reveal that the time between pumping and recovery periods is too short to allow full recovery of the potentiometric surface in each of the three monitoring wells.

5.3 Beneficial Use Survey

Domestic, community, and industrial supply wells are used for potable supply in the vicinity of the Hidden Valley Landfill (Brown and Caldwell, 1985). Four supply wells have been located at less than 1 mile but greater than 2,000 feet, and 34 wells at less than 2 miles but greater than 1 mile from the landfill site. Two private wells (Paul Bunyan Rifle and Sportsman Club and Puyallup Sand and Gravel) are located less than 2,000 feet from the landfill site (see Figure 5-6).

The Puyallup Sand and Gravel well is located approximately 200 feet south of the landfill site and is completed at 326 feet bgs. It is deeper than any on- or off-site monitoring well, and is thought to be completed in a deeper portion of the Lower Regional Aquifer.

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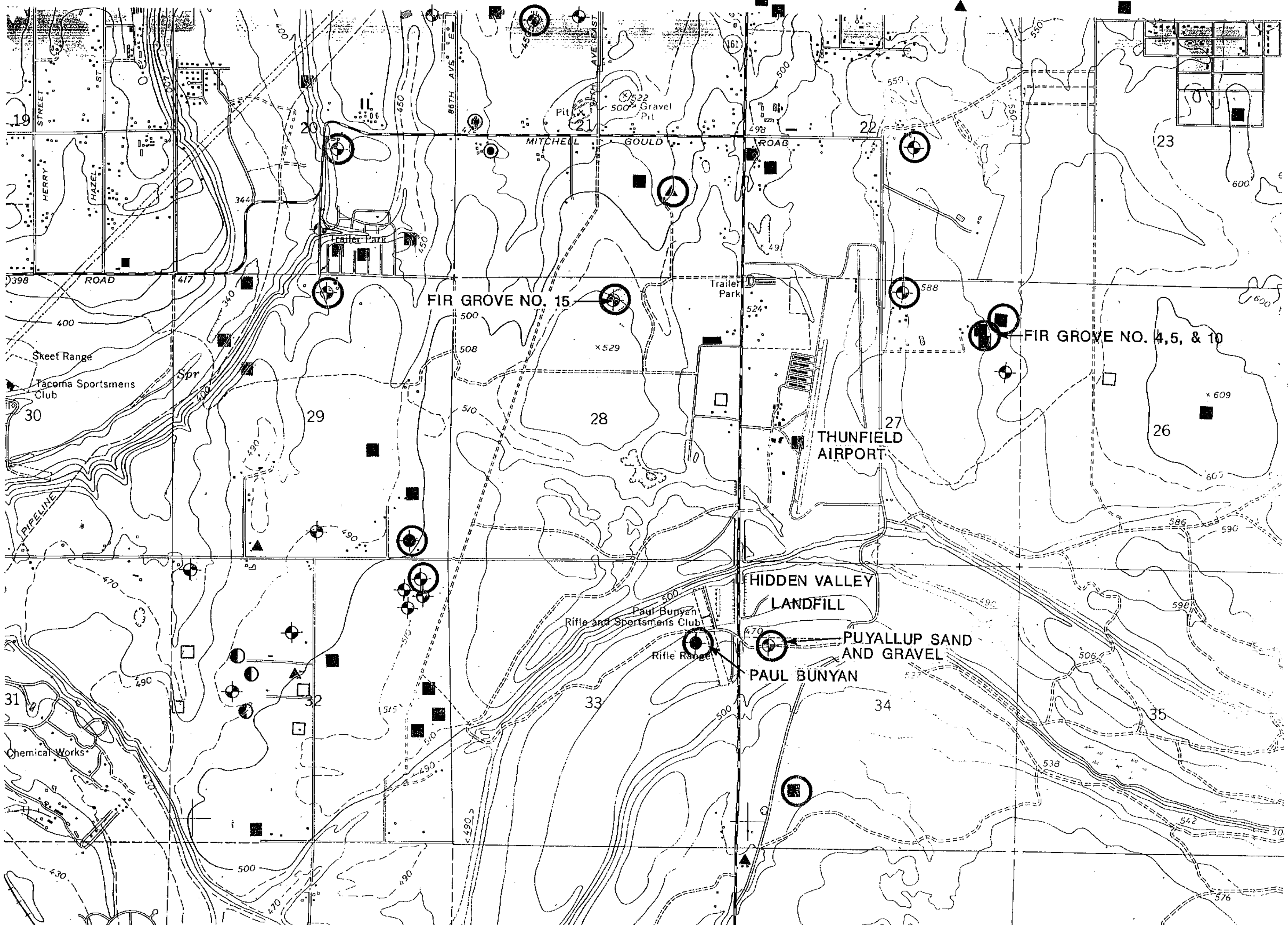

EXPLANATION

- 0-50(ft)
- 50-100(ft)
- 100-150(ft)
- 150-Deeper

Well Depth

- ▲ Depth Unknown
- ■ Public Well
- □ No Information
- ○ Wells Sampled By Health Department

N

0 2000 4000
SCALE(ft)

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Figure 5-6
HIDDEN VALLEY LANDFILL

LOCATION OF WATER SUPPLY WELLS

The Paul Bunyan well is located approximately 600 feet west of the southwest corner of the landfill site and is reported to be less than 100 feet deep. Based on the driller's well log it appears that the well is completed in the Upper Regional Aquifer. Hydraulically, this well is in a lateral location to the refuse and does not appear to have been impacted from landfilling operations. The well has been sampled bi-weekly since November 1989 for nitrate, dissolved metals, and ammonia. These data are included in Appendix F, Ground Water Quality.

Well log information for each of the off-site water supply wells is insufficient to determine how many wells are completed in the Shallow Perched, Upper Regional, and Lower Regional Aquifers. TPCHD has sampled many of the nearby wells and regularly samples Firgrove Wells No. 1, 2, 3, and 5; Paul Bunyan; Puyallup Sand and Gravel; and the Pierce County Airport (no longer in use) wells. No adverse water quality data have ever been reported to LRI concerning any of the wells sampled by TPCHD. Discharge information on Firgrove supply wells (the major water purveyor in the area of the landfill) is shown on Table 5-4.

Table 5-4

Firgrove Water Supply Wells
Discharge Data

Well #	Location	Rated Capacity (gpm)	Recent Capacity (gpm)	Depth (ft)
Zone 1				
4	164th St and 114th Ave	170	170	231
5	164th St and 114th Ave	210	130	221
10	164th St and 114th Ave	210	190	624
Zone 2				
1	144th St - Office	26	26	236
2	144th St - Office	176	176	250
3	154th St - Meridian	75	75	399
7	82nd Ave - Colony Park	450	450	246
12	144th St - 80th Ave.	250	150	318
15	Mountain Park	210	210	?
Zone 3				
13	161st St - 74th Ave	460	460	130
Satellite				
6	Regis Park	30	60	192
9	86th Ave - 134th St.	50+	30	440

6 GROUND WATER QUALITY

Ground water quality beneath the site has been evaluated using data collected in the Shallow Perched and Upper Regional Aquifers since 1982, and in the Lower Regional Aquifer since 1985. Prior to Round I Consent Order sampling, monthly and quarterly ground water sampling had been performed since 1985 under agreements between LRI and TPCHD. These agreements were modified whenever additional monitoring wells were installed around the perimeter of the site. Ground water data have been validated in accordance with current EPA guidelines for data validation, as appropriate. A summary of the validation results, and data usability, are summarized in Appendix G. The usability of data has also been identified in the data summary tables (see Appendix G). All available water quality data are included in Appendix G, Ground Water Quality Database.

6.1 Shallow Perched Aquifer

The Shallow Perched Aquifer is the most susceptible to ground water impacts resulting from landfilling operations. A review of the water quality data based on the collection and analysis of samples from monitoring wells located hydraulically downgradient of the solid waste area indicates the presence of compounds typical of municipal solid waste landfills (see Appendix F). Selected metals (particularly iron and manganese), non-metals (including chloride, ammonia, nitrate, and sulphate), and specific conductance are elevated above background levels measured in the upgradient well MW-10(S).

6.1.1 Nonmetals

The analysis of nonmetals in ground water samples collected from the Shallow Perched Aquifer have included the following:

Chloride	Total Dissolved Solids (TDS)
Fluoride	Methylene Blue Active Substances (MBAS)
Conductivity (field)	Ammonia as Nitrogen
Conductivity (laboratory)	Nitrate as Nitrogen
pH (field)	Nitrite as Nitrogen
pH (laboratory)	Sulfate
Phenol	Total Organic Halides (TOX)
Cyanide	Chemical Oxygen Demand (COD)
Temperature (field)	

Only nitrate as nitrogen has exceeded the state and federal MCL of 10 mg/L. No other non-metal parameter has exceeded the MCL in any other sample collected and analyzed from any well.

Phase II field work included continuous monitoring of water levels and specific conductance, and semi-monthly monitoring of ammonia-nitrogen, nitrate-nitrogen, and total Kjeldahl nitrogen in seven monitoring wells completed in the Shallow Perched Aquifer (TF-10(S), TF-11(S), TF-12(S), TF-13(S), TF-14(S), MW-17(S), and MW-18(S)). The monitoring was performed between November 1989 and June 1990 to evaluate possible correlations between water levels and ground water quality.

Pressure transducers and specific conductance probes were installed in each of the seven wells. Ground water elevation and specific conductance measurements were obtained with data acquisition systems every six hours during the monitoring period. Specific conductance was selected for monitoring as a general indication of water quality. Ammonia, nitrate, and total Kjeldahl nitrogen were monitored to assess nitrogen oxidation/reduction reactions.

During the one year period from the fall of 1989 until the fall of 1990, water level elevations displayed the following trend: a gradual elevation decline through the fall until the beginning of November; a relatively constant elevation through November and December; a 10 to 15 foot elevation increase in January and the first half of February; and a gradual elevation decline throughout the spring and summer, with a slight water level increase during the first part of June. Figure 6-1 includes hydrographs for six wells located downgradient of the landfill. The one year hydrographs are considered typical seasonal fluctuations; however, actual annual water level elevation fluctuations will depend on the amount and timing of precipitation.

Ground water conductivity recordings did not display a consistent correlation with fluctuations in ammonia or nitrate concentration, or water level elevation. Specific conductance fluctuations appear to result from both

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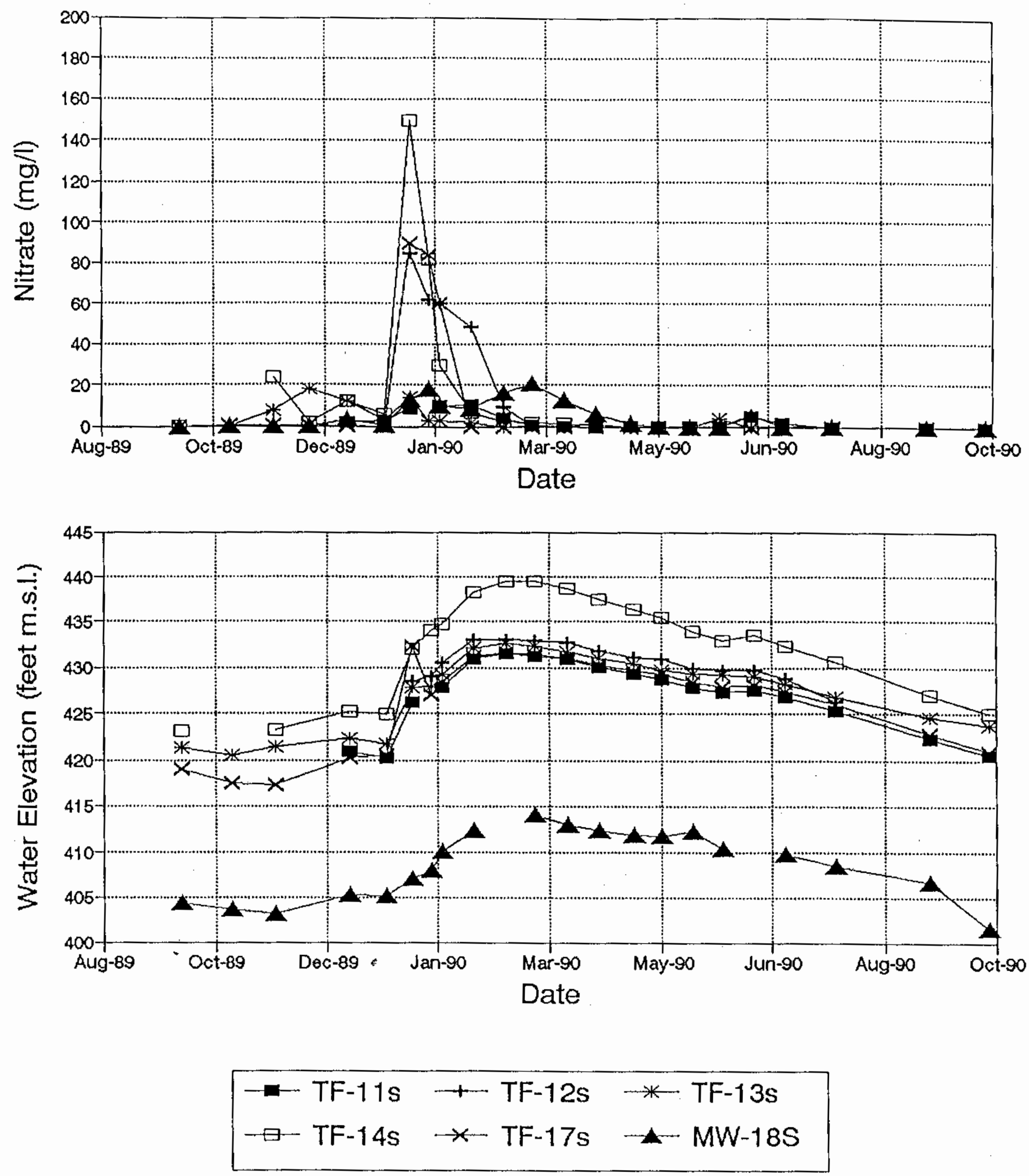

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Figure 6-1
HIDDEN VALLEY LANDFILL
CORRELATION OF WATER LEVEL ELEVATION AND NITRATE CONCENTRATION

ground water recharge not affected by the landfill (conductance decreases), and recharge that is affected by the landfill (conductance increases).

Background specific conductance measurements recorded at well TF-10(S) are shown in Figure 6-2. Downgradient specific conductance measurements recorded in wells TF-11(S), TF-12(S), and TF-13(S) displayed an increase of two to three times during February and March 1990 (Figures 6-3, 6-4, and 6-5). Conductance recordings from TF-14(S) displayed a decrease in January and February 1990 (Figure 6-6). Conductance recordings at MW-17(S) remained relatively high and constant during the monitoring period (Figure 6-7). Conductance recordings at MW-18(S) decreased gradually from November 1989 through February 1990, followed by a gradual increase from March through June 1990 (Figure 6-8).

Nitrate analyses display low to non-detect levels except for periods of ground water recharge. For the one-year period from the fall of 1989 to the fall of 1990, nitrate concentrations were recorded from mid-November through March, and again in June. The highest nitrate concentrations were recorded in January and February, when water level elevations were increasing rapidly. Nitrate detected in June 1990 was also associated with a recharge event. Figure 6-1 includes nitrate time series plots for six wells located downgradient of the landfill.

Total Kjeldahl nitrogen (TKN) and ammonia analyses were included to evaluate the nitrogen balance in the Shallow Perched Aquifer. TKN results were inconclusive because the presence of nitrate tended to interfere with TKN analyses. Ammonia concentrations tended to decrease when nitrate concentrations increased; however, a one-to-one relationship was not established.

Fluctuations in ammonia-nitrogen and nitrate-nitrogen concentrations are interpreted as follows. During periods of aquifer recharge (typically winter and early spring), the aquifer receives oxygenated water and the water table rises. Under these conditions, nitrogen is present primarily in the oxidized form as nitrate. During non-recharge periods, nitrogen in the ground water is reduced to ammonia due to anaerobic conditions in the vicinity of the landfill.

Nitrate occurrence at concentrations greater than 10 mg/l and maximum concentrations of other non-metals are summarized in Tables 6-1 and 6-2.

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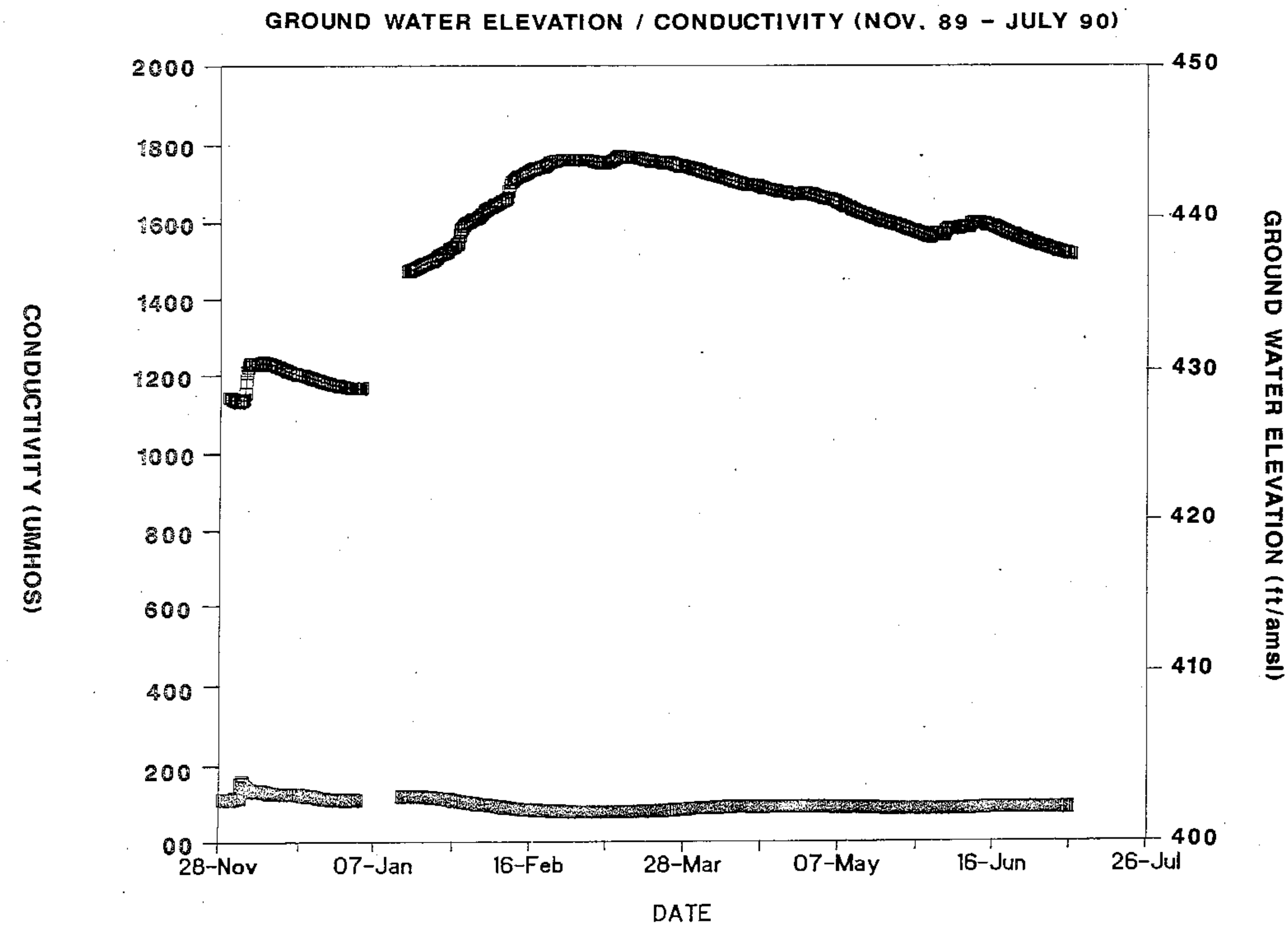

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Figure 6-2
HIDDEN VALLEY LANDFILL
TRANSDUCER DATA, TF-10(S)

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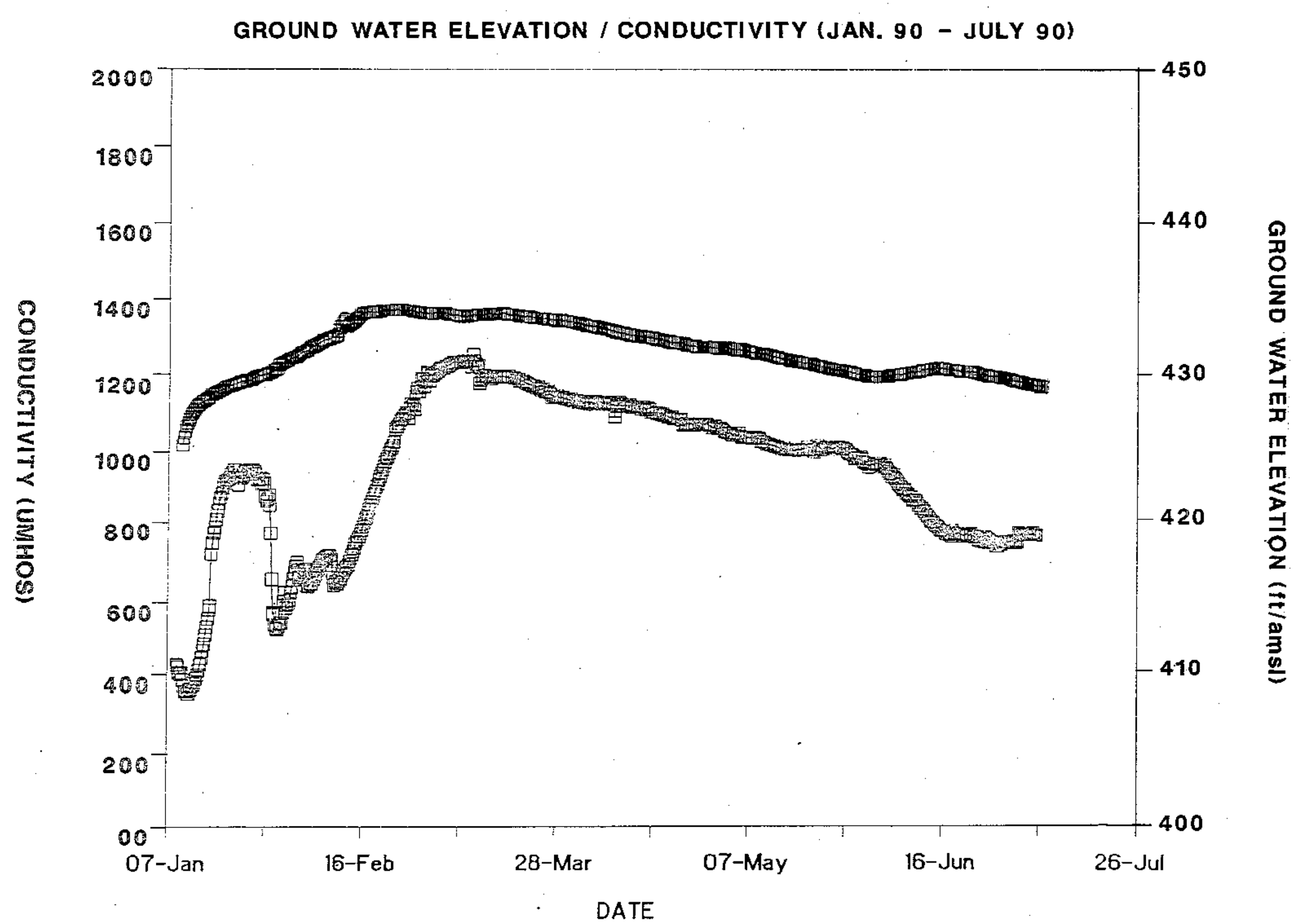

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Figure 6-3
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, TF-11(S)

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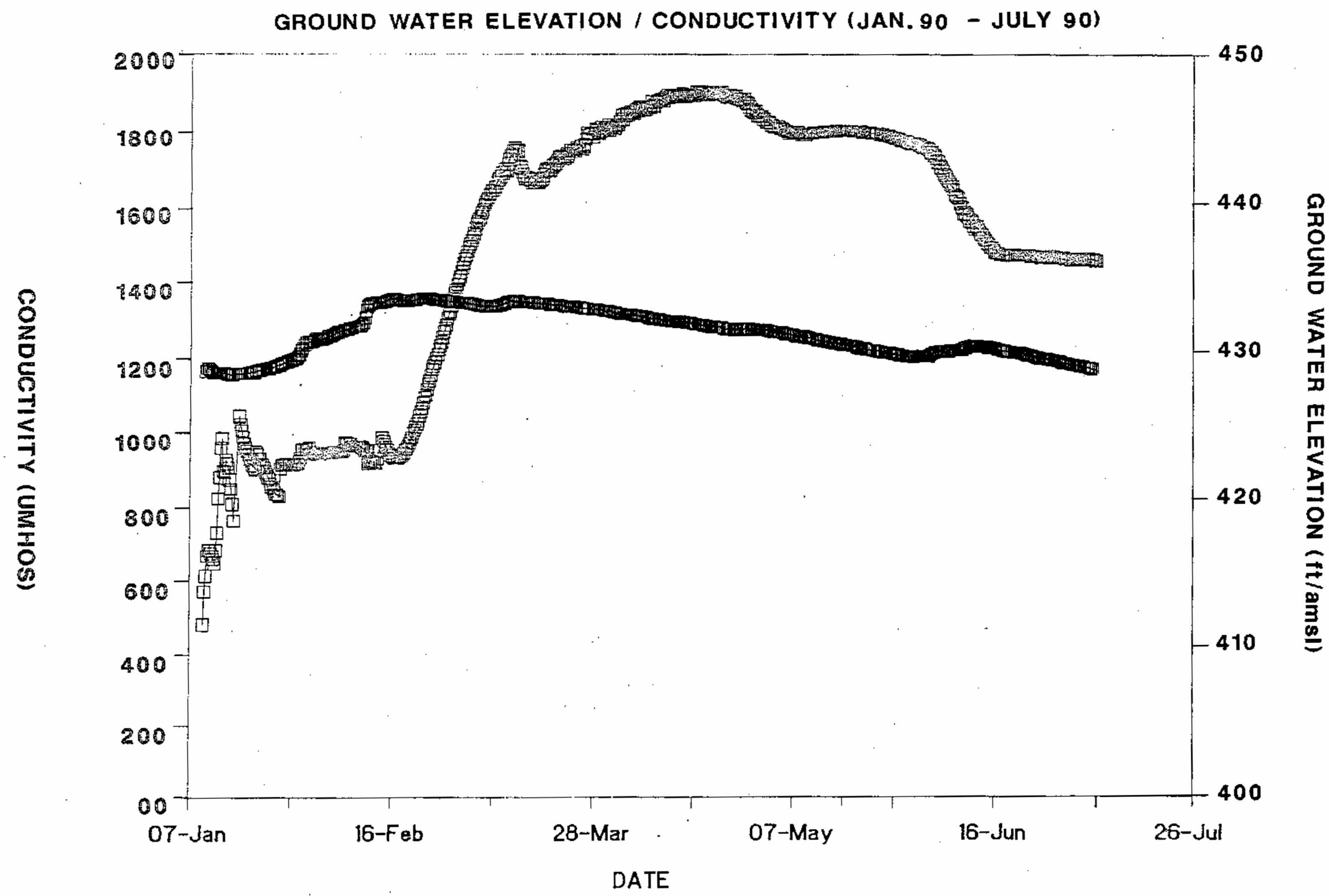

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Figure 6-4
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, TF-12(S)

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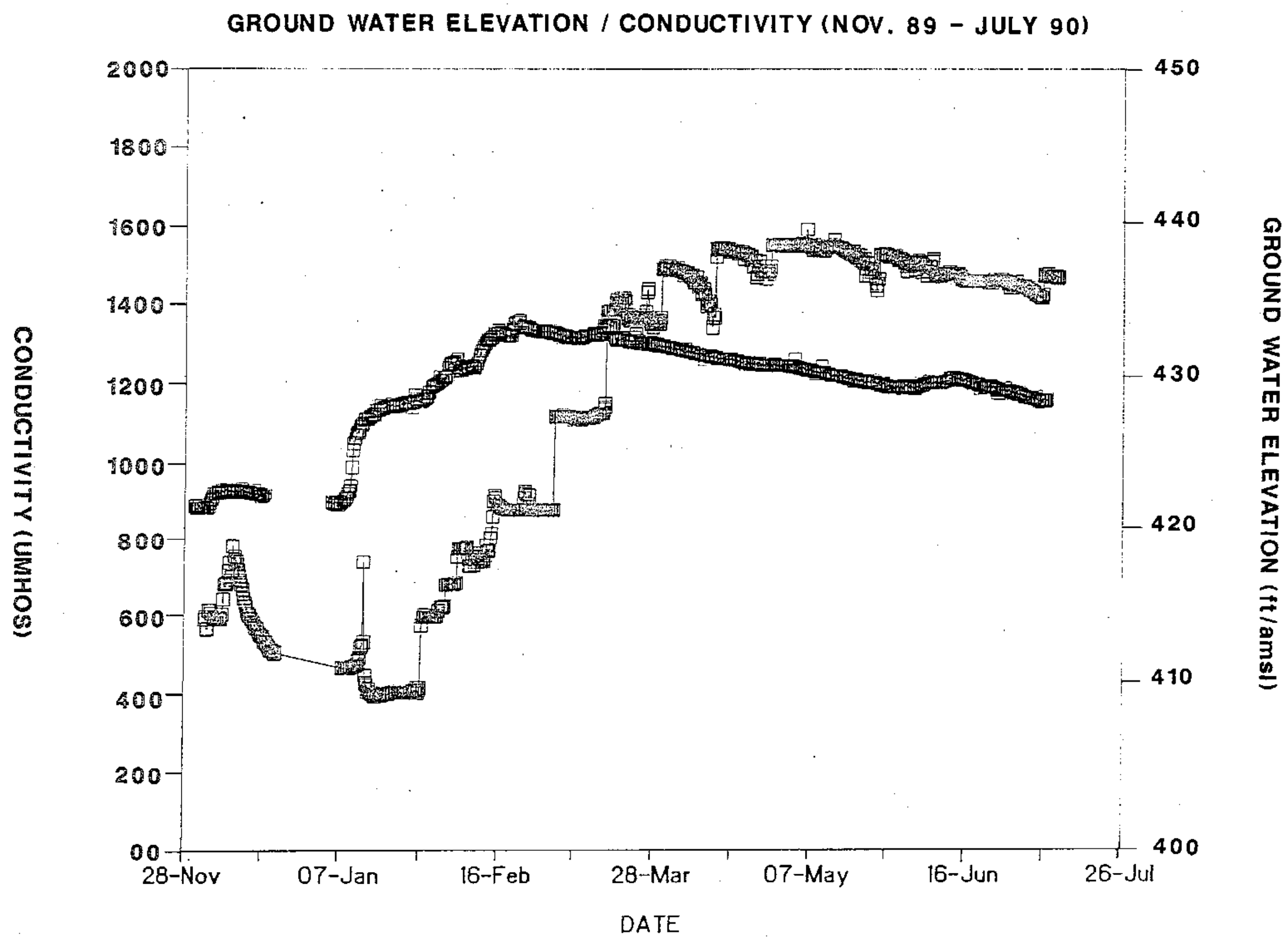

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Figure 6-5
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, TF-13(S)

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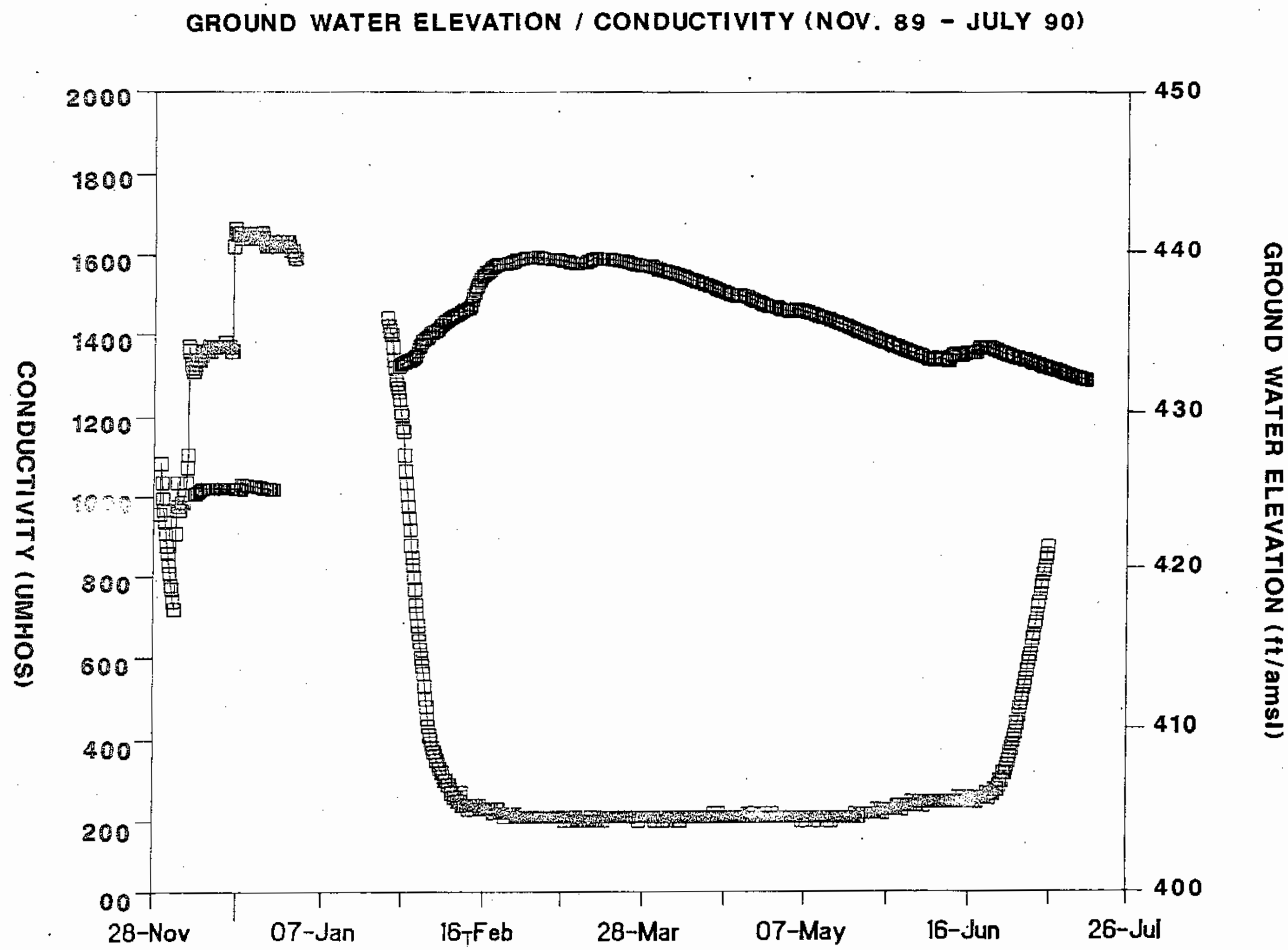

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Figure 6-6
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, TF-14(S)

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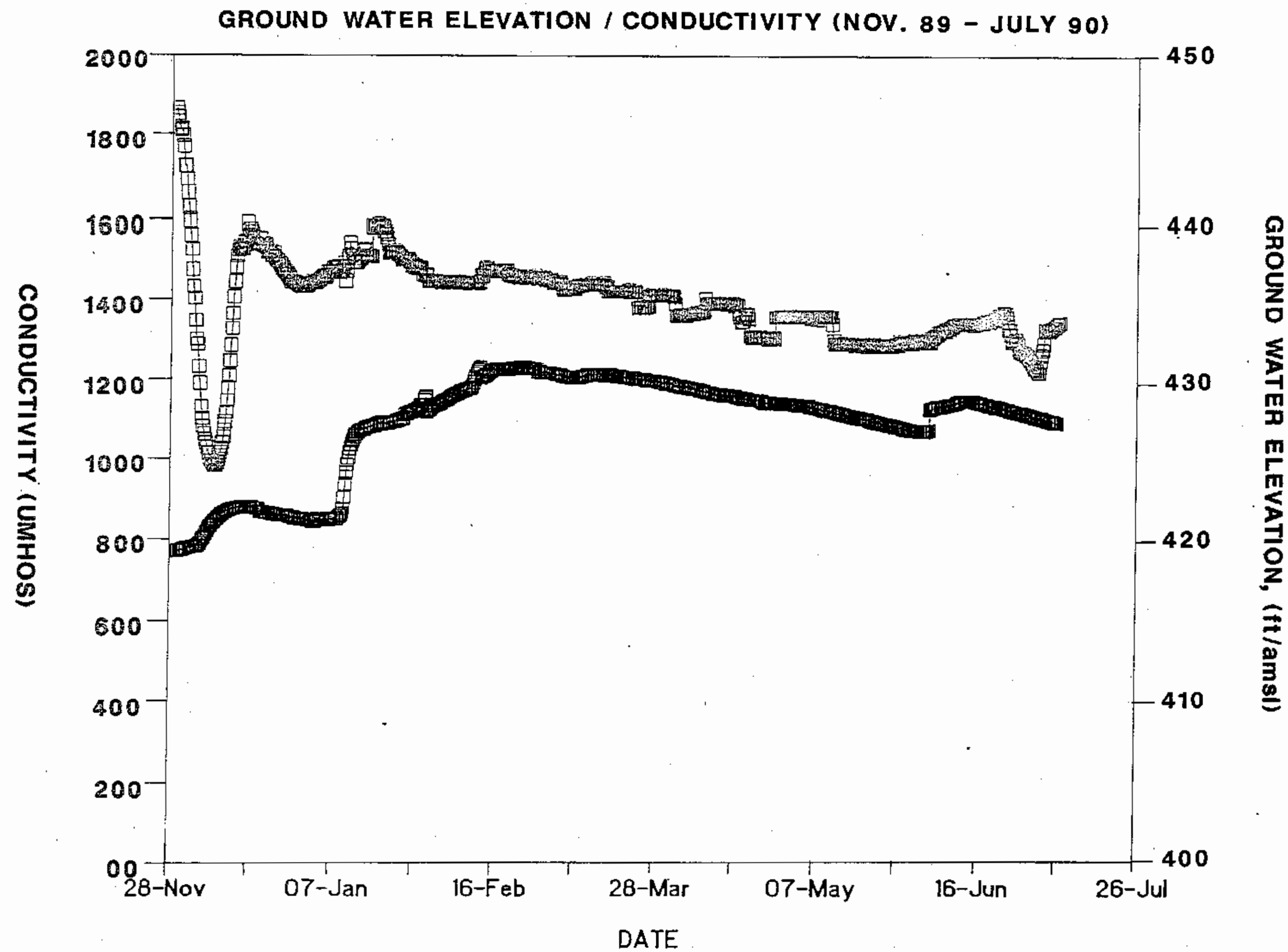

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Figure 6-7
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, MW-17(S)

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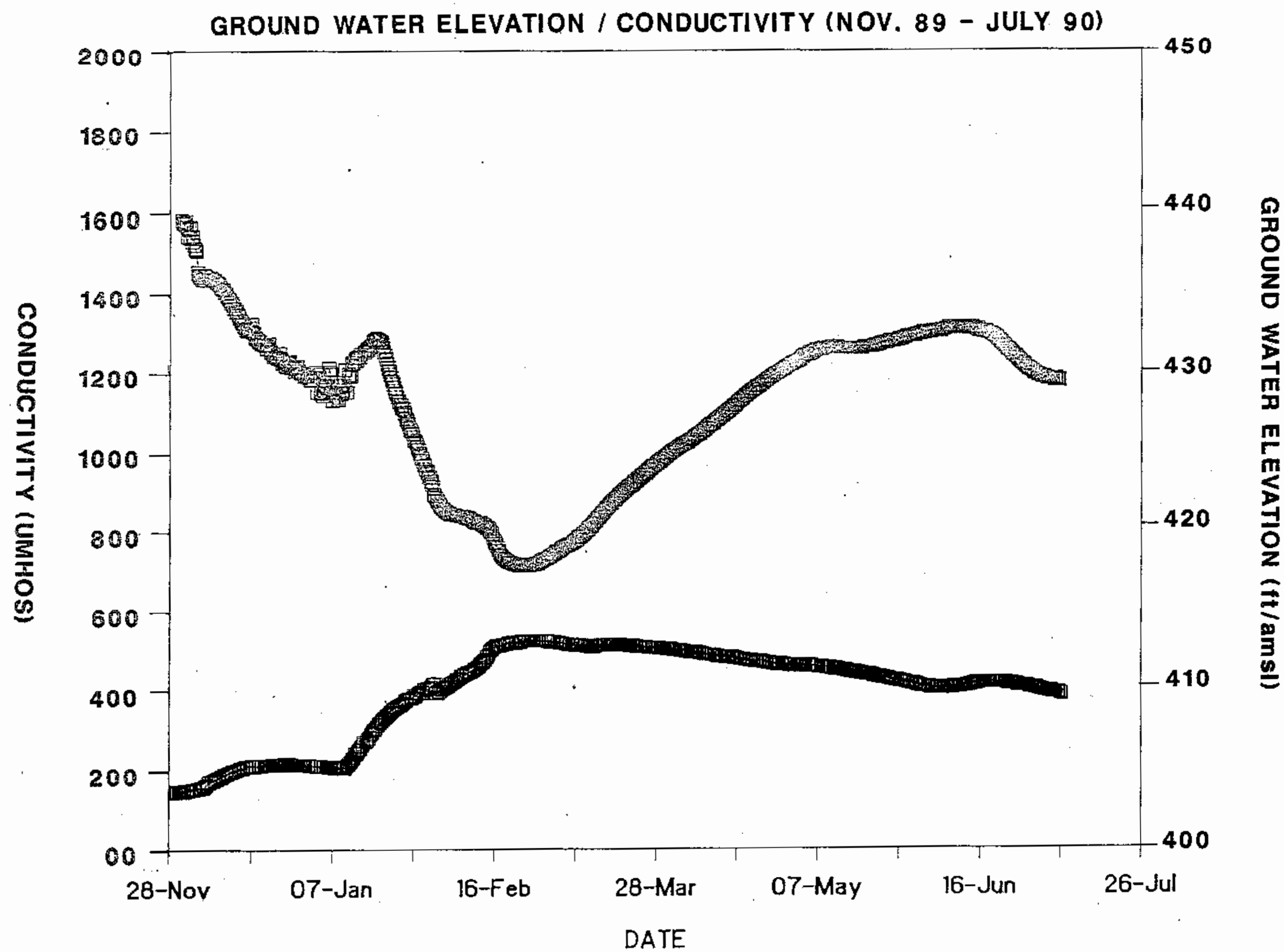

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Figure 6-8
HIDDEN VALLEY LANDFILL

TRANSDUCER DATA, MW-18(S)

Table 6-1

Nitrate Concentrations Greater Than 10 mg/L
Shallow Perched Aquifer

Well	Date	Nitrate Concentration (mg/L)	
TF-11(S)	1/25/89	19	
	3/3/89	18	
	2/12/90	10.4	
TF-12(S)	4/14/86	16.8	
	2/25/87	20	
	5/24/88	49	
	1/25/89	48	
	4/26/89	12	
	1/15/90	85	
	1/25/90	62	
	1/30/90	60	
	2/12/90	48.6	
TF-13(S)	3/29/88	17	
	12/1/89	18	
	12/18/89	12	
	1/16/90	14	
	1/16/90	14	
TF-14(S)	4/27/88	30	
	4/27/88	21	DUP*
	5/24/88	47	
	1/25/89	79	
	1/25/89	79	DUP*
	3/3/89	26	
	11/15/89	24	
	12/18/89	12	
	1/16/90	150	
	1/25/90	82	
	1/31/90	30	
	1/31/90	30	DUP*

*Indicates duplicate sample

Table 6-1 (cont.)
Nitrate Concentrations Greater Than 10 mg/L
Shallow Perched Aquifer

Well	Date	Nitrate Concentration (mg/L)
MW-17(S)	1/25/89	32
	1/16/90	90
	1/25/90	84
	1/30/90	60
MW-18(S)	1/26/89	15
	3/15/89	10.3
	4/27/89	14
	5/25/89	13
	1/16/90	13
	1/25/90	18
	2/26/90	16.4
	3/13/90	20.8
	3/27/90	12.4
MW-22(U)	3/13/90	16.6
	3/27/90	12.8
B1-A	1/23/86	92
	4/2/86	11.5

Table 6-2

Maximum Concentration of Non-Metals Shallow Perched Aquifer (mg/L)

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (mg/L)	Well Number	Date
Chloride	7.2	672	TF-14(S)	2/25/87
Fluoride	.04	.5	MW-17(S)	1/30/90
Ammonia	1.37	178	MW-17(S)	7/18/89
Nitrite	.01	.04	MW-18(S)	7/21/88
Nitrate	4.5	150	TF-14(S)	1/16/90
Sulfate	36	100	TF-14(S)	4/27/88
Cyanide	.01 L	.02	TF-14(S)	4/27/88
TDS	207	2,820	TF-14(S)	2/25/87
MBAS	.11	.28	TF-14(S)	4/27/88
COD	1.0 L	308	TF-14(S)	8/18/88
TOC	5.0 L	145	TF-14(S)	8/18/88
Phenol	.02 L	.06	TF-13(S)	6/19/86
TOX	.02	.27	TF-11(S)	7/15/85

Note: L = Indicates less than detection limit

6.1.2 Dissolved Metals

Dissolved metals that have been analyzed for in ground water samples collected from the Shallow Perched Aquifer include the following:

aluminum	calcium	manganese	silver
arsenic	copper	gold	sodium
barium	iron	nickel	thallium
beryllium	lead	potassium	zinc
cadmium	magnesium	selenium	

Laboratory analytical results for dissolved metals indicate that several of the above listed metals, including calcium, iron, magnesium, and manganese have been identified at concentrations that are elevated relative to background levels detected in samples collected from the upgradient monitoring well. However, no health-based MCL has been exceeded in any water sample collected from monitoring wells completed in the Shallow Perched Aquifer. Maximum levels of dissolved metals detected in monitoring wells are summarized in Table 6-3.

6.1.3 Volatile Organic Compounds

No existing or proposed federal standard for a volatile organic compound has ever been exceeded in samples collected from monitoring wells completed in the Shallow Perched Aquifer. Volatile organic compounds that have been detected above background levels are shown in Table 6-4.

6.1.4 Base, Neutral, and Acid Extractables

Detections of base, neutral, and acid extractables (BNAs) have occurred primarily in wells northwest of the site. With the exception of the anomalous detections occurring during May, 1987 in samples collected from well TF-11(S), BNAs have been detected only sporadically in ground water samples collected from wells in the Shallow Perched Aquifer. Maximum detections of BNAs in the Shallow Perched Aquifer are summarized in Tables 6-5 through 6-7.

6.1.5 Polynuclear Aromatics

Ground water samples analyzed for polynuclear aromatics, (PNAs), have shown detections of very few compounds with the exception of samples collected from TF-11(S) during May, 1987. Acenaphthene, fluorene,

Table 6-3

Maximum Concentration of Dissolved Metals Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (mg/L)	Well Number	Date
Aluminum	.05 L	.08	TF-14(S)	8/27/87
Arsenic	.003 L	.04	TF-14(S)	6/20/86
Barium	.067	.36	TF-14(S)	2/25/87
Calcium	14	90.8	TF-13(S)	8/26/87
Chromium	.002 L	.015	TF-14(S)	2/25/87
Copper	.097	.097	TF-10(S)	10/21/85
Iron	.47	11	TF-14(S)	10/14/86
Lead	.009	.002	TF-13(S)	5/19/87
Magnesium	4.8	40.6	TF-13(S)	4/23/90
Manganese	.066	10.3	TF-13(S)	4/23/90
Potassium	1.4	60.1	TF-14(S)	8/27/87
Selenium	.005 L	.004	TF-14(S)	1/25/89
Sodium	12	345	TF-14(S)	8/27/87
Zinc	.04	.07	TF-11(S)	10/21/85

Note: L = Indicates less than detection limit

Table 6-4

Maximum Concentration of Volatile Organic Compounds Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (μg/L)	Well Number	Date
Acetone	5.5	4.5	MW-17(S)	4/27/88
Benzene	.8 M	4.3	TF-14(S)	2/15/87
Chlorobenzene	.6 L	3.2	TF-12(S)	4/23/90
Chloroethane	.6 L	2.2	TF-13(S)	4/23/90
Chloroform	.9 L	2.5	MW-15(S)	4/26/88
Chloromethane	.9 L	2.4	MW-16(S)	7/19/88
1,2-dichlorobenzene	1 L	1.8	TF-14(S)	7/17/89
1,4-dichlorobenzene	1 L	8.1	MW-15(S)	7/18/88
Total dichlorobenzene	.6 L	.8	TF-13(S)	12/15/87
1,1-dichloroethane	.5 L	5.9	TF-13(S)	7/18/89
Cis-1,2-dichloroethene	.7 L	.3 J	MW-17(S)	4/27/88
Trans-1,2-dichloroethene	.8 L	5 LB 2.7 M	TF-11(S) TF-14(S)	1/15/86 2/15/87
Methylene chloride	13 B	30	TF-11(S)	4/2/86
Toluene	3	10 LB	TF-11(S)	1/15/86
1,1,1-trichloroethane	.6 L	7.2	MW-19(S)	1/24/89
Trichlorofluoromethane	1 L	13.2	MW-19(S)	1/24/89
Vinyl chloride	1 L	1.1	TF-13(S)	7/18/89
Total xylenes	1 L	7	TF-14(S)	1/15/87

Notes:
- L = Indicates less than detection limit.
- B = Indicates analyte found in blank as well as in sample. Indicates probable blank contamination.
- J = Indicates an estimated value when result is less than specified detection limit.
- M = Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters.

Table 6-5

Maximum Concentration of Semi-Volatile Base Extractables Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (µg/L)	Well Number	Date
3,3-dichlorobenzidine	1.6 L	.9	TF-11(S)	5/15/87
4-chloroaniline	1.7 L	.9	TF-11(S)	5/15/87
2-nitroaniline	3.2 L	1.6	TF-11(S)	5/15/87
3-nitroaniline	1.9 L	.9	TF-11(S)	5/15/87
4-nitroaniline	3.7 L	1.8	TF-11(S)	5/15/87
N-nitroso-di-n-propylamine	1.6 L	.8	TF-11(S)	5/15/87
N-nitrosodiphenylamine	2 L	1.6	TF-11(S)	5/15/87

Note: L = Indicates less than detection limit.

Table 6-6

Maximum Concentration of Semi-Volatile Neutral Extractables Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (μg/L)	Well Number	Date
Benzyl alcohol	1 L	.5	TF-11(S)	5/15/87
Bis(-2-chloroethyl)ether	.9 L	.4	TF-11(S)	5/15/87
Bis(-2-chloroethoxy)methane	2 L	1.2	TF-11(S)	5/15/87
Bis(2-chloroisopropyl)ether	2 L	1.3	TF-11(S)	5/15/87
Bis(2-ethylhexyl)phthalate	2 L	17	TF-11(S)	4/27/88
4-bromophenyl-phenylether	1.3 L	.6	TF-11(S)	5/15/87
Butylbenzylphthalate	2 L	2	TF-11(S)	5/15/87
4-chlorophenyl-ether	1.4 L	.7	TF-11(S)	5/15/87
Dibenzofuran	1.6 L	10	TF-11(S)	9/15/87
1,2-dichlorobenzene	.2 L	32	TF-14(S)	6/20/86
1,3-dichlorobenzene	.3 L	.2	TF-11(S)	5/15/87
1,4-dichlorobenzene	.9 L	230	TF-14(S)	6/20/86
Diethylphthalate	.8 L	3.5	TF-13(S)	6/19/86
Dimethylphthalate	1 L	7.2	TF-14(S)	6/20/86
Di-n-butylphthalate	1.5 L	.6	TF-11(S)	5/15/87
Di-n-octyl phthalate	2 L	1.6	TF-11(S)	5/15/87
2,4-dinitrotoluene	1 L	.5	TF-11(S)	5/15/87
2,6-dinitrotoluene	2.7 L	6.1	TF-11(S)	6/23/86
Hexachlorobenzene	1.7 L	.9	TF-11(S)	5/15/87
Hexachlorobutadiene	1.8 L	.9	TF-11(S)	5/15/87
Hexachlorocyclopentadiene	1.7 L	.8	TF-11(S)	5/15/87
Hexachloroethane	1.6 L	.8	TF-11(S)	5/15/87
Isophorone	2 L	1.2	TF-11(S)	5/15/87n
Nitrobenzene	1.1 L	.5	TF-11(S)	5/15/87
1,2,4-trichlorobenzene	1.8 L	.9	TF-11(S)	5/15/87

Note: L = Indicates less than detection limit.

Table 6-7

Maximum Concentration of Semi-Volatile Acid Extractables Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (µg/L)	Well Number	Date
Benzoic acid	3.3 L	1.5	TF-11(S)	5/15/87
2-chlorophenol	1 L	.5	TF-11(S)	5/15/87
4-chloro-3-methylphenol	1.8 L	.9	TF-11(S)	5/15/87
2,4-dichlorophenol	3.3 L	1.7	TF-11(S)	5/15/87
2,4-dimethylphenol	2.8 L	16	TF-14(S)	2/15/87
2-methyl-4,6-dinitrophenol	6.6 L	3.3	TF-11(S)	5/15/87
2,4-dinitrotoluene	6.3 L	3.2	TF-11(S)	5/15/87
2-methylphenol	1.2 L	.6	TF-11(S)	5/15/87
4-methylphenol	.6 L	.3	TF-11(S)	5/15/87
2-nitrophenol	3.1 L	1.6	TF-11(S)	5/15/87
4-nitrophenol	2 L	1	TF-11(S)	5/15/87
Pentachlorophenol	1.3 L	4.2	TF-14(S)	6/20/86
Phenol	.8 L	.4	TF-11(S)	5/15/87
2,4,6-trichlorophenol	.6 L	.3	TF-11(S)	5/15/87
2,4,5-trichlorophenol	.7 L	.4	TF-11(S)	5/15/87

Note: L = Indicates less than detection limit.

naphthalene, 2-methylnaphthalene, and phenanthrene have been detected primarily in wells TF-11(S) or TF-14(S). Maximum detected concentrations of PNAs in the Shallow Perched Aquifer are summarized in Table 6-8.

6.1.6 Pesticides

No detectable concentrations of any pesticides were found in any sample collected from any monitoring well. Analyses results are summarized in Appendix G.

6.2 Upper Regional Aquifer

A review of available ground water quality data indicates that the Upper Regional Aquifer has been impacted in the vicinity of the landfill. Analysis of ground water samples collected from monitoring wells located downgradient of the site have exhibited concentrations of constituents typical of municipal solid waste landfills. These constituents are elevated above-background concentrations detected in upgradient monitoring wells. The impact to the Upper Regional Aquifer is more localized than the impact to the Shallow Perched Aquifer, with most of the above-background detections of metals and non-metals occurring in samples collected from MW-14(D). These results may indicate preferential ground water movement and greater hydraulic connection between the Shallow Perched and the Upper Regional Aquifers in the vicinity of MW-14(D).

6.2.1 Nonmetals

Nonmetal parameters that have been detected in ground water samples collected from monitoring wells completed in the Upper Regional Aquifer are similar to those detected in the Shallow Perched Aquifer (see Appendix G). The data indicate that no health-based MCL has been exceeded in any sample collected from any monitoring well. Maximum levels detected in the Upper Regional Aquifer for each parameter since ground water monitoring began (February 1982) are shown in Table 6-9.

6.2.2 Dissolved Metals

A review of the water quality results for dissolved metals in the Upper Regional Aquifer indicates that no health-based MCLs were exceeded in any well. Selected metals have been detected above background in the Upper Regional Aquifer, particularly in monitoring wells TF-11(D), TF-12(D), TF-13(D), and TF-14(D) (see Table 6-10).

Table 6-8

Maximum Concentration of Polynuclear Aromatics Shallow Perched Aquifer

Parameter	TF-10(S) Background Concentration	Maximum Concentration Detected in a Downgradient Well (μg/L)	Well Number	Date
Acenaphthene	1.1 L	17	TF-11(S)	9/15/87
Acenaphthylene	.2 L	.1	TF-11(S)	5/15/87
Benzo(a)anthracene	2 L	1.3	TF-11(S)	5/15/87
Benzo(k)fluoranthene	2 L	.5	TF-11(S)	5/15/87
Benzo(a)pyrene	.4 L	.2	TF-11(S)	5/15/87
Benzo(g,h,i)perylene	1.8 L	.9	TF-11(S)	5/15/87
2-chloronaphthalene	.1 L	.1	TF-11(S)	5/15/87
Chrysene	.6 L	.3	TF-11(S)	5/15/87
Dibenzo(g,h)anthracene	2 L	1	TF-11(S)	5/15/87
Fluoranthene	2 L	1.8	TF-11(S)	5/15/87
Fluorene	1.2 L	8	MW-15(S)	4/26/88
Ideno(1,2,3-cd)pyrene	1.7 L	.9	TF-11(S)	5/15/87
Naphthalene	2 L	22	TF-14(S)	8/27/87
2-methylnaphthalene	1.7 L	13	TF-14(S)	8/27/87
Phenanthrene	1.7 L	1.9	TF-14(S)	8/27/87
Pyrene	2 L	1.6	TF-11(S)	5/15/87

Note: L = Indicates less than detection limit

Table 6-9

Maximum Concentration of Nonmetals
Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Concentration Detected in a Downgradient Well (mg/L)	Well Number	Date
Chloride	5.2	470	TF-14(D)	4/27/88
Fluoride	.13	.76	TF-14(D)	4/27/88
Ammonia	.11	100	TF-14(D)	6/20/86
Nitrate	3.2	7.5	TF-13(D)	4/28/88
Nitrite	.2 L	.02	TF-14(D)	7/18/88
Sulfate	24	27	TF-12(D)	2/25/87
TOX	.025	.15	TF-11(D)	10/21/85
Phenol	.02 L	.046	TF-14(D)	6/20/86
TDS	122	2,270	TF-14(D)	6/20/86
MBAS	.045	.36	TF-14(D)	4/27/88
COD	8	252	TF-14(D)	7/18/88
TOC	.5 L	71	TF-14(D)	7/18/88

Note: L = Indicates less than detection limit.

Table 6-10

Maximum Concentration of Dissolved Metals Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Concentration Detected in a Downgradient Well (mg/L)	Well Number	Date
Aluminum	.18	.8	TF-14(D)	2/23/88
Arsenic	.003	.033	TF-14(D)	6/20/86
Barium	.206	.36	TF-14(D)	2/25/87
Calcium	11	132	TF-14(D)	2/23/88
Chromium	.002 L	.005	TF-14(D)	1/25/89
Copper	.007	.024	TF-13(D)	6/19/86
Iron	.6	10	TF-14(D)	10/27/88
Lead	.003 L	.06	TF-11(D)	10/21/85
Magnesium	3.8	49	TF-12(D)	2/23/88
Manganese	.037	10.2	TF-13(D)	4/23/90
Potassium	1.2	36	TF-14(D)	2/23/88
Sodium	8	379	TF-14(D)	2/23/88
Zinc	.04	.042	TF-13(D)	6/19/86

Note: L = Indicates less than detection limit.

6.2.3 Volatile Organic Compounds

Sporadic detections of volatile organic compounds have occurred in the Upper Regional Aquifer beneath the site. Maximum detected levels are shown in Table 6-11. A review of these data indicates that isolated detections of certain volatile organic compounds exceeded a federal MCL in 1986. Subsequent testing of ground water samples has not found any exeedance since 1986. This indicates that volatile organic compounds do not appear to be a significant source of contamination in the Upper Regional Aquifer (see Table 6-11). Although it is possible that other sources have contributed volatile organics to the Upper Regional Aquifer, the ground water elevation data, in conjunction with the presence of other constituents characteristic of landfill leachate, suggest that the landfill is the source for the low levels of volatile organic compounds in the Upper Regional Aquifer.

6.2.4 BNA Organics

6.2.4.1 Base Extractable Compounds

Based on a review of the ground water monitoring data, N-nitroso-di-n-propylamine at 1 μg/L (in B-1B on October 15, 1985) is the only base extractable compound detected in the Upper Regional Aquifer. The maximum detected level is shown in Table 6-12.

Table 6-11

Maximum Concentration of Volatile Organic Compounds Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Level Detected in a Downgradient Well (µg/L)	Well Number	Date
Acetone	.6 L	31 B 7.8	TF-11(D) TF-14(D)	2/24/88 2/23/88
Benzene	.4 L	5.6	TF-11(D)	11/13/86
Chlorobenzene	.6 L	3.4	TF-11(D)	11/13/86
Chloroethane	.9 L	2.1	TF-13(D)	4/23/90
Chloromethane	1 L	12 B	TF-12(D)	6/18/86
1,4-dichlorobenzene	1 L	4.2	TF-12(D)	10/26/89
Total dichlorobenzene	.6 L	.8	TF-13(D)	12/15/87
1,1-dichloroethane	.5 L	5.5	TF-13(D)	10/27/89
1,2-dichloroethane	.6 L	4	TF-14(D)	6/20/86
Cis-1,2-dichloroethene	.7 L	1.5	TF-12(D)	2/23/88
Trans-1,2-dichloroethene	.8 L	2.7	TF-12(D)	11/15/86
1,2-dichloropropane	.6 L	4.7	TF-12(D)	11/15/87
Methylene chloride	1.2 B	28	TF-11(D)	4/2/86
Toluene	.6 L	6.1	TF-11(D)	4/2/86 2/24/88
1,1,1-trichloroethane	.6 L	.68	TF-14(D)	11/15/86
Trichlorofluoromethane	1 L	2.8	MW-23(D)	4/26/90
Vinyl chloride	1 L	2.2	TF-11(D)	11/13/86
Total xylenes	1 L	3.6	TF-14(D)	2/15/87

Notes:

B = Indicates analyte found in blank as well as in sample. Indicates probable blank contamination.

L = Indicates less than detection limit.

Table 6-12

Maximum Concentration of Semi-Volatile Base Extractables Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Concentration Detected in a Downgradient Well ($\mu g/L$)	Well Number	Date
N-nitrosodiphenylamine	3.2 L	12 B	TF-11(D)	6/23/86

Notes: B = Indicates analyte found in blank as well as in sample. Indicates probable blank contamination.
L = Indicates less than detection limit.

6.2.4.2 Neutral Extractable Compounds

Neutral extractable organic compounds (phthalates and chlorobenzene isomers) have been detected sporadically at low levels in monitoring wells TF-11(D) and TF-14(D). Maximum detected concentrations are summarized in Table 6-13.

6.2.4.3 Acid Extractable Compounds

2,4-Dimethylphenol is the only acid extractable semi-volatile organic compound detected above detection limits in the Upper Regional Aquifer. This compound was detected at 6.3 $\mu g/L$ in TF-14(D) on June 20, 1986. Maximum detected levels are shown in Table 6-14.

6.2.5 Polynuclear Aromatics

Since 1986 ground water samples have been collected from each monitoring well for the analysis of polynuclear aromatics (PNAs). The data indicate that acenaphthene, fluorene, naphthalene, 2-methyl-naphthalene, phenanthrene, and pyrene have been sporadically detected above background levels in the Upper Regional Aquifer. Maximum levels at which compounds have been detected are summarized in Table 6-15.

Table 6-13

Maximum Concentration of Semi-Volatile Neutral Extractables Upper Regional Aquifer

Parameter	TF-10(D) Background Detection Level	Maximum Level Detected in a Downgradient Well (μg/L)	Well Number	Date
Bis(2-ethylhexyl)phthalate	2 L	4	TF-11(D)	4/27/88
Butylbenzylphthalate	2 L	1.4	TF-11(D)	6/23/86
Dibenzofuran	1.6 L	4.9	TF-11(D)	12/15/87
1,2-dichlorobenzene	.2 L	1.3	TF-13(D)	6/19/86
1,4-dichlorobenzene	.9 L	11	TF-13(D)	6/19/86
Diethylphthalate	.8 L	6.3	TF-13(D)	6/19/86
Dimethylphthalate	1 L	.9	TF-12(D)	2/15/87
Di-n-butylphthalate	1.5 L	1.7	TF-11(D)	2/15/87
Di-n-octyl phthalate	2 L	1.8	TF-12(D)	6/19/86
2,6-dinitrotoluene	2.7 L	2.1	TF-11(D)	6/23/86
Hexachloroethane	1.6 L	1	TF-11(D)	6/23/86

Notes: L = Indicates less than detection limit.

Table 6-14

Maximum Concentration of Semi-Volatile Acid Extractables Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Concentration Detected in a Downgradient Well (μg/L)	Well Number	Date
2,4-dimethylphenol	2.8 L	6.3	TF-14(D)	6/20/86
4-nitrophenol	2 L	11 M	MW-15(D)	4/26/88

NOTES:
L = Indicates less than detection limit.
M = Indicates an estimated value of analyte found and confirmed by analyst but with low spectral match parameters

Table 6-15

Maximum Concentration of Polynuclear Aromatics Upper Regional Aquifer

Parameter	TF-10(D) Background Concentration	Maximum Concentration Detected in a Downgradient Well (µg/L)	Well Number	Date
Acenaphthene	1.1 L	17	TF-14(D)	4/27/88
Fluorene	1.2 L	2.6	TF-11(D)	12/15/87
Naphthalene	2 L	13	TF-14(D)	2/15/87
2-methylnaphthalene	1.7 L	5	TF-14(D)	2/23/88 4/27/88
Phenanthrene	1.7 L	3	TF-14(D)	2/23/88 4/27/88
Pyrene	2 L	8	MW-15(D)	4/26/88

NOTES:
L = Indicates less than detection limit.

6.2.6 Pesticides

No pesticide has ever been detected in any sample collected from any monitoring well in the Upper Regional Aquifer.

6.3 Lower Regional Aquifer

Quarterly monitoring of ground water quality has been performed since April 1988 in monitoring wells MW-14(R) and MW-20(R), and in MW-26(R) since April 1990. No impact to the Lower Regional Aquifer has been identified in field measurements of specific conductance, pH, and temperature or reported in the laboratory analyses of ground water samples collected from this aquifer. Detections of metal and non-metal parameters are summarized in Tables 6-16, 6-17, and 6-18. No health-based MCL has been exceeded for any parameter in ground water samples collected from any well completed in the Lower Regional Aquifer. Available ground water quality data are summarized in Appendix G.

Table 6-16

Maximum Concentrations of Metals
Lower Regional Aquifer

Parameter	MW-14(R) Date	MW-14(R) Concentration (mg/L)	MW-20(R) Date	MW-20(R) Concentration (mg/L)	MW-26(R) Date	MW-26(R) Concentration (mg/L)
Calcium	2/1/90	7.9	1/29/90	8.55	2/2/90	8.51
Iron	7/18/88	.48	7/19/88	.44	2/2/90	.03
Magnesium	4/25/90	4.78	4/24/90	4.5	4/26/90	4.17
Manganese	7/18/88	.22	10/26/89	.19	4/26/90	.16
Potassium	2/1/90	2.1	1/29/90	2.1	2/2/90	1.5
Sodium	2/1/90	5.9	4/24/90	5.9	2/2/90	6.6
Zinc	5/5/88	6.6				

Table 6-17

Maximum Concentrations of Non-Metals
Lower Regional Aquifer

Parameter	MW-14(R) Date	MW-14(R) Concentration (mg/L)	MW-20(R) Date	MW-20(R) Concentration (mg/L)	MW-26(R) Date	MW-26(R) Concentration (mg/L)
Ammonia	7/18/89	.23	4/29/88	.13	4/26/90	.31
Chloride	1/25/89	2.2	1/26/89	4	2/2/90	1.7
COD			7/19/88	22	4/26/90	18
Fluoride	5/5/88	.05	4/29/88	.03		
MBAS	5/5/88	.04	4/29/88	.01		
Nitrate	5/5/88	.16	4/29/88	.09		
Nitrite	5/5/88	.01	4/29/88	.03		
Phenol	5/5/88	.06				
Sulfate	4/26/89	3.3	7/19/88	14	2/2/90	5.2
TDS	5/5/88	120	4/29/88	116		

Table 6-18

Maximum Concentrations of Semi-Volatile Neutral Extractables Lower Regional Aquifer

Parameter	Date	Well Number	Concentration (μg/L)
Bis(2-ethylhexyl)phthalate	4/29/88	MW-20(R)	15

7 LANDFILL GAS INVESTIGATION

7.1 Previous Landfill Gas Management

Landfill gas management at the Hidden Valley Landfill began in August 1985 because of the presence of gas odors in the vicinity of the landfill. Initial attempts to improve air quality included the installation of a number of candle flares over the landfill surface. The flares were mounted over the top of polyvinyl chloride (PVC) well casings installed in gravel-filled vertical borings ranging in depth from 8 to 28 feet. These initial control wells provided a conduit for the landfill gas to passively vent from the solid waste to the atmosphere.

In early 1986, in an effort to improve gas collection efficiency, the passive candle flares were replaced by an active landfill gas odor control system. The active collection system consisted of six horizontal gas collection trenches installed over an area of approximately 9 acres. A PVC header system connected the trench collectors and several of the previously installed vertical wells to a centrifugal blower. The blower provided the vacuum necessary to extract the gas from the landfill and supply it to a single 30-foot-tall candle flare.

In April 1986, under a memorandum of agreement with the Tacoma-Pierce County Health Department, LRI developed a landfill gas management plan to enable the Hidden Valley Landfill to meet the operational and post-closure criteria for landfill gas control. This plan included a gas migration monitoring program that called for the installation and monitoring of gas migration probes to be located along the landfill property boundary (see Figure 7-1). The objective of this program was to:

- Investigate subsurface geologic conditions as they relate to landfill gas migration
- Determine the existence of combustible methane gas in concentrations exceeding the performance criteria for landfill gas control

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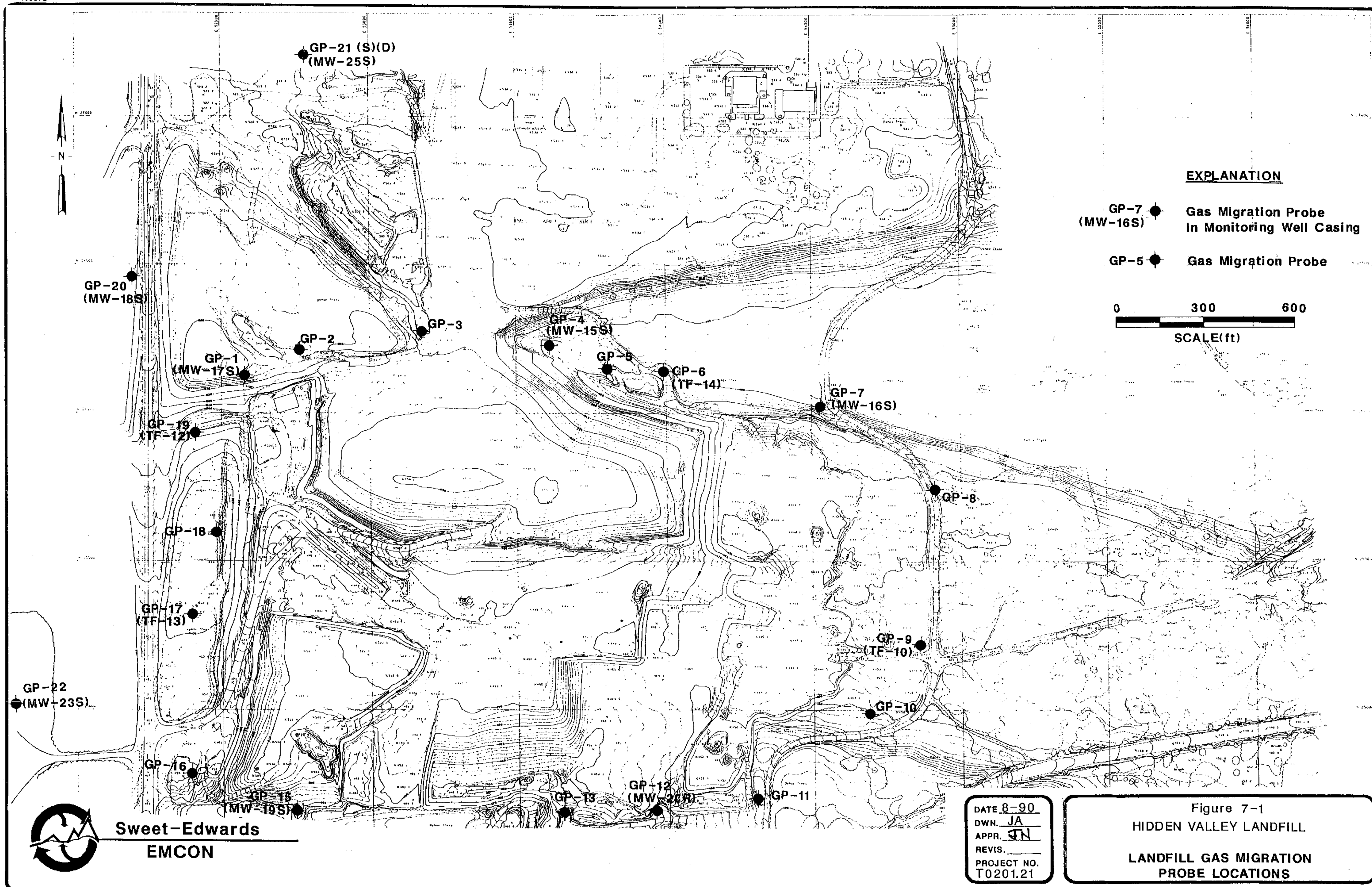

Figure 7-1
HIDDEN VALLEY LANDFILL

LANDFILL GAS MIGRATION
PROBE LOCATIONS

- Provide a monitoring system capable of meeting all landfill gas migration monitoring requirements for future landfill operations and post-closure periods

- Determine areas of the landfill requiring the installation of active landfill gas control facilities

- Provide data necessary to evaluate effectiveness of the landfill's gas control systems

Initial monitoring indicated migration was occurring along the northern end of the site. Consequently, in October 1987, ten vertical gas extraction wells were installed in the refuse at 150- to 200-foot intervals along the northern boundary of the landfill.

An above ground PVC header system connected the new extraction wells to the existing gas collection system. These additional wells were activated on October 26, 1987. Seven additional temporary vertical extraction wells were installed in December 1988 to help mitigate landfill gas odor at the site.

In September 1988, LRI purchased and installed two centrifugal blowers to increase the existing gas system's effectiveness. The gas system's cumulative extraction flowrate was increased to approximately 1,000 cfm. This increase in the system's flowrate was needed to meet TPCHD's compliance schedule for mitigation of the off-site migration of landfill gas.

Increased collection rates created problems with the gas collection system. The existing 30-foot candle flare was forced to operate at flowrates greater than those for which it was designed. The velocity of the gas passing through the combustion zone increased to a point where the destruction of the odor-causing constituents in the landfill gas began to decrease, which resulted in an increase of odors in the vicinity of the site. To correct this situation, a 2,100-cfm-capacity hidden flame flare was activated in March 1989.

Between April and August, 1989, ten additional vertical gas extraction wells were installed prior to the final closure of the northern portion of the landfill. Two of the original ten wells, installed in 1987, had to be buried by refuse to allow the landfill to achieve the designed elevations necessary for closure. In June 1989, removal of the gas collection piping was necessary to allow construction activities to be performed during the closure work. Following completion of the closure in September 1989, the gas collection system was reassembled and the system reactivated in October 1989.

7.2 Subsurface Landfill Gas Investigation

7.2.1 Gas Migration Probe Installation

Between June 1985 and March 1988, a total of 19 gas migration probes (GP-1 through GP-20) were installed around the perimeter of the landfill. GP-21 and GP-22 were installed concurrent with the installation of ground water monitoring wells MW-25(S) and MW-23(S) during November, 1989. GP-14 was not installed due to access constraints. The probe locations are shown in Figure 7-1.

Probes were installed as single- or multiple-completion probes, depending on the geologic conditions encountered. All probes except GP-6 monitor subsurface soils to a depth greater than or equal to the elevation of the base of the refuse. GP-6 was installed to within 15 feet of the refuse base elevation. Typical single- and triple-completion probe details and a table indicating the completed depths and elevations are presented in Appendix I. The gas probes are constructed of solid 1/2-inch PVC pipe joined to a length of 18-inch, slotted 1/2-inch PVC pipe, which acts as the sensing tip. At ground surface, the solid PVC pipe is connected to a threaded cap that prevents any moisture or dirt from entering and potentially obstructing the probe. A length of flexible 1/8-inch tubing is installed inside the PVC pipe and connects both ends of the probe. This tubing allows the withdrawal of smaller gas sample volumes, resulting in faster response times for the detection instrumentation. The slotted probe tip is embedded in pea gravel to provide a gas-permeable path to the probe's sensing tip. Each probe tip is located within the upper 3 feet of the gravel-filled monitoring zone. Methane, being lighter than air, has a tendency to rise up through the gravel towards the probe tip. Each probe and monitored zone is separated by an impermeable seal of hydrated bentonite. All probes are encased within a lockable security casing at ground surface. Each probe is labeled by means of a brass tag attached to the probe shaft just below the cap assembly. The tag identifies each individual probe (GP-9A, GP-16B, etc.) and the elevation (amsl) of its sensing tip. The exterior of each security casing is visibly marked to identify the probe (GP-8, GP-15, etc.).

7.2.2 Probe Monitoring Instrumentation

The primary purpose of the probe monitoring program is to determine whether adequate control of the migration of landfill gas is being maintained. The evaluation criteria are based on the results of monitoring at the probes and within the occupied structures.

The parameters measured at all probe locations include gas composition and static pressures. Monitoring performed within the occupied structures was for gas composition only.

A Gastech Model 1939-OX portable combustible gas/oxygen detector was used to perform the gas composition monitoring for the Hidden Valley Landfill gas probes. It is a three-channel instrument capable of measuring combustible gas between 0 and 100 percent by volume and between 0 and 100 percent of the lower explosive limit (LEL). It is also equipped to measure oxygen concentrations between 0 and 25 percent by volume.

Static pressures at the probes were monitored using Magnehelic pressure gauges capable of measuring 0 to 50 inches of water column.

7.2.3 Monitoring Frequency and Procedures

Monitoring was performed following the completion of each probe. The probes were allowed to equilibrate at least 48 hours prior to any monitoring to allow any entrained oxygen trapped during the construction process to purge. Since the probes were installed at various times over a two-year period, the initial monitoring was not performed according to a set schedule. By January 1988, all but three of the probes (GP-20, GP-21, and GP-22) had been installed. Monitoring was performed on all probes at least quarterly during 1988. Between January and December 1989, monitoring of the probes influenced by the gas control system (GP-1 through GP-6) was conducted monthly as part of the landfill's gas collection system operation and maintenance schedule and, due to disruption of the gas collection system during final closure activities being performed on a portion of the landfill. Since then, all probes continue to be monitored at least quarterly in accordance with the EPA's proposed Subtitle D rules 40 CFR Part 258.31 (a)(4).

In August 1988, an intensive period of probe monitoring was performed to reveal any site-specific migration characteristics. This schedule included monitoring of all probes twice daily, on three separate days, for a period of one week. This was followed by one additional round of monitoring a week later.

When possible, monitoring was performed in the afternoon to account for observed diurnal variations in the landfill's internal static pressures. Attempts were made to schedule the probe monitoring during periods of falling barometric pressures, or during conditions of a barometric pressure of less than 30.00" Hg.

All monitoring was performed by qualified personnel proficient in the proper use of the field monitoring equipment. All field monitoring data were recorded on appropriate data forms. In addition to the monitoring data, the date, time, and barometric pressure were recorded to help evaluate the monitoring data.

If at any time a detectable concentration of gas was found at a probe where combustible gas had never been detected, the combustible gas detector was immediately recalibrated and the probe again monitored to verify the reading.

7.2.4 Probe Monitoring Results

Initial probe monitoring showed relatively high levels of methane gas beneath the surface at the northern end of the landfill. The concentrations exceeded those allowable under the MFS performance criterion that landfill-derived methane not exceed five percent by volume at the property boundary. Additionally, methane concentrations at probe GP-13, which is located along the southern landfill boundary, were measured in excess of the performance standards. All monitoring results are presented in Appendix I.

Between the months of July and December 1989, while the gas collection system was dismantled for the closure activities, gas migration significantly increased along the northern landfill boundary. This resulted in a reservoir of gas accumulating within the subsurface soils outside the refuse.

Since then, the collection system has been reassembled and has been in continuous operation. The gas concentrations at the probes have decreased to the point that only on days exhibiting low barometric pressures is gas still being detected along the norther boundary in excess of the lower explosive limit. Adjustments to the gas extraction wells are still being made to enable the gas collection system to maintain constant control of migration at all times.

A sand and gravel extraction operation is located immediately adjacent to the south side of the Hidden Valley Landfill. Following the discovery of subsurface gas along the south boundary, a gas survey of the interiors of the gravel operation buildings was performed to determine the presence of any methane gas within the buildings that could be potentially hazardous to life or property. The survey indicated no detectable concentrations of methane.

The overall master plan for the Hidden Valley Landfill includes the eventual installation of landfill gas collection facilities in the southern portion of the landfill. This system, when installed, will provide the gas control measures for the southern half of the landfill for final closure.

7.3 Monitoring Of On-site Landfill Structures

The interior spaces in on-site structures at the landfill were periodically monitored to determine compliance with the MFS requirement of no more than 1.25 percent methane inside any on-site structures. Also, whenever an employee or any individual complained of strange odors within any on-site building, the building's interior was immediately tested for the presence of landfill gas.

Monitored locations included the inside of the building and around any conduits entering the building from below grade, confined areas which lacked adequate ventilation, structural joints, and any other potential point of entry through which migrating subsurface landfill gas may have been able to enter the building.

Monitoring performed in 1989 within the interiors of the on-site structures failed to find any detectable concentrations of combustible gas within any of the buildings.

7.4 Ambient Air Investigation

7.4.1 Landfill Gas Combustor Emission Testing

7.4.1.1 Purpose

In accordance with Puget Sound Air Pollution Control Agency, (PSAPCA) requirements, source emission evaluations are being performed to determine emission levels during typical operation of the landfill gas flare installed at the Hidden Valley Landfill. Following the combustion of the landfill gases within the flare, combustion products are released to the atmosphere. The source tests were performed to determine whether potentially hazardous constituents within the landfill gas are being destroyed.

An initial test was performed by AmTest, Inc.'s Air Quality Division, Carnation, Washington, on April 21, 1989, in the presence of Mr. Fred

Austin, reviewing engineer with PSAPCA. A second test was performed by AmTest, Inc. on May 30, 1990.

7.4.1.2 Test Methodology

An atmospheric emission evaluation test plan was prepared by AmTest, which described the test methods, protocol, and quality control procedures. The evaluation generally includes the measurement of the following parameters:

- Velocity, airflow, temperature, and residence time at the flare outlet
- Combustion gas concentration for carbon dioxide, oxygen, and carbon monoxide at the flare inlet and outlet
- Percent moisture at the flare outlet
- Hydrochloric acid (HCl) emission concentration at the flare outlet (analyzed as chlorides)
- Sulfur dioxide (SO_2) emission concentration and mass rate at the flare outlet
- Volatile organic compounds (VOCs, or those with boiling points in the range of approximately 30° to 100° C) were identified and quantified at the inlet and outlet of the landfill gas flare to determine destruction efficiency

7.4.1.3 Summary of Test Results

Field measurements taken prior to the test showed that the landfill gas collection system was extracting approximately 1,050 cfm of landfill gas. The flare's flame temperature was observed to be approximately 1,380°F, as shown on the flare's temperature indicator.

Copies of AmTest's April, 1989 and May, 1990 Hidden Valley Landfill gas combustor testing reports are presented in Appendix I. The following presents a summary of the April, 1989 tests results for each of the parameters tested.

7.4.1.3.1 Velocity, Airflow, and Temperature

At the flare inlet, landfill gas is discharged from the gas system's centrifugal blower and fed to the flare through a 12-inch nominal PVC pipe. The average velocity of the gas measured 24.52 ft/sec within the 12-inch PVC pipe. The resulting flow rate of the landfill gas stream was calculated to be 1,029.7 dry cubic feet per minute (dcfm), with an average inlet temperature of 100°F.

At the flare outlet, the average velocity of the flare's discharge gases measured 10.34 ft/sec, resulting in an air flow of 10,211.4 dcfm through a 9.0-foot diameter cylindrical shell, with an average outlet temperature of 1,366.5°F. With a vertical distance of 34 feet, as measured from the flare's burner head to the top of the flare stack, a calculated residence time of approximately 3.3 seconds was determined.

The procedures for measuring these parameters were conducted in accordance with EPA Methods 1 and 2 as specified in 40 CFR, Part 60.

7.4.1.3.2 Combustion Gas Analysis

EPA Method 3 was used to determine the composition of carbon dioxide, oxygen, and carbon monoxide at both the flare inlet and outlet. The methane concentration at the flare inlet was also determined by gas chromatography (GC) analysis of gas samples that were collected in Tedlar® bags and returned to AmTest's laboratory for analysis.

The results of the composition analysis are as follows:

Compound	Average Inlet Concentration	Average Outlet Concentration
Methane (%)	32.8	-
Carbon Dioxide (%)	24.2	6.8
Oxygen (%)	5.4	12.4
Carbon Monoxide (ppm)	0	4

7.4.1.3.3 Moisture and Hydrochloric Acid Emissions

EPA Method 4 was used to measure the percent moisture in the flare's discharge gases. Hydrochloric acid emissions (expressed as chlorides) were also determined in this procedure by bubbling the gas through water and analyzing the liquid using ion chromatography.

An average moisture content of the exhaust gases measured 9.02 percent by weight.

Hydrochloric acid emissions are currently regulated by PSAPCA's Regulation I. The criterion for hydrochloric acid emissions is as follows:

- It shall be unlawful for any person to cause or allow the emission of hydrochloric acid (HCl) from any equipment in excess of one hundred (100) ppm on a dry basis, one hour average corrected to 7 percent oxygen for combustion sources. [PSAPCA, Regulation I, Section 9.10(a)]

The results of the hydrochloric acid analysis determined that the flare exhaust gases were emitting an average hydrochloric acid emission concentration of 15.7 ppm, corrected to 7 percent oxygen.

7.4.1.3.4 Total Sulfur Emissions

The analysis for sulfur emissions from the Hidden Valley Landfill flare was performed using EPA Methods 6C and 16A. This procedure determined the sulfur dioxide concentrations (expressed as total sulfur) by converting hydrogen sulfide and total reduced sulfur to sulfur dioxide. Sulfur dioxide emissions are also currently regulated by PSAPCA's Regulation I. The criterion for sulfur dioxide emissions is as follows:

- It shall be unlawful for any person to cause or allow the emission of sulfur dioxide (SO_2) from any equipment in excess of one thousand (1,000) ppm on a dry basis, one hour average corrected to 7 percent oxygen for combustion sources. [PSAPCA, Regulation I, Section 9.07(b)]

The results of the sulfur dioxide analysis determined that the flare exhaust gases were emitting an average total sulfur emission concentration of 1.7 ppm, corrected to 7 percent oxygen.

7.4.1.3.5 Total Nitrogen Oxide Emissions

EPA Method 7E was used to determine the total nitrogen oxide emission concentration. The results of the nitrogen oxide analysis determined that the flare exhaust gases were emitting an average nitrogen oxide concentration of 27.4 ppm, corrected to 7 percent oxygen. PSAPCA currently has no emission standards for nitrogen oxide emissions from combustion sources.

7.4.1.3.6 Volatile Organic Compound Emissions and Destruction Efficiency Determination

Total volatile organic compounds (VOCs) were determined at the flare inlet and outlet. Gas samples were collected from the flare inlet in Tedlar^R bags.

Light hydrocarbons (C_2 - C_4) were quantified using gas chromatography analysis in Am Test's laboratory.

Outlet volatile organic sample train (VOST) samples were collected and desorbed in accordance with EPA Method 5040. The samples were then analyzed in accordance with EPA Method 8240 procedures. The average mass rate for VOCs for both the inlet and outlet and their destruction efficiency are presented in Table 7-1.

There are several compounds that have been listed in Table 7-1 as being identified in the outlet samples but were not identified in the inlet samples. There is concern by Am Test that some of the sample tubes used for the field and trip blanks were not properly baked out prior to shipment. As a result, those tubes may have been contaminated prior to use, which may have affected the laboratory results for the VOC analysis. Additional work is continuing to clarify this issue.

The destruction efficiencies were calculated using the mass rates for only those compounds quantified in the inlet samples. Those additional compounds listed in the outlet were assumed to have originated from an outside source and were not being incinerated in the landfill gas flare. The destruction efficiency ranged from 98.60 percent for methylene chloride to 100.00 percent for several of the compounds. Overall, the destruction efficiency averages 99.90 percent, based on 137,523 mg/hr total VOCs at the inlet with 131 mg/hr total VOCs being released at the outlet.

Assuming that only the undestroyed portion of the identified inlet compounds were being released by the landfill gas flare, the following calculation determines the mass rate (lbs/hr) of the total VOCs being exhausted:

- Average total VOC emission at outlet (lbs/day):

  $(\sim 131 \text{ mg/hr}) \times (1.0 \times 10^{-3} \text{ g/mg}) \times (2.205 \times 10^{-3} \text{ lbs/g})$
  $\times \ (24 \text{ hr/day})$
  $= \ \sim 0.007 \text{ lbs/day total VOCs.}$

7.4.2 Ambient Air Quality Testing

An ambient air quality evaluation was to be performed at the Hidden Valley Landfill in accordance with Task 4.8.2 of the Thun Field Remedial Investigation Work Plan submitted to Ecology in September 1987 and pursuant to the consent order. The primary purpose of this study was to characterize and define expected air emissions from the landfill after completion of the landfill gas migration and control systems. This evaluation

Table 7-1

Volatile Organic Compound Concentrations and Their Destruction Efficiency

Compound	Average Inlet Mass Rate (mg/hr)	Average Outlet Mass Rate (mg/hr)	Destruction Efficiency (%)
Chloromethane	<DL	<DL	--
Vinyl chloride	25,428	<DL	100.00
Bromomethane	<DL	<DL	--
Chloroethane	33,827	~29	~99.91
Dichlorodifluoromethane	<DL	~26	--
Trichlorofluoromethane	~2,712	~22	~99.18
1,1-dichloroethylene	<DL	57	--
Methylene chloride	2,094	~29	~98.60
Trans-1,2-dichloroethylene	<DL	<DL	--
1,1-dichloroethane	<DL	278	--
Chloroform	<DL	96	--
1,1,1-trichloroethane	<DL	<DL	--
Carbon tetrachloride	<DL	~537	--
1,2-dichloroethane	<DL	278	--
Trichloroethylene	1,359	<DL	100.00
1,2-dichloropropane	<DL	<DL	--
Dichlorobromomethane	<DL	<DL	--
Trans-1,3-dichloropropene	<DL	<DL	--
Cis-1,3-dichloropropene	<DL	<DL	--
1,1,2-trichloroethane	2,939	<DL	100.00
Tetrachloroethylene	<DL	~18	--
Dibromochloromethane	<DL	<DL	--
Bromoform	<DL	<DL	--
1,1,2,2-tetrachloroethane	<DL	<DL	--
Benzene	~2,613	~20	~99.23
Toluene	18,558	~31	~99.84
Chlorobenzene	<DL	<DL	--
Ethylbenzene	18,488	<DL	100.00
M+P-xylene*	20,588	<DL	100.00
O-xylene	8,917	<DL	100.00
1,3-dichlorobenzene	<DL	<DL	--
1,4-dichlorobenzene	<DL	<DL	--
1,2-dichlorobenzene	<DL	<DL	--

Notes:
* = Coeluted
< DL = Indicates less than the detection limit was found; given the value 0 for mathematical calculations
~ = Indicates an average that was greater than the detection limit for 1 or 2 of the values for three runs

would also assess the effective performance of the landfill cover and the gas collection systems. However, for the reasons described below, this evaluation was not performed.

The basis for determining a landfill's cover performance is a function of the permeability of the landfill cover. In the past, permeable soils have been used at Hidden Valley as daily and intermediate cover. Since 1986, LRI has covered all inactive landfill areas with a synthetic geomembrane weighted down with discarded tires. This geomembrane reduces the landfill cover's permeability and minimizes the infiltration of precipitation. It also seals and reduces odor emissions resulting from the venting of landfill gas through the surface cover soils.

The proposed ambient air quality test was to include the collection of ambient air samples at the landfill property boundary. These samples were to be analyzed for the presence of specific contaminants that could be in the landfill gas as it vents through the surface of the landfill and disperses in the air. However, since most of the landfill surface is covered by the temporary geomembrane cover, the results of such an evaluation may not be truly representative of actual site conditions under final cover.

At present there are no standard test methods for performing such an evaluation that have been endorsed in the state of Washington. The current ambient air quality assessment testing being performed under the Calderon legislation in the state of California follows state-issued guidelines for performing the testing. Specific sampling equipment and methods for collecting and analyzing the samples are, however, left up to those who are performing the test program and the analytical laboratories. As a result, the methods and equipment used have varied from site to site. It has been reported that initial test results submitted to the California Air Resources Board have shown some inconsistencies. These have included such things as higher trace constituent concentrations being found in the ambient air samples collected upwind from the landfill than those collected downwind, and higher constituent concentrations being found in the blanks than those samples collected upwind and downwind of the site. Further, the air resources board has stated that the Calderon air quality assessment tests are only an initial survey and that the results may not be used to determine site-specific mitigative recommendations.

However, due to the lack of standard testing methods, the proposed ambient air quality test for the Hidden Valley Landfill was to be performed under the quality assurance and control guidelines prepared by the state of California for their Calderon ambient air assessment test. Due to concern for accuracy of the test data, the guidelines include certain criteria for climatic conditions during the time the testing is conducted. This criterion states that sampling will not be conducted under the following adverse meteorological conditions:

- Precipitation
- Twenty-four hour average wind speeds greater than ten miles per hour as measured at the test site

The results of the ambient air quality investigation at the Hidden Valley Landfill were to be based upon the impacts from the completed landfill gas migration control system, including the system's permanent gas flare. As previously discussed in Section 7.1, the landfill gas collection system has been constantly undergoing major expansions over the past two years. The more efficient hidden flame flare has only been in operation since March 1989. At no time during Phase II of the remedial investigation could an ambient air investigation be performed with the gas collection system operating under steady-state conditions and with permanent gas collection equipment installed, or during periods when the climatic conditions were favorable for ambient air sampling.

8 SOURCE AND RELEASE ASSESSMENT

8.1 Leachate Characterization and Production

A review of the ground water quality data indicates that leachate-derived inorganic and organic constituents are sporadically present in the Shallow Perched and Upper Regional Aquifers beneath the site. Landfill leachate includes liquids that are produced during decomposition of wastes as well as liquid that has passed through the refuse both vertically and horizontally. Liquid percolating through landfill wastes has the potential to extract dissolved and suspended materials, including both biological and chemical constituents (Tchobanoglous et al., 1977).

The Hydrologic Evaluation of Landfill Performance (HELP II) computer model was used to determine the relative volume(s) of leachate that would be generated at the landfill site under three scenarios: (1) no cap with a 12-inch soil cover over the refuse, (2) a 40-mil cap with a 12-inch soil cover over refuse, and 3) state-of-the-art composite cap. Results of the HELP model indicated that present and future engineering design, i.e., run-off control and placement of the infiltration basin will continue to reduce the volume of leachate generated, see Appendix K.

Leachate migration can occur both horizontally and vertically depending on the permeability of the solid waste material and the hydraulic head within the waste. Horizontal movement may produce surface seeps while downward movement below the fill may allow the leachate derived constituents to reach ground water. Leachate surface seeps have not been identified at the Hidden Valley Landfill site. However, due to the permeable nature of the gravelly soils underlying the site, vertical migration of leachate toward and into the Shallow Perched Aquifer has occurred. Past placement of refuse below the seasonal high ground water elevation in the Shallow Perched Aquifer is thought to generate leachate through direct contact in the refuse resulting in the release of leachate-derived constituents into the ground water.

8.2 Contaminant Source Characteristics

The amount and composition of the leachate generated at a landfill site is dependent upon numerous conditions including:

- Landfill size
- Waste composition
- Stage of decomposition
- Moisture content
- Age of fill
- Past and current handling of wastes
- Compaction methods
- Subsurface temperatures

Laboratory analysis of leachate collected from leachate head wells LH-1, LH-2, and LH-3 has shown levels of metal, nonmetal, and volatile organic indicator parameters at concentrations significantly above the levels detected in ground water, (see Appendix G). The ammonia-rich leachate (>1100 mg/l) present within the solid waste is considered the most probable source of ammonia as nitrogen and nitrate as nitrogen in ground water beneath the site. Sewage and pulp mill sludges that were accepted at the landfill in the early stages of operation are the likely source of ammonia as nitrogen in the leachate.

8.3 Fate and Transport of Contaminants

Ground water movement is the mechanism by which leachate-derived constituents are transported downgradient of the landfill site. Leachate is released to the ground water via direct contact when the ground water elevation is greater than the elevation at the base of the solid waste. It may also be released to the ground water, when the ground water elevations are below the base of the waste, via infiltration and percolation through the seasonally unsaturated recessional outwash deposits.

The hydraulic properties and apparent interconnection of the geologic materials beneath the site provide pathways for the leachate-derived constituents to migrate both in the Shallow Perched Aquifer and the Upper Regional Aquifer.

A thick sequence of inter-glacial deposits, which consist of silts, clays, and very fine sands, limits the vertical movement of these constituents toward, and into, the Lower Regional Aquifer. This is reflected in the ground water quality results, which indicate that there is no adverse impact to the Lower Regional Aquifer from the landfill operation.

8.4 Analytical Modelling

Mass transport modeling was performed during the Phase I work effort and was included as part of the Draft Phase I Remedial Investigation Report. The model was run in order to estimate downgradient distances from the landfill at which specified concentrations of nitrate (4 mg/l and 10 mg/l) could occur based on past nitrate levels detected in ground water samples collected from a monitoring well [MW-18(S)] located hydraulically downgradient of the landfill.

A similar modeling effort was proposed for the Phase II Remedial Investigation using data collected since the Draft Phase I Remedial Investigation Report was submitted to Ecology. This data provided information which indicated that the ground water flow velocities in the Shallow Perched Aquifer were higher (estimated at 32.8 ft/day) than those used in the initial modeling effort (2.7 feet/day). Simulations using the decay/dispersion model provide less reliable results when the source concentration is poorly understood, permeable aquifer materials (10^{-2} cm/sec or greater) are present, and hydraulic gradients are equal to those present in the Shallow Perched Aquifer. Consequently, the model was not run to simulate nitrate as nitrogen concentrations at any given distance hydraulically downgradient from the landfill site in the Phase II Remedial Investigation.

It is our understanding that Ecology may be pursuing access agreements with owners of property located to the northwest of the landfill. Previous discussions with these owners by LRI and its representatives did not provide LRI an opportunity to install and sample additional monitoring wells at these locations. However, if Ecology is granted permission to install monitoring wells, the ground water data collected from these new sampling locations will provide information on water quality which is more representative of aquifer conditions than that which could have been calculated using modeling techniques.

9 RISK ASSESSMENT

The baseline risk assessment (BRA), conducted in accordance with risk assessment guidance developed by the U.S. Environmental Protection Agency (EPA 1989a and 1989b), has been presented in a separate document. The BRA, prepared in response to a consent order signed between LRI and the state of Washington, is based on data represented in this RI report.

10 SUMMARY

This section presents the summary of the remedial investigation findings at the landfill site. Information collected prior to implementation of the RI has also been used in the development of these conclusions.

10.1 Geology

The site is underlain by a complex sequence of glacial deposits, which consists of the following units:

Unit	Thickness Range (ft)	Elevation Range (MSL)
Upper Vashon Till (Unit A)	0-75	550-471
Vashon Recessional Outwash (Unit B)	35-120	480-380
Lower Vashon Till (Unit C)	10-26	425-375
Vashon Advance Outwash (Unit D)	11-50	400-350
Salmon Springs Till (Unit E)	20-31	370-325
Salmon Springs Interglacial (Unit F)	48-65	325-260
Salmon Springs Till (Unit G)	37-59	275-225
Salmon Springs Outwash (Unit H)	Unknown	235-<200

10.2 Hydrogeology

- Three distinct aquifers have been identified beneath the site. A Shallow Perched Aquifer occurs in the Vashon Recessional Outwash, an Upper Regional Aquifer in the Vashon Advance Outwash, and a Lower Regional Aquifer in the Salmon Springs Outwash.

- Ground water flow direction in the Shallow Perched and Upper Regional Aquifers is generally to the northwest.

- Flow direction in the Lower Regional Aquifer is not known.

- Recharge occurs to the Shallow Perched Aquifer and Upper Regional Aquifer via infiltration of runoff and precipitation both on-site and off-site.

- Recharge occurs to the Lower Regional Aquifer from off-site sources.

- Discharge of the Shallow Perched and Upper Regional Aquifers is to the Clover/Chamber Creek drainage basin.

- The Lower Regional Aquifer is thought to discharge to the Puyallup and Nisqually River drainage systems.

- Flow velocities in the Shallow Perched Aquifer are estimated to range from 3.2 feet/day to 6.5 feet/day; in the Upper Regional Aquifer from .05 feet/day to 13 feet/day.

- The Shallow Perched Aquifer is separated from the Upper Regional Aquifer by the Lower Vashon Till unit. Vertical downward movement of ground water may occur locally through the Lower Vashon Till beneath the site. The nature and degree of hydraulic connection are not fully understood.

- A thick, low permeability aquitard composed of Salmon Springs till separates the Upper and Lower Regional Aquifers. Little, if any, hydraulic connection occurs between the Upper and Lower Regional Aquifers at the Hidden Valley Landfill site.

10.3 Ground Water Quality

- Both the Shallow Perched Aquifer and the Upper Regional Aquifer have been impacted beneath the site from landfill operations.

- Leachate-derived constituents have been detected in ground water samples collected from most on-site downgradient monitoring wells completed in the Shallow Perched Aquifer and the Upper Regional Aquifer at levels that exceed background concentrations.

- Off-site impacts to ground water quality in both the Shallow Perched Aquifer and the Upper Regional Aquifer have only been identified in the vicinity of MW-11(S)(D), MW-18(S)(D), MW-22(U)(L), and BC-4(S)(D).

- The extent of impact to water quality in the Shallow Perched Aquifer and the Upper Regional Aquifer downgradient of MW-18(S) and MW-18(D) is not known.

- Nitrate-N in the Shallow Perched Aquifer has sporadically exceeded the drinking water standard in winter months since ground water sampling began in 1985. Isolated exceedances of benzene and vinyl chloride MCL's have occurred in the Upper Regional Aquifer in ground water samples collected from TF-11(D).

- No adverse impacts to water quality have been identified in the Lower Regional Aquifer.

10.4 Source Evaluation

- Final closure of the northern part of the landfill and temporary plastic cover placed over the south portions of the landfill have greatly reduced infiltration of precipitation into the landfill. Only the active area is uncovered at the present time. Consequently, the availability of moisture within the solid waste for leachate generation has been significantly reduced.

- Seasonal ground water elevations in the Shallow Perched Aquifer can exceed the elevation at the base of the solid waste. Under these conditions, leachate may be in direct contact with the ground water.

11 LIMITATIONS

The services described in this report were performed consistent with generally accepted professional consulting principles and practices. No other warranty, express or implied, is made. These services were performed consistent with our agreement with our client. This report is solely for the use and information of our client unless otherwise noted. Any reliance on this report by a third party is at such party's sole risk.

Opinions and recommendations contained in this report apply to conditions existing when services were performed and are intended only for the client, purposes, locations, time frames, and project parameters indicated. We are not responsible for the impacts of any changes in environmental standards, practices, or regulations subsequent to performance of services. We do not warrant the accuracy of information supplied by others, nor the use of segregated portions of this report.

The purpose of a geologic/hydrogeologic study is to reasonably characterize existing site conditions based on the geology/hydrogeology of the area. In performing such a study, it is understood that a balance must be struck between a reasonable inquiry into the site conditions and an exhaustive analysis of each conceivable environmental characteristic. The following paragraphs discuss the assumptions and parameters under which such an opinion is rendered.

No investigation is thorough enough to describe all geologic/ hydrogeologic conditions of interest at a given site. If conditions have not been identified during the study, such a finding should not therefore be construed as a guarantee of the absence of such conditions at the site, but rather as the result of the services performed within the scope, limitations, and cost of the work performed.

We are unable to report on or accurately predict events that may change the site conditions after the described services are performed, whether occurring naturally or caused by external forces. We assume no responsibility for conditions we were not authorized to evaluate, or conditions not generally recognized as predictable when services were performed.

Geologic/hydrogeologic conditions may exist at the site that cannot be identified solely by visual observation. Where subsurface exploratory work was performed, our professional opinions are based in part on interpretation of data from discrete sampling locations that may not represent actual conditions at unsampled locations.

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