PNL-7613
UC-903

Limited Site Investigation of Landfills 1 and 4, Fort Lewis, Washington

G. V. Last
P. A. Eddy
S. P. Airhart
K. R. Olsen
J. R. Raymond
D. R. Dahl

August 1990

Prepared for the U.S. Army, I Corps
and Fort Lewis, Washington
under a Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830

Pacific Northwest Laboratory
Operated for the U.S. Department of Energy
by Battelle Memorial Institute

Battelle

PNL-7613

PACIFIC NORTHWEST LABORATORY
operated by
BATTELLE MEMORIAL INSTITUTE
for the
UNITED STATES DEPARTMENT OF ENERGY
under Contract DE-AC06-76RLO 1830

Printed in the United States of America

Available to DOE and DOE contractors from the Office of Scientific and Technical Information, P.O. Box 62, Oak Ridge, TN 37831; prices available from (615) 576-8401. FTS 626-8401.

Available to the public from the National Technical Information Service, U.S. Department of Commerce, 5285 Port Royal Rd., Springfield, VA 22161.

PNC-7613
UC-903

LIMITED SITE INVESTIGATION OF LANDFILLS 1 AND 4, FORT LEWIS, WASHINGTON

G. V. Last
P. A. Eddy
S. P. Airhart
K. R. Olsen
J. R. Raymond
D. R. Dahl

August 1990

Prepared for
the U.S. Army, I Corps and Fort Lewis,
Washington under Related Services Agreement
with the U.S. Department of Energy
Contract DE-AC06-76RLO 1830
Interagency Agreement 11832B

Pacific Northwest Laboratory
Richland, Washington 99352

SUMMARY

Fort Lewis has been in operation since 1917, when the citizens of Pierce County donated 77,320 acres of land to the Federal government for the establishment of a permanent military base. During the period of its operation, the Fort has provided facilities for troop induction, training, embarkation, and debarkation. The normal operation of this facility has included the disposal of generated waste into landfill sites and disposal pits.

The information presented in this report was collected during limited site investigation activities conducted in the vicinity of Landfills 1 and 4 at Fort Lewis between April and December 1988. The purpose of this work was to provide a means of detecting and evaluating the impacts of these inactive landfills on ground-water quality and adjacent lands. This effort included the design and construction of ground-water monitoring systems for compliance with applicable Federal and State regulations governing Resource Conservation and Recovery Act (RCRA)-type landfills.

Landfill 1 operated as a trench cut-and-fill operation for the disposal of sanitary solid waste until at least late 1951. The landfill was then used for surface dumping of construction rubble. Waste materials exposed at the surface include broken concrete, broken asphalt, and various types of wood. Aerial photographs taken in 1951 appear to indicate that additional areas were used for open-pit dumping (waste materials unknown), burning, and storage. Unauthorized surface dumping of trash wood and paper, old asphalt shingles, various automobile parts, and Christmas trees has also occurred.

Landfill 4 also operated as a trench cut-and-fill operation for the disposal of sanitary solid waste until at least 1967. Four separate trench areas were interpreted from aerial photographs of the site. Waste materials exposed at the surface consisted of household waste, automobile parts, construction rubble, tires, and various large metal objects. Surface dumping of tree stumps and some unauthorized dumping have also occurred at this site. This site has also been used for training of heavy equipment and military vehicle operators.

Three principal activities were conducted during this limited site investigation. The first activity involved 1) field reconnaissance of each landfill, 2) visual inspection of monitoring wells and collection of water levels from the existing monitoring wells, and 3) personal interviews with Fort Lewis Directorate of Engineering and Housing (DEH) employees concerning the operational history and waste inventory of the landfills and with the U.S. Army Corps of Engineers concerning aerial photographs and the hydrogeology of the area. The second activity, conducted in July 1988, involved surface geophysical surveys to determine the physical boundaries of Landfill 4. A ground-penetrating radar unit, ground conductivity surveys, and metal detector surveys were used to delineate the waste boundaries. The third activity, conducted between August and October 1988, involved installing 10 new monitoring wells, remediating 8 existing wells installed in 1981 and 1984, and abandoning 1 existing (1981) well.

Boreholes for the 10 new wells were drilled using either cable-tool or hollow-stem auger methods. Sediment samples were collected and classified in the field throughout the drilling effort. Generally, the sediment from the different boreholes consisted of sandy gravel to muddy sandy gravel with minor layers of sand and clay. On completion of the drilling, eight of the boreholes were logged using a gamma-ray (natural-gamma) geophysical probe. Water-level data from Landfill 1 indicate that ground-water flow is toward the northeast. Water-level data from Landfill 4 suggest that ground-water flow is to the north away from Sequalitchew Lake.

Ground-water samples were collected from both existing (1981 and 1984) wells and the newly installed (1988) wells. Five field sampling events were conducted commencing in late August 1988 and ending in mid-December 1988. The analytical results from the water samples indicate that the ground water in and around Landfill 1 contains limited contamination. Contaminants may include volatile organic compounds and nitrate. The primary concern in the area around Landfill 1 was the determination that ground water from two wells may contain cis-1,2-dichloroethylene and 1,1,1-trichloroethylene above drinking water standards. Nitrate levels in the downgradient wells were greater than those in upgradient wells and exceeded drinking water standards in some of the less-representative samples. Analyses of ground-water samples from wells in and around Landfill 4 indicate several contaminants may be present. These include volatile organic compounds (principally cis-1,2-dichloroethylene and 1,1,1-trichloroethylene), coliform, oil and grease, and perhaps some metals (iron and magnesium). The primary concern in the area around Landfill 4 was the determination that ground water from five wells contained cis-1,2-dichloroethylene and 1,1,1-trichloroethylene above drinking water standards. The source of contaminants beneath either landfill cannot yet be identified. Insufficient data exist to disprove or confirm either landfill as possible contributors.

CONTENTS

FIGURES

TABLES

1.0 INTRODUCTION

The 86,000-acre Fort Lewis Facility (the Fort) is located approximately 12 miles southwest of Tacoma, Washington, and 18 miles northeast of Olympia, Washington (Figure 1.1). The Fort has been an army facility since 1917 with onsite industrial operations including maintenance of aircraft and vehicles and repairs and refurbishing of weapons.

During the Fort's more than 70 years of operation, several landfill sites were used for the disposal of large quantities of solid waste material. These waste materials slowly degrade and/or mobilize in the subsurface and can result in the release of contaminants through the vadose zone and into shallow underlying aquifer systems.

Information presented in this report was collected by the Pacific Northwest Laboratory (PNL)[a] at the request of the U.S. Army. Work was performed under a related services agreement with the U.S. Department of Energy (Contract DE-AC06-76RLO 1830 Interagency Agreement 11832B). This information was collected during site investigations conducted at Landfills 1 and 4 located on the Fort. The goal of the site investigations was to provide a means for detecting and evaluating the impacts of inactive Landfills 1 and 4 on the ground water and adjacent lands. This goal was to be achieved through the design and construction of ground-water monitoring systems at the landfills that would comply with applicable federal and state regulations.

Three principal activities were conducted at the landfills. The first activity involved 1) field reconnaissance of both landfills to determine the types of materials present and the areal extent of each landfill, 2) visual inspection of existing monitoring wells to determine their usefulness and for the collection of water-level data, and 3) interviewing Fort Lewis Directorate of Engineering and Housing (DEH) employees concerning the operation, use, and waste inventories of the landfills and the U.S. Army Corps of Engineers personnel concerning available aerial photographs and existing hydrogeologic

---

(a) The Pacific Northwest Laboratory is operated by Battelle Memorial Institute for the U.S. Department of Energy under Contract DE-AC06-76RLO 1830.

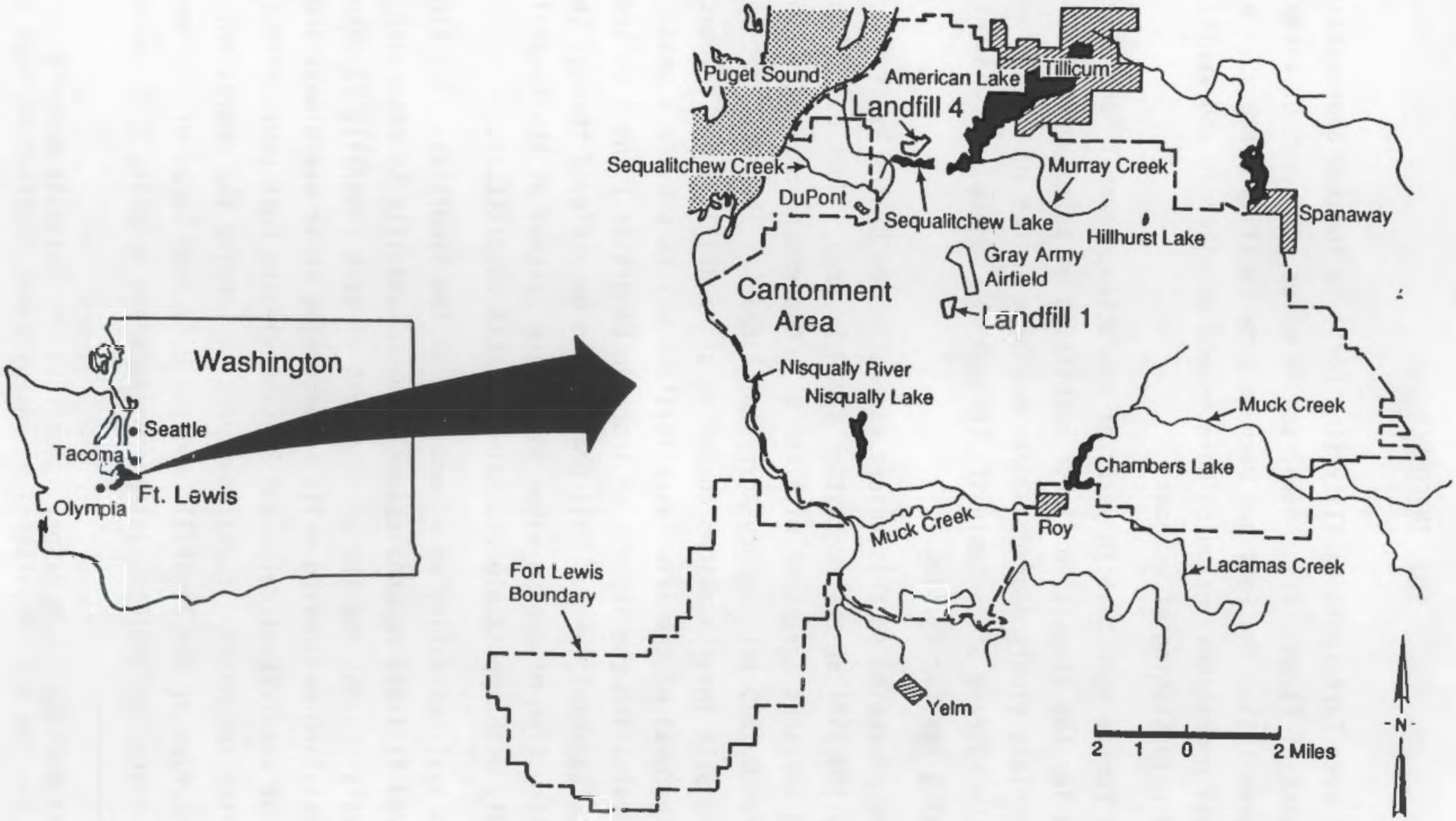


FIGURE 1.1. Location Map of Fort Lewis

information. The second activity was to perform surface geophysical surveys over Landfill 4 to determine its physical boundaries. Ground-penetrating radar, ground conductivity surveys, and metal detector surveys were conducted in July 1988. The third activity, performed in August through October 1988, consisted of drilling and installing 10 new wells, remediating 8 existing wells installed in 1981 and 1984, and abandoning 1 of the 1981 wells. Sediment samples were collected at 5-ft intervals throughout the drilling effort. These sediments were generally classified by using the percentages of gravel, sand, and mud (silt plus clay) found in the sample. Five ground-water sampling events were performed, each involving all or portions of the 10 new (1988) wells and 8 existing (1981 and 1984) wells.

This report contains background information on the Fort and its environmental setting. The report also discusses the investigative methods used in the study, the specific hydrogeologic characteristics of the landfills, and the possible impacts of these landfills on the ground-water quality.

information. The second activity was to perform surface geophysical surveys over Landfill 4 to determine its physical boundaries. Ground-penetrating radar, ground conductivity surveys, and metal-detector surveys were conducted in July 1988. The third activity, performed in August through October 1988, consisted of drilling and installing 10 new wells, resampling 8 existing wells installed in 1981 and 1986, and abandoning 1 of the 1981 wells. Sediment samples were collected at 5-ft intervals throughout the drilling effort. These sediments were generally classified by using the percentages of gravel, sand, and mud (silt plus clay) found in the sample. Five ground-water sampling events were performed, each involving all or portions of the 10 new (1988) wells and 8 existing (1981 and 1986) wells.

This report contains background information on the Fort and its environmental setting. The report also discusses the investigative methods used in the study, the specific hydrogeologic characteristics of the landfills, and the possible impacts of these landfills on the ground-water quality.

2.0 SITE BACKGROUND

This chapter describes the location and physical layout of the Fort and Landfills 1 and 4, the history of the Fort, the photographs and sketches available for these landfills, the operational history of the landfills, and the permit and regulatory history of the landfills.

2.1 SITE LOCATION AND LAYOUT

The Fort is located along Interstate 5, approximately 12 miles southwest of Tacoma, Washington, and 18 miles northeast of Olympia, Washington (see Figures 1.1 and 2.1). The Fort encompasses approximately 86,000 acres and is configured in a general hourglass shape, with its long axis oriented northeast to southwest. The Nisqually River crosses the Fort at its narrowest point, dividing the Fort into northeastern and southwestern sectors. The northeastern sector is the largest and contains the two landfills of interest (Landfills 1 and 4). These two landfills are located on opposite sides of the west-southwest to east-northeast-oriented Interstate 5, which cuts through this portion of the Fort (Figure 2.1). Landfill 1 is located south of Interstate 5, approximately 0.5 mile southwest of Gray Army Airfield. Landfill 4 is located north of Interstate 5, immediately north of Sequalitchew Lake.

2.2 GENERAL HISTORY

The Fort is an active facility that has been owned and operated by the U.S. Army since 1917. McMaster (1982) indicated that this facility serves as the focal point for induction, training, embarkation, and debarkation of troops in the northwest. Activities at this installation include the operational use, handling, storage, and disposal of various hazardous materials. A summary of these activities, taken from McMaster (1982), is provided below.

Industrial operations at the Fort include vehicle and aircraft maintenance, weapons repair and refinishing, and limited furniture refinishing. Vehicle and aircraft maintenance activities currently use 1,1,1-trichloroethane (TCA) in degreaser baths and caustic sodium hydroxide for

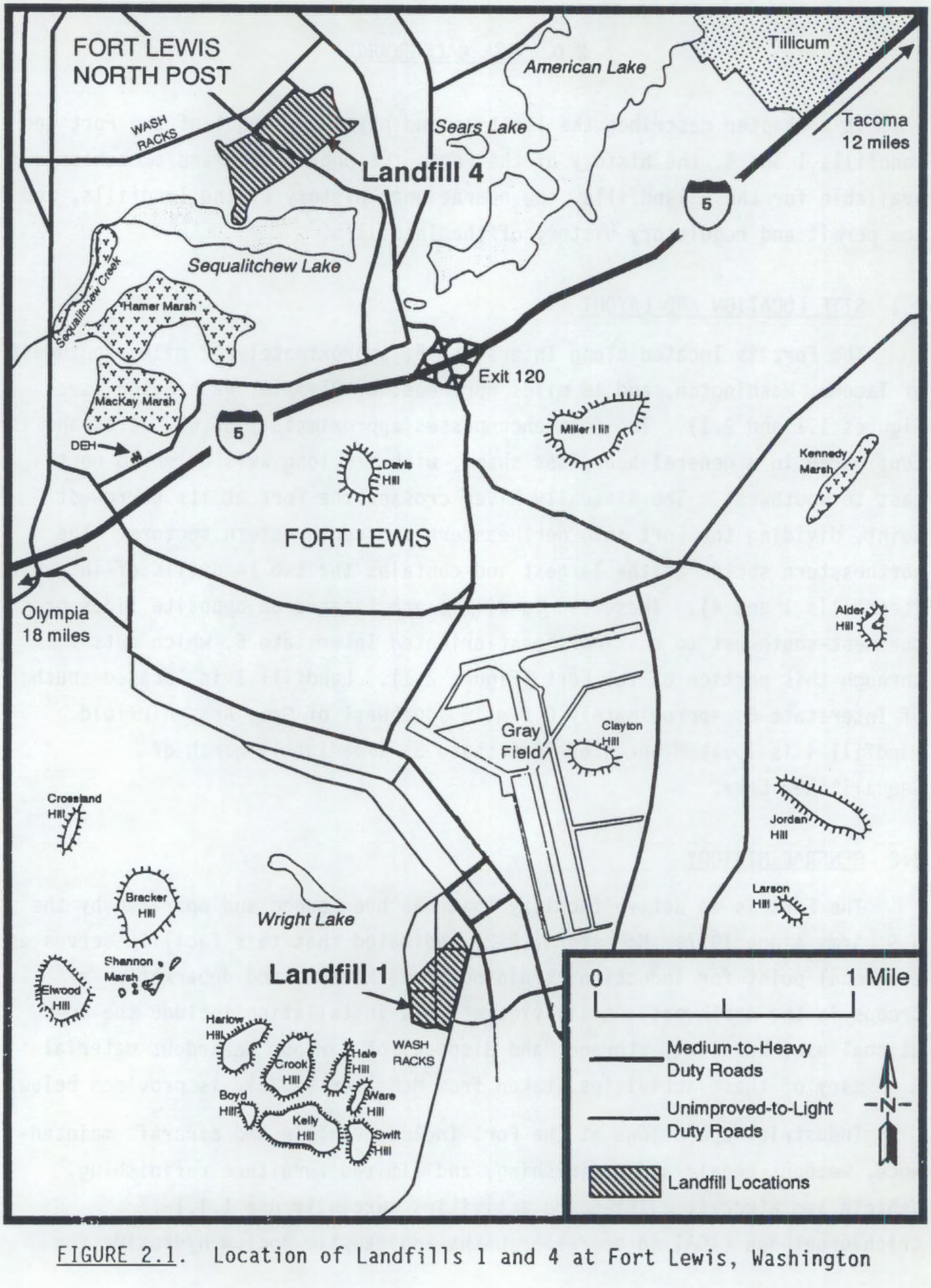


FIGURE 2.1. Location of Landfills 1 and 4 at Fort Lewis, Washington

for paint stripping. Trichloroethylene (TCE) was used at Fort Lewis until the mid-1970s, when its use was discontinued. Small-armament maintenance activities involve sand blasting, degreasing, acid rinsing, and oil dipping. Furniture refinishing involves the use of commercial paint strippers, paint, and varnish.

Hazardous materials have been and are currently handled and/or stored at numerous locations throughout the Fort. These materials include 1) pesticides (insecticides, herbicides, fungicides, and rodenticides), 2) polychlorinated biphenyls (PCBs), 3) industrial and laboratory chemicals, 4) radiological materials, and 5) petroleum, oils, and lubricants.

Waste disposal and treatment operations have been and are currently being performed at the Fort. These operations involve 1) offsite and onsite industrial waste treatment and disposal, 2) onsite waste water treatment, 3) solid waste landfill disposal, 4) explosive ordnance demolition, and 5) demilitarization activities.

2.3 AERIAL PHOTOGRAPHY AND SITE MAPS

Two sets of aerial photographs of Landfill 1 and three sets of Landfill 4 were available for review (Table 2.1). No drawing could be found of these landfills, other than some general site maps. These aerial photographs and site maps can be obtained from the Engineering Division, Survey Branch, Seattle District, U.S. Army Corps of Engineers, Seattle, Washington.

TABLE 2.1. Aerial Photographs Available for Landfills 1 and 4

Landfill	Aerial Photograph Set		Date
1	2	-- 113, 114 and 115	7-21-51
	KP-70	-- 7-12-13 and -14 7-13-18	5-24-70
4	1	-- 172 through 176	7-21-51
	KP-70	-- 7-11-18 and -19 7-12-19	5-24-70
	NW-C-76	-- 15A-24 and -25	7-15-76

2.4 HISTORY OF LANDFILLS 1 AND 4

Landfills 1 and 4 are two of 14 reported solid waste landfills/disposal sites that have been used at the Fort (McMaster 1982). McMaster reported that both these landfills were used for the disposal of "sanitary" wastes. Landfill 1 was reportedly used between 1946 and 1951, and Landfill 4 was reportedly used between 1951 and 1967 (McMaster 1982). No records or first-hand personal accounts could be obtained to estimate the waste constituents or inventories of these landfills. Those staff interviewed from the DEH believed that Landfill 1 was used primarily for surface dumping of construction debris and that Landfill 4 was used primarily for disposal of domestic garbage. Additional interpretations of the disposal history and waste inventory are based on available aerial photographs and visual observations of the landfills.

2.4.1 Landfill 1

Aerial photographs taken in July 1951 indicate that a portion of Landfill 1 was still in operation at that time. However, this trench cut-and-fill operation may have been discontinued in late 1951, as reported by McMaster (1982). Several isolated disposal pits and/or burn pits near this trench/fill area can also be observed in these photographs. Aerial photographs taken in May 1970 suggest that the landfill may have been extended farther to the southwest, possibly by overbank dumping along the western escarpment created by the later stages of the trenching operation. Some surface storage was also indicated near the southern tip of the landfill.

Field inspections made during May through July 1988 found evidence of more recent (post-1970) surface dumping of (primarily) construction rubble. Waste materials observed at the surface included sand and gravel, broken cement, broken asphalt, old concrete structures, and various types of wood debris. Unauthorized surface dumping of trash wood and paper, old asphalt shingles, various automobile parts, and Christmas trees was also apparent.

2.4.2 Landfill 4

Aerial photographs taken in May 1970 show that operations at Landfill 4 had apparently ceased. Other aerial photographs taken in July 1976 show no change in the landfill configuration since the 1970 photographs. Thus, it is believed that the landfill was used before 1970 and perhaps closed in 1967 as reported by McMaster (1982). The photographs suggest at least four trench cut-and-fill areas.

Visual inspection and surface geophysical surveys made during May through July 1988 suggest numerous isolated open-pit dumps surrounding these trench areas. Waste materials observed on the landfill surface included domestic garbage, automobile parts, industrial debris (steel cables, reinforced concrete), tires, and asphalt. More recent surface dumping of tree stumps and some unauthorized surface dumping of trash wood and paper, automobile parts, old lumber, trees, barbed wire, etc., were also observed. This site has also been used for heavy equipment and military vehicle operator training.

2.5 PERMIT AND REGULATORY HISTORY

McMaster (1982) indicated that the Fort has filed a Notification of Hazardous Waste Activity under the Resource Conservation and Recovery Act (RCRA) (40 CFR 265) and has received U.S. Environmental Protection Agency (EPA) identification number WA 9214053465 for generation, storage, and treatment of hazardous waste. The wastes listed on the notification include solvents, battery acid waste, pesticides, and explosive waste. The Fort has applied for a RCRA permit to cover a hazardous waste storage facility located on the Fort Lewis Logistics Center.

No operating permits are known to be in place for Landfills 1 and 4. As part of the Installation Restoration Program and to monitor past disposal sites, four monitoring wells were installed around Landfill 1 in 1984, and five wells were installed around Landfill 4 in 1981.

change in the landfill configuration since the 1970 photographs. Thus, it is believed that the landfill was used before 1970 and perhaps closed in 1967 as reported by McMaster (1982). The photographs suggest at least four trench cut-and-fill areas.

Visual inspection and surface geophysical surveys made during May through July 1988 suggest numerous filled open-pit areas surrounding these trench areas. Waste materials observed on the landfill surface included domestic garbage, automobile parts, industrial debris (steel cans, reinforced concrete), tires, and asphalt. More recent surface dumping of tree stumps and some unauthorized surface dumping of trash wood and paper, automobile parts, old lumber, tires, barbed wire, etc., were also observed. This site has also been used for heavy equipment and military vehicle operator training.

2.3 PERMIT AND REGULATORY HISTORY

McMaster (1982) indicated that the Fort has filed a Notification of Hazardous Waste Activity under the Resource Conservation and Recovery Act (RCRA) (40 CFR 265) and has received a U.S. Environmental Protection Agency (EPA) identification number (WA 92[illegible]) for generation, storage, and treatment of hazardous waste. The wastes listed on the notification include solvents, battery acid waste, pesticides, and explosive waste. The Fort has applied for a RCRA permit to cover a hazardous waste storage facility located on the Fort Lewis Logistics Center.

No operating permits are known to be in place for Landfills 1 and 4. As part of the Installation Restoration Program and to monitor past disposal sites, four monitoring wells were installed around Landfill 1 in 1984, and five wells were installed around Landfill 4 in 1981.

3.0 ENVIRONMENTAL SETTING

To thoroughly investigate the landfills, the environmental setting was characterized including physiography, climate, regional geology and hydrology, water use, and critical habitats.

3.1 PHYSIOGRAPHY

The two landfills of interest are located within the Tacoma Upland subarea (Figure 3.1) of the central Puget Sound Lowland as defined by the U.S. Geological Survey (USGS 1962). The Puget Sound Lowland is a broad plain that extends from the Cascade Range on the east to the Olympic Mountains and Willapa Hills on the west, and into the Willamette Valley to the south. The Tacoma Upland is located on a poorly drained drift plain that ranges from sea level to approximately 600 ft above mean sea level (msl).

The topography of the Tacoma Upland is a product of processes from the most recent (Vashon) Pleistocene glaciation and subsequent Recent glaciofluvial deposition and erosion; it is characterized by rolling hills (moraines and drumlins) and depressions (kettles) that are scattered across the plain. Numerous lakes and swamps exist in the depressions.

Two major rivers edge the Tacoma Upland. The Puyallup River forms the northeastern and eastern boundaries of the Tacoma Upland, and the Nisqually River forms the southwestern boundary. A number of small creeks and streams drain the interior of the Tacoma Upland. Figure 3.2 shows locations of streams, lakes, and cultural features within the Tacoma Upland and adjacent areas. Landfill 1 lies within the Murray Creek subbasin, and Landfill 4 is in the Sequalitchew Creek/Lake subbasin.

3.2 CLIMATE

The climate of the study area is moderate/humid, with winter temperatures generally above freezing and summer temperatures generally below 80°F. Mean annual precipitation in the lowland is approximately 40 in./yr, with

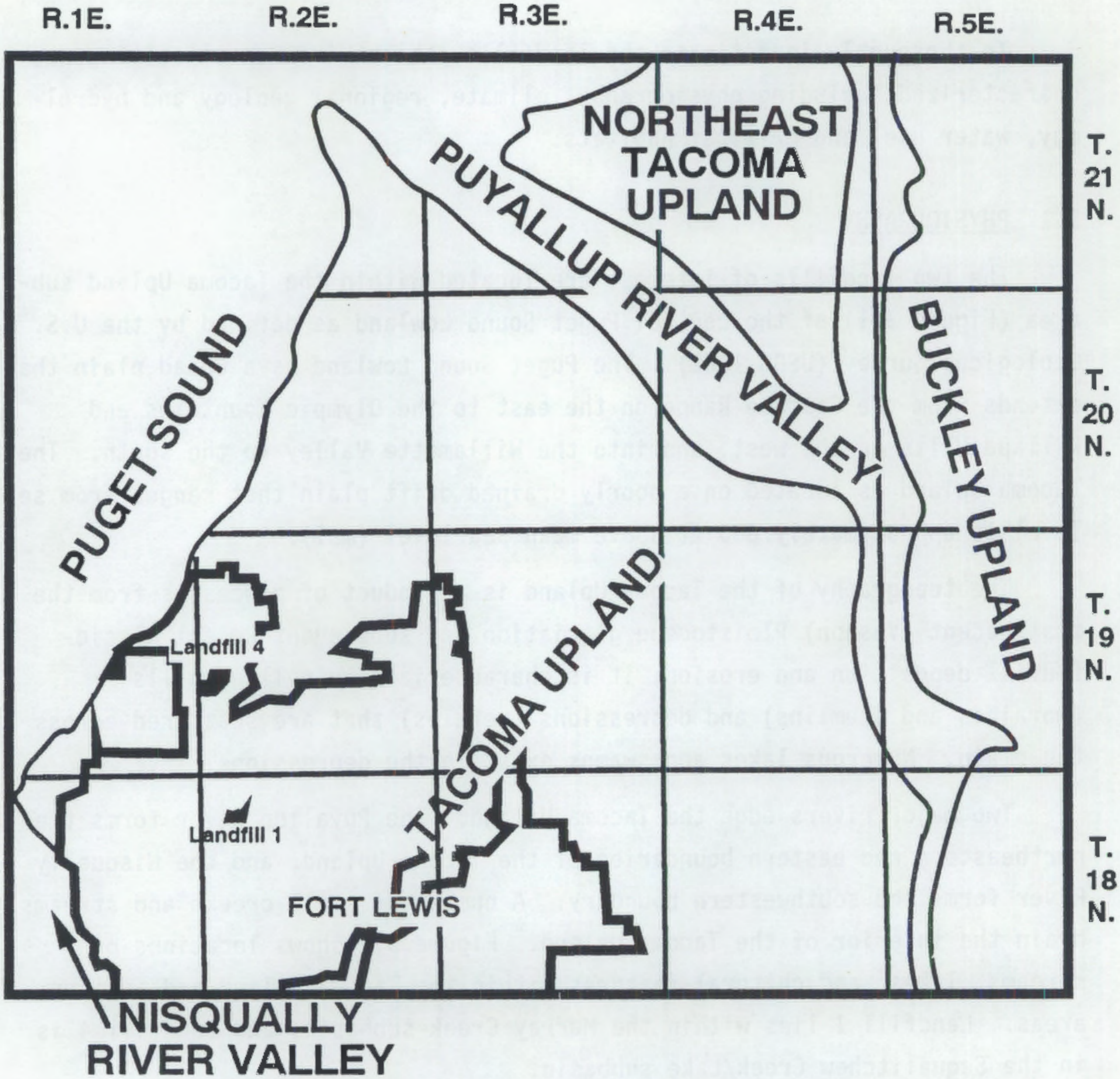


FIGURE 3.1. Location of the Tacoma Upland (from USGS 1962)

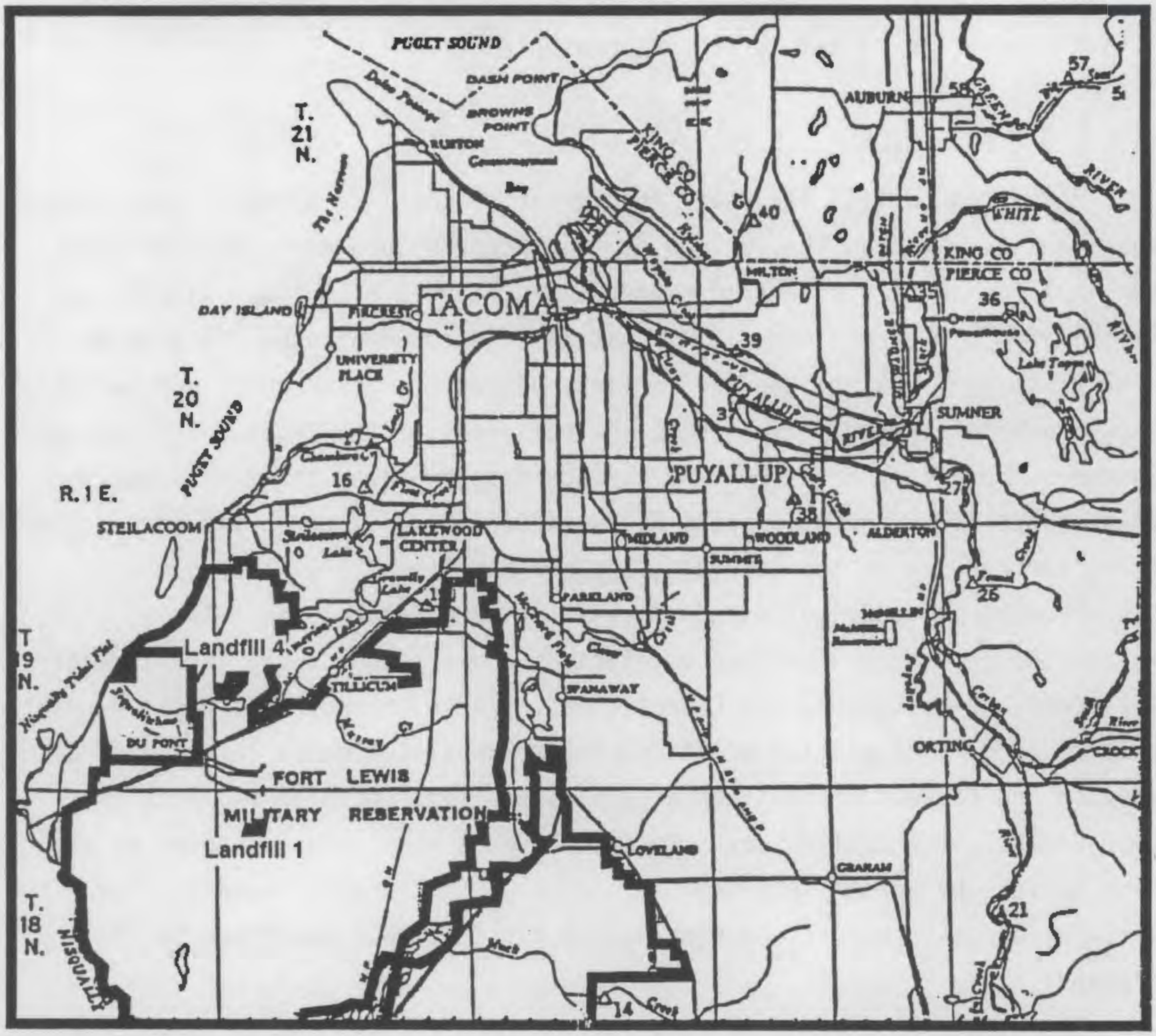


FIGURE 3.2. Location of Streams, Lakes, and Cultural Features Within the Tacoma Upland and Adjacent Areas (from USGS 1962)

most of the rain falling during the spring and winter months. Puget Sound, the Pacific Ocean, and the mountain ranges to the west provide moderating influences on the climate of the Tacoma Upland.

3.3 REGIONAL GEOLOGY

The Tacoma Upland lies near the center of the Tacoma low, a deep structural basin. Data on the geology of the Tacoma Upland were compiled from publications on this area (Brown and Caldwell 1983; USGS 1962; Walters and Kimmel 1968). Bedrock underlying this area is assumed to be the same or similar to the Tertiary and pre-Tertiary volcanic, metamorphic, and consolidated sedimentary rocks exposed at the periphery of the Puget Sound Lowland. However, these rock units have no surface exposure near the landfills, and they do not occur in the deepest wells (>2000 ft) drilled in the area. Overlying the bedrock in the Tacoma Upland are more than 2000 ft of semi-consolidated and unconsolidated clay, silt, sand, gravel, and glacial till. These sediments were deposited by glaciers and streams during late Tertiary (Pliocene), Pleistocene, and Recent times. The Pliocene/Pleistocene deposits consist largely of glacial drift and interglacial sediments laid down from advance and retreat of continental ice sheets that occupied the area from approximately 2.5 million years to 11,000 years ago. Final shaping of the land surface by stream incision of valleys and subsequent deposition of alluvial deposits occurred during Recent times (11,000 years ago to the present).

The Pleistocene glacial and interglacial intervals are of most interest in the present study because the resulting sediments deposited by these events make up the majority of the subsurface geologic materials, and these sediments provide the framework for the ground-water regime in the Tacoma Upland. Four Pleistocene glaciation intervals have been recognized in the Tacoma Upland. These are, from oldest to youngest (Crandall et al. 1958) 1) Orting, 2) Stuck, 3) Salmon Springs (and upper Salmon Springs), and 4) Vashon [possibly a stade within the broader "Fraser" glaciation described by Armstrong et al. (1965)]. Interglacial episodes, where the area was free from ice for an extended time, follow each glaciation. Table 3.1 (modified

TABLE 3.1. Climatic and Stratigraphic Units in the Tacoma Upland (all Pleistocene Epoch)[a]

Climatic Unit	Stratigraphic Unit
Vashon Glaciation	Vashon Drift Steilacoom Gravels Vashon Recessional Outwash Vashon Till Vashon Advance Outwash Colvos (Esperance) Sand
Olympia Interglaciation	None identified
Upper Salmon Springs Glaciation	None identified
Unnamed Interglaciation	Kitsap Formation
Salmon Springs Glaciation	Salmon Springs Drift
Puyallup Interglaciation	Puyallup Formation
Stuck Glaciation	Stuck Drift
Alderton Interglaciation	Alderton Formation
Orting Glaciation	Orting Drift

(a) Modified from Brown and Caldwell (1983).

from Brown and Caldwell 1983) shows the relationships and names of the climatic units and resultant geologic (stratigraphic) units in the Tacoma Upland.

The glacial drift units generally consist of three depositional facies: 1) outwash deposited by advancing glaciers, 2) till deposited by stagnant glaciers, and 3) outwash deposited by receding glaciers. The outwash deposits (advance and recessional) typically consist of well-sorted gravel or stratified sand and gravel. The tills generally consist of semiconsolidated, poorly sorted gravel in a silty/clayey matrix.

The interglacial units generally consist of fluvial and lacustrine deposits. Sands, silts, and clays deposited in lakes or over broad alluvial plains are most common, although gravels occur locally in mainstream channels.

The upper two units, the Kitsap Formation and the Vashon Drift, are the most significant to this study, because they are believed to control the uppermost aquifer beneath the Fort. Figure 3.3 illustrates a generalized geologic column of these two formations.

3.3.1 Kitsap Formation

The Kitsap Formation, overlying the Salmon Springs Drift, is widespread. It is of nonglacial origin (lacustrine and fluvial) and consists of clay, silt, and fine sand. The Kitsap Formation is typically 50 to 150 ft thick in the Tacoma Upland.

3.3.2 Vashon Drift

The Vashon Drift is the youngest glacial deposit in the area and is exposed at the surface. Several subunits have been described within the Vashon Drift. These are in ascending order (oldest to youngest) Colvos (Esperance) Sand, Vashon Advance Outwash, Vashon Till, Vashon Recessional Outwash, and Steilacoom Gravels.

The Colvos (Esperance) Sand overlying the Kitsap Formation, although considered an advance outwash deposit, is mapped and defined independently because of its easily identified characteristics of a loose, well-sorted sand with occasional gravel occurrences (and a basal clay section in some areas). The Colvos Sand is up to 150 ft thick in the Upland area.

Overlying the Colvos Sand is the Vashon Advance Outwash. The advance outwash is a stratified, well-sorted pebble- to cobble-sized gravel that is present under most of the Tacoma Upland in thicknesses of 25 to 50 ft.

The Vashon Till overlies the Vashon Advance Outwash in much of the Tacoma Upland. The till may be present as a semiconsolidated matrix of silt and clay with intercalated sand and gravel, or it may take the form of unconsolidated, unstratified gravel, sand, and silt. Although the till may be as much as 100 ft thick in places, it more typically is from 5 to 30 ft thick.

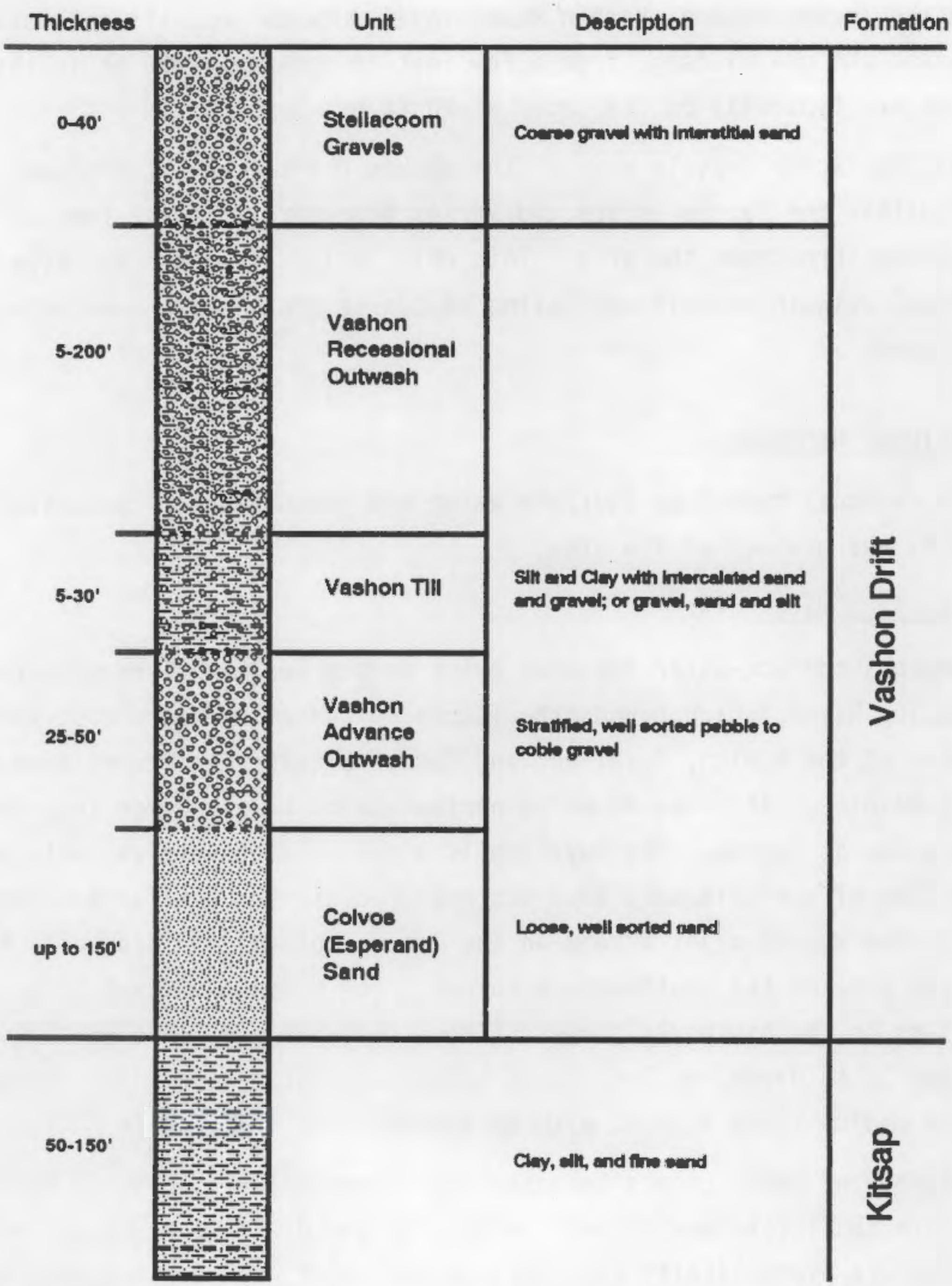


FIGURE 3.3. Upper Stratigraphic Column for the Fort Lewis Area

In the Tacoma Upland, Vashon Recessional Outwash deposits consisting of coarse sand and gravel range from a few feet to more than 200 ft in thickness, but are typically on the order of 20 ft or so thick.

The Steilacoom Gravels unit of the Vashon Drift covers the ground surface within the Tacoma Upland and varies from zero to a few tens of feet in thickness throughout the area. This unit is locally a special type of recessional outwash deposit consisting of coarse gravel with some interstitial sand.

3.4 REGIONAL HYDROLOGY

The regional hydrology (surface water and ground water) is controlled largely by the geology of the area.

3.4.1 Surface Water

Numerous surface-water features exist in the Tacoma Upland (Figure 3.2). The Puyallup River, which bounds the Tacoma Upland on the northeast and east, originates at the Mowich, Puyallup, and Tahoma Glaciers on the western slopes of Mount Rainier. It flows 46 miles northwestward to discharge into Commencement Bay at Tacoma. The Puyallup is a medium-sized stream, with an average flow of approximately 3300 cfs measured at the Puyallup gauging station. The second major stream in the Tacoma Upland, the Nisqually River, bounds the area on the southwestern corner. The Nisqually River originates at glaciers on the southerly slopes of Mount Rainier and winds westerly to northwesterly to discharge into Puget Sound south of DuPont. The Nisqually also is a medium-sized stream, with an average flow of 1370 cfs.

A number of small creeks traverse the Tacoma Upland. Most of these streams are small (average flows of <100 cfs) and drain local subbasins. The creeks are hydraulically connected to the upper ground-water aquifers in the area, in some places gaining water from and in other locations contributing water to the aquifers.

Murray Creek is a small, ungauged creek that originates in Kinsey Marsh located on the Fort east of Madigan General Hospital and the Logistics Center (Mount Rainier Ordnance Depot). Murray Creek runs westerly for approximately

4 miles and discharges into American Lake. Sequalitchew Creek is a small ungauged stream that serves as the outlet of Sequalitchew Lake and runs westerly for a distance of approximately 2.5 miles to discharge into Puget Sound near the Nisqually tidal flat.

Numerous springs exist throughout the Tacoma Upland. The springs are located along the Puget Sound Bluffs, along the creek and river channels, and along the edges of the deeper kettle depressions. The springs deliver a significant amount of ground water to the surface stream, lake, and swamp environments. Springs in the Tacoma Upland discharge an estimated 100,000 acre-ft/yr (Walters and Kimmel 1968). Many springs discharge at rates greater than 1 cfs.

Lakes are the most prominent hydrologic features in the western part of the Tacoma Upland. Major lakes (>100 acres in area) are American, Steilacoom, Spanaway, Gravelly, and Sequalitchew. These lakes are the surface expressions of the shallow ground-water system and occur in the deepest topographic depressions (kettles). The bottoms of the major lakes are in the coarse Steilacoom Gravels, allowing interchange of the surface and ground waters.

3.4.2 Ground Water

The thick sequence of unconsolidated glacial, fluvial, and lacustrine sediments underlying the Tacoma Upland provides the framework for ground-water systems with extremely productive aquifers (water-bearing geologic media). Ground-water recharge from precipitation in the Tacoma Upland is estimated at approximately 400,000 acre-ft/yr (USGS 1962). Ground-water discharge occurs through springs and seeps, which eventually discharge into the Puyallup and Nisqually rivers or directly into Puget Sound along the boundaries of the Tacoma Upland.

The coarse sands and gravels of the Vashon Recessional Outwash are the most productive aquifers in the Tacoma Upland. This outwash often lies in the vadose zone (above the zone of saturation and above the water table) and, thus, does not produce ground water. However, where the outwash is below the water table, it is highly productive. The Vashon Recessional Outwash aquifer is highly susceptible to contamination from surface sources because of its high permeability and near-surface location.

The Vashon Till, which lies beneath most of the Tacoma Upland, is not a particularly productive aquifer. Where it lies below the zone of saturation and consists of mostly sand and gravel at least 20 ft thick, it will yield sufficient water to wells for single or small group domestic supply of a few to a few tens of gallons per minute. In most places, however, the Vashon Till consists mostly of silt and clay and can be considered an aquiclude (or aquitard) that protects the underlying water-bearing zones from surface or near-surface sources of contamination.

The Vashon Advance Outwash is generally below the water table; thus, it provides a productive and important aquifer in the Tacoma Upland. It exhibits extremely high transmissivities (up to and exceeding 2 million gpd/ft). Wells completed in the Vashon Advance Outwash can deliver water in amounts up to several thousand gallons per minute. The Vashon Advance Outwash aquifer is moderately isolated from surface contamination where it is overlain by low-permeability materials of the Vashon Till.

The contact between the Vashon glacial deposits and the underlying pre-Vashon unconsolidated sediments is unconformable throughout most of the Tacoma Upland; thus, the contact ranges from 700 ft above msl to more than 300 ft below msl. The sand and gravel aquifers of the pre-Vashon unconsolidated deposits (undefined as to formation) have considerably lower transmissivities than the Vashon Advance Outwash aquifers. Transmissivity appears to range from approximately 10,000 to 30,000 gpd/ft (USGS 1962), and wells constructed in the pre-Vashon deposits can be adequate for moderately large water supplies. Wells yielding up to 1000 gpm have been completed in these deposits, but yields of a few hundred gallons per minute from wells completed in the pre-Vashon deposits are more common.

Figure 3.4 (after USGS 1962) shows the potentiometric surface (contour lines of water-table elevation above msl) of the upper, unconfined aquifer located primarily in the Vashon Drift of the Tacoma Upland. Also shown on the figure are general directions of ground-water flow near the study areas.

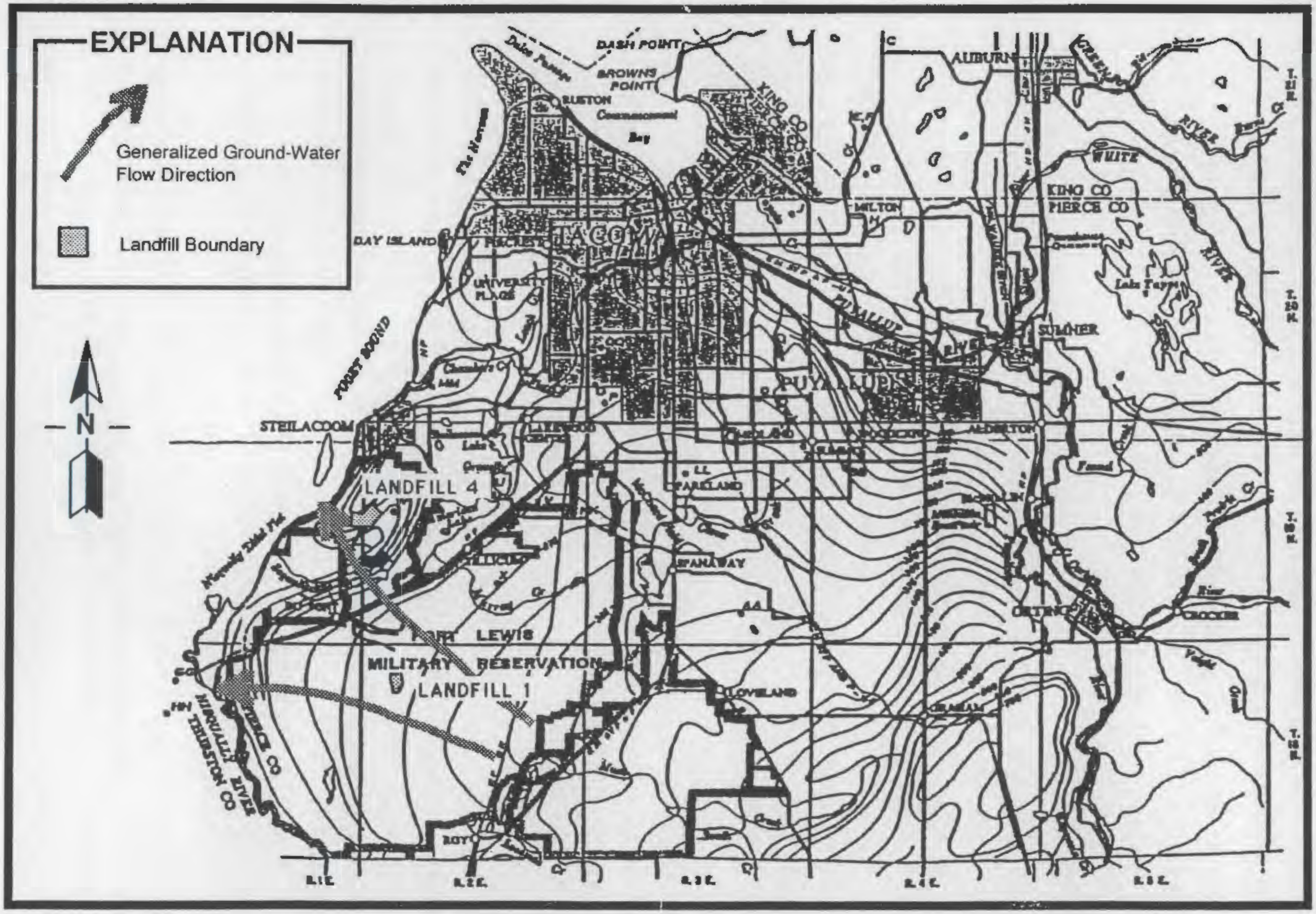


FIGURE 3.4. Regional Potentiometric Surface Map of the Uppermost Unconfined Aquifer Beneath the Tacoma Upland

Ground-water flow is generally westerly and northwesterly. Ground water in this area ultimately discharges into Puget Sound or the Nisqually River.

The availability of ground water in the pre-Tertiary and Tertiary formations underlying the Tacoma Upland is unknown (but probably small), because no wells penetrate to these zones in the area.

3.5 WATER USE

Until the early 1900s, ground water was the sole source for most water supplies in the Tacoma Upland. With exception of the City of Tacoma, which started importing large amounts of water from the Green River in 1913, the area still relies on ground water to meet most of the various demands and needs for water. Major users of ground water adjacent to the landfills of interest are the military installations [Camp Murray, Fort Lewis, McChord Air Force Base, Madigan General Hospital, Logistics Center (Mount Rainier Ordnance Depot), etc.], and the communities of DuPont, Tillicum, and Lakewood.

The Lakewood Water District, which supplies municipal and domestic water for much of the American Lake area (including Tillicum), uses an average of approximately 12 million gpd of ground water (Ecology and Environment, Inc. 1986). McChord Air Force Base uses an average of 1.8 million gpd of ground water.

In 1982, six wells and Sequalitchew Spring provided the principal water supply for Fort Lewis. Other smaller wells are used that are not connected to the main supply system. The amount of water used per day for the main supply system varies from 5 to 23 million gpd (an average of approximately 7.8 million gpd) (McMaster 1982). Of this amount, Sequalitchew Spring may supply from 5.5 to 9 million gpd. Although the spring technically may be considered "ground water," the water derived from this source is actually subflow from adjacent American Lake.

Shallow wells completed in the Vashon Drift may be subject to contamination from surface and near-surface sources. Some of the older municipal water-supply wells and most of the wells used for domestic water supply in the Tacoma Upland are relatively shallow and do derive ground water from the

Vashon Drift aquifers. Wells completed below the Vashon Drift and that produce water from the lower aquifers in the area are generally isolated and protected from sources of surface and near-surface contamination.

Most of the wells adjacent to Landfills 1 and 4 are believed to be completed far below the Vashon Drift, and, thus, should not be affected by past waste disposal activities. Sequalitchew Spring is an exception, as this water source could be affected by surface contamination and also may be affected by changes in adjacent lake-water quality.

3.6 CRITICAL HABITATS

No known threatened or endangered species of plants or animals exist within the vicinity of Landfills 1 and 4. Additions are made to both the Federal and State lists when new species are approved for addition, and these lists should be checked periodically. There are also no wildlife refuges or game preserves within this area. At present, there are no known critical habitats. Two active bald eagle nests are present, although both are outside the landfill areas: one near Camp Murray and one near the Veteran's Hospital. One inactive nest is known, which is also outside the study areas.

Coho salmon and rainbow trout are reared in pens within Sequalitchew Lake under an ongoing cooperative agreement with the State of Washington.

Migratory waterfowl, primarily ducks and geese, are found at American and Sequalitchew lakes during the migration season. A certain number of ducks, geese, and coots winter at these lakes. Wright Lake is also used by waterfowl, but goes dry in some years.

A number of sites of former cultural activity are known, particularly around the lake shores. Any major construction or modification activities would require more detailed reconnaissances, but the scope of activities under this study should not affect any of these sites.

Vashon Drift aquifers. Wells completed below the Vashon Drift and that produce water from the lower aquifers in the area are generally isolated and protected from sources of surface and near-surface contamination.

Most of the wells adjacent to Landfills 1 and 4 are believed to be completed far below the Vashon Drift, and, thus, should not be affected by past waste disposal activities. Sequalitchew Spring is an exception, as this water source could be affected by surface contamination and also may be affected by changes in adjacent lake-water quality.

2.6 CRITICAL HABITATS

No known threatened or endangered species of plants or animals exist within the vicinity of Landfills 1 and 4. Additions are made to both the Federal and State lists when new species are approved for addition, and these lists should be checked periodically. There are also no wildlife refuges or game preserves within this area. At present, there are no known critical habitats; two active bald eagle nests are present, although both are outside the landfill areas: one near Gray Army Airfield and one near the Veteran's Hospital. One inactive nest is known, which is also outside the study areas.

Coho salmon and rainbow trout are reared in pens within Sequalitchew Lake under an ongoing cooperative agreement with the State of Washington.

Migratory waterfowl, primarily ducks and geese, are found at American and Sequalitchew Lakes during the migration season. A certain number of ducks, geese, and coots winter at these lakes. Gravelly Lake is also used by waterfowl, but goes dry in some years.

A number of sites of former cultural activity are known, particularly around the lake shores. Any major construction or modification activities would require more detailed reconnaissances, but the scope of activities under this study should not affect any of these sites.

4.0 SITE INVESTIGATION METHODS

Investigations at the two landfills included activities aimed at locating the landfill boundaries, installing new ground-water monitoring wells, remediating existing monitoring wells, sampling the ground-water, and analyzing samples. The methods used in these investigations are described below, along with quality assurance and control activities.

4.1 LOCATING LANDFILL BOUNDARIES

To locate landfill boundaries, numerous aerial photographs of the two landfills were examined, and the physical features of the landfills were plotted on base maps. Two sets of aerial photographs were available for Landfill 1. These were taken in July 1951 and May 1970. Three sets of aerial photographs were available for Landfill 4. These were taken in July 1951, May 1970, and July 1976 (see Table 2.1).

Because aerial photographs did not provide sufficient information to determine the boundaries of Landfill 4, surface geophysical surveys were conducted on July 18 and 19 and July 27 and 28, 1988. Geophysical data were collected along 30 traverse lines located in one area where the boundary was fairly well known and three areas where the boundaries were poorly known. These lines varied in length from 200 to 1200 ft and were marked with wooden stakes at 100-ft intervals along their lengths. The locations of the stakes were established using a Brunton Compass and pacing. Geophysical-sensing instruments used in this survey were 1) a ground-penetrating radar unit, 2) a ground-conductivity meter, and 3) a metal detector. Each of these instruments is discussed below. An informal report on the results of this survey is presented in Appendix A.

4.1.1 Ground-Penetrating Radar

The ground-penetrating radar unit used in this survey was a Geophysical Survey Systems, Inc. (GSSI), Model SIR 7 with a 120-MHz (nominal) antenna (GSSI Model 3110) that transmits and receives radar signals in a frequency band of approximately 50 to 250 MHz. The antenna, mounted on a fiber-glass sled, was pulled along the survey lines by a small all-terrain vehicle (ATV).

Radar signals reflected from subsurface objects or interfaces were detected by the antenna and were transmitted by cable to control and recording modules mounted on the ATV. There, the signals were amplified, digitized, and recorded on digital tape cartridges for later playback and processing. This instrument exhibits good spatial resolution and can produce quasi-pictorial images of both metallic and nonmetallic objects or materials in the ground.

4.1.2 Ground-Conductivity Meter

The ground-conductivity meter used in the survey was a Geonics EM31 electromagnetic induction sensor. This hand-carried device operates by transmitting an oscillatory magnetic field into the ground, then detecting the secondary magnetic field produced by the electric currents that are induced in the ground. The device exhibits relatively poor spatial resolution, but can respond to both metallic and nonmetallic waste deposits. The data produced by this instrument were digitized and recorded by a small data recorder carried by the operator. The data were subsequently transferred to a computer for scaling and display.

4.1.3 Metal Detector

The metal detector used in the survey was a Fisher M-Scope, Model TW-6. This instrument was originally marketed as a pipe and cable detector, but has proven to be effective in detecting buried metallic waste materials at depths of a few feet. The metal detector was carried by hand along the survey lines until a response was obtained. The location of the response was then recorded in a field notebook.

4.2 INSTALLING MONITORING WELLS

Ten ground-water monitoring wells were installed from August through October 1988 as part of this study (six in the vicinity of Landfill 4 and four near Landfill 1). These wells were designated by the corresponding landfill number, the designation "PNL," and the consecutive number at the time they were drilled (e.g., LF1-PNL2 corresponds to the second well drilled during the PNL study at Landfill 1). The new wells were installed by Onwego Drilling Co., Kennewick, Washington. Specifications for these wells are provided in Appendix B and are consistent with the requirements of

WAC 173-160. This section describes the methods used for drilling, sediment sampling, construction, geophysical logging, development, and surveying of the new wells.

4.2.1 Drilling Methods

Boreholes, for installation of the monitoring wells, were drilled with continuous flight, hollow-stem auger and cable-tool methods. The auger-drilled boreholes were drilled using 8-in.-OD, 4-in.-ID (outside and inside diameter) hollow-stem auger flights. The boreholes drilled with a cable-tool rig used either hard-tool or drive-barrel methods. Hard-tool drilling consisted of driving a solid metal bit into the sediments, breaking them up, and mixing them with added water (obtained from a nearby fire hydrant) to form a slurry, which was then bailed out of the borehole. After reaching the desired sampling depth, the borehole was bailed clean so that sediment samples could be collected. When using the drive-barrel method, a drive barrel (a short length of heavy-walled pipe) was driven into the sediments and withdrawn, and the sediments were removed from the drive barrel.

4.2.2 Geologic Sampling and Sediment Characterization Methods

Sediment samples were collected at 5-ft intervals or at major lithologic changes encountered during drilling. The samples were collected using a 2-in. split-spoon sampler when auger drilling, a 4-in. split-spoon sampler when hard-tool drilling, and directly from the drive barrel when drive-barrel drilling. The procedure used for collecting split-spoon samples is provided in Appendix C. These samples were photographed, and subsamples were collected in glass, pint jars. The samples have been placed in storage for a permanent record of the sediments encountered during drilling.

Once the sample was photographed, it was physically described by a well-site geologist, and the information was recorded on daily drill logs. The sediments were characterized based on estimated particle-size distribution, sorting, gross mineralogy, clast roundness, general color of the fines, reaction to 10% hydrochloric acid (HCl), consolidation of the formation, changes from the previous sample, and any unusual findings. These samples were collected and documented in accordance with the procedure provided in Appendix D and the guidance found in Last and Liikala (1987). The as-built diagrams found in Appendix E show the geologic sediment classification names given to the sediments at each sample interval at each well. The criteria used by the well-site geologist to classify the sediments are based on the ternary diagram shown in Figure 4.1.

In addition to sampling the sediment for physical characterization, sediment moisture samples were collected for information on the moisture profile of the unsaturated zone. These samples were collected immediately after the sampler was pulled from the borehole. The samples were placed in airtight tin containers, sealed with Teflon tape, labeled, and enclosed in plastic bags to prevent moisture loss. The samples were kept shaded and transferred at the end of the week to a refrigerator at PNL's Richland,

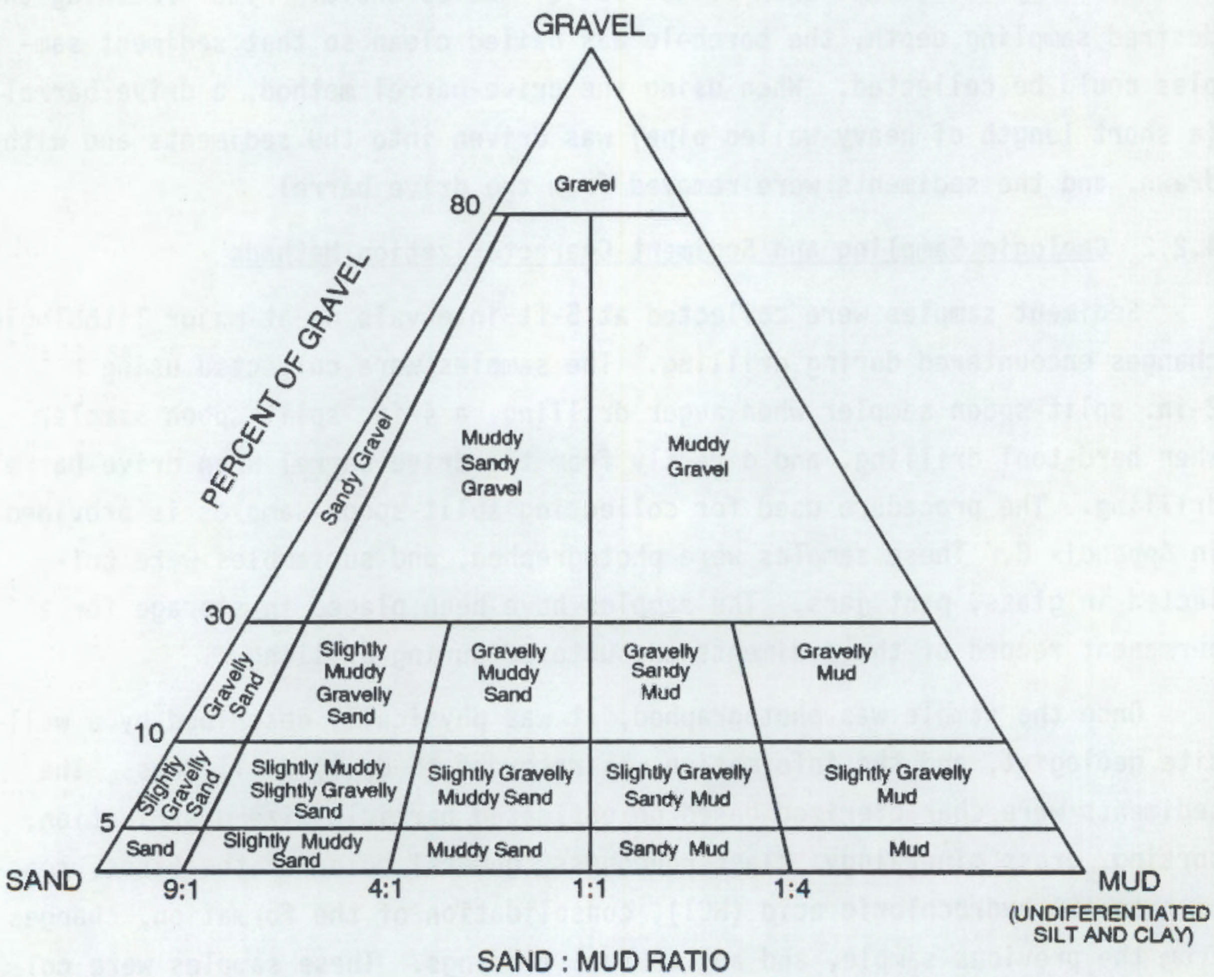


FIGURE 4.1. Ternary Diagram for Naming Sediments (from Folk 1974)

Washington, location. Within a few days after their arrival, the samples were removed from the plastic bags, weighed, oven-dried at 105°C for 24 hr, and, finally, reweighed. This routine is in accordance with ASTM procedure D 2216 (ASTM 1986). These data are presented in Appendix F.

Water-level measurements were taken by a well-site geologist using an electrical tape (E-tape) during drilling. These measurements provided information on the static water level that was then used to determine the placement depth of the screened interval. These measurements can be found on the drilling logs in Appendix E.

4.2.3 Monitoring Well Construction

The monitoring wells were constructed as shown in Figure 4.2. These wells were constructed with polyvinyl chloride (PVC) casing (schedule 40, ASTM 1785) and 15 ft of slotted PVC screen (20 slot, 0.02-in. opening). The screen was placed with 5 ft extending above and 10 ft below the static water level. This design was selected to compensate for fluctuations in the water level. Only 10 ft of screen were installed in well LF4-PNL4 because of a thin saturated zone encountered above a clay/silt layer. In the auger boreholes, wells were constructed with 2-in.-dia PVC casing and screen (because of the small inside diameter of the auger flights), while those constructed in cable-tool boreholes were constructed with 4-in.-dia PVC. After installing the PVC casing and screen, silica sand was installed in the annulus to approximately 3 to 5 ft above the top of the PVC screen. Three to 5 ft of 0.25-in. bentonite pellets were then placed on top of the sandpack. The remaining annulus, to approximately 1 to 3 ft below land surface, was sealed using medium-sized bentonite chunks. Note that the annular seal materials were added while the auger flights or temporary casing (depending on drilling method) were extracted from the ground. The field geologist and driller carefully monitored the annular seal placement during completion, so that the natural formation would not cave around the PVC and thus jeopardize the integrity of the annular seal. Once the casing or auger flights were completely removed, a 1- to 3-ft-deep void around the PVC remained. A 5-ft-long, 6-in.-dia protective steel surface casing was installed around the PVC, and a 4-ft by 4-ft concrete surface pad and surface seal were poured in

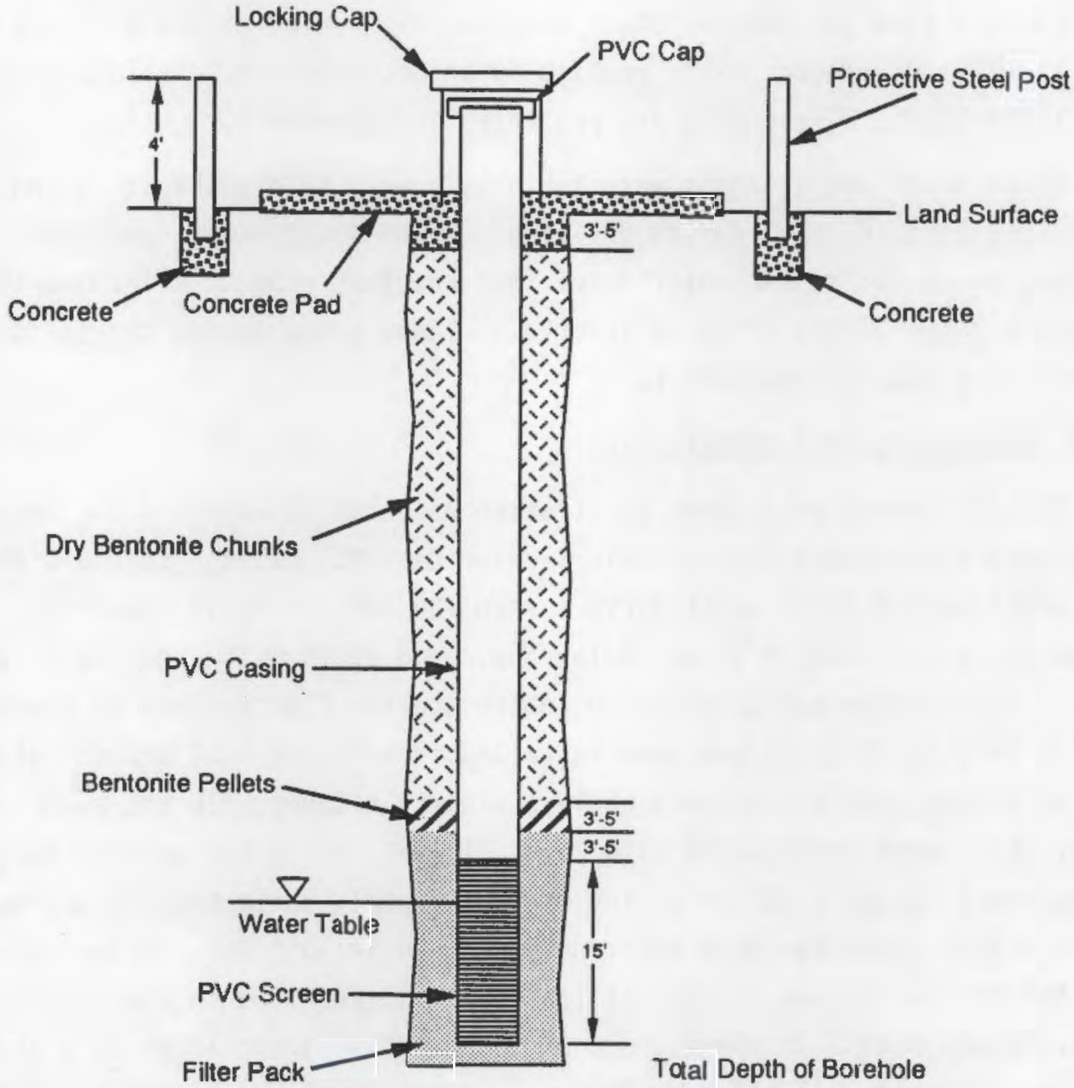


FIGURE 4.2. Schematic Design of the Newly Installed (1988) Monitoring Wells at Landfills 1 and 4

the remaining void. Pre-mix concrete or Portland cement mixed with local sand and gravel was used for the concrete pad and surface seal.

A brass marker provided by the U.S. Army Corps of Engineers was placed in each pad and embossed with the well identification number on completion of the surveying effort (see Subsection 4.2.7). Four protective posts were placed in concrete around each well. Finally, the four protective posts and the surface protective casing were painted safety yellow, and an aluminum cap and lock were attached to the top of the surface protective casing.

A field geologist documented the construction of each well on daily drill logs, well completion inspection forms, and as-built diagrams. The procedure used to collect and document drilling data is provided in Appendix D. The well completion inspection forms, as-built diagrams, and daily logs for each new (1988) well are presented in Appendix E.

4.2.4 Gamma-Ray Borehole Geophysical Logging

Gamma-ray borehole geophysical logging was conducted when the borehole reached maximum depth and before the well was completed. There were two exceptions to this: well LF4-PNL1 was logged after well completion, and well LF4-PNL3 was not logged.

The boreholes were logged using a gross-gamma probe. This probe is designed to measure the naturally occurring gamma radiation found in the sediments in the borehole. This probe is most useful in identifying clay or clay-rich zones that characteristically contain elevated concentrations of natural gamma-emitting radioactive isotopes, such as potassium-40. Sand and gravel, on the other hand, can be identified by a low natural-gamma response. Results of the natural-gamma logging are useful in confirming the lithologic divisions identified by the well-site geologist and in identifying the location of low-permeability (clay-rich) zones. The results of the natural-gamma logging are presented with the as-built diagrams in Appendix E.

4.2.5 Water-Level Measurement

Periodic water-level measurements were taken on all newly completed (1988) and existing (1981 and 1984) wells on the same day. These measurements were made in duplicate using either a steel tape or an electrical tape, according to the PNL procedure (provided in Appendix G). These measurements can be found in the discussions on ground-water flow in the evaluation of each landfill.

4.2.6 Well Development Methods

The new 2-in.-dia wells were developed using a 1-in.-dia dart bailer, air-lifting, and/or a HydroStar positive displacement pump (product of Instrumentation Northwest, Incorporated, Redmond, Washington). The HydroStar pump (discharging at a rate of 3 to 5 gpm) proved to be the most effective in developing these small-diameter wells.

The new 4-in.-dia wells and existing Landfill 4 (1981) wells were developed using a dart bailer and a 1/3-h.p. submersible pump (discharging at a rate of 10 to 12 gpm). A HydroStar pump was also used in well LF1-PNL3; however, the low permeability sediments encountered by this well yielded too little water to enable adequate development. The existing wells at Landfill 1 (1984) were not re-developed as part of this study because no subsurface remediation was performed on these wells.

All new wells except LF1-PNL3 were developed until the turbidity of the discharge water was visibly low or absent. This was determined by visually examining water discharged into a clean white 5-gal bucket. Tables 4.1 and 4.2 provide a summary of the well development activities associated with each well. These tables include information on the date the wells were structurally complete, the date well development started, the date it was completed, the total number of saturated zone well volumes extracted during development, and the final water quality description. Further discussion of well development activities is provided in Section 4.4.

4.2.7 Surveying

Existing wells near Landfills 1 (1984 wells) and 4 (1981 wells) were initially surveyed in 1988 and 1982, respectively. These surveys were conducted by the Seattle District, U.S. Army Corps of Engineers, using the Washington State coordinate system for horizontal control and the National Geodetic Vertical Datum 1927 (NGVD 1927) for vertical control. Elevations for the 1981 wells were surveyed to the top of the casing. Those for the 1984 wells were surveyed to a 2- by 2-ft wooden hub installed 2 ft from the well. All horizontal locations were surveyed to the center of each casing.

TABLE 4.1. Development Information for Wells at Landfill 1

Well Number	Well Diameter (in.)	Date Well Completed	WELL DEVELOPMENT HISTORY				
			Date Development Started	Date Development Completed	Develpment Methods Used	Total Well Volumes Removed	Final Water Quality
84-CD-LF-1*	4	11-05-84	NA	NA	NA	NA	NA
84-CD-LF-2*	4	10-31-84	NA	NA	NA	NA	NA
84-CD-LF-3*	4	11-09-84	NA	NA	NA	NA	NA
84-CD-LF-4*	4	11-15-84	NA	NA	NA	NA	NA
LF1-PNL1	2	08-19-88	08-25-88	12-13-80	Bailer Hydrostar	341	Slightly Turbid
LF1-PNL2	2	08-19-88	08-17-88	09-08-88	Istr. NW pump Bailer Hydrostar	287	Slightly Turbid
LF1-PNL3	4	08-25-88	08-24-88	ND	Submersible Bailer Hydrostar	7 (distilled water added)	Very Turbid
LF1-PNL4	4	09-01-88	08-31-88	09-08-88	Bailer Submersible	48	Clean

* These wells were not re-developed as part of this study.
NA: Not Applicable.
ND: Not Adequately Developed.

TABLE 4.2. Development Information for Wells at Landfill 4

Well Number	Well Diameter (in.)	Date Completed	WELL DEVELOPMENT HISTORY				
			Date Development Started	Date Development Completed	Develpment Methods Used	Total Well Volumes Removed	Final Water Quality Description
LF4-1*	4	04-28-81	10-30-88	10-30-88	Bailer Submersible	80	Clear
LF4-2*	4	04-29-81	10-30-88	10-30-88	Bailer Submersible	40	Clear
LF4-4*	4	05-01-81	10-30-88	10-30-88	Bailer Submersible	110	Clear
LF4-11*	4	05-12-81	10-30-88	10-30-88	Bailer Submersible	61	Clear
LF4-PNL1	4	08-09-88	08-08-88	09-01-88	Bailer Submersible	218	Clear
LF4-PNL2	2	08-09-88	08-23-88	09-07-88	Bailer Hydrostar	30	Clear
LF4-PNL3	2	08-09-88	08-08-88	12-14-88	Air Lift Bailed Hydrostar	187	Clear
LF4-PNL4	4	10-05-88	10-06-88	10-06-88	Submersible	57.5	Clear
LF4-PNL5	4	10-07-88	10-07-88	10-14-88	Bailer Submersible	151	Clear
LF4-PNL6	4	10-12-88	10-12-88	10-14-88	Bailer Submersible	70	Clear

* These wells were re-developed as part of this studiy.

All new (1988) and existing (1981 and 1984) wells were surveyed in the spring of 1989 by Horton Dennis and Associates, Inc., using the Washington State coordinate system for horizontal control and NGVD 1929 for vertical control. Horizontal and vertical values were established for the center of the brass marker installed in each well pad. Vertical values were also established for the north rim of the PVC well casing located inside each carbon-steel protective casing. An error was observed in the horizontal location of well LF4-PNL5. It was also noted that the identification of wells LF4-1 and LF4-2 were backwards. These errors were later corrected via personal communication with Ms. Joan Shafer (U.S. Army Corps of Engineers - Seattle district). These data are provided in Appendix H.

4.3 REMEDIATING AND ABANDONING WELLS

In addition to the drilling and installation of the new monitoring wells, remediation was performed on the existing wells near Landfills 1 and 4. The existing wells were geophysically logged (by the methods noted above) before remediation.

The existing wells near Landfill 1 were drilled in 1984 by Richardson Drilling. The wells were drilled using a cable-tool rig and were completed with 4-in.-dia PVC casing and 20-slot PVC screen. The original drilling logs for the drilling and completion of these wells are found in Appendix I. These wells (identified as 84-CD-LF-1, -LF-2, -LF-3, and -LF-4) were in good physical condition, except for the surface completion. All of the wells had a carbon steel protective casing and locking well cap; however, none of the wells had a concrete surface pad or protective posts, and well 84-CD-LF-1 had a very loose protective surface casing. The remedial work performed at each of these wells consisted of installing 1) a 4-ft by 4-ft concrete surface pad, 2) four protective posts around the pad, 3) a brass marker in the concrete pad, and 4) an aluminum cap with lock at the top of the protective surface casing. The protective posts and casing were painted safety yellow. The protective surface casing on well 84-CD-LF-1 was reset in concrete before placing the surface pad. Drill logs of the remedial work are also presented in Appendix I.

The existing wells at Landfill 4, identified as Fort Lewis 1, 2, 3, 4, and 11 (referred to in this report as LF4-1, -2, -3, -4 and -11), were drilled in 1981 by Tacoma Pump and Drilling Co., Inc., Graham, Washington. The wells were drilled with a rotary rig and were completed using 4-in.-dia, schedule-40 PVC pipe. The PVC sections were connected by nonthreaded slip-type couplings, and it appears that glue was used in connecting the male/female ends. The screened intervals were perforated by drilling evenly spaced, 0.25-in. holes in the PVC casing. No plug or end cap was installed in the bottom of the perforated section. More information on the completion of these wells can be found in the original drilling logs in Appendix I. Except for the pipe in well LF4-3, the PVC pipe in these wells appeared to be in good condition.

The overall physical condition of these wells was fair to very poor, and remedial work was necessary both above and below ground. Well LF4-3 had 30 ft of 8-in.-dia carbon steel casing in the ground, and the PVC was broken apart approximately 21 ft below land surface. There were approximately 13 ft of bentonite annular seal extending from the top of the perforated PVC pipe to 29 ft below ground. The water bailed from inside the PVC pipe was very stagnant smelling and contained pieces of wood and decayed animal and insect remains. This well was abandoned in accordance with WAC-173-160-915 as follows: 1) the PVC casing and screen were speared and removed from the hole, 2) medium-sized bentonite chunks were emplaced in the borehole as the 8-in. carbon steel casing was removed, 3) a cement grout with 5% bentonite was set in the upper 6.5 ft of the borehole to provide a rigid surface seal, and 4) a 2-ft by 2-ft concrete pad with a 6-in. surface casing (2.5-ft stickup) was emplaced to permanently mark the abandoned well.

The remaining 1981 wells at Landfill 4 were in fair physical condition. These wells required removal of the 8-in. carbon steel casing and installation of the bentonite annular seal as the steel casing was removed and the 4-in. PVC casing was left in place. Bentonite slurry was required in two of the wells, because the dry bentonite tended to form a bridge at the bottom of the casing. Finally, a 1- to 2-ft cement surface seal was poured, and the surface completion work (pad, posts, brass marker, cap, and painting) was performed.

The only complication encountered during the remediation effort was at well LF4-11. At this well, the PVC casing was pulled back approximately 8 ft in an attempt to remove a bentonite plug that had formed inside the PVC. The benonite was successfully washed out of the PVC casing by jetting with clean drilling water. Pulling back the PVC casing should not pose any problems, however, because the top of the perforated PVC casing is still below the bentonite seal. Drill logs kept during the remediation work are included in Appendix I.

The four existing (1981) wells at Landfill 4 were redeveloped using a dart bailer and 1/3-h.p. submersible pump. None of the existing (1984) wells at Landfill 1 were redeveloped because of time constraints.

4.4 GROUND-WATER SAMPLING

Ground-water samples were collected from the new (1988) and existing (1981 and 1984) wells around Landfills 1 and 4. Two sets of samples were collected from each new (1988) well, and one set of samples was collected from the existing (1984) wells around Landfill 1. Three sets of samples were collected from all new (1988) and existing (1984) wells around Landfill 4 except well LF4-PNL6, which was sampled only twice. All samples were collected during five separate sampling events: 1) August, 2) September, 3) early October, 4) late October, and 5) December 1988. The August, September, and early October sampling events were conducted only to indicate what chemical constituents might be present in each well and to assist in identifying the need and location of additional wells. The late October and December sampling events were conducted to evaluate the concentrations and distribution of potential contaminants beneath the landfills. The ground-water sampling procedures followed during each sampling event are presented in Appendix J.

A description of each sampling event is provided below. Tables 4.3 and 4.4 summarize the sampling history for each landfill. These tables provide the sampling dates, indicate if the well had been developed before sampling, the sampling methods used, the number of saturated well volumes purged before sampling, and a qualitative estimate of the sample's representativeness. A

TABLE 4.3. Landfill 1 Ground-Water Sampling History

Well Number	Sampling Date	Development Complete?	Sample Collection Method	Well Volumes Purged	Sample Represntativeness
84-CD-LF-1	12-13-88	NR	Bailer	0.4	Fair
84-CD-LF-2	12-14-88	NR	Bailer	0.4	Fair
84-CD-LF-3	12-14-88	NR	Bailer	0.4	Fair
84-CD-LF-4	12-14-88	NR	Bailer	0.4	Fair
LF1-PNL1	08-24-88 12-13-88	No Yes	Bailer Hydrostar	1.7 341	Poor Good (water turbid)
LF1-PNL2	09-08-88 12-14-88	Yes Yes	Hydrostar Bailer	198 1.7	Good (water turbid) Good
LF1-PNL3	09-09-88 12-14-88	No No	Hydrostar Bailer	4 0.4	Poor Poor
LF1-PNL4	09-08-88 12-13-88	Yes Yes	Hydrostar Bailer	12 0.4	Very Good Good

NR: No Record. These wells were not developed as part of this study.

TABLE 4.4. Landfill 4 Ground-Water Sampling History

Well Number	Sampling Date	Development Complete?	Sample Collection Method	Well Volumes Purged	Sample Represntativeness
LF4-1	10-06-88	No	Bailer	0.4	Poor
	10-30-88	Yes	Submersible	15	Very Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-2	10-06-89	No	Bailer	0.4	Poor
	10-30-88	Yes	Submersible	80	Very Good
	12-14-88	Yes	Bailer	0.4	Good
LF4-4	10-06-88	No	Bailer	0.4	Poor
	10-30-88	Yes	Submersible	77	Very Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-11	10-06-88	No	Bailer	0.4	Poor
	10-30-88	Yes	Submersible	21	Very Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-PNL1	08-24-88	No	Bailer	0.4	Poor
	10-06-88	Yes	Bailer	0.4	Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-PNL2	09-08-88	Yes	Hydrostar	28	Very Good
	10-06-88	Yes	Bailer	1.7	Good
	12-15-88	Yes	Bailer	1.7	Good
LF4-PNL3	08-24-88	No	Bailer	1.7	Poor
	10-06-88	No	Bailer	1.7	Poor
	12-14-88	Yes	Hydrostar	184	Very Good
LF4-PNL4	10-06-88	Yes	Bailer	56	Very Good
	10-30-88	Yes	Submersible	15	Very Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-PNL5	10-07-88	No	Steel Bailer	21	Good (water turbid)
	10-30-88	Yes	Submersible	20	Very Good
	12-15-88	Yes	Bailer	0.4	Good
LF4-PNL6	10-30-88	Yes	Submersible	27	Very Good
	12-15-88	Yes	Bailer	0.4	Good

NR: No Record

sample was considered very good if the well had been developed and at least three well volumes purged before sample collection. A sample was still considered good if the well was developed but had not been purged before sample collection. All other samples are considered poor.

4.4.1 August Sampling

The purpose of the August sampling event was simply to obtain an initial indication of the chemical constituents in the ground-water beneath various portions of Landfill 4. This information would then be used in selecting the location of additional wells. The objective was to collect ground-water samples from the first three new (1988) wells installed around Landfill 4. However, one of these wells (LF4-PNL2) produced very turbid water, and a lot of mud was recovered during the sampling attempt. Sampling of this well was delayed. A newly completed well from Landfill 1 (LF1-PNL1) was sampled just to use the sample bottles and to make the sampling trip more worthwhile.

Ground-water samples were collected from wells LF4-PNL1, LF4-PNL3, and LF1-PNL1 on August 24, 1988, shortly after construction and bailing, but before the wells were fully developed. The samples were collected using dedicated Teflon bailers, which were filled with well water and emptied three times before taking samples. This comprised the only purging performed before sample collection; the purging amounted to approximately 1.7 well volumes for the 2-in.-dia wells and 0.4 well volumes for the 4-in.-dia wells. Single temperature and pH measurements were recorded on the field record sheet for each well sampled. A duplicate sample was collected at well LF1-PNL1 for quality assurance purposes.

4.4.2 September Sampling

The September sampling event was conducted to obtain an indication of the chemical constituents present beneath various portions of Landfill 1 to assist in identifying the need and location for additional wells. The objective was to collect an initial set of ground-water samples from the first four new (1988) wells installed around Landfill 1. However, one of these new wells (LF1-PNL1) had been sampled in late August, and the one new Landfill 4 well (LF4-PNL2), not sampled in August as originally scheduled, was sampled instead.

Four wells (LF1-PNL2, LF1-PNL3, LF1-PNL4, and LF4-PNL2) were sampled September 8 and 9, 1988, using a different HydroStar sampling pump at each well. These newly completed wells were still undergoing development. Well LF1-PNL4 had been fully developed using a 1/3-h.p. submersible pump. Approximately 80 gal of water (12 well volumes) were purged from this well using the HydroStar pump before sampling. Wells LF1-PNL2 and LF4-PNL2 were fully developed using the HydroStar pump immediately before sampling. Approximately 325 gal (198 well volumes) and 46 gal (28 well volumes), respectively, were pumped from these wells. Although several attempts were made to develop well LF1-PNL3 via bailing and the HydroStar pump immediately before sampling, the low yield of the well prevented its full development (refer to Subsection 4.2.6 for further information). This well was nearly completely evacuated and allowed to recover three times over the 2-day period just before sampling. Ground-water samples were collected at the end of the final recovery.

A series of field pH, temperature, and conductivity measurements were recorded during the purging/development of all four wells. A duplicate sample was collected at well LF1-PNL4.

4.4.3 Early October Sampling

The early October sampling event was conducted to indicate the areal extent of volatile organic constituents in the ground-water beneath Landfill 4 and to address the need for and location of any additional wells. The objective was to collect a spatially complete set of samples from wells around Landfill 4, using all six new (1988) and four existing (1981) wells.

The early October sampling event was conducted on October 6 and 7, 1988. Eight wells (LF4-PNL1, LF4-PNL2, LF4-PNL3, LF4-PNL4, LF4-1, LF4-2, LF4-4, and LF4-11) were sampled using a Teflon bailer, and one well (LF4-PNL5) was sampled using the 2.5-in.-dia carbon steel dart bailer being used for initial well development. Many of these wells still had not been completely developed before initiating this sampling. Three wells (LF4-PNL1, LF4-PNL2, and LF4-PNL4) had been fully developed. Before sampling each well, the bailer was filled and emptied with well water three times, providing a limited purging of the well. The degree of this purging is estimated at approximately 1.7 well volumes for each 2-in.-dia well and 0.4 well volumes for each 4-in.-dia well. Two wells, LF4-PNL4 and LF4-PNL5, had been extensively purged by well development activities within 24 hr of sample collection. Following collection of the samples at each well, the used bailer was rinsed three times with distilled water. Field pH, temperature, and specific conductivity measurements were not deemed pertinent to the objectives of this sampling event and were not collected. A field blank sample was collected at well LF4-PNL2.

4.4.4 Late October Sampling

The late October sampling event was conducted to complete the hydrochemical analyses around Landfill 4 to assist the determination of the concentrations and distribution of selected chemical constituents, primarily anions and cations. The objective was to collect samples from these wells for which these analyses did not already exist.

On October 30, 1988, seven wells from Landfill 4 (LF4-PNL4, LF4-PNL5, LF4-PNL6, LF4-1, LF4-2, LF4-4, and LF4-11) were sampled using a 1/3-h.p. submersible pump. The submersible pump was used to also completely develop and/or purge the wells before sampling. Volumes of water pumped before sampling range from approximately 100 gal (15 well volumes) at wells LF4-1 and LF4-PNL4 to approximately 520 gal (80 well volumes) at well LF4-2. The submersible pump was steam cleaned between wells. Field pH, temperature, and specific conductivity measurements were mistakenly omitted. Duplicate samples were taken at wells LF4-PNL1 and LF4-PNL4.

4.4.5 December Sampling

The December sampling event was conducted to provide spatially complete, time-equivalent sets of representative samples from each landfill to compare selected chemical constituents. In addition, chemical data from Sequalitchew Lake were collected to evaluate the potential impact on ground-water quality near Landfill 4.

All 18 existing (1981 and 1984) and new (1988) wells from Landfills 1 and 4, as well as Sequalitchew Lake, were sampled December 13 through 15, 1988. The samples were collected using dedicated and/or decontaminated

Teflon bailers similar to the early October sampling event. Those samples at wells LF1-PNL1 and LF4-PNL3 were collected with HydroStar pumps. Approximately 556 gal (341 well volumes) and 300 gal (184 well volumes) of water were pumped from wells LF1-PNL1 and LF4-PNL3, respectively, before sampling. A sample was taken from Sequalitchew Lake using a Teflon bailer. The sample was taken from a barge ~300 yd from the east shore (Spring Station).

Three quality control samples including a duplicate sample at well LF1-PNL1, a field blank sample, and a sample containing standard solutions were taken during this sampling event.

4.5 ANALYZING GROUND-WATER SAMPLES

The procedures used to analyze for ground-water quality parameters are listed in Table 4.5 and provided in Appendix J. In addition to the listed procedures, the analysis of the volatile organic samples at PNL was conducted according to the method provided in Appendix J. In brief, water samples were analyzed with a Hewlett-Packard Model 5880A gas chromatograph (GC). The GC was equipped with two identical J&W DB-624 30-m x 0.53-mm fused-silica capillary columns. The DB-624 columns were coated with a cross-linked and bonded stationary phase comprising cyanopropyl, phenyl, and dimethylsiloxane. The two columns were teed together at the inlet and routed to separate electron capture and flame ionization detectors. Sample introduction was via a Tekmar Model LSC-3 purge and trap unit. The LSC-3 contained a Tenax sorption trap. Samples were thermally desorbed from the Tenax trap and transferred to the columns through a heated transfer line. The Hewlett-Packard Model 5880A GC was equipped with two separate integrators to simultaneously integrate data from both detectors.

Nearly all sample analyses were performed by Am Test, Inc., Redmond, Washington, during the first four field sampling events. Am Test results are presented in their entirety in Appendix K. Only volatile organic analyses (VOA) on the October 6, 1988, samples from Landfill 4 were performed by PNL. Samples from the December sampling were sent to both Am Test and PNL. Semivolatile organic constituents, coliform, and oil and grease analyses were conducted by Am Test. PNL analyzed for pH, specific conductivity, volatile

TABLE 4.5. List of Analytical Methods Used on the Fort Lewis Ground-Water Study

Parameter	Analytical Method Reference[a]
Field pH	PNL Procedures
Field Conductivity	PNL Procedures
Laboratory pH	EPA Method 150.1
Laboratory Conductivity	EPA Method 120.1
Pesticides, Herbicides	EPA Method 608
PCBs	EPA Method 608
Coliform	Standard Methods 909
Oil and Grease	EPA Method 413.2
Total Organic Halogens	EPA Method 450.1
Volatile Organic Analysis	EPA Method 601
Total Dissolved Solids	EPA Method 160.1
Total Organic Carbon	EPA Method 415.2
ICAP Metals	EPA Method 200.7
Cyanide	EPA Method 335.3
Anions (F^-, Cl^-, NO_3^-, $SO_4^=$)	EPA Method 300.1
Phenol	EPA Method 420.1

(a) Detection limits reported in results tables and/or actual analytical reports (Appendix K).

organic constituents, alkalinity, anions, total dissolved solids, and filtered and unfiltered metals analyzed by the inductively coupled argon plasma method (ICAP metals). These results are presented in the text of the report.

4.6 QUALITY ASSURANCE

The primary PNL Quality Assurance (QA) Program is based on ANSI/ASME NQA-1, Quality Assurance Program Requirements for Nuclear Facilities, as it is applicable to the technical services and research and development performed by PNL. Under the PNL QA Program, each project is classified into one of three impact levels (I, II, or III); Impact Level I possesses the greatest potential impact in the event of failure, based on such areas as safety, data defensability, programmatic, and regulatory concerns. Written QA plans are developed for projects classified as Impact Level I or II, specifically identifying applicable elements of the PNL QA Program. Projects classified as Impact Level III are performed in accordance with the minimum standards for all work at PNL specified in the PNL Good Practices Standard and do not require a project-specific QA Plan. The work performed in this investigation was classified as Impact Level II.

Because of its relevance in the acquisition of environmental data, a QA Project Plan was developed for this investigation, in accordance with the criteria in EPA QAMS-005/80, Guidelines and Specifications for Preparing Quality Assurance Project Plans, with elements of the PNL QA Program incorporated to supplement areas not adequately addressed by the EPA program.

Written technical procedures used by PNL's Environmental Monitoring Program (PNL 1989) were employed to collect and characterize drilling data and collect water-samples.

Only qualified, professional geologists were used in the oversight of well-installation activities, and the logging and characterization of soils encountered during well construction as required by the EPA/RCRA Ground-Water Monitoring Technical Enforcement Guidance Document, OSWER-9950.1 (EPA 1986). All PNL staff performing work at the sites received a minimum of 40-hr prior training in hazardous material handling as required by 29 CFR 1910.

Applicable QA requirements were passed on to subtier organizations. Procurement controls were implemented to verify that suppliers and subcontractors were capable of providing quality services. This control included a pre-award evaluation of the analytical laboratory performing analyses of ground-water samples by the PNL Quality Control Section to verify the laboratory's ability to meet the QA requirements passed on.

The PNL QA Department audited both drilling and sampling to verify conformance with drilling specification and sampling procedure requirements. The data quality and traceability of the results package were also audited.

Deficiencies encountered were documented, along with an assessment of their root cause, impact on results, and corrective actions designed to preclude recurrence.

4.7 QUALITY CONTROL

In contrast to inspecting hardware items to verify they met the dimensional requirements of a specification, data cannot be inspected as they are generated. To inspect data, indirect techniques must be used, such as the preparation and analysis of quality control samples. Analyzing these samples along with the unknown samples gives an indication of the quality of data being generated by a given analytical process in terms of accuracy and precision. Quality control measures implemented included the collection and analysis of duplicate, blank, and standard solution samples.

During the August 24 sampling event, a set of blanks was prepared for all the laboratory parameters analyzed by Am Test, Inc. No contamination was observed in the blank samples. A blind duplicate sample was also prepared from one of the wells (LF1-PNL1) chosen at random and submitted to the analytical laboratory. The results from this analysis can be seen in the data tables contained in Chapter 5.0 of this report. In general, the comparison is acceptable, but could be better. The coliform, total dissolved solids, sulfate, iron, barium, manganese, calcium, and sodium did not compare well. The discrepancies in the iron, barium, manganese, calcium, and sodium results are probably caused by the high solids (mud) content in the water sample. This well had not been adequately developed before sampling (refer to Subsection 4.4). If the well were less turbid, the results may have been more comparable. The reason for the discrepancy in the coliform, total dissolved solids, and sulfate results is unknown, but could also be related to the high turbidity of the water samples. A blind USGS ground-water standard was also submitted for analysis. The results of the analysis can be seen in Table 4.6. In general, the Am Test results compare well with the USGS value. However, the Am Test iron and chromium values deviated significantly from the actual value. This discrepancy cannot be explained by the results, except that the concentrations in the sample are approaching the detection limit of the analytical method.

TABLE 4.6. Comparison of U.S. Geological Survey Standard Concentration with Am Test, Inc., Results (ppm)

	AM Test Result	USGS Value
Iron	<0.01	0.042 ± 0.010
Barium	0.044	0.040 ± 0.002
Cadmium	<0.002	<0.002
Manganese	0.009	0.008 ± 0.001
Calcium	55	54.8 ± 2.2
Silver	<0.01	<0.01
Sodium	110	107.0 ± 3.0
Chromium	0.022	0.008 ± 0.002
Palladium	<0.02	<0.02
Arsenic	<0.002	0.003 ± 0.001

During the September 8 and 9 sampling event, a duplicate sample from well LF1-PNL4 was submitted to the laboratory for analysis. The results of this analysis can be seen in the data tables contained in Chapter 5.0 of this report. In general, the results of this analysis were considerably better than the August sample results. Most parameters were in good agreement with each other. Because of an oversight, no blank or standards were submitted with the samples during this sampling episode.

During the October 6 sampling event, only samples for VOA were collected from the wells in the Landfill 4 area. These samples were analyzed at PNL. A blind blank was submitted for analysis with the samples. No contamination was observed in the blank sample.

During the October 30 sampling event, three wells were sampled in the Landfill 4 area. These ground-water samples were analyzed by Am Test. A duplicate sample was collected from well LF4-PNL4. The results of the duplicate analysis are reported in Chapter 6.0 with the analytical results from Landfill 4.

During the December 13 through 15 sampling event, wells at both the landfills were sampled. These samples were analyzed by Am Test, Inc., for semivolatile organic constituents, coliform, and oil and grease. Samples were analyzed by PNL for volatile organic compounds, total organic carbon, pH, conductivity, and filtered and unfiltered ICAP metals. A duplicate sample was collected from well LF1-PNL1. A comparison of the results from the duplicate analysis is reported in Chapter 5.0 with the analytical results from Landfill 1. The results from the duplicate analysis agreed very well. A blank sample was generated in the field and sent to each laboratory for the respective analyses. The analytical results from the blank indicate a problem with the oil and grease analysis. Am Test reported 8.3 ppm of oil and grease in the blank sample. The lowest concentration reported for that suite of samples was 8.2 ppm. These results indicate either a blank or laboratory contamination problem. No other problems were observed with the analytical results from the blank analysis. A USGS sample was submitted to the PNL laboratory conducting inorganic analysis. Table 4.7 compares the analytical results with the certified USGS value. The results of the analysis compare very well with the USGS reported results.

TABLE 4.7. Comparison of the U.S. Geological Survey Standard Concentration With PNL Results

	PNL Results	USGS Value
pH	8.21	8.2 ± 0.1
Conductivity	2410 μmho/cm	2451 ± 150 μmho/cm
Chloride (Cl^-)	79 ppm	79.6 ± 3.5 ppm
Sulfate ($SO_4^=$)	1130 ppm	1170 ± 33.5 ppm
Alkalinity ($CaCO_3$)	132.5 ppm	132.5 ± 4.0 ppm

5.0 EVALUATION OF LANDFILL 1

Using the information gained from examining aerial photographs, characterizing the environmental setting, and drilling and sampling, the boundaries of Landfill 1 were located and the geologic framework, ground-water flow characteristics, ground-water quality, and monitoring well network were evaluated.

5.1 LOCATION OF LANDFILL 1 BOUNDARIES

The boundaries of Landfill 1 were defined by visual interpretation of available aerial photographs and by field reconnaissance. Aerial photographs taken in July 1951 show a portion of Landfill 1 as still active and also show that the landfill was originally operated as a trench cut-and-fill-type operation. The aerial photographs also show two open-pit dumps, of isolated extent, and one suspected burn area located to the west of the trenching operation. These landfill features were located on a map, based on their correlation to cultural features (i.e., roads and buildings; Figure 5.1). Aerial photographs taken in May 1970 show that Landfill 1 was extended to the southwest, possibly by overbank dumping along the western escarpment created during the trenching operation (see Figure 5.1). An area of surface dumping/storage to the south was also indicated in these photographs. The interpreted boundaries indicate that the trenching area extended under the road (South 22nd Street) and parking lot of the tank repair shop to the north. The area where isolated pit dumping and burning were observed in historical photographs appears to be located under the tank repair shop and other maintenance yards to the west.

Field reconnaissance found areas of subsidence in the northern portion of Landfill 1 and along South 22nd Street that runs through this portion of the landfill. These areas of subsidence are thought to be associated with the decay and compaction of waste materials in the trenches, thus confirming that the landfill extended under at least a portion of South 22nd Street. Surface dumping of construction rubble was also apparent; this dumping must have occurred after the May 1970 photographs were taken. Also, the topography of the site suggests that overbank dumping may also have occurred after

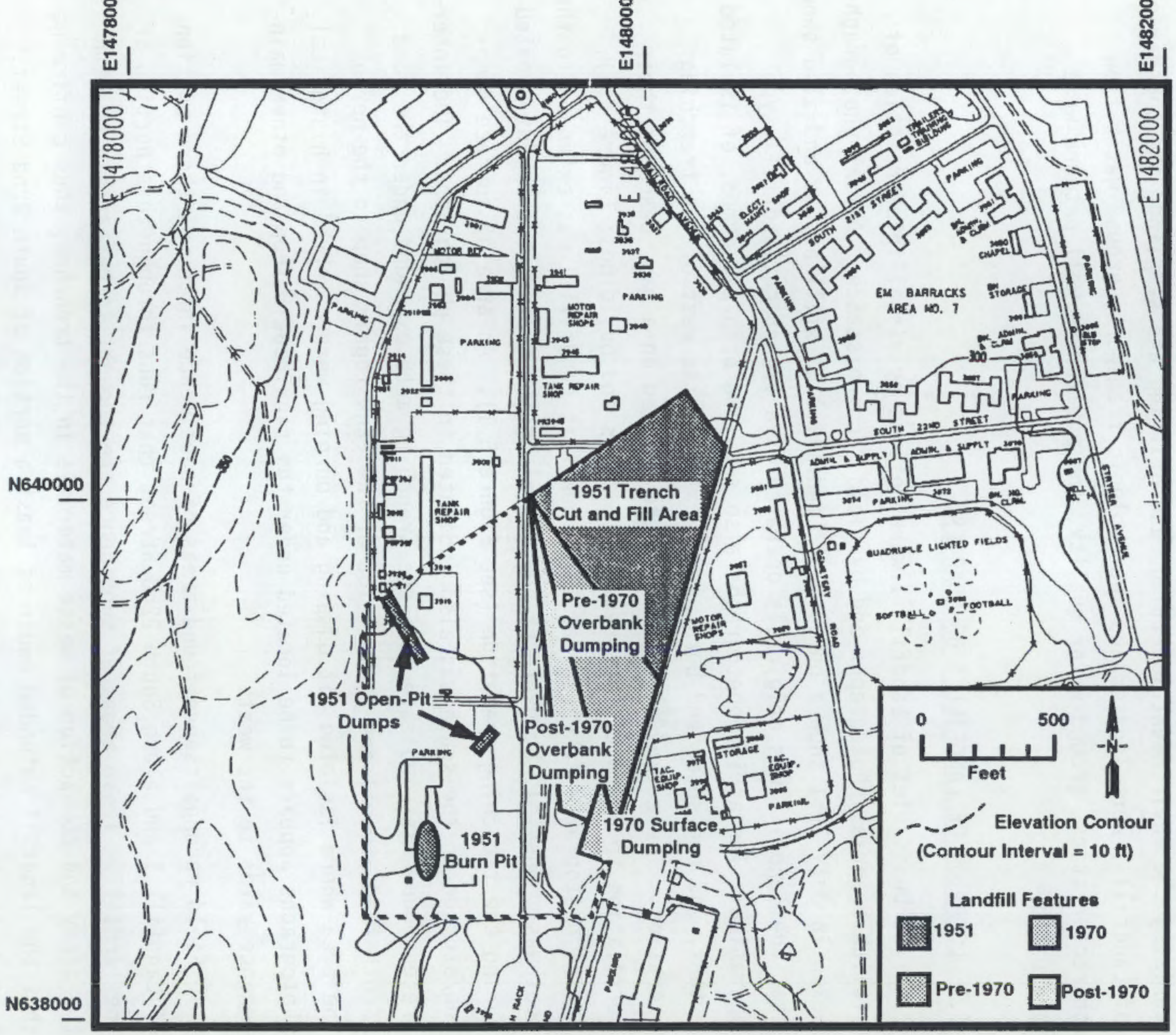


FIGURE 5.1. Location of Landfill 1 Boundaries and Historical Configurations

May 1970, extending the embankment farther to the west. Figure 5.1 illustrates the current interpretation of Landfill 1 and of the suspected area of isolated pit dumping and burning.

5.2 GEOLOGIC FRAMEWORK

The stratigraphy beneath Landfill 1 has been interpreted primarily from field analysis of split-spoon and core-barrel samples collected during the installation of four new (1988) ground-water monitoring wells. These wells ranged in depth from 33 to 48 ft below land surface. The actual field records are presented in Appendix E. Additional geologic information was gathered from drilling logs compiled during earlier (1984) drilling operations (Appendix I). The location of the new and existing wells is shown in Figure 5.2, and the well completion data are summarized in Table 5.1. Subsurface data collected from each new (1988) borehole are summarized in Figures 5.3 through 5.6. A generalized geologic cross section through the site is provided in Figure 5.7.

The sediments encountered in the new (1988) boreholes generally consist of poorly sorted, muddy sandy gravel with minor layers of gravel and sandy gravel. The general classification name (i.e., muddy sandy gravel) follows the ternary classification system of Folk (1974) (see Figure 4.1) and is based on a field estimate of the grain-size distribution comprising each sediment sample. These sediments are believed to be part of the Vashon Drift Formation of Walters and Kimmel (1968) and equivalent to hydrostratigraphic layer A of Brown and Caldwell (1983). Ground-water lies within this unit at depths between 20 and 40 ft below land surface.

Based on information gathered from an existing production well drilled in this area, it appears that a clay/silt layer, interpreted to be the top of the Kitsap Formation, is located approximately 70 ft below land surface. This is considered to be the contact between hydrostratigraphic layers A and B of Brown and Cadwell (1983). Assuming this layer is continuous, it most likely represents a hydrologic boundary and would, therefore, represent the bottom of the uppermost aquifer.

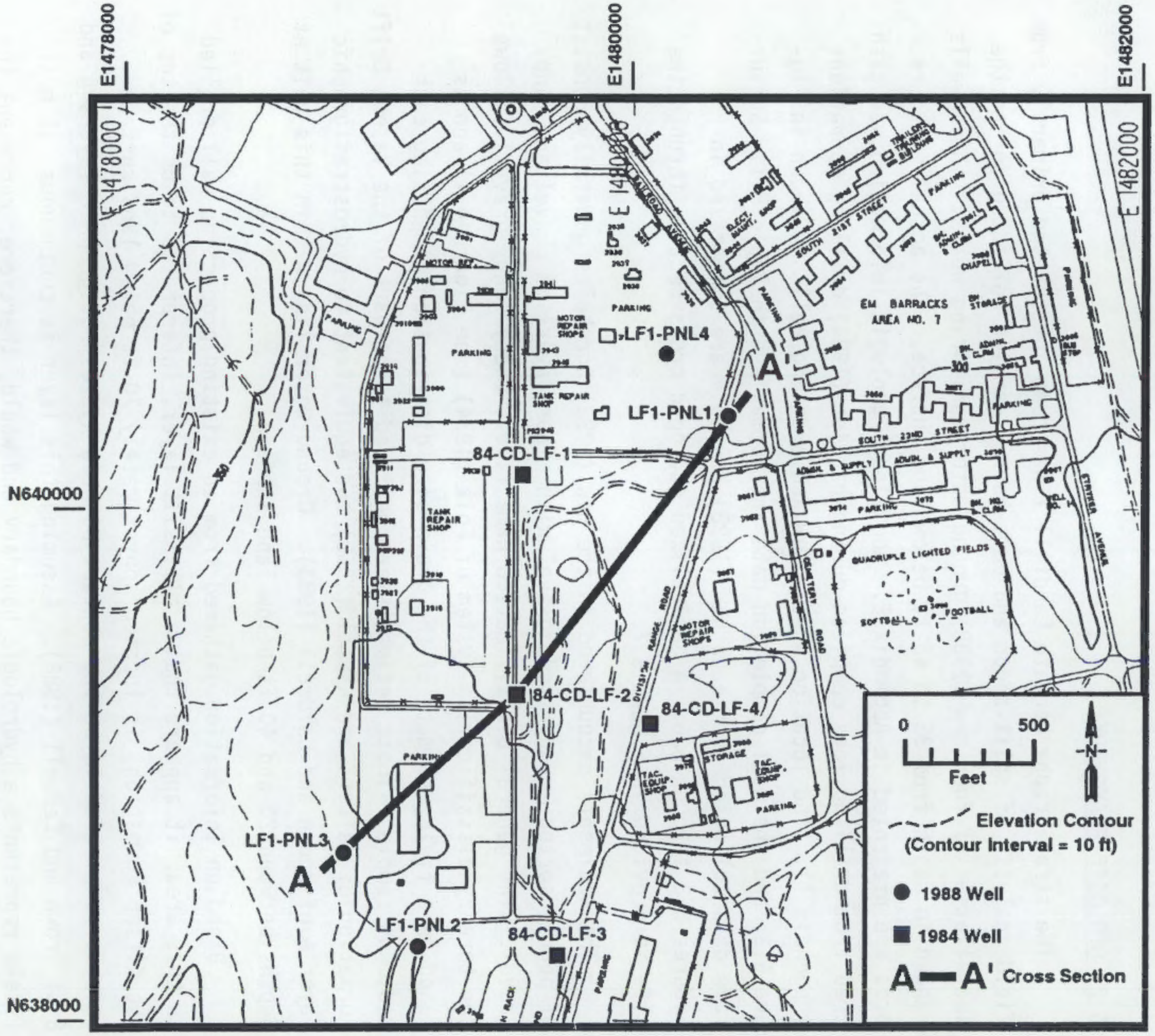


FIGURE 5.2. Location of Monitoring Wells Around Landfill 1

TABLE 5.1. Well Completion Data for Landfill 1

Well Number	Washington State Coordinates North,East	PVC Casing Elevation (ft-MSL) (a)	Drilled Depth (ft below land)(b)	Depth to Water (ft below land)(b)	Well Diameter (in.)	Screened Interval (ft below land) (c)	Date Completed
84-CD-LF-1	640126, 1479595	303.64	61.0	28	4	20 - 60	11-05-84
84-CD-LF-2	639271, 1479573	303.48	61.0	23	4	20 - 60	10-31-84
84-CD-LF-3	638243, 1479727	297.69	61.0	21	4	20 - 60	11-09-84
84-CD-LF-4	639159, 1480091	312.59	61.0	39	4	20 - 60	11-15-84
LF1-PNL1	640371, 1480403	308.66	48.0	38	2	33 - 48	08-19-88
LF1-PNL2	638285, 1479185	298.37	33.0	21.5	2	17 - 32	08-19-88
LF1-PNL3	638634, 1478888	307.74	40.5	28.5	4	24 - 39	08-25-88
LF1-PNL4	640612, 1480157	305.00	44.0	34.0	4	29 - 44	09-01-88

(a) All elevations are to the north rim of the PVC casing.
(b) Measurements are to the nearest 0.5 ft.
(c) Measurements are rounded down to the nearest foot.

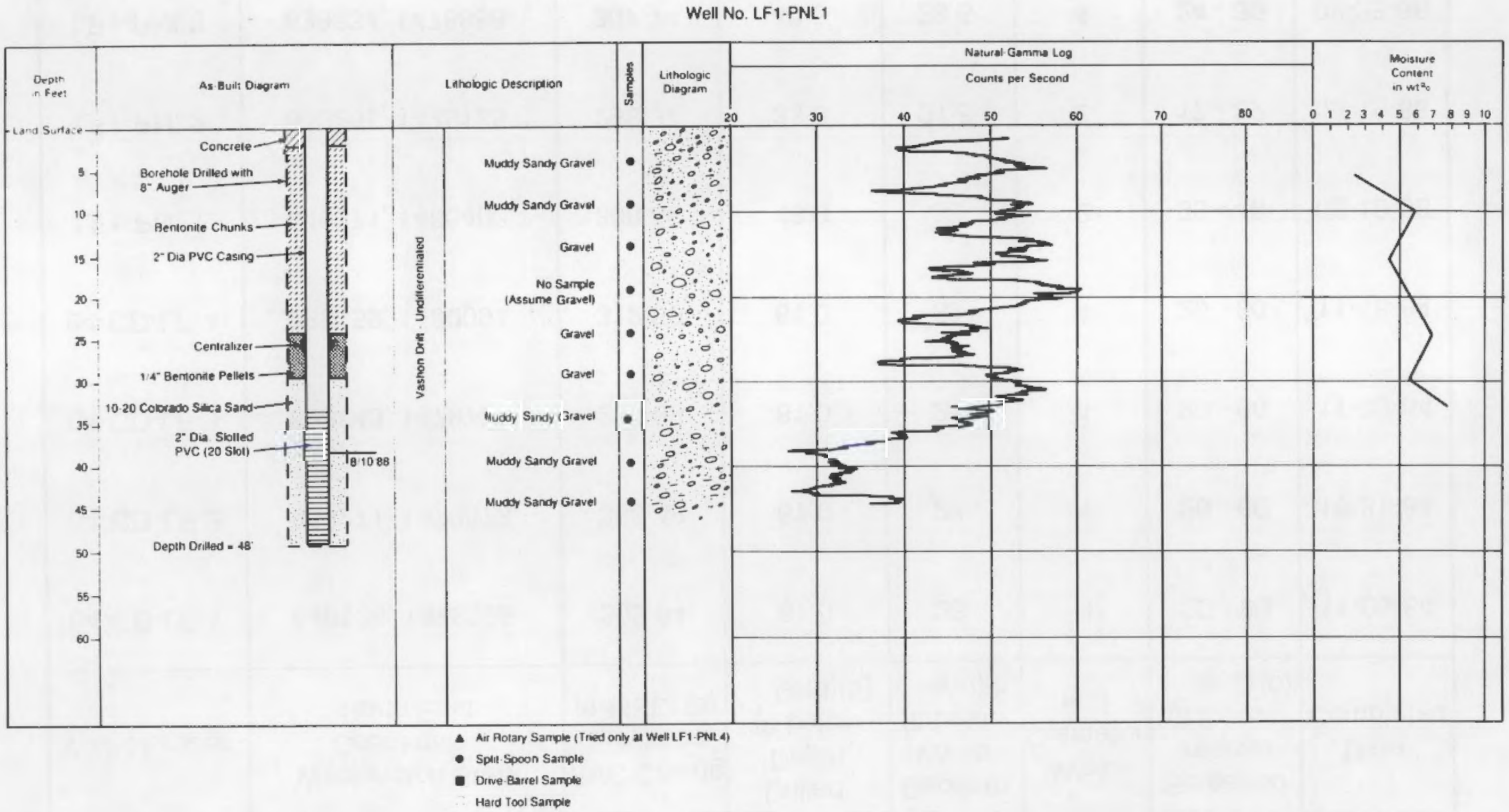


FIGURE 5.3. Subsurface Correlation Chart of Well LF1-PNL1

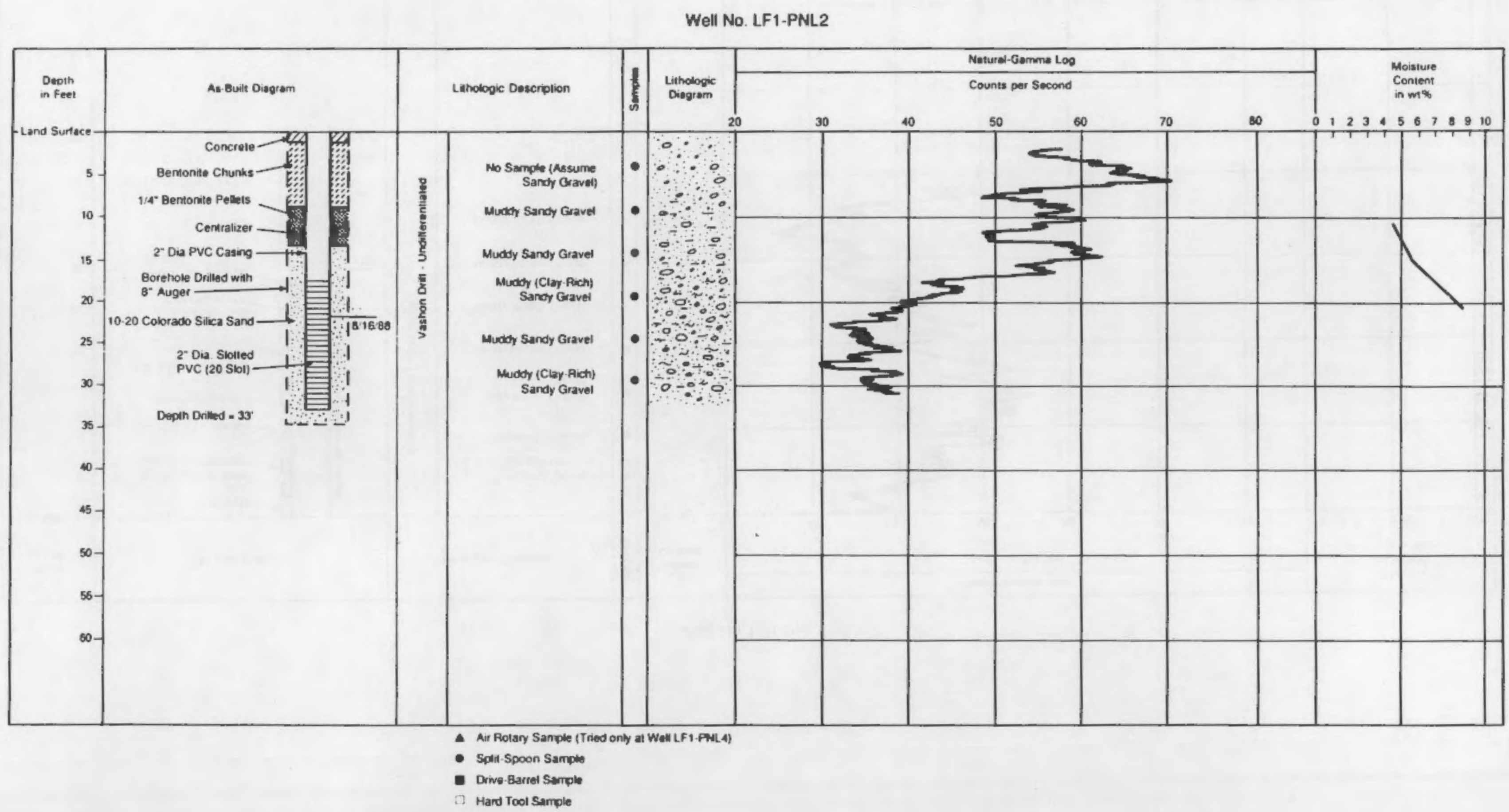


FIGURE 5.4. Subsurface Correlation Chart of Well LF1-PNL2

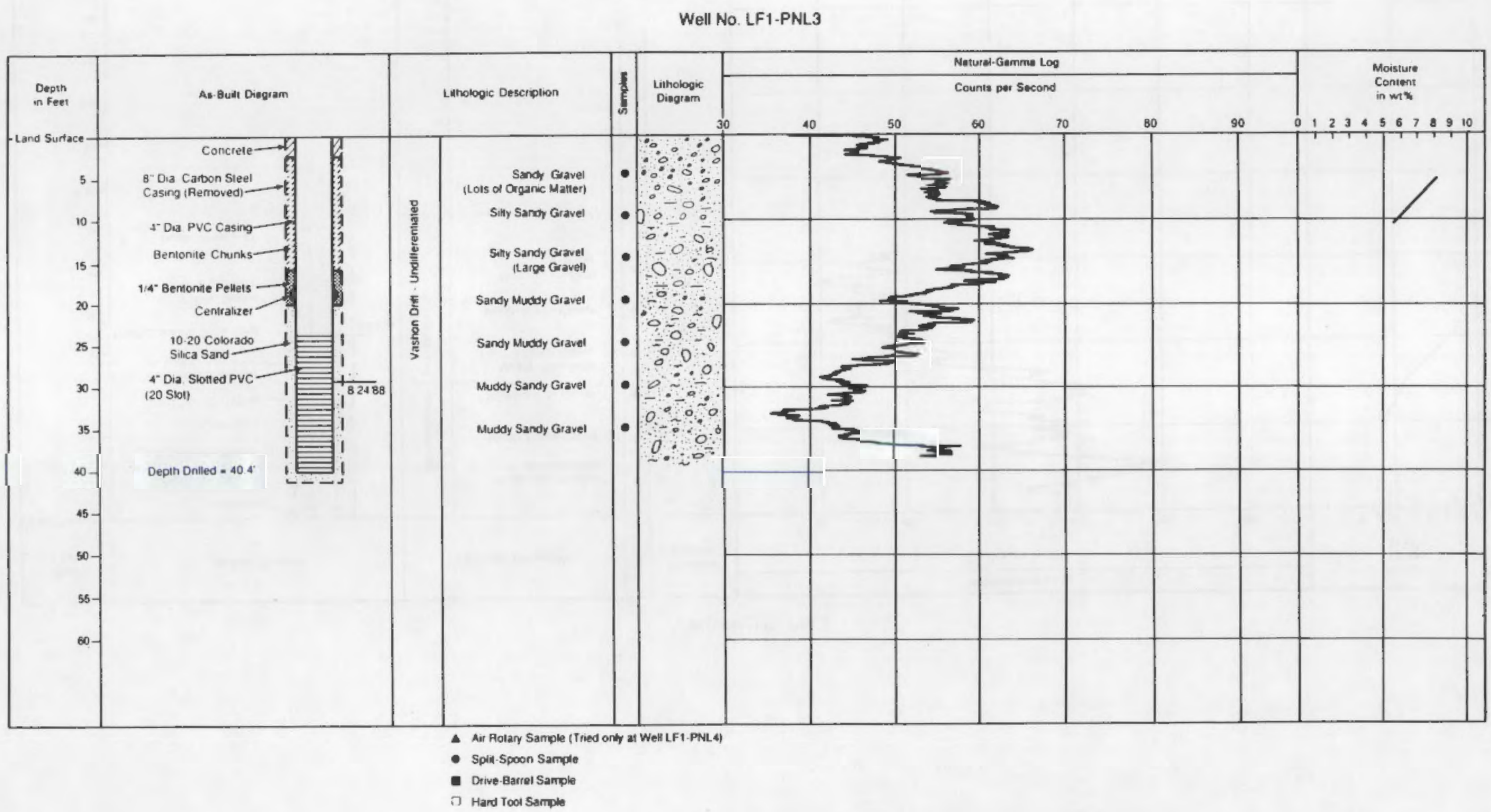


FIGURE 5.5. Subsurface Correlation Chart of Well LF1-PNL3

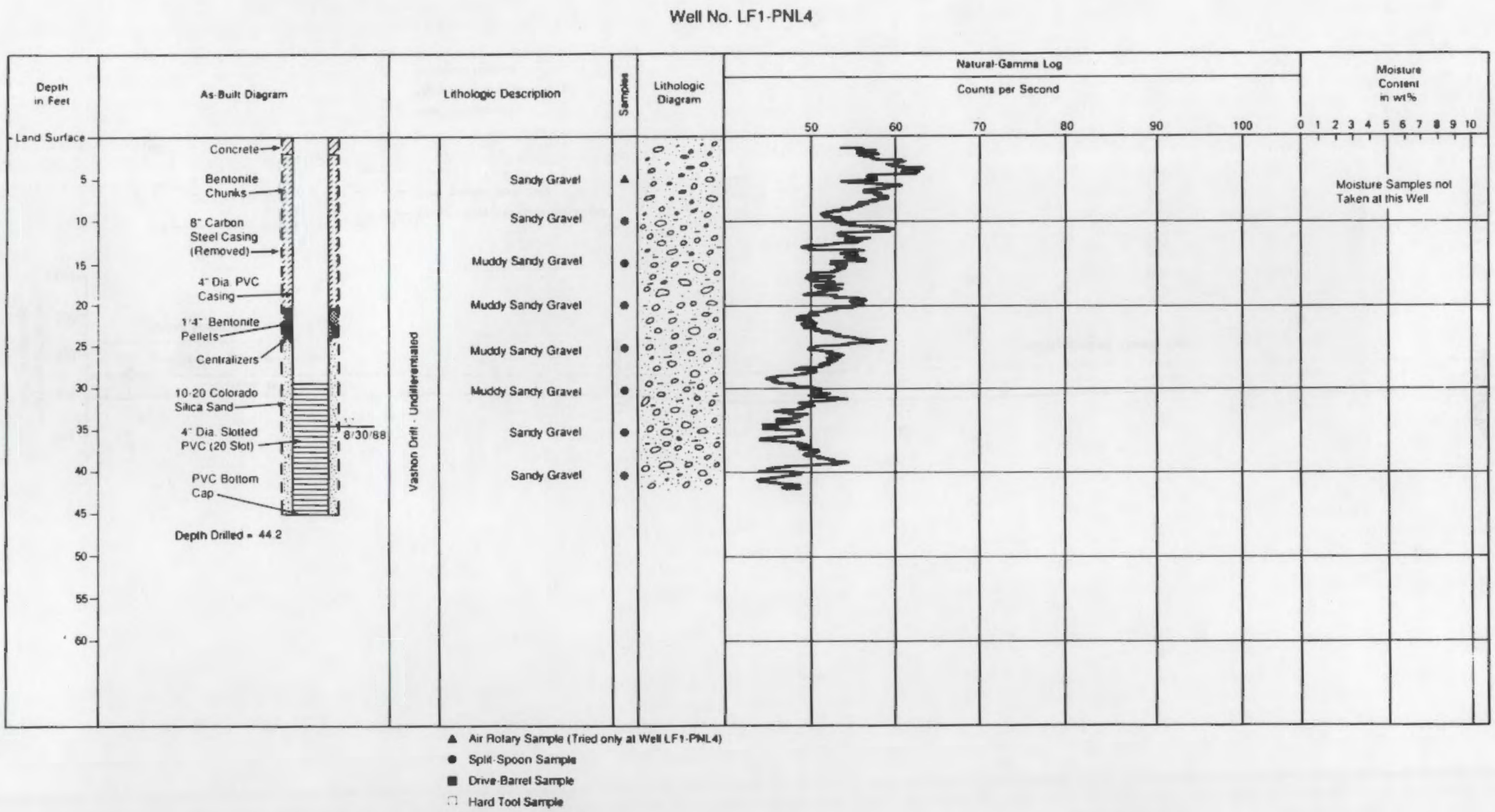


FIGURE 5.6. Subsurface Correlation Chart of Well LF1-PNL4

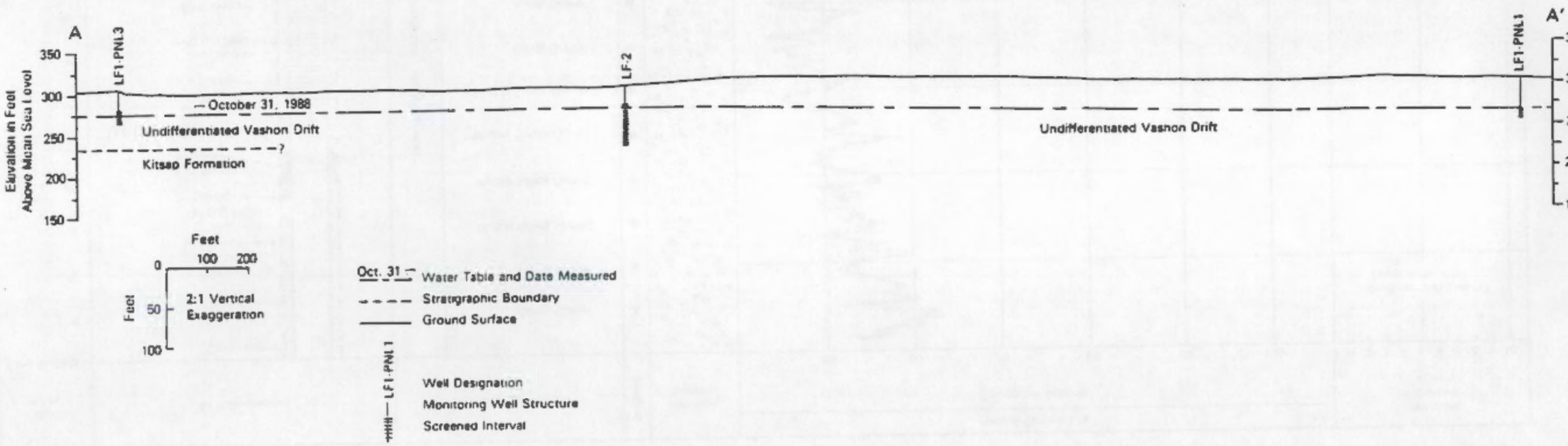


FIGURE 5.7. Generalized Geologic Cross Section Through Landfill 1

5.3 GROUND-WATER FLOW

Ground-water flow in the vicinity of Landfill 1 is dominated by a local ground-water mound superimposed on a general, easterly sloping ground-water surface. Figures 5.8 and 5.9 illustrate the configuration of the water table as interpreted from water-level measurements collected on October 25 and December 14, 1988, respectively. The ground-water gradient across the landfill ranges from approximately 2 to 7 ft/500 ft or 0.004 to 0.14 ft/ft.

The localized ground-water mound near the center of the landfill results from artificial recharge from an unlined holding pond located immediately southwest of well 84-CD-LF-2. It is believed that this pond receives precipitation runoff from the parking areas to the north and west. Thus, recharge is expected to be intermittent. This pond may also be a potential source of contaminants upgradient of the Landfill 1 trenching area (see Figures 5.8 and 5.9).

The general easterly ground-water flow direction is opposite from the regional westerly gradient depicted in Figure 3.4. However, this easterly flow is interpreted to relect natural recharge from surface runoff and precipitation along the nearby steep-sided hills (interpreted to be drumlins) just west of the landfill. As ground water moves east away from the hills, it will likely turn to the north and west, eventually aligning with the westerly regional gradient depicted in Figure 3.4.

Figure 5.10 illustrates the generalized ground-water flow directions and locations of upgradient and downgradient monitoring wells surrounding Landfill 1. Three monitoring wells (LF1-PNL2, LF1-PNL3, and 84-CD-LF-1) are interpreted to be hydraulically upgradient of Landfill 1 and the associated open-pit dumping areas. The five remaining wells are interpreted to be either directly or indirectly downgradient of these waste sites. Variations in water levels, particularly those caused by changes in the local ground-water mound, influence the downgradient status of these wells. Wells LF1-PNL1 and 84-CD-LF-2 are the most directly downgradient and are the most likely to have been affected by waste-disposal activities in and around Landfill 1.

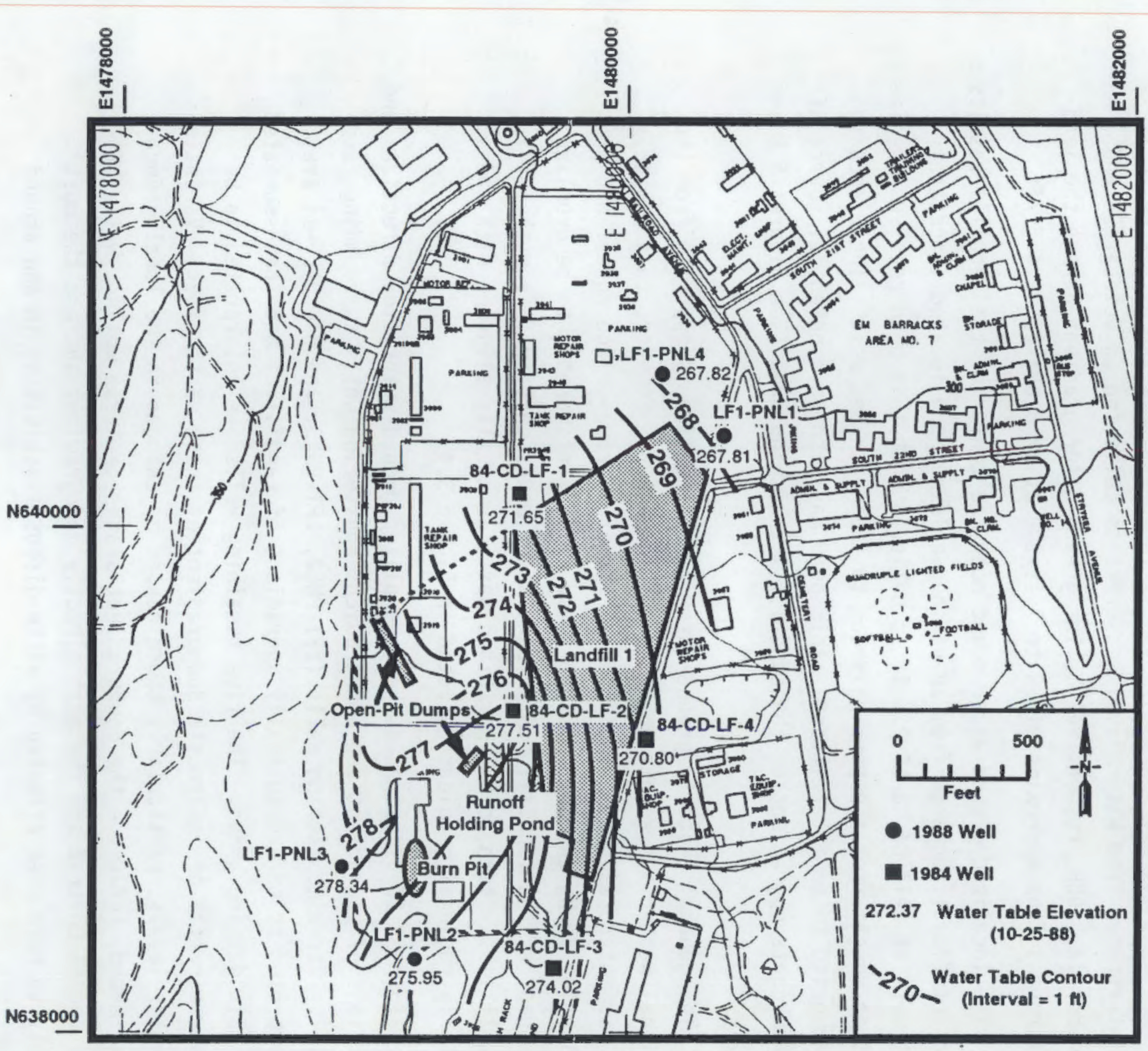


FIGURE 5.8. Water-Table Surface Beneath Landfill 1 as Interpreted from Water Levels Measured on October 25, 1988

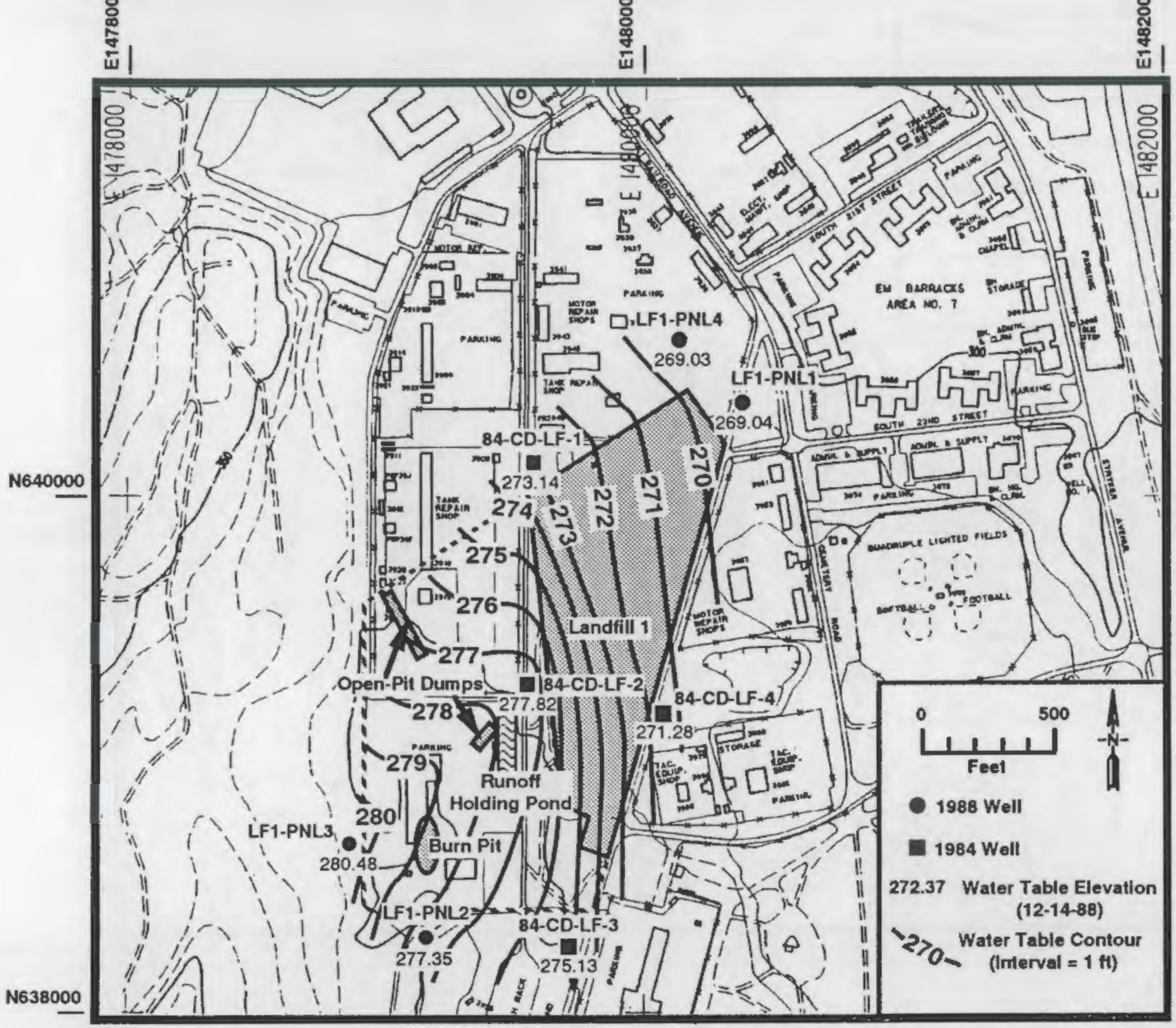


FIGURE 5.9. Water-Table Surface Beneath Landfill 1 as Interpreted from Water Levels Measured on December 14, 1988

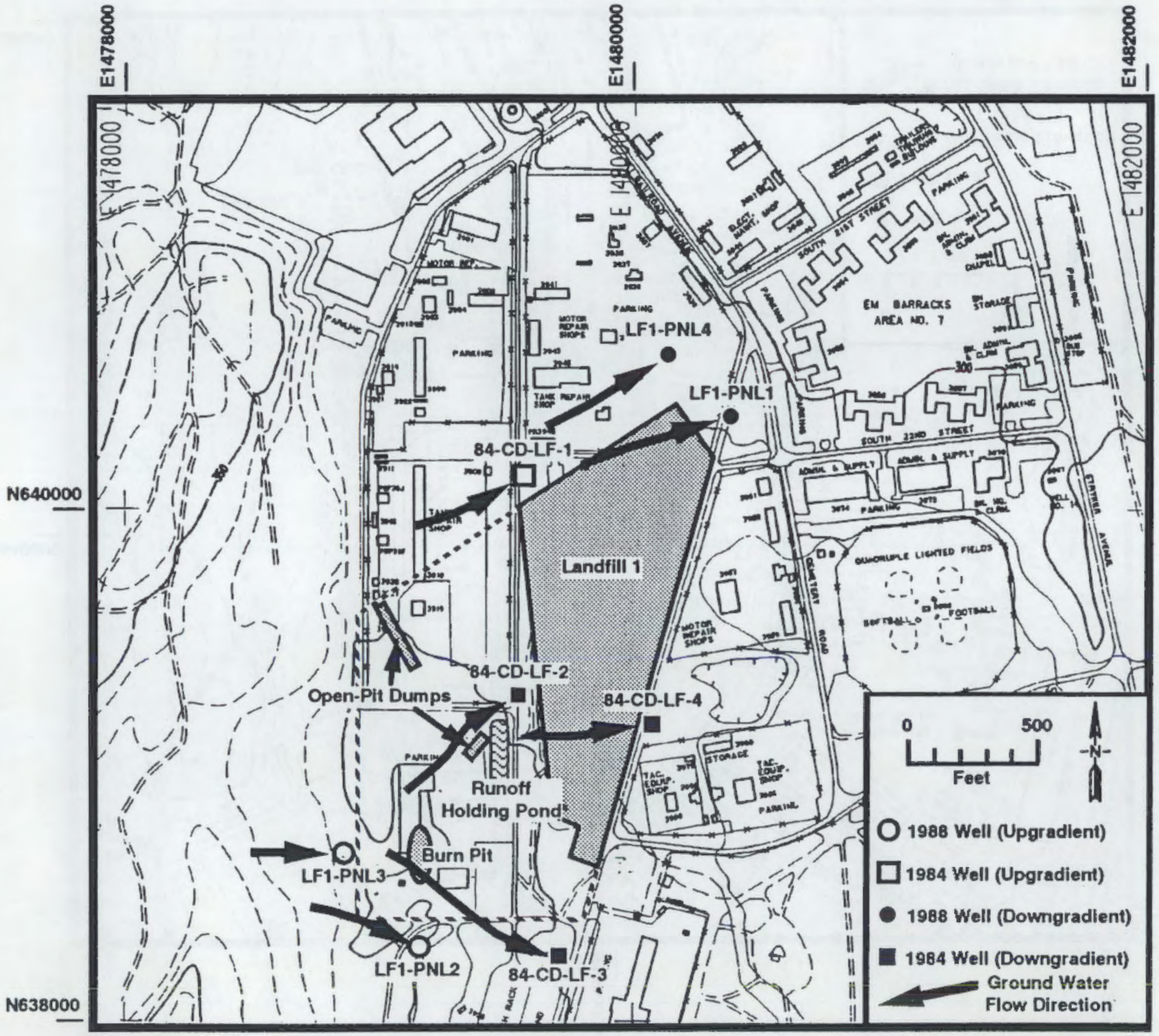


FIGURE 5.10. Generalized Ground-Water Flow Directions and Location of Upgradient and Downgradient Wells at Landfill 1

Over the 8-month time frame of this study (Spring to Winter of 1988), water levels fluctuated approximately 1.5 to 2.5 ft. Table 5.2 provides a summary of the water-level measurements collected between April and December 1988.

5.4 GROUND-WATER QUALITY

Ground-water samples were collected from each of the four existing (1981) wells and the four newly installed (1988) wells surrounding Landfill 1. At least one sample was collected from each well. The representativeness of these samples varies according to the well development and purging history of each well before sample collection. Wells LF1-PNL1, LF1-PNL2, and LF1-PNL4 produced good to very good samples after development. Wells 84-CD-LF-1, -2, -3, and -4 were not developed nor extensively purged during this study and produced only fair samples. Well LF1-PNL3 is completed in a low-yielding portion of the aquifer and produced only poor samples. Refer to Subsection 4.2.6 and Section 4.4 for further details.

Analytical results for the complete set of ground-water samples collected from the vicinity of Landfill 1 are summarized in Tables 5.3 and 5.4. The analytical reports received from AM Test are provided in Appendix K. As stated above, the representativeness of the ground-water samples varies. Some of the analytical results may be an artifact of the drilling, well construction, poor well development, and/or lack of adequate purging before sampling; these results may not accurately represent the ground-water quality. Thus, these results should be considered preliminary. Results from the good and very good ground-water samples (Tables 5.3 and 5.4) are considered the most representative of ground-water quality beneath Landfill 1. These results indicate the presence of several constituents [some of which exceed either primary or secondary drinking water standards (DWS) or maximum contaminant levels (MCL)] that may be of some concern. A discussion of these results is presented below.

Two wells (LF1-PNL2 and LF1-PNL4) produced ground-water samples that contained fecal coliform in excess of the DWS. However, both these samples

TABLE 5.2. Water-Level Measurements from Landfill 1

Well Number	6-in. Casing Elevation, ft above msl[(a)]	Measurement Date	Depth to Water, ft	Type of Measurement	Head Elevation, ft above msl
84-CD-LF-1	304.41[(b)]	04/20/88	30.49	ST[(c)]	273.92
	304.41[(b)]	08/12/88	32.29	ST	272.12
	305.62	10/25/88	33.97	ST	271.65
	305.62	10/31/88	34.16	ET[(d)]	271.46
	305.62	12/13/88	32.45	ST	273.17
	305.62	12/14/88	32.48	ST	273.14
84-CD-LF-2	304.53[(b)]	04/20/88	26.29	ST	278.24
	304.53[(b)]	08/12/88	27.26	ST	277.27
	304.47	10/25/88	26.96	ST	277.51
	304.47	10/31/88	27.10	ET	277.37
	304.47	12/14/88	26.65	ST	277.82
84-CD-LF-3	299.17[(b)]	04/20/88	24.13	ST	275.04
	299.17[(b)]	08/12/88	25.62	ST	273.55
	299.13	10/25/88	25.11	ST	274.02
	299.13	10/31/88	25.36	ET	273.77
	299.13	12/14/88	24.00	ST	275.13
84-CD-LF-4	313.66[(b)]	04/20/88	41.29	ST	272.37
	313.66[(b)]	08/12/88	42.40	ST	271.26
	313.67	10/25/88	42.87	ST	270.8
	313.67	10/31/88	42.95	ET	270.72
	313.67	12/14/88	42.39	ST	271.28
LF1-PNL1	309.36	10/25/88	41.55	ST	267.81
	309.36	10/31/88	41.69	ET	267.67
	309.36	12/13/88	40.30	ST	269.06
	309.36	12/14/88	40.32	ST	269.04
LF1-PNL2	299.22	10/25/88	23.27	ST	275.95
	299.22	10/31/88	23.46	ET	275.76
	299.22	12/14/88	21.87	ST	277.35
LF1-PNL3	308.48	10/25/88	30.14	ST	278.34
	308.48	10/31/88	30.43	ET	278.05
	308.48	12/14/88	28.00	ST	280.48
LF1-PNL4	305.72	10/25/88	37.90	ST	267.82
	305.72	10/31/88	38.05	ET	267.67
	305.72	12/13/88	36.67	ST	269.05
	305.72	12/14/88	36.69	ST	269.03

(a) Calculated from the 1989 survey of the brass cap installed in each well pad and the measured casing stickup. Variations in the casing elevation can be attributed to remedial actions performed on the 1984 wells as well as variations in the surveying and/or measurement of the casing stickup.
(b) Calculated from the 1988 survey of a 2- by 2-ft wooden survey plug installed 2 ft from each well and the measured casing stickup.
(c) ST = Steel tape.
(d) ET = Electric tape.

TABLE 5.3. Analytical Results of All Ground-Water Samples Collected Near Landfill 1

Well	Date Sampled	Sample Representativeness	ph	Conductivity, µmhos/cm	Coliform, MPN/100mL[a]	Grease and Oil, mg/L	TOX, µg/L as Cl	Gross Beta, pCi/L	Radium, pCi/L	Gross Alpha, pCi/L	TDS, mg/L
LF1-PNL1	24-Aug-88	Poor	6.35	310	220	<1.4	<10	<2	<1	<1	418
Duplicate	24-Aug-88	Poor	6.64	310	140	<2.9	<10	<2	<1	<1	298
LF1-PNL1	13-Dec-88	Good	6.46	246	<1.8	7.7[b]	NA[c]	NA	NA	NA	112
Duplicate	13-Dec-88	Good	6.68	245	<1.8	11.8[b]	NA	NA	NA	NA	152
LF1-PNL2	08-Sep-88	Good	7.17	245	<2.5	<1.2	<10	<2	<1	<1	151
LF1-PNL2	14-Dec-88	Good	6.16	89	13	9.2[b]	NA	NA	NA	NA	47
LF1-PNL3	09-Sep-88	Poor	7.26	120	20	<1.1	<10	<2	1.3	<1	124
LF1-PNL3	14-Dec-88	Poor	7.06	124	21	8.2[b]	NA	NA	NA	NA	76
LF1-PNL4	08-Sep-88	Very Good	6.36	267	<2.5	<1.2	<10	<2	<1	<1	177
Duplicate	08-Sep-88	Very Good	6.32	270	<2.5	<1.2	<10	<1	<1	<1	183
LF1-PNL4	13-Dec-88	Good	7.01	258	22	8.2[b]	NA	NA	NA	NA	165
LF #1	13-Dec-88	Fair	6.36	191	4.5	7.6[b]	NA	NA	NA	NA	122
LF #2	14-Dec-88	Fair	7.10	322	<1.8	9.4[b]	NA	NA	NA	NA	204
LF #3	14-Dec-88	Fair	6.45	179	<1.8	11.5[b]	NA	NA	NA	NA	87
LF #4	14-Dec-88	Fair	6.53	488	<1.8	8.5[b]	NA	NA	NA	NA	312

Well	Date Sampled	TOC, mg/L	Cl^-, mg/L	Phenol, mg/L	Nitrate, mg/L	F^-, mg/L	Sulfate, mg/L	CN^-, mg/L	Aromatic Compounds	Herbicides	Pesticides and PCBs	Acid Base/Neutral Organics
LF1-PNL1	24-Aug-88	3.33	4.89	<0.008	2.62	<0.10	61.6	<0.006	ND	ND	ND	NA
Duplicate	24-Aug-88	3.45	4.95	<0.016	2.84	<0.10	27.2	<0.006	ND	ND	ND	NA
LF1-PNL1	13-Dec-88	0.60	4.2	NA	4.3	<0.02	19.8	NA	NA	NA	NA	ND
Duplicate	13-Dec-88	0.86	4.1	NA	4.8	<0.02	20.2	NA	NA	NA	NA	ND
LF1-PNL2	08-Sep-88	0.76	2.74	<0.008	0.23	0.72	3.5	<0.006	ND	ND	ND	NA
LF1-PNL2	14-Dec-88	0.80	2.8	NA	0.7	<0.02	7.3	NA	NA	NA	NA	ND
LF1-PNL3	09-Sep-88	0.73	4.60	<0.008	<0.01	<0.01	12.5	<0.006	ND	ND	ND	NA
LF1-PNL3	14-Dec-88	0.59	4.1	NA	0.9	<0.02	12.7	NA	NA	NA	NA	ND
LF1-PNL4	08-Sep-88	2.12	3.65	<0.008	1.83	<0.01	23.6	<0.006	ND	ND	ND	NA
Duplicate	08-Sep-88	2.52	3.35	<0.008	1.94	<0.01	23.9	<0.006	ND	ND	ND	NA
LF1-PNL4	13-Dec-88	1.48	3.6	NA	3.0	<0.02	23.4	NA	NA	NA	NA	ND
LF #1	13-Dec-88	2.62	2.9	NA	10.9	<0.02	10.9	NA	NA	NA	NA	ND
LF #2	14-Dec-88	0.78	2.5	NA	16.2	<0.02	8.7	NA	NA	NA	NA	ND
LF #3	14-Dec-88	0.96	1.4	NA	5.0	<0.02	5.6	NA	NA	NA	NA	ND
LF #4	14-Dec-88	1.88	3.8	NA	23.9	<0.02	39.4	NA	NA	NA	NA	ND

(a) MPN = most probable number.
(b) Result is suspect, because the sample blank contained 8.2 mg/L oil and grease.
(c) NA = not analyzed.

TABLE 5.3. (contd)

Well	Date Sampled	Fe, ppm	Ba, ppm	Se, ppm	Cd, ppm	Mn, ppm	Ca, ppm	Ag, ppm	Na, ppm	Cr, ppm	Pb, ppm	As, ppm	Hg, ppm
LF1-PNL1	24-Aug-88	600.0	4.00	<0.002	0.004	20.000	210.0	0.029	24.0	0.680	<0.02	<0.002	0.0028
Duplicate	24-Aug-88	480.0	2.25	<0.002	0.005	12.800	114.0	0.024	16.5	0.510	<0.02	<0.002	0.0031
LF1-PNL1	13-Dec-88	0.7	<0.01	<0.012	<0.0006	0.71	21.9	NA	9.9	<0.01	<0.006	<0.012	<0.0008
Filtered		0.2	<0.01	NA	<0.0005	0.93	28.4	NA	7.8	<0.01	<0.005	<0.010	NA
Duplicate	13-Dec-88	0.5	0.01	<0.012	<0.0006	0.77	21.6	NA	6.5	<0.01	<0.006	<0.012	<0.0008
Filtered		0.2	<0.01	NA	<0.0005	0.89	29.6	NA	8.0	<0.01	<0.005	<0.010	NA
LF1-PNL2	08-Sep-88	1.5	0.012	<0.002	<0.002	0.080	23.0	<0.010	5.3	0.073	<0.02	<0.002	<0.0002
Filtered		<0.1	<0.01	NA	<0.01	<0.01	24.5	<0.01	8.7	<0.01	<0.1	NA	NA
LF1-PNL2	14-Dec-88	66.5	0.34	<0.012	<0.0006	1.4	19.9	NA	10.2	0.08	0.025	0.023	0.004
Filtered		<0.2	<0.01	NA	<0.0005	<0.01	10.5	NA	12.8	<0.01	<0.005	NA	NA
LF1-PNL3	09-Sep-88	11.0	0.078	<0.002	<0.002	0.368	13.0	<0.010	3.3	0.100	<0.02	0.004	<0.0002
LF1-PNL3	14-Dec-88	1.4	0.02	<0.012	<0.0006	0.25	9.0	NA	8.8	<0.01	<0.006	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.33	13.3	NA	19.0	<0.01	<0.005	NA	NA
LF1-PNL4	08-Sep-88	2.7	0.026	<0.002	<0.002	1.070	30.0	<0.010	5.3	0.110	<0.02	<0.002	<0.0002
Duplicate	08-Sep-88	3.4	0.033	<0.002	<0.002	1.000	29.0	<0.010	4.6	0.100	<0.02	<0.002	<0.0002
Filtered		0.6	<0.01	NA	<0.01	<0.01	32.7	<0.01	7.7	<0.01	<0.1	NA	NA
LF1-PNL4	13-Dec-88	2.3	0.02	<0.012	<0.0006	<0.01	23.6	NA	7.9	<0.01	<0.006	<0.012	<0.0008
Filtered		1.0	0.02	NA	<0.0005	1.41	33.9	NA	8.8	<0.01	<0.005	<0.010	NA
LF #1	13-Dec-88	17.9	0.10	<0.012	<0.0006	0.20	19.9	NA	7.3	<0.01	0.011	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.03	20.4	NA	6.0	<0.01	<0.005	<0.010	NA
LF #2	14-Dec-88	4.1	0.04	<0.012	0.0007	0.60	29.2	NA	8.2	<0.01	0.014	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	<0.01	37.4	NA	9.8	<0.01	<0.005	<0.010	NA
LF #3	14-Dec-88	8.1	0.05	<0.012	<0.0006	0.50	16.3	NA	6.4	<0.01	0.014	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.02	19.4	NA	6.8	<0.01	<0.005	<0.010	NA
LF #4	14-Dec-88	2.6	0.03	<0.012	0.0011	0.70	45.6	NA	24.5	<0.01	0.008	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.63	60.2	NA	13.5	<0.01	<0.005	<0.010	NA

TABLE 5.4. Volatile Organic Compound Concentrations in All Ground-Water Samples from Landfill 1

Well	Sample Representativeness	Date Sampled	Laboratory	Trans-1,2 DCE, ppb	Cis-1,2 DCE, ppb	TCE, ppb	Benzene, ppb	Carbon Tetrachloride, ppb
LF1-PNL1	Poor	24-Aug-88	AM Test	<0.6	NA[a]	<0.6	NA	<0.6
Duplicate	Poor	24-Aug-88	AM Test	<0.6	NA	<0.6	NA	<0.6
LF1-PNL1	Good	13-Dec-88	PNL	<0.5	<0.2	0.06	<0.5	<0.01
Duplicate	Good	13-Dec-88	PNL	<0.5	<0.2	0.07	<0.5	<0.01
LF1-PNL2	Good	08-Sep-88	AM Test	<2	NA	<2	NA	<0.6
LF1-PNL2	Good	14-Dec-88	PNL	<0.5	<0.2	0.16	<0.5	0.01
LF1-PNL3	Poor	09-Sep-88	AM Test	<2	NA	<2	NA	<0.6
LF1-PNL3	Poor	14-Dec-88	PNL	<0.5	<0.2	<0.03	<0.5	<0.01
LF1-PNL4	Very Good	08-Sep-88	AM Test	<2	NA	<2	NA	<0.6
Duplicate	Very Good	08-Sep-88	AM Test	<2	NA	<2	NA	<0.6
LF1-PNL4	Good	13-Dec-88	PNL	<0.5	<0.2	0.74	<0.5	<0.01
LF #1	Fair	13-Dec-88	PNL	<0.5	<0.2	<0.03	<0.5	<0.01
LF #2	Fair	14-Dec-88	PNL	<0.5	<0.2	0.25	<0.5	<0.01
LF #3	Fair	14-Dec-88	PNL	<0.5	12.0	16.0	<0.5	0.05
LF #4	Fair	14-Dec-08	PNL	<0.5	17.0	7.1	<0.5	0.02

(a) NA = not analyzed.

were collected using a Teflon bailer after only a limited amount of purging. Previous samples collected from these wells soon after well development, or extensive purging, yielded no measurable coliform. Although less-representative samples from other wells (Table 5.3) also indicate the presence of coliform, it is not believed that coliform is a constituent of concern.

Chromium exceeded the DWS (0.05 ppm) in unfiltered samples from wells LF1-PNL2 and LF1-PNL4. However, filtered samples from the same wells contained no detectable levels of chromium. This difference suggests that the chromium is associated with particulates suspended in the water samples. Slight turbidity was noted during the collection of samples from well LF1-PNL2. Turbidity was also evidenced by high iron content in the December 1988 sample. Thus, the unfiltered samples from this well are not considered representative. The unfiltered chromium values in the December 13, 1988, samples from well LF1-PNL4 fell below the 0.01 detection limit. Although chromium results from other less-representative samples have also indicated the presence of chromium in unfiltered samples, chromium has not been observed in any filtered sample. Thus, chromium is not believed to be a constituent of concern.

Mercury exceeded the DWS (0.002 ppm) in the December 13, 1988, unfiltered sample from well LF1-PNL2; however, the unfiltered samples from this well are not considered representative as stated above. Although mercury was also observed in the initial (poorly representative) unfiltered sample from well LF1-PNL1, it has not been observed in any other unfiltered samples and is not believed to be a constituent of concern.

The December 1988 samples indicated the presence of oil and grease ranging in concentrations from 7.6 to 11.8 ppm (Table 5.3). However, these values are suspect because the blank sample submitted to the laboratory at this same time was reported to contain 8.2 ppm. Furthermore, oil and grease were not detected in any other sample. Thus, oil and grease are not considered to be constituents of concern.

The presence of TCE was observed in several wells. However, concentrations exceed the MCL only in two less-representative samples from wells 84-CD-LF-3 and -LF-4 (Table 5.4). Other volatile organic compounds [cis-1,2-dichloroethylene (DCE) and tetrachloromethane (carbon tetrachloride)] were also observed in these less-representative samples. Although these results must be considered tentative, it does appear that volatile organic constituents (principally TCE and DCE) may be present at least at very low concentrations within the aquifer, and thus TCE and DCE may be constituents of concern. Further investigation is needed to verify these results.

No phenols, cyanide, aromatic compounds, herbicides, pesticides, or PCBs have been detected.

Examination of the inorganic constituent results from the upgradient samples (principally from well LF1-PNL2) versus those from the downgradient wells (principally from LF1-PNL1 and -PNL4) indicates slight differences in ground-water chemistry. Specifically, downgradient samples have slightly lower pH and higher total organic carbon (TOC), sulfate, and nitrate than the upgradient samples. This contrast suggests that Landfill 1 may have some influence on the ground-water chemistry.

Nitrate concentrations exceeded the DWS (10 ppm) only in less-representative ground-water samples from wells 84-CD-LF-1, -LF-2, and -LF-4 (Table 5.3); thus, these results should only be considered tentative.

However, comparison of the nitrate concentrations in the more-representative samples from wells LF1-PNL1, -PNL2, and -PNL4 indicates a higher concentration of nitrate downgradient of the landfill than upgradient. This suggests that nitrate may be originating from the landfill and is therefore a constituent of concern.

5.5 EVALUATION OF THE MONITORING NETWORK

Eight monitoring wells (four 1984 wells and four 1988 wells) are located in the vicinity of Landfill 1. Water-level data suggest that three of these wells (LF1-PNL2, LF1-PNL3, and 84-CD-LF-1) are located hydraulically upgradient of the landfill and associated open-pit dumping areas. The five remaining wells are interpreted to be either directly or indirectly downgradient of these waste sites. Fluctuations in the local ground-water mound near well 84-CD-LF-2 can influence the downgradient status of these wells. Wells LF1-PNL1 and 84-CD-LF-4 appear to be directly downgradient of the landfill and therefore would be most likely to indicate any ground-water quality impacts from Landfill 1.

Ground-water samples collected from each well varied in representativeness according to the well development and purging history of the well before sample collection. Wells LF1-PNL1, LF1-PNL2, and LF1-PNL4 were extensively developed and produced good to very good samples. Wells 84-CD-LF-1, -2, -3, and -4 were not developed or extensively purged during this study. Samples from these wells were considered only fair. However, these wells should produce very good samples after an extensive purging is performed at each well. Well LF1-PNL3 is completed in a low-yielding portion of the aquifer, which prevented adequate development. This well produced only poor (unrepresentative) samples and should be used only for water-level measurements.

The limited analytical results from these ground-water monitoring wells suggest that some volatile organic compounds (principally TCE and DCE) and nitrate are the two chemical constituents of primary concern. In addition, a slight inorganic chemistry difference apparently exists in the upgradient and downgradient wells, suggesting that the landfill (or some other nearby source such as the runoff holding pond) may have some influence on the ground-water chemistry. Further investigation is needed to determine the impacts (if any) that Landfill 1 has had on the local ground-water system.

6.0 EVALUATION OF LANDFILL 4

Using the information gained from examining aerial photographs, characterizing the environmental setting, and drilling and sampling, the boundaries of Landfill 4 were located and the geologic framework, ground-water flow characteristics, ground-water quality, and monitoring well network were evaluated.

6.1 LOCATION OF LANDFILL 4 BOUNDARIES

The boundaries of Landfill 4 were determined based on 1) aerial photograph interpretation, 2) field reconnaissance, and 3) surface geophysical surveys. Aerial photographs taken in May 1970 and July 1976 show four distinct areas of trench-type landfill operations. Field reconnaissance allowed mapping of portions of the landfill boundaries based on visual inspection of surface debris and by the topographic expressions of the landfill. Evidence was also found to suggest several areas of localized open-pit dumping and some surface dumping of tree stumps and trash. These field observations were recorded on a 7.5-min quadrangle map of the area. Surface geophysical surveys were conducted over four areas where the landfill boundaries were poorly located. These surveys included the use of 1) a ground-penetrating radar unit, 2) a ground-conductivity meter, and 3) a metal detector. The results of the surveys were summarized on a map of the area (Figure 6.1). The actual data are reported in Appendix A. All aerial photograph, field reconnaissance, and surface geophysical observations were transferred to a common base map to illustrate the current interpretation of Landfill 4 boundaries (Figure 6.2).

6.2 GEOLOGIC FRAMEWORK

The stratigraphy beneath Landfill 4 has been interpreted primarily from field analysis of split-spoon and core-barrel samples collected during the installation of six (1988) ground-water monitoring wells. These wells ranged in depth from 32 to 46.5 ft below land surface. The actual field records are provided in Appendix E. Additional geologic information was gathered from

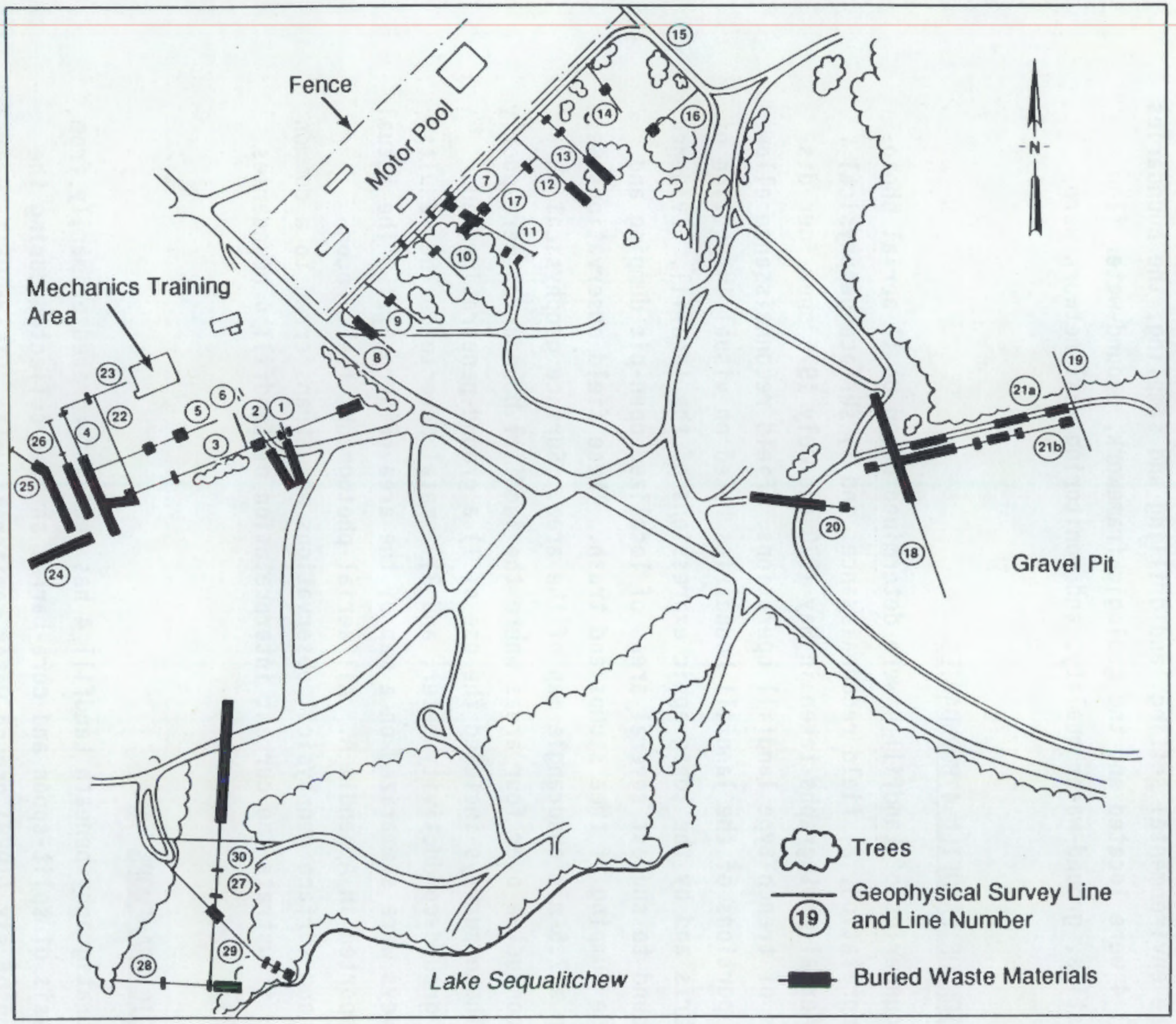


FIGURE 6.1. Location of Surface Geophysical Surveys, Showing Location of Suspected Waste Materials

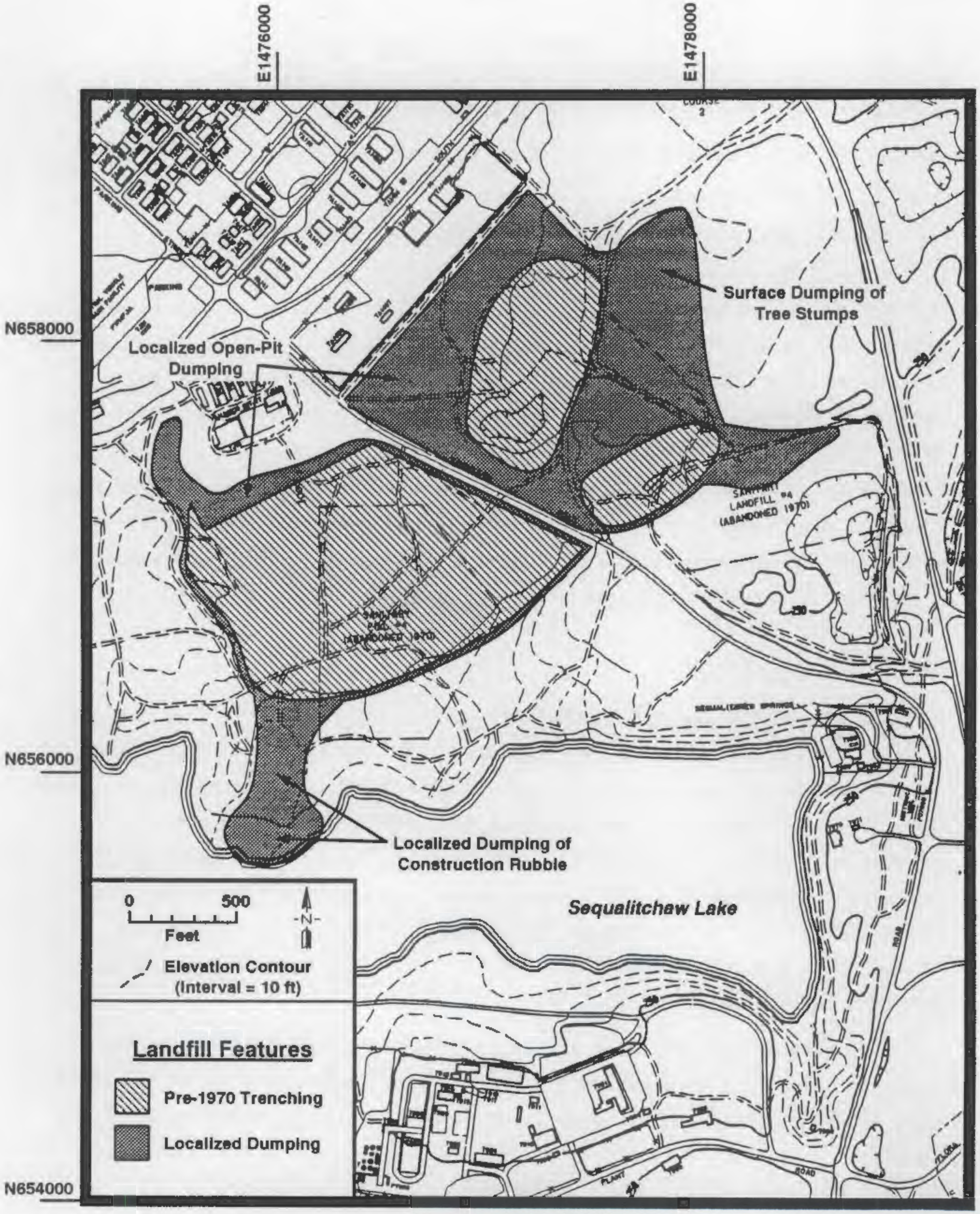


FIGURE 6.2. Boundaries and Configuration of Landfill 4

drilling logs compiled during earlier (1981) drilling operations (Appendix I). The location of the new (1988) and existing (1981) wells is shown in Figure 6.3, and the well completion data are summarized in Table 6.1. The subsurface data generated from drilling each new borehole are summarized in Figures 6.4 through 6.9.

The sediments encountered in the vicinity of Landfill 4 consist primarily of muddy sandy gravel with minor lenses of sand and gravel. These sediments are considered part of the Vashon Drift Formation. A 3- to 4-ft-thick layer of clay/silt was encountered at approximately 31 ft below land surface at well LF4-PNL4. This unit was not encountered in any of the other new wells; however, it is evident in the drill logs for existing (1981) wells LF4-3 and -4. This layer appears to represent the top of the Kitsap Formation and is, therefore, the boundary between hydrostratigraphic units A and B of Brown and Caldwell (1983). The clay layer at well LF4-PNL4 overlies a water-bearing dark-gray to black-colored, fine-grained, silty/sand sequence. A generalized geologic cross section is illustrated in Figure 6.10.

6.3 GROUND-WATER FLOW

Ground-water flow in the uppermost aquifer beneath Landfill 4 is generally to the north-northwest. This general north-northwesterly ground-water flow direction is consistent with the regional ground-water gradient depicted by others (see Figure 3.4) and supports the concept that the uppermost ground-water system discharges to Puget Sound. Figures 6.11 and 6.12 illustrate the configuration of the water table as interpreted from water-level measurements recorded on October 31 and December 15, 1988, respectively. The ground-water gradient across the landfill site ranges from very small to nearly 3 ft/1000 ft or 0.003 ft/ft.

Two ground-water features appear to have the greatest effect on local flow directions: a gentle ground-water divide located along the far eastern side of the landfill and a ground-water depression located just north of the landfill. The ground-water divide, centered around well LF4-4, cannot be readily explained at this time. However, as with other major lakes in the area, Sequalitchew Lake and nearby American Lake are believed to be

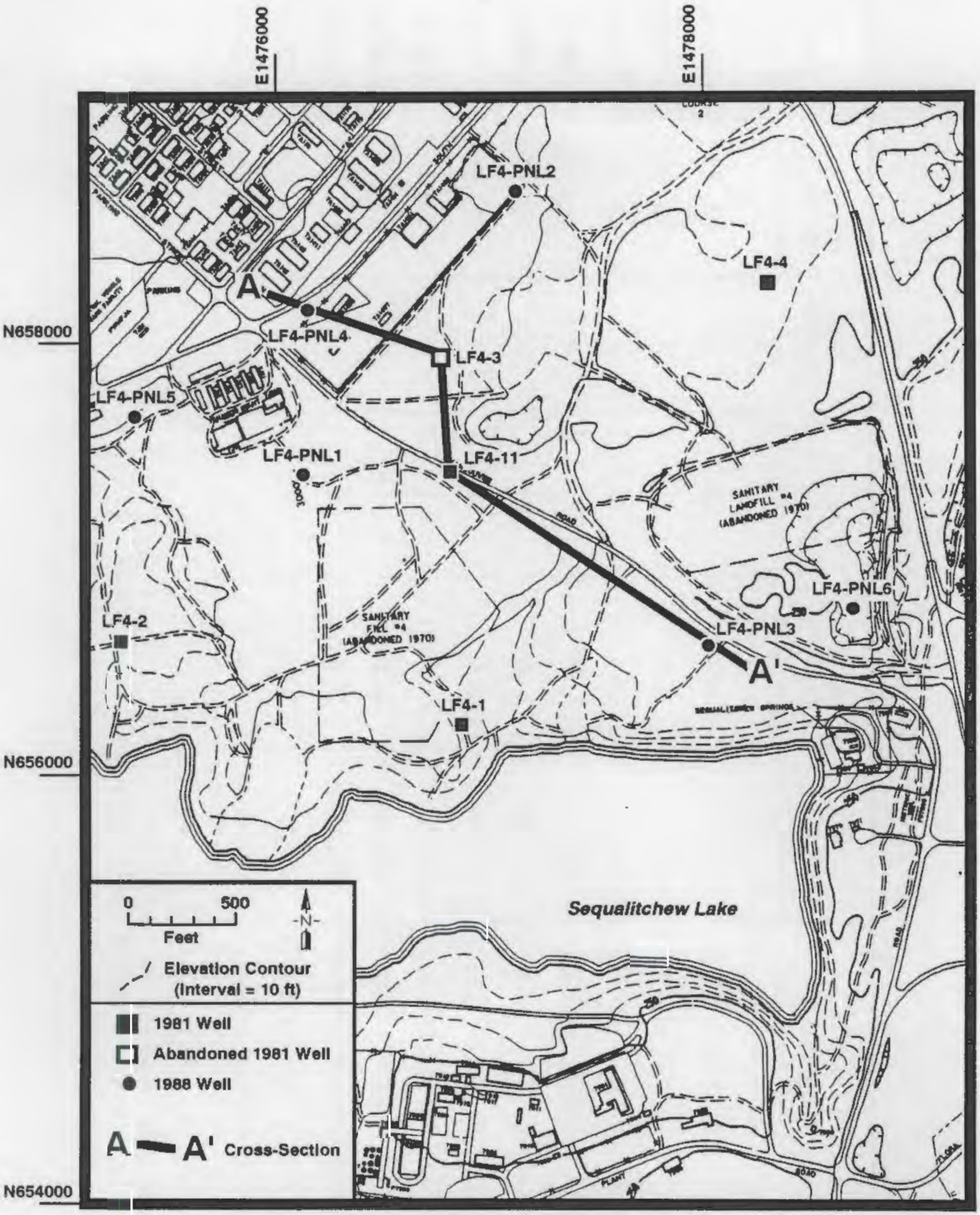


FIGURE 6.3. Location of Monitoring Wells Around Landfill 4

TABLE 6.1. Well Completion Data for Landfill 4

Well	Coordinates North, East (State Plane)	Casing Elevation, ft above MSL[a]	Drilled Depth, ft below land[b]	Depth to Water, ft below land[b]	Well Diameter, in.	Screened Interval, ft below land[c]	Date Completed
LF4-1	656276, 1476795	225.37	38.0	10	4	22 - 38	04/28/81
LF4-2	656697, 1475243	218.27	36.0	5	4	20 - 36	04/29/81
LF4-3[d]	657932, 1476792	238.79	60.0	26	4	42 - 58	04/30/81
LF4-4	658202, 1478294	235.41	98.0	27	4	39 - 55	05/01/81
LF4-11	657397, 1476814	234.05	44.0	19	4	30 - 46	05/12/81
LF4-PNL1	657439, 1476136	237.82	41.0	26.5	4	22 - 37	08/09/88
LF4-PNL2	658639, 1477139	240.48	40.0	29	2	23 - 38	08/09/88
LF4-PNL3	656576, 1477955	246.59	46.5	34.5	2	28 - 43	08/09/88
LF4-PNL4	658162, 1476174	235.72	39.0	26.5	4	23.5 - 33.5	10/05/88
LF4-PNL5	657661, 1475355	237.46	36.0	26.5	4	20.5 - 35.5	10/07/88
LF4-PNL6	656714, 1478619	232.19	30.0	20	4	15 - 30	10/12/88

(a) All elevations on the PVC casing are to the north rim.
(b) Measurements are to the nearest 0.5 ft.
(c) Measurements are rounded down to the nearest foot or 0.5 foot.
(d) This well is abandoned. This information pertains to the well prior to abandonment.

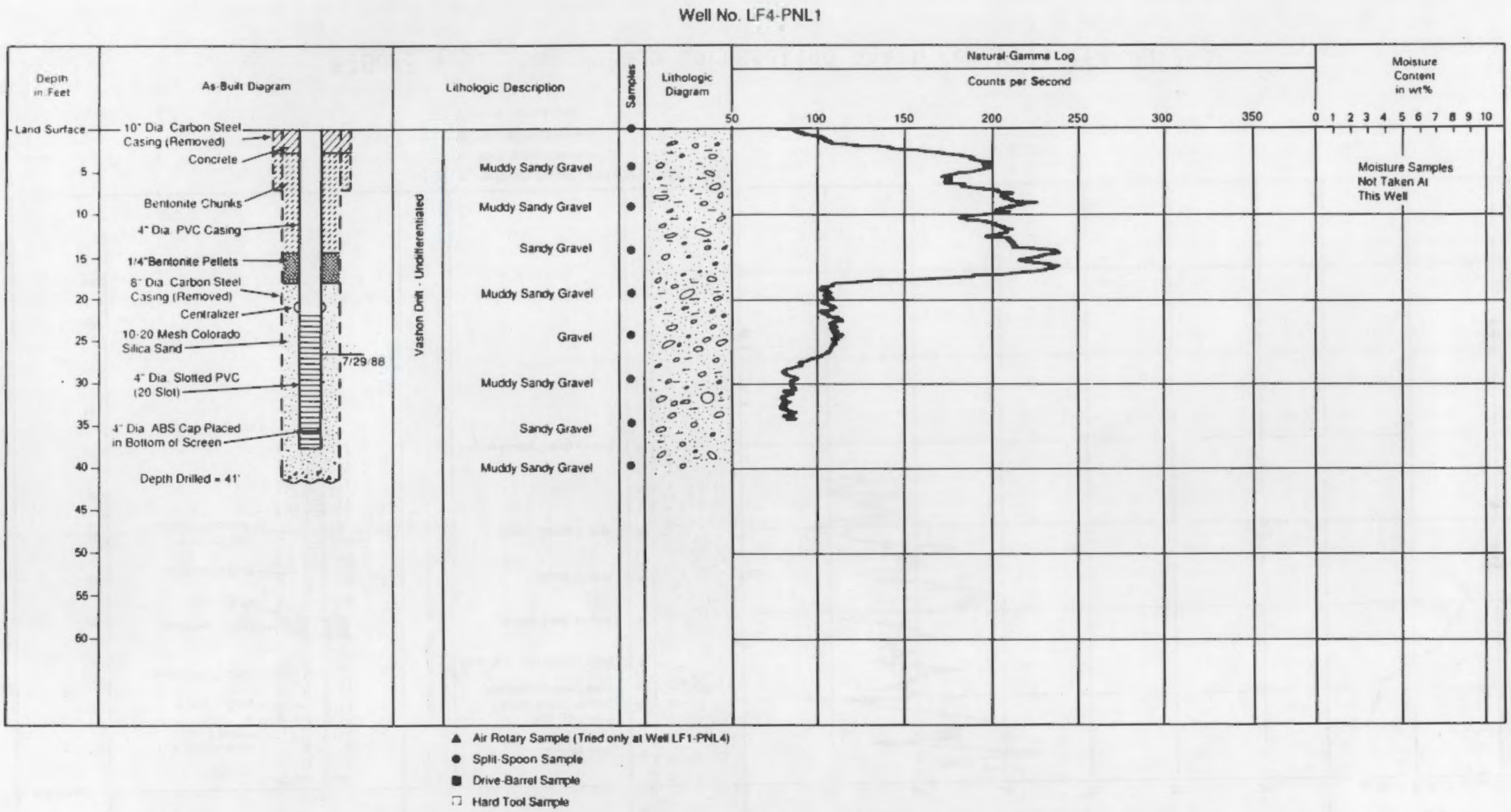


FIGURE 6.4. Subsurface Correlation Chart for Well LF4-PNL1

Well No. LF4-PNL2

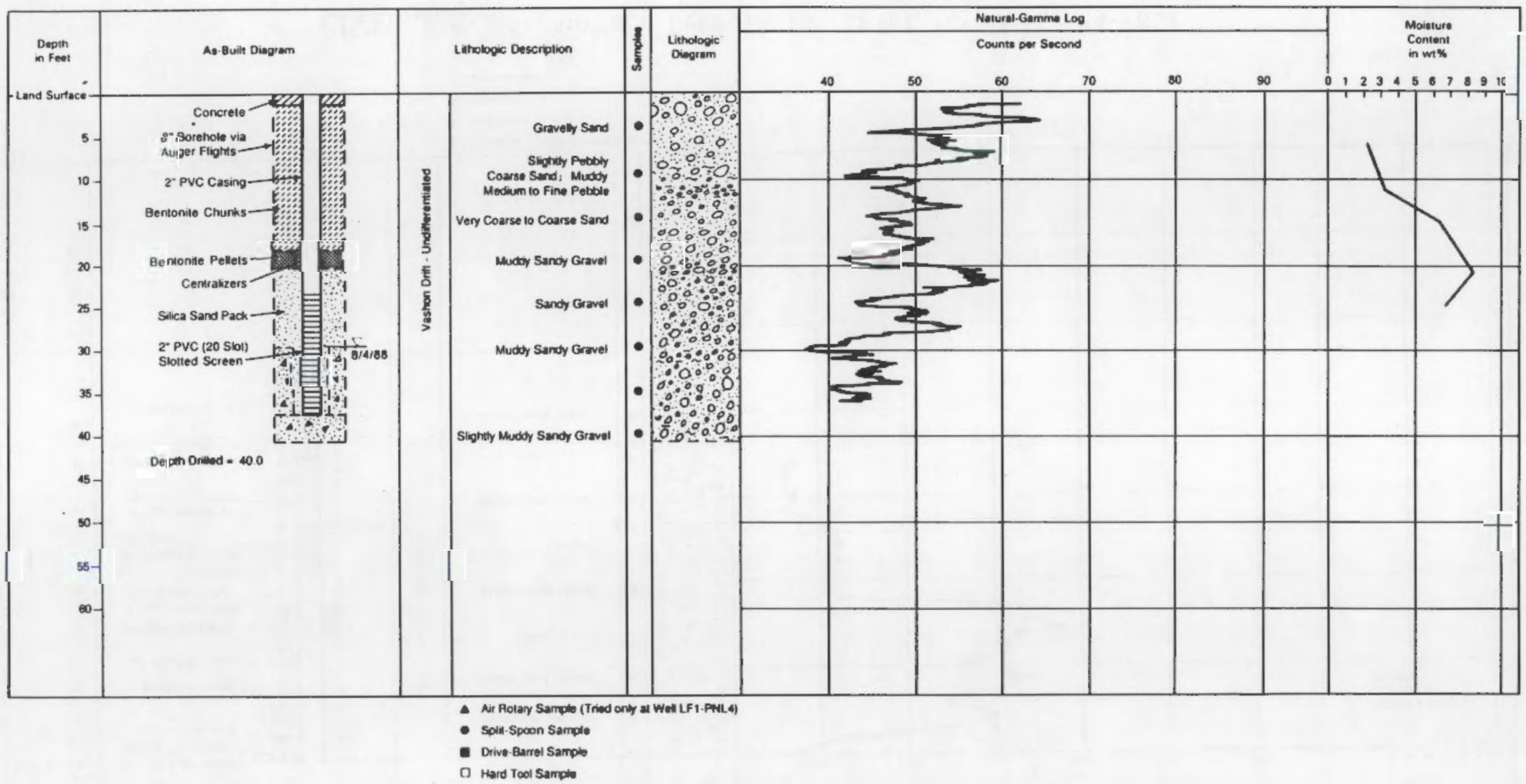


FIGURE 6.5. Subsurface Correlation Chart for Well LF4-PNL2

Well No. LF4-PNL3

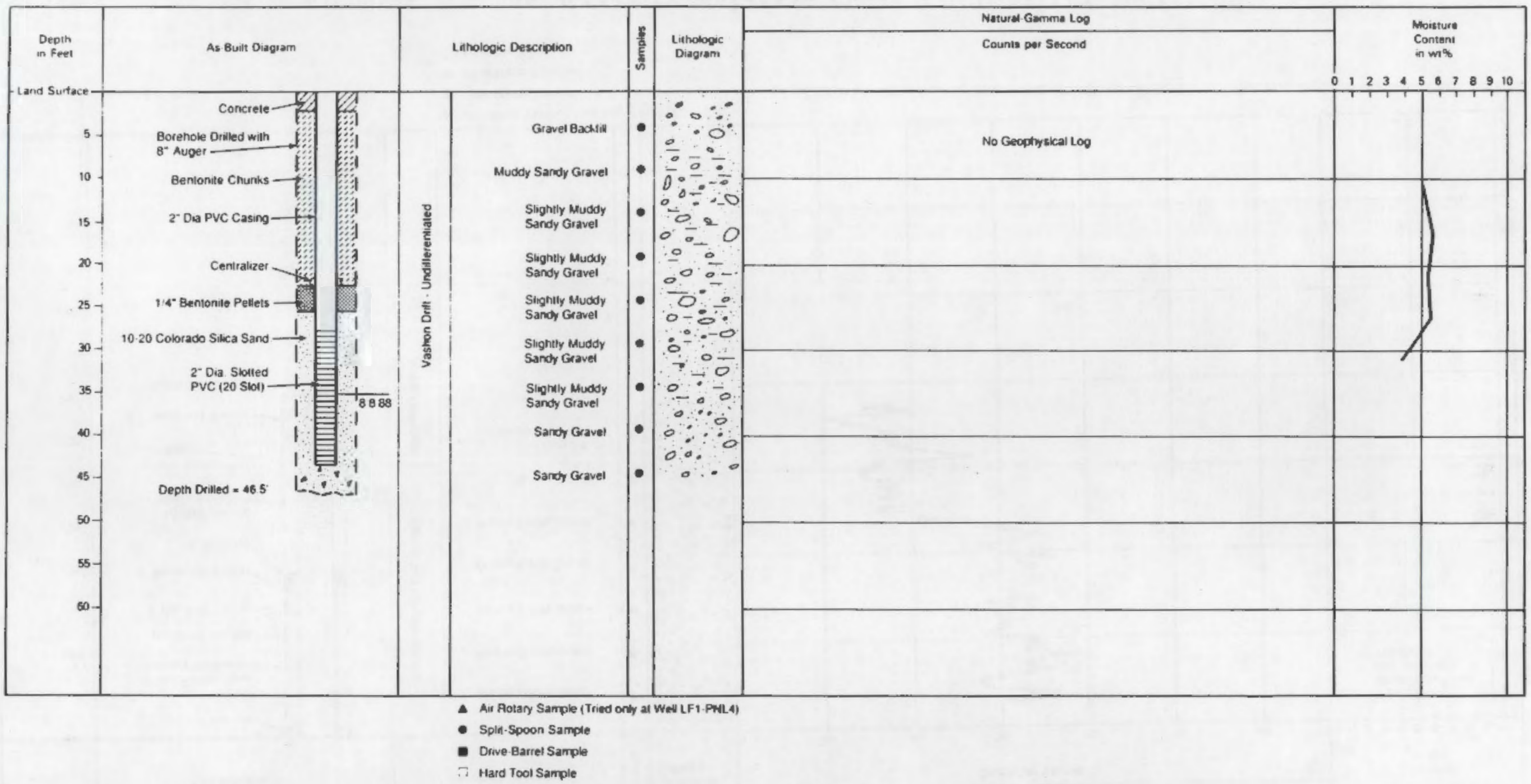


FIGURE 6.6. Subsurface Correlation Chart for Well LF4-PNL3

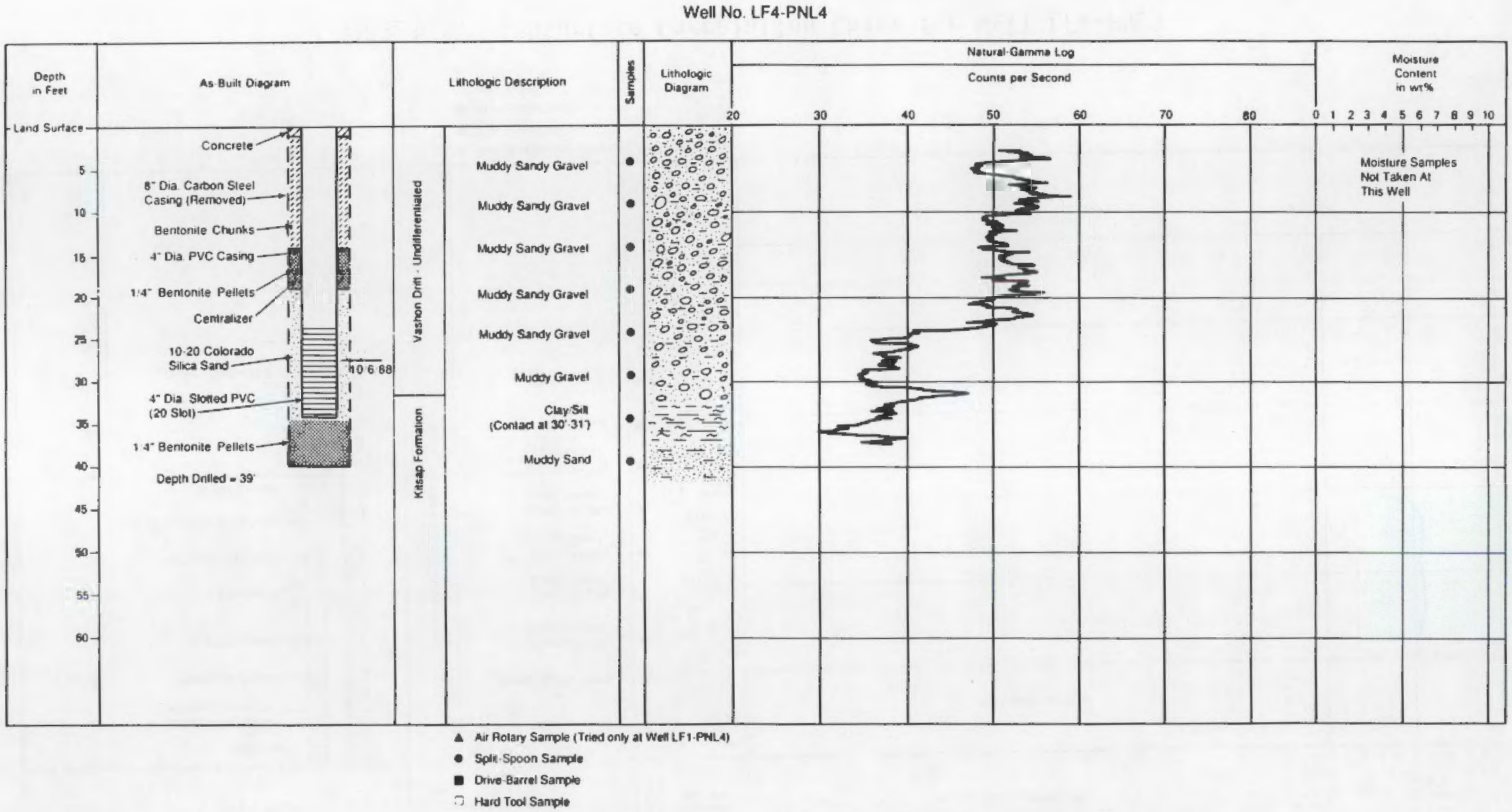


FIGURE 6.7. Subsurface Correlation Chart for Well LF4-PNL4

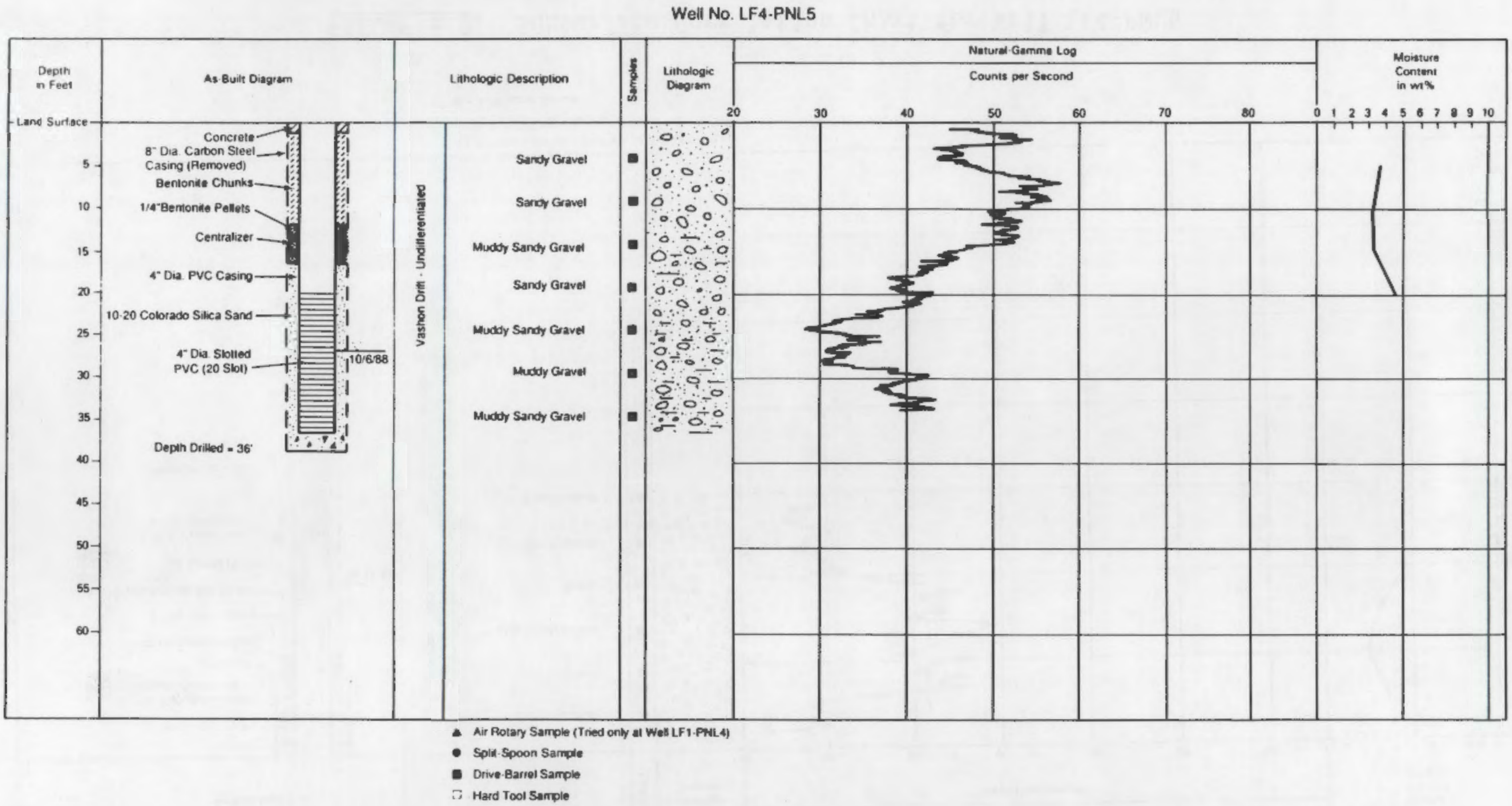


FIGURE 6.8. Subsurface Correlation Chart for Well LF4-PNL5

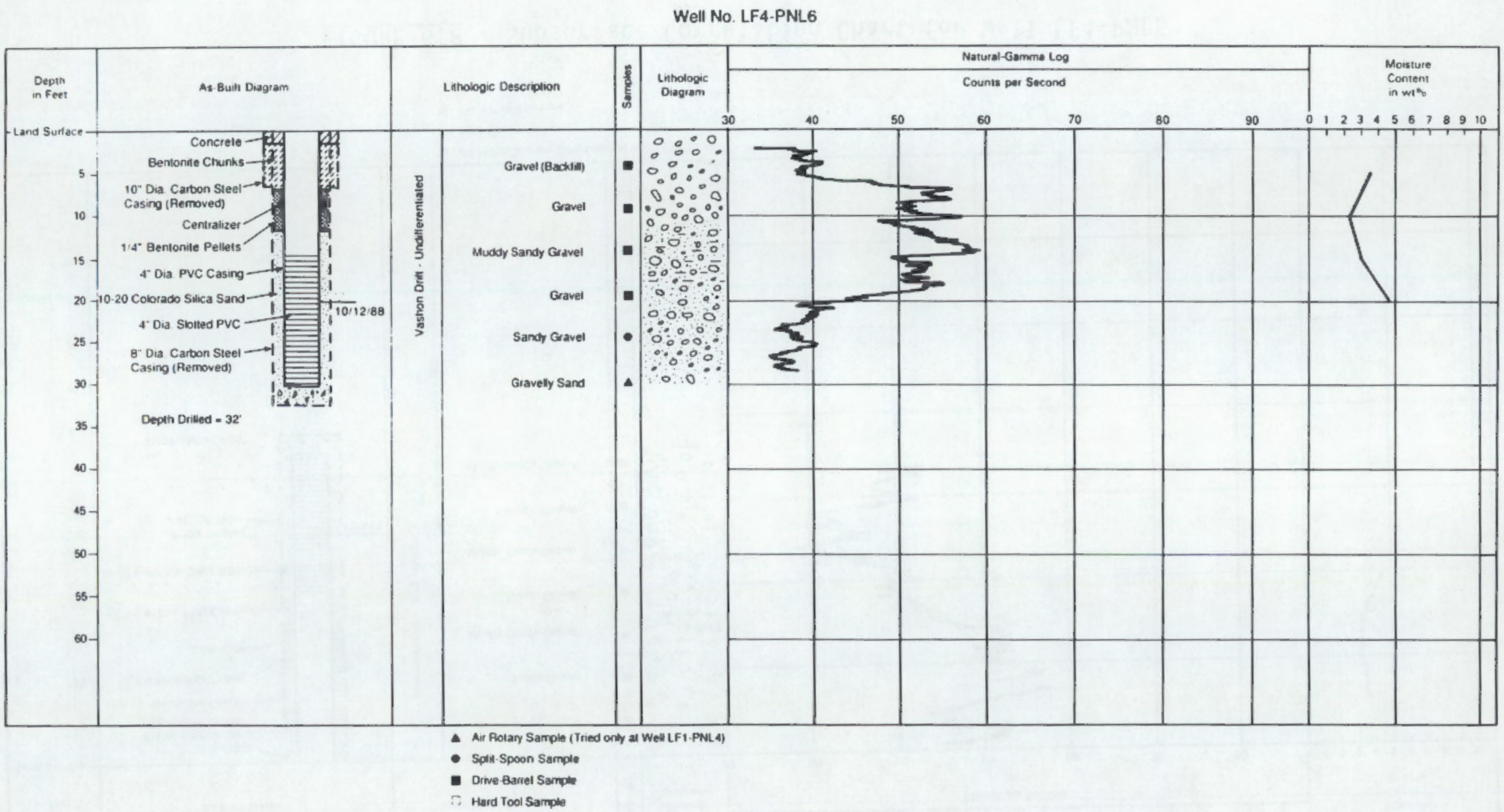


FIGURE 6.9. Subsurface Correlation Chart for Well LF4-PNL6

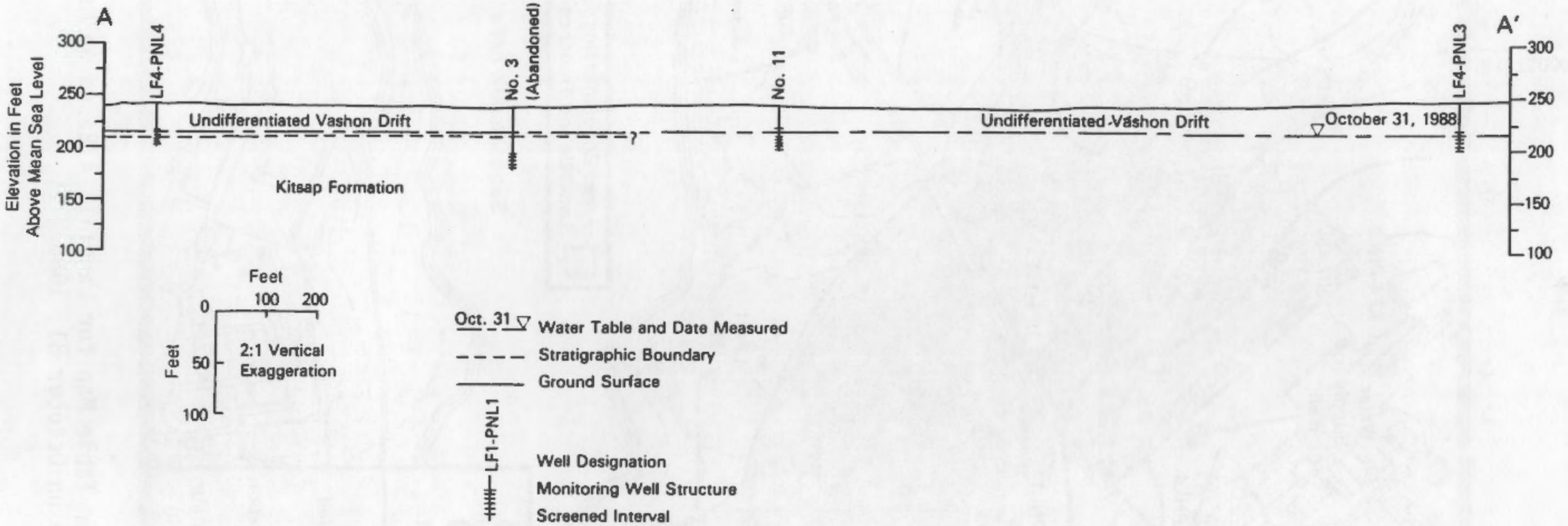


FIGURE 6.10. Generalized Geologic Cross Section Through Landfill 4

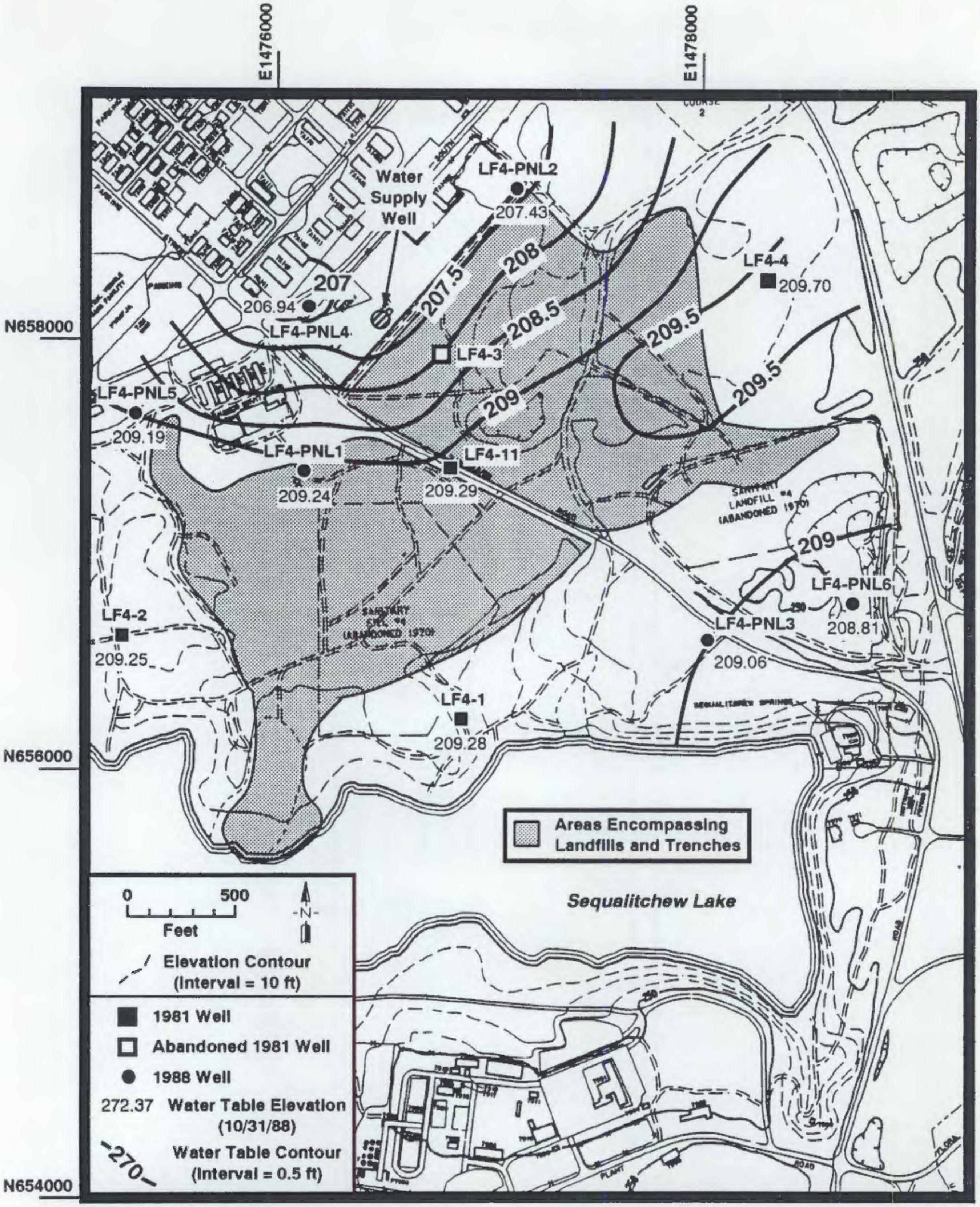


FIGURE 6.11. Water-Table Map for Landfill 4 Based on Measurements Made on October 31, 1988

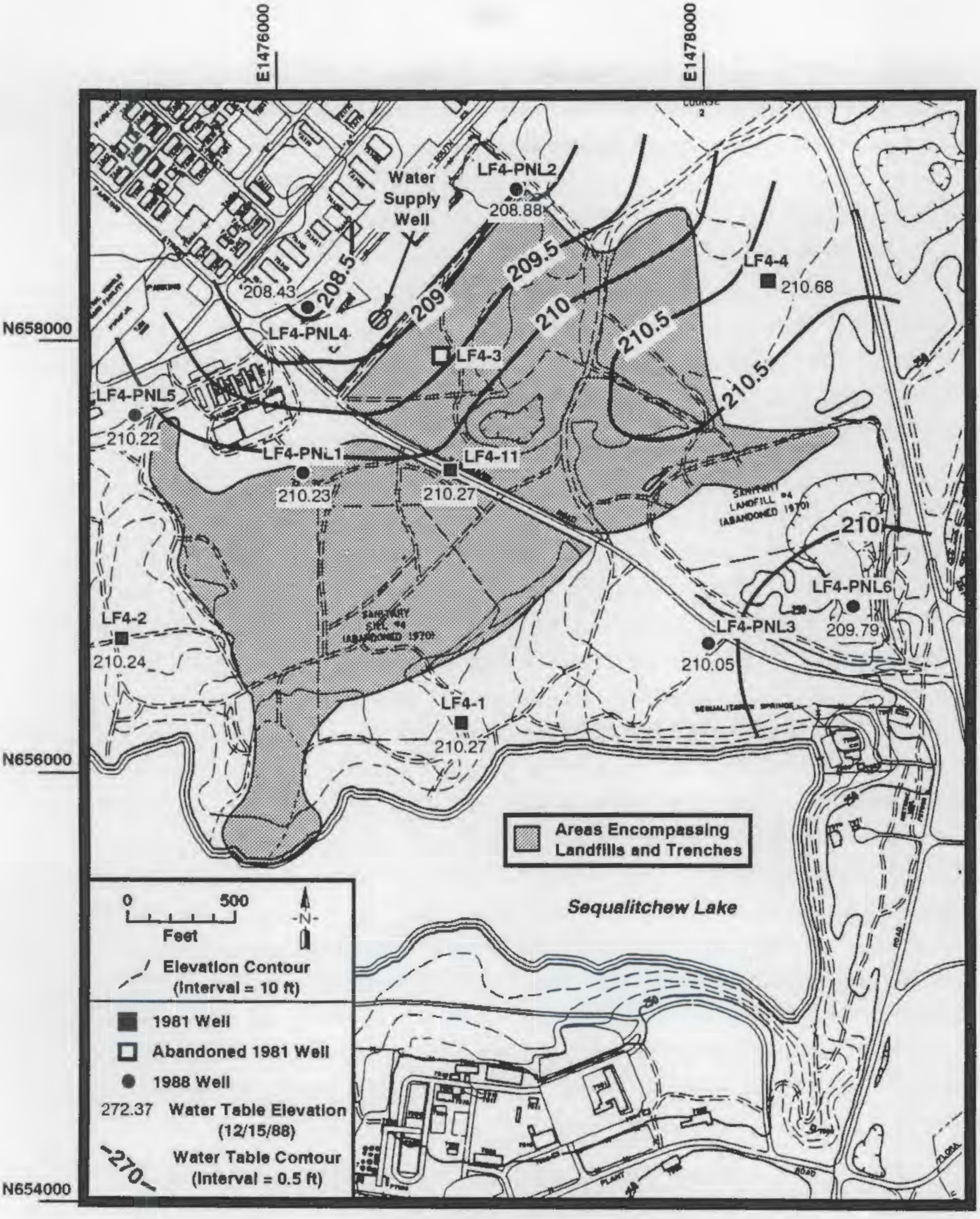


FIGURE 6.12. Water-Table Surface Beneath Landfill 4 as Interpreted from Water Levels Measured on December 15, 1988

hydraulically connected with the shallow ground-water system beneath Landfill 4, allowing the interchange of surface and ground-water. At times the lake may recharge the local ground-water system, while at other times it may act as a discharge area for local ground water, reversing the local ground-water gradient and creating a temporary ground-water divide, perhaps like that observed in the eastern portion of the landfill area (Figures 6.11 and 6.12). The lower ground-water level at well LF4-PNL4 may not only reflect the natural northerly dipping ground-water surface, but may also reflect the operation of a water supply well located approximately 400 ft to the east (Figures 6.11 and 6.12). The operational history of this water supply well during the time frame of this study has not been investigated.

Figure 6.13 illustrates the generalized ground-water flow directions and location of upgradient and downgradient wells, based on the October 31 and December 15, 1988, water-level measurements. Only one monitoring well, LF4-4, is interpreted to be hydraulically upgradient of Landfill 4. Wells LF4-1 and LF4-2 (located adjacent to Sequalitchew Lake) may be either upgradient or downgradient of the landfill depending on the relationship between the lake, the shallow aquifer, and the water-table configuration at the time. However, these two wells are expected to reflect the hydrochemistry of the lake more so than that of the aquifer directly underlying the landfill. The same generalizations also apply to wells LF4-PNL3 and LF4-PNL6, which are located over 600 ft southeast (just opposite of the general northwestern ground-water gradient) of the landfill boundary. Although these wells are shown to be downgradient of the landfill at the time of this study, it is expected that their hydrochemistry may be more indicative of the regional aquifer than of the ground water immediately beneath the landfill. The remaining monitoring wells (LF4-PNL1, LF4-PNL2, LF4-PNL4, LF4-PNL5, and LF4-11) are considered to be truly downgradient of the landfill and are expected to most accurately reflect the ground-water quality beneath Landfill 4.

Variations in ground-water levels, particularly those caused by surface water/ground-water interactions or by the operation of nearby water supply wells, could greatly affect the upgradient/downgradient status of monitoring

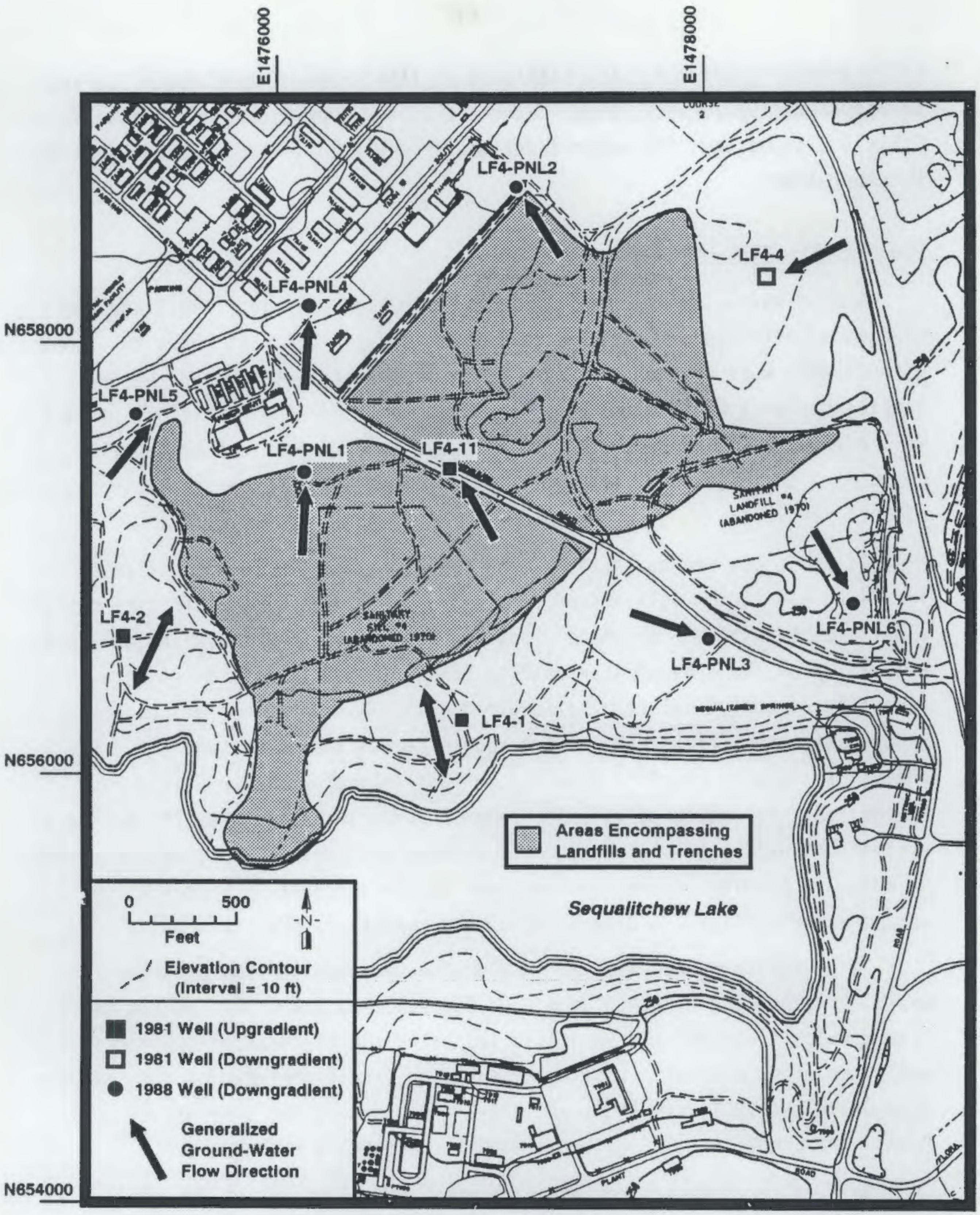


FIGURE 6.13. Generalized Ground-Water Flow Directions and Location of Upgradient and Downgradient Wells at Landfill 4

wells around Landfill 4. Over the 8-month time frame of this study (Spring to Winter of 1988), water levels have fluctuated over 2.5 ft in some wells. Table 6.2 summarizes the water-level measurements collected between April and December 1988.

6.4 GROUND-WATER QUALITY

Ground-water samples were collected from four existing (1981) and the six newly installed (1988) wells surrounding Landfill 4. At least two sampling events were conducted at each well. The representativeness of these samples varies according to the well development and purging history of each well before sample collection. Refer to Section 4.4 for further details concerning the objectives of each sampling event and the representativeness of each sample.

At least one representative (good to very good) sample was collected from each monitoring well around Landfill 4. However, a complete time equivalent set of analyses for these ground-water samples is not available. Thus, evaluation of the ground-water quality beneath Landfill 4 is based on a composite of analytical results acquired primarily in October and December 1988. These analytical results are summarized in Tables 6.3 and 6.4. The analytical reports received from the AM Test laboratory are provided in Appendix K. As indicated earlier, some of these analytical results may be an artifact of drilling, well construction, poor well development, and/or a lack of adequate purging before sampling, and may not accurately represent the ground-water quality. A discussion of the results is presented below.

Fecal coliform was detected in ground-water samples from at least two wells, LF4-PNL5 and LF4-PNL6, and from Sequalitchew Lake. One of the duplicate samples from well LF4-PNL4 also indicated the presence of coliform, while the other did not. Less-representative (and therefore suspect) samples from wells LF4-PNL1, LF4-PNL3, and LF4-2 also suggest the presence of coliform. Thus, coliform is believed to be a constituent of concern.

An unfiltered sample contained chromium in excess of the DWS (0.05 ppm) only in well LF4-PNL2 on one occasion. However, the filtered sample from this same well contained no detectable levels of chromium. This sample had

TABLE 6.2. Water-Level Summary for Wells Near Landfill 4

Well	6-in. Casing Elevation, ft above msl[a]	Measurement Date	Depth to Water, ft	Type of Measure	Head Elevation, ft above msl
Fort Lewis #1	224.69[b]	04/20/88	12.95	ST[c]	211.74
	224.69[b]	08/12/88	15.50	ST	209.19
	226.70	10/31/88	17.42	ET[d]	209.28
	226.70	12/15/88	16.43	ST	210.27
Fort Lewis #2	219.19[b]	04/20/88	7.57	ST	211.62
	219.19[b]	08/12/88	9.97	ST	209.22
	219.63	10/31/88	10.38	ET	209.25
	219.63	12/15/88	9.39	ST	210.24
Fort Lewis #3	238.79[b]	04/20/88	27.78	ST	211.01
	238.79[b]	08/12/88	30.29	ST	208.50
Fort Lewis #4	235.93[b]	04/20/88	23.12	ST	212.81
	235.93[b]	08/12/88	25.71	ST	210.22
	236.78	10/31/88	27.08	ET	209.70
	236.78	11/23/88	26.50	ST	210.28
	236.78	12/15/88	26.10	ST	210.68
Fort Lewis #11	234.79[b]	04/20/88	23.08	ST	211.71
	234.79[b]	08/12/88	25.58	ST	209.21
	235.21	10/31/88	25.92	ET	209.29
	235.21	12/15/88	24.94	ST	210.27
LF4-PNL1	238.72	08/12/88	29.45	ST	209.27
	238.72	10/31/88	29.48	ET	209.24
	238.72	12/15/88	28.49	ST	210.23
LF4-PNL2	240.85	08/12/88	32.08	ST	208.77
	240.85	10/31/88	33.42	ET	207.43
	240.85	12/15/88	31.97	ST	208.88
LF4-PNL3	247.18	08/12/88	38.24	ST	208.94
	247.18	10/31/88	38.12	ET	209.06
	247.18	12/14/88	37.12	ST	210.06
	247.18	12/15/88	37.13	ST	210.05
LF4-PNL4	236.68	10/31/88	29.74	ET	206.94
	236.68	12/15/88	28.25	ST	208.43
LF4-PNL5	238.30	10/31/88	29.11	ET	209.19
	238.30	12/15/88	28.08	ST	210.22
LF4-PNL6	232.56	10/31/88	23.75	ET	208.81
	232.56	11/23/88	23.07	ST	209.49
	232.56	12/15/88	22.77	ST	209.79

(a) Calculated from the 1989 survey of the brass cap installed in each well pad and the measured casing stickup. Variations in the casing elevation can be attributed to remedial actions performed on the 1981 wells as well as variations in the surveying/measurement of casing stickup.
(b) From the 1982 survey.
(c) ST = steel tape.
(d) ET = electrical tape.

TABLE 6.3. Analytical Results from Fort Lewis Ground-Water Wells at Landfill 4

Well	Date Sampled	Sample Representativeness	pH	Conductivity, µmhos/cm	Coliform, MPN/100mL[(a)]	Grease and Oil, mg/L	TOX, µg/L as Cl	Gross Beta, pCi/L	Radium, pCi/L	Gross Alpha, pCi/L	TDS, mg/L
LF4-PNL1	08/24/88	Poor	6.25	390	1600	<1.0	18	<2	<1	<1	295
LF4-PNL2	09/08/88	Very good	6.58	440	<2.5	<1.2	<10	<1	<1	<1	296
LF4-PNL3	08/24/88	Poor	6.20	138	17	8.4	44	<2	<1	<1	524
LF4-PNL3	12/14/88	Very good	6.60	131	<1.8	8.6[(b)]	NA[(c)]	NA	NA	NA	53
LF4-PNL4	10/30/88	Very good	6.29	260	<1.8	<1	94	<2	<2	<1	239
Duplicate	10/30/88	Very good	6.35	270	4.5	5.4	<10	<2	<2	<1	288
LF4-PNL5	10/30/88	Very good	6.67	92	23	3.2	102	<2	<2	<1	150
LF4-PNL6	10/07/88	Very good	6.88	124	49	4.2	202	<2	<2	<1	275
LF4-1	10/30/88	Very good	6.53	NA	NA	NA	NA	NA	NA	NA	86
Duplicate	10/30/88	Very good	6.35	NA	NA	NA	NA	NA	NA	NA	67
LF4-2	10/30/88	Very good	6.59	NA	NA	NA	NA	NA	NA	NA	181
LF4-2	12/14/88	Good	6.89	186	13	21.6[(b)]	NA	NA	NA	NA	135
LF4-4	10/30/88	Very good	6.74	NA	NA	NA	NA	NA	NA	NA	62
LF4-11	10/30/88	Very good	6.21	NA	NA	NA	NA	NA	NA	NA	101
Sequalitchew Lake	12/15/88	NA	7.30	122	17	11.8[(b)]	NA	NA	NA	NA	53

Well	Date Sampled	TOC, mg/L	Cl^-, mg/L	Phenol, mg/L	NO_3^-, mg/L	F^-, mg/L	$SO_4^=$, mg/L	CN^-, mg/L	Aromatic Compounds	Herbicides	Pesticides and PCBs	Acid-Base-Neutral/Organics
LF4-PNL1	08/24/88	3.01	15.60	<0.008	<0.10	<0.10	11.2	<0.006	ND[(d)]	ND	ND	NA
LF4-PNL2	09/08/88	2.28	4.14	<0.008	<0.01	<0.01	26.4	<0.006	ND	ND	ND	NA
LF4-PNL3	08/24/88	1.14	4.10	<0.016	0.76	<0.10	10.9	<0.006	ND	ND	ND	NA
LF4-PNL3	12/14/88	0.44	3.50	NA	3.7	<0.20	10.6	NA	NA	NA	NA	ND
LF4-PNL4	10/30/88	1.23	3.59	<0.008	1.34	<0.01	20.5	<0.006	NA	ND	ND	NA
Duplicate	10/30/88	1.26	2.32	<0.008	1.38	<0.01	20.9	<0.006	NA	ND	ND	NA
LF4-PNL5	10/30/88	0.72	1.41	<0.008	0.416	<0.01	7.2	<0.006	NA	ND	ND	NA
LF4-PNL6	10/07/88	0.69	2.92	<0.008	0.377	<0.01	6.9	<0.006	NA	ND	ND	NA
LF4-1	10/30/88	NA	3.8	NA	0.2	<0.02	9.3	NA	NA	NA	NA	NA
Duplicate	10/30/88	NA	3.8	NA	0.1	<0.02	9.8	NA	NA	NA	NA	NA
LF4-2	10/30/88	NA	4.8	NA	<0.1	<0.02	16.4	NA	NA	NA	NA	NA
LF4-2	12/14/88	1.28	4.4	NA	2.0	<0.02	14.4	NA	NA	NA	NA	ND
LF4-4	10/30/88	NA	3.3	NA	1.6	<0.02	8.7	NA	NA	NA	NA	NA
LF4-11	10/30/88	NA	3.6	NA	<0.1	<0.02	19.8	NA	NA	NA	NA	NA
Sequalitchew Lake	12/15/88	4.07	4.3	NA	1.7	<0.02	6.7	NA	NA	NA	NA	ND

TABLE 6.3. (contd)

Well	Date Sampled	Fe, ppm	Ba, ppm	Se, ppm	Cd, ppm	Mn, ppm	Ca, ppm	Ag, ppm	Na, ppm	Cr, ppm	Pb, ppm	As, ppm	Hg, ppm
LF4-PNL1	08/24/88	16.0	0.130	<0.002	<0.002	3.600	41.0	<0.01	11.0	0.026	<0.02	<0.002	<0.0002
LF4-PNL2	09/08/88	15.0	0.106	<0.002	<0.002	4.300	54.0	<0.010	10.4	0.20	<0.02	<0.002	<0.0002
Filtered		0.8	<0.01	NA	<0.01	<0.01	43.4	<0.01	10.5	<0.01	<0.1	NA	NA
LF4-PNL3	08/24/88	29.0	0.360	<0.002	<0.002	1.290	16.0	<0.01	6.4	0.037	<0.02	<0.002	<0.0002
LF4-PNL3	12/14/88	0.09	<0.01	<0.012	<0.0006	0.02	9.7	NA	13.7	<0.01	<0.006	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.02	12.8	NA	7.5	<0.01	<0.005	<0.010	NA
LF4-PNL4	10/30/88	0.22	0.011	<0.002	<0.0005	0.027	32.0	0.0008	8.1	0.013	<0.001	<0.002	<0.0002
Duplicate	10/30/88	0.073	0.010	<0.002	<0.0005	0.020	32.0	0.0016	8.1	0.012	<0.001	<0.002	<0.0002
LF4-PNL5	10/30/88	7.1	0.098	<0.002	0.001	0.333	10.5	0.0014	3.9	0.012	0.004	0.006	<0.0002
LF4-PNL6	10/07/88	0.17	0.006	<0.002	<0.0005	0.007	6.0	0.0016	6.0	<0.006	<0.001	<0.002	<0.0002
LF4-1	10/30/88	0.032	0.002	<0.005	0.0003	0.005	10.3	NA	4.9	<0.02	<0.005	<0.010	<0.0003
Duplicate	10/30/88	<0.005	0.019	<0.005	<0.0001	0.002	10.1	NA	5.0	<0.02	<0.005	<0.010	<0.0003
LF4-2	10/30/88	1.69	0.008	<0.005	<0.0001	2.88	29.0	NA	9.0	<0.02	<0.005	<0.010	<0.0003
LF4-2	12/14/88	1.72	<0.01	<0.012	<0.0006	1.1	14.7	NA	6.5	<0.01	0.059	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.45	19.8	NA	6.8	<0.01	<0.005	<0.010	NA
LF4-4	10/30/88	0.006	0.002	<0.005	<0.0001	<0.002	10.9	NA	5.4	<0.02	<0.005	<0.010	<0.0003
LF4-11	10/30/88	2.54	0.011	<0.005	<0.0001	1.34	20.1	NA	6.2	<0.02	<0.005	<0.010	<0.0003
Sequalitchew Lake	12/15/88	<0.1	<0.01	<0.012	<0.0006	0.02	7.1	NA	6.0	<0.01	<0.006	<0.012	<0.0008
Filtered		<0.1	<0.01	NA	<0.0005	0.02	9.8	NA	8.3	<0.01	<0.005	<0.010	NA

(a) MPN = most probable number.
(b) Analytical result is suspect. Blank sample contained 8.2 mg/L oil and grease.
(c) NA = not analyzed.
(d) ND = not detected.

TABLE 6.4. Analytical Results for Volatile Organic Compounds at Landfill 4

Well	Sample Representativeness	Date Sampled	Laboratory	Trans-1,2 DCE, ppb	Cis-1,2 DCE, ppb	TCE, ppb	Benzene, ppb	Carbon Tetrachloride, ppb
LF4-PNL1	poor	08/24/88	AM Test	0.9	NA[a]	13.9	<1.0	<0.6
LF4-PNL1	good	10/06/88	PNL	1.0	9.0	17.00	1.0	0.31
LF4-PNL1	good	12/12/88	PNL	2.4	11.0	20.0	0.9	<0.01
LF4-PNL2	very good	09/08/88	AM Test	<2	NA	5.7	<1.0	<0.6
LF4-PNL2	good	10/06/88	PNL	<0.5	<1.0	0.02	<0.5	<0.01
LF4-PNL2	good	12/15/88	PNL	<0.5	<0.2	0.25	<0.9	<0.01
LF4-PNL3	poor	08/24/88	AM Test	<0.6	NA	13.0	<1.0	<0.6
LF4-PNL3	poor	10/06/88	PNL	<0.5	<1.0	22.0	<0.5	<0.01
LF4-PNL3	very good	12/14/88	PNL	<0.5	2.7	32.0	<0.5	<0.01
LF4-PNL4	very good	10/06/88	PNL	<0.5	<1.0	19.0	<0.5	<0.01
LF4-PNL4[b]	very good	10/30/88	AM Test	0.8	NA	22.0	NA	<0.7
Duplicate	very good	10/30/88	AM Test	0.8	NA	19.0	NA	<0.7
LF4-PNL4	good	12/15/88	PNL	1.5	5.3	21.0	<0.5	0.04
LF4-PNL5	good	10/06/88	PNL	<0.5	<1.0	0.02	<0.5	<0.01
LF4-PNL5	very good	10/30/88	AM Test	<0.7	NA	<0.7	NA	<0.7
LF4-PNL5	good	12/15/88	PNL	<0.5	<0.2	<0.03	<0.5	0.41
LF4-PNL6	very good	10/30/88	AM Test	<0.7	NA	<0.7	NA	<0.7
LF4-PNL6	good	12/15/88	PNL	<0.5	<0.2	<0.03	<0.5	<0.01
LF4-1	poor	10/06/88	PNL	<0.5	<1.0	1.8	<0.5	<0.01
LF4-1	good	12/15/88	PNL	<0.5	<0.2	2.4	<0.5	<0.01
LF4-2	poor	10/06/88	PNL	<0.5	<1.0	0.56	<0.5	<0.01
LF4-2	good	12/14/88	PNL	<0.5	0.9	0.32	<0.5	<0.01
LF4-4	poor	10/06/88	PNL	<0.5	<1.0	<0.02	<0.5	<0.01
LF4-4	good	12/15/88	PNL	<0.5	<0.2	<0.03	<0.5	<0.01
LF4-11	poor	10/06/88	PNL	<0.5	<1.0	5.0	<0.5	<0.01
LF4-11	good	12/15/88	PNL	1.4	6.8	19.0	0.1	0.03
Sequalitchew Lake	NA	12/15/88	PNL	<0.5	<1.0	<0.03	<0.5	<0.01

(a) NA = not analyzed.
(b) This sample also contained 26 ppb of methylene chloride (believed to be a laboratory contaminant).

been collected immediately after well development and probably contained a slight amount of suspended particulates. Thus, chromium is not believed to be a constituent of concern.

Lead [in concentrations exceeding the DWS (0.05 ppm)] was detected in the unfiltered portion of a less-representative sample (unpurged) from well LF4-2. However, the filtered sample from the same well contained no detectable level of lead. Lead is not believed to be a constituent of concern.

Iron and manganese concentrations exceeded secondary DWS (0.3 and 0.05 ppm, respectively) in ground-water samples from four wells (LF4-2, LF4-11, LF4-PNL2, and LF4-PNL5). In all but two cases (iron in well LF4-PNL2 and manganese in well LF4-2), the concentrations decreased below the secondary DWS when the samples were filtered. Because of the lack of data to the contrary, iron and manganese are assumed to be constituents of concern at Landfill 4. However, iron and manganese are secondary drinking water parameters.

Oil and grease were detected in samples from at least two wells (LF4-PNL5 and LF4-PNL6). One of the duplicate samples from well LF4-PNL4 also indicated the presence of oil and grease, while the other did not. Other samples have also indicated the presence of oil and grease; however, the values from the December sampling event are suspect because all samples submitted to the laboratory were found to contain oil and grease, including the blank sample submitted to the laboratory at the same time. These results indicate that oil and grease may be present in the aquifer beneath Landfill 4 and thus are constituents of concern.

Cis-1,2-dichloroethylene and/or TCE were identified in concentrations above MCLs (5 ppb) in ground-water samples from wells LF4-PNL1, -PNL2, -PNL3, -PNL4, and LF4-11 (Table 6.4). The results from wells LF4-PNL1 and LF4-11 are considered less representative because the wells were not purged before sampling. Other less-representative samples from wells LF4-1 and LF4-2 also suggest the presence of these two constituents. Figure 6.14 illustrates the distribution of TCE concentration ranges for the good to very good ground-water samples collected between September and December 1988. Analytical results from wells LF4-PNL1, LF4-PNL4, and LF4-11 also indicate the presence of trans-1,1-dichloroethylene, carbon tetrachloride, and benzene (except well LF4-PNL4). Volatile organic compounds are considered the principal constituents of concern.

No phenols, cyanide, aromatic compounds, herbicides, pesticides, or PCBs were detected.

6.5 EVALUATION OF THE MONITORING NETWORK

Ten ground-water monitoring wells (four 1981 wells and six 1988 wells) are located in the vicinity of Landfill 4. Water-level data from these wells suggest that at least one of these wells (LF4-4) is located hydraulically upgradient of the landfill. Five wells (LF4-11, LF4-PNL1, LF4-PNL2,

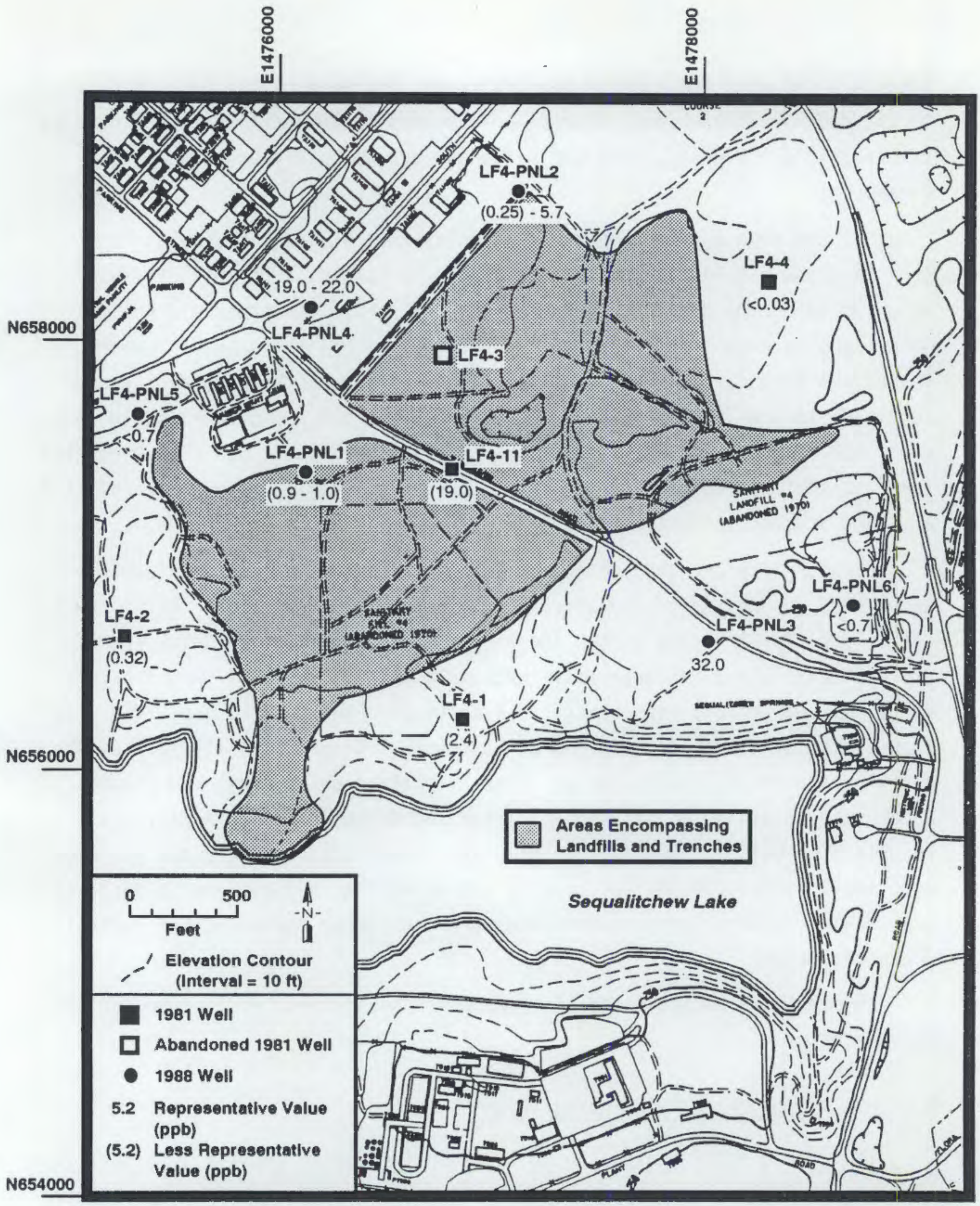


FIGURE 6.14. TCE Concentration Ranges Based on Analyses of September Through December Sampling Events

LF4-PNL4, and LF4-PNL5) are interpreted to be either directly or indirectly downgradient of the landfill. The four remaining wells (LF4-1, LF4-2, LF4-PNL3, and LF4-PNL6) are considered to be located in areas that at times could be either upgradient or downgradient of the landfill, depending on the hydraulic relationship between Sequalitchew Lake, the shallow aquifer, and the water-table configuration. Variations in the ground-water levels, particularly those influenced by surface water/ground-water interactions and the operation of water supply wells, could greatly affect the upgradient/downgradient status of these monitoring wells.

Ground-water samples collected from each of these wells varied in representativeness according to the well development and purging history of each well before sample collection. Although it appears that the existing 1981 wells were constructed of glued PVC sections, no analytical results have suggested the presence of organic compounds (Tetrahydrofuran, Methyl Ethyl Ketone, and Cyclohexanone) typically used in this type of glue. All 10 monitoring wells are now considered fully developed and capable of producing representative samples.

The limited analytical results collected to date suggest that coliform, oil and grease, volatile organic compounds (principally TCE and cis-1,2-DCE), and perhaps some metals (iron and manganese) are the chemical constituents of primary interest. A comparison of the upgradient and downgradient wells suggests that the landfill (or perhaps some other nearby source) may have affected the hydrochemistry of the uppermost aquifer. Further investigation is needed to determine the sources and extent of the impact that Landfill 4 may have had on the local ground-water system.

LF4-PM14, and LF4-PM34 are interpreted to be either directly or indirectly downgradient of the landfill. The four remaining wells (LF4-1, LF4-2, LF4-PM12, and LF4-PM10) are considered to be located in areas that at times could be either upgradient or downgradient of the landfill, depending on the hydraulic relationship between Spradlin-Mew Lake, the shallow aquifer, and the water-table configuration. Variations in the ground-water levels, particularly those influenced by surface-water/ground-water interactions and the operation of water supply wells, could greatly affect the upgradient/downgradient status of these monitoring wells.

Ground-water samples collected from each of these wells varied in representativeness according to the well development and purging history of each well before sample collection. Although it appears that the existing IRP wells were constructed of glued PVC sections, no analytical results have suggested the presence of organic compounds (tetrahydrofuran, methyl ethyl ketone, and cyclohexanone) typically used in this type of glue. All 10 monitoring wells are now considered fully developed and capable of producing representative samples.

The limited analytical results collected to date suggest that coliform, oil and grease, volatile organic compounds (principally TCE and cis-1,2-DCE), and perhaps some metals (iron and manganese) are the chemical constituents of primary interest. A comparison of the upgradient and downgradient wells suggests that the landfill (or perhaps some other nearby source) may have affected the hydrochemistry of the uppermost aquifer. Further investigation is needed to determine the sources and extent of the impact that Landfill 4 may have had on the local ground-water system.

7.0 CONCLUSIONS

Several conclusions were drawn from the results of this study, and each of these is discussed below.

7.1 OVERALL SITE INVESTIGATION

- No records are available on the landfill histories and waste inventories, and no employees in the DEH at the Fort had any first-hand knowledge nor could they identify anyone with first-hand knowledge of the landfill operations.
- Aerial photograph interpretation and field reconnaissance proved useful in locating the general boundaries of the landfills.
- Surface-based geophysical-sensing methods of the type used in this investigation proved useful in locating the boundaries of the landfills where aerial photograph interpretation and field reconnaissance results were uncertain. These methods were successful in locating both large trench-type landfill operations and some localized open-pit dumps.
- The drive-barrel method of cable-tool drilling proved to be more efficient than either hollow-stem auger drilling or the hard-tool method of cable-tool drilling.
- The 4-in. PVC-cased wells proved to be superior to the 2-in. wells, primarily because of their ease of development.
- The ground-water monitoring systems installed at each landfill meet the requirements of 40 CFR 265, Subpart F; WAC 173-303; and WAC 173-160. Both of these monitoring systems are considered acceptable for detecting and evaluating the impacts of the inactive landfills on the ground water and adjacent lands. Thus, the goal of this investigation was achieved.

7.2 STATUS OF LANDFILL 1

- The landfill operation included trench disposal of unknown waste (possibly domestic garbage) and surface dumping of construction rubble (sand and gravel, broken concrete, broken asphalt, etc.).
- Isolated open-pit dumps, burn pits, and surface dumping have also occurred at or near this landfill.
- The boundaries of the landfill extend farther to the north than previously recorded, and an area of isolated open-pit dumping and burning extends to the west of the landfill proper.
- The uppermost aquifer beneath this landfill occurs in the Vashon Drift Formation at a depth of approximately 20 to 40 ft. The bottom of the aquifer is considered to be the top of a clay/silt layer at a depth of approximately 70 ft. Using the limited water-level data available for this site, ground-water flow appears to be to the east and northeast.
- Four new (1988) monitoring wells and four existing (1984) monitoring wells are located around the site. Three monitoring wells are located upgradient of both the open-pit dumping/burning areas and the landfill. The remaining five wells are located either directly or indirectly downgradient of these waste sites. Variations in the water levels, particularly those influenced by the ground-water mound near well 84-CD-LF-2, can alter the downgradient status of these monitoring wells.
- The representativeness of ground-water samples collected during this study varied according to the development and purging history of the well before sample collection. Thus, much of the analytical data must be considered preliminary and used only for indication purposes.
- Examination of the inorganic results from the upgradient wells versus the downgradient wells suggests that the landfill may have influenced the ground-water chemistry downgradient of the site.

- Nitrate and volatile organic compounds (principally TCE and DCE) appear to be the two chemical constituents of primary interest. Nitrate exceeded the DWS in wells 89-CD-LF-1, -2, and -4, while TCE exceeded the MCLs in wells 84-CD-LF-3 and -LF-4.

- Although coliform, chromium, mercury, and oil and grease were detected above DWS in some of these ground-water wells, these samples were not considered to accurately represent the ground-water quality. Thus, none of these constituents is believed to be of concern.

- Wells LF1-PNL1, -PNL2, and -PNL4 were extensively developed and produced representative samples. Well 84-CD-LF-1, -LF-2, -LF-3, and -LF-4 were not developed as part of this study but should produce representative samples after a good, extensive purging is performed on each well. Well LF1-PNL3 produces only poor (unrepresentative) samples and should be used only for water-level measurements.

7.3 STATUS OF LANDFILL 4

- Landfill operations included at least four areas of trench disposal and several areas of surface dumping. Waste materials disposed to the trenches are believed to be domestic garbage (glass, tin cans, rubber goods, paper and wood products, automobile parts, etc.). Surface dumping consisted of asphalt and concrete blocks, construction rubble, tree stumps, at least one truck body, household appliances, etc.

- Isolated open-pit dumps and surface dumping have also occurred in areas surrounding the landfill. Some of these dumps may have included petroleum products, as well as trash, automobile parts, and yard debris.

- The boundaries of the landfill area extend farther to the north, east, and west than previously recorded, and perhaps not as far south as previously reported.

- The uppermost aquifer beneath this landfill occurs in the Vashon Drift Formation at a depth of approximately 10 to 40 ft. The bottom of the aquifer is considered to be the top of the clay/silt of the Kitsap Formation, which lies at a depth between 26 ft to over 45 ft. Ground-water flow is primarily to the north-northwest, under the influence of a fairly flat gradient.

- One monitoring well (LF4-4) is interpreted to be upgradient of the landfill, and five wells (LF4-11, LF4-PNL1, LF4-PNL2, LF4-PNL4 and LF4-PNL5) are interpreted to be either directly or indirectly downgradient of the landfill. Four other wells are located in areas that at times may be upgradient while at other times downgradient, depending on the hydraulic relationship between Sequalitchew Lake, the aquifer, and the water-table configuration.

- The representativeness of ground-water samples collected during this study varied according to the development and purging history of the well before sample collection. Therefore, the analytical results from some samples must be considered tentative and used for indication purposes only.

- The limited analytical results collected to date suggest that coliform, oil and grease, volatile organic compounds (principally TCE and cis-1,2-DCE) and perhaps some metals (iron and manganese) are the principal chemical constituents of concern at this site.

- Fecal coliform exceeded the DWS in well LF4-PNL2.

- Iron and manganese exceeded the secondary DWS in wells LF4-2, LF4-11, LF4-PNL2, and LF4-PNL5.

- Oil and grease were detected in wells LF4-PNL5 and LF4-PNL6, and perhaps LF4-PNL4.

- Cis-1,2-DCE and TCE exceeded the MCLs in wells LF4-PNL1, -PNL2, -PNL3, -PNL4, and LF4-11, and are considered the principal constituents of concern.

- A comparison of the hydrochemistry found in the downgradient wells versus that found in the upgradient well suggests that the landfill may have affected the hydrochemistry of the uppermost aquifer.

- All 10 of the monitoring wells around Landfill 4 can produce representative samples of the uppermost aquifer and are suitably located to provide adequate monitoring of the landfill. However, additional investigations and sampling will be necessary to determine the sources and extent of impacts attributed to Landfill 4.

8.0 RECOMMENDATIONS

The following recommendations are made concerning future work at these landfills. These are listed in order of highest priority.

1. Collect and analyze ground-water samples from all wells at both landfills on a quarterly basis for a period of 1 year, and perform statistical analyses in accordance with 40 CFR 265, Subpart F. Examine trends in the various contaminants observed at each site. Determine which contaminants remain above DWS or MCLs and re-evaluate the impacts of the landfills on the ground water.
2. Collect periodic and several continuous water-level measurements in wells at both landfills and lakes near Landfill 4 for a period of 1 year to assess the effects of water-level fluctuations and lake/aquifer interactions on the ground-water flow directions. Determine lake-level elevations by surveying. Evaluate and interpret these data to determine ground-water flow directions with more certainty.
3. Test the ability for soil-gas sampling to locate and track the TCE plume at Landfill 4, and, if successful, locate the source(s) of the TCE.
4. Accurately locate (using aerial photographs, field mapping, and surface geophysics), stake, and survey the locations of the landfill boundaries. Fence off and/or install signs on the landfills to prevent unauthorized dumping.

9.0 REFERENCES

29 CFR 1910. Occupational Safety and Health Administration, "Hazardous Waste Operations and Emergency Response." U.S. Code of Federal Regulations.

40 CFR 265. U.S. Environmental Protection Agency, "Interim Status Standards for Owners and Operators of Hazardous Waste Treatment, Storage, and Disposal Facilities." U.S. Code of Federal Regulations.

ANSI/ASME (American National Standards Institute/American Society of Mechanical Engineers). 1986. Quality Assurance Program Requirements for Nuclear Facilities. ANSI/ASME NQA-1-1986, American National Standards Institute, New York.

Armstrong, J. E., D. R. Crandall, D. J. Easterbrook, and J. B. Noble. 1965. "Late Pleistocene Stratigraphy and Chronology in Southwestern British Columbia and Northwestern Washington." Bulletin of the Geological Society of America, 76(3).

ASTM (American Society for Testing and Materials). 1986. "Standard Method for Penetration Test and Split-Barrel Sampling of Soils." In 1986 Annual Book of ASTM Standards, American Society for Testing and Materials, Philadelphia, Pennsylvania.

Brown and Caldwell. 1983. Clover/Chambers Creek Geohydrologic Study. Draft Report Prepared for the Tacoma-Pierce County Health Department, Tacoma, Washington.

Crandall, D. R., D. R. Mullineaux, and H. H. Waldron. 1958. "Pleistocene Sequence in Southeastern Part of the Puget Sound Lowland, Washington." American Journal of Science 256.

Ecology and Environment, Inc. 1986. Tillicum Municipal Well Investigation, Tillicum, Washington. TDD R10-8601-02, Prepared for the U.S. Environmental Protection Agency, Region X, Seattle, Washington.

EPA (U.S. Environmental Protection Agency). 1986. Resource Conservation and Recovery Act (RCRA) Ground-Water Monitoring Technical Enforcement Guidance Document. OSWER-9950.1, U.S. Environmental Protection Agency, Washington, D.C.

Folk, R. L. 1974. Petrology of Sedimentary Rocks. Hemphill, Austin, Texas.

Last, G. V. and T. L. Liikala. 1987. A Field Guide for Well Site Geologists: Cable Tool Drilling. PNL-6392, Pacific Northwest Laboratory, Richland, Washington.

McMaster, B. N. 1982. Installation Assessment of the Headquarters, I Corps and Fort Lewis, Washington and the Subinstallations Yakima Firing Center, Camp Bonneville, and Vancouver Barrack, Washington, Report No. 325. DRXTH-AS-1A-82325, U.S. Army Toxic and Hazardous Materials Agency, Aberdeen Proving Grounds, Maryland.

PNL (Pacific Northwest Laboratory). 1989. Procedures for Ground-Water Investigations. PNL-6894, Pacific Northwest Laboratory, Richland, Washington.

Stanley, T. W., and S. S. Verner. 1983. Interim Guidelines and Specifications for Preparing Quality Assurance Project Plans. QAMS-005/80, EPA-600/4-83-004, U.S. Environmental Protection Agency, Washington, D.C.

USGS (U.S. Geological Survey). 1962. Water Resources of the Tacoma Area, Washington. Water Supply Paper 1499-B, U.S. Geological Survey, Tacoma, Washington.

USGS (U.S. Geological Survey). 1971. Water Resources Data for Washington. Water-Data Report WA-71-1, U.S. Geological Survey, Tacoma, Washington.

WAC 173-160. Washington State Department of Ecology, "Minimum Standards for Construction and Maintenance of Wells." Washington Administrative Code.

WAC 173-303. Washington State Department of Ecology, "Dangerous Waste Regulations." Washington Administrative Code.

Walters, K. L., and G. E. Kimmel. 1968. Ground-Water Occurrence and Stratigraphy of Unconsolidated Deposits, Central Pierce County, Washington. Water Supply Bulletin No. 22, State of Washington Department of Water Resources, Olympia, Washington.

APPENDIX A

RESULTS OF GEOPHYSICAL SURVEYS AT LANDFILL 4

APPENDIX A

RESULTS OF GEOPHYSICAL SURVEYS AT LANDFILL 4

This appendix contains an internal Pacific Northwest Laboratory memo discussing the results of geophysical surveys conducted at Landfill 4. Figures cited in the memo are also provided.

Battelle
Pacific Northwest Laboratories

Project Number ______________

Internal Distribution

File/LB

Date November 7, 1988

To George Last

From Jerry Sandness

Subject Geophysical Reconnaissance Surveys at Fort Lewis

This memo describes the objectives, procedures, and results of a set of geophysical surveys that Kevin Schwartz, Paul Porath, and I performed with your assistance and direction at Fort Lewis, Washington. The work was performed during the periods July 18-19 and July 27-28, 1988.

Objective

The objective of our geophysical surveys was to determine the boundaries of waste deposits associated with Landfill 4. This landfill, located just to the north of Lake Sequalitchew, covers an area of at least 60 acres. It is roughly bounded by relatively undisturbed forest on its south and west sides. It is further bounded by a mechanics training area and a motor pool along its northwest edge and by a gravel pit at its east end. The boundary of the waste deposit along the south and west sides of the landfill is easy to locate because the landfill is distinctly elevated relative to the surrounding ground in that area. Elsewhere, however, the topography or appearance of the ground surface does not provide an unambiguous indication as to the precise location of the waste boundary. Near-surface geophysical exploration methods were employed to locate buried waste materials in those areas.

Procedure

The approach taken in this study was to collect geophysical data along 30 traverse lines. These lines varied in length from a minimum of 200 ft to a maximum of 1200 ft and were marked by wooden stakes at intervals of 100 ft. They were concentrated in four areas where the waste boundaries were most obscure and where it seemed important to more accurately define them. These four areas can be identified by reference to the site map of Figure 1. This map shows the locations of the survey lines, some of the major surface features of the site (e.g., the lake, trees, roads, and buildings), and the results of the geophysical surveys.

The first area (lines 1-6 and 22-26) is adjacent to the mechanics training facility near the west end of the landfill. A section of flat ground and a shallow ditch appear to separate that facility from the landfill although some shallow pits have obviously been used for the disposal of small amounts of waste (probably oil, grease, rags, etc.) in the area between the ditch and the buildings of the training facility. The landfill between the ditch and the woods to the south is characterized by many long shallow depressions that seem to be caused by the settling of waste materials in trenches.

The second survey area (lines 7-17) is adjacent to the motor pool fence at the north side of the landfill. The general appearance of the ground and the presence of two shallow, partially open trenches shows that some waste burial activity has taken place there, apparently in a rather unplanned or random fashion.

The third area is located in the northwest portion of a cleared area that includes an active gravel pit at its east end. No waste materials are evident in the gravel pit, but we could not determine by visual inspection whether waste materials extend into the west end of the cleared area.

The fourth survey area is a strip of bare ground (fill) between the north shore of Lake Sequalitchew and the apparent southwest corner of the landfill. The question is whether waste materials were included in the fill material that was deposited at this site.

Three geophysical sensing instruments were used in this study: 1) a ground-penetrating radar unit, 2) a ground conductivity meter, and 3) a metal detector. These are briefly described in the following paragraphs.

The radar system was a Geophysical Survey Systems, Inc. (GSSI), Model SIR 7 with a 120-MHz (nominal) antenna (GSSI Model 3110) which transmits and receives radar signals in a frequency band of approximately 50-250 MHz. The antenna, mounted on a fiberglass sled, was pulled along the survey lines by a small all-terrain vehicle (ATV). Radar signals reflected from subsurface objects or interfaces were detected by the antenna and were transmitted by cable to control and recording modules mounted on the ATV. There the signals were amplified, digitized, and recorded on digital tape cartridges for later playback and processing in our laboratory. This instrument exhibits good spatial resolution and can produce quasi-pictorial images of both metallic and nonmetallic objects or materials in the ground.

The ground conductivity meter was a Geonics EM31 electromagnetic induction (EMI) sensor. This hand-carried device operates by transmitting an oscillatory magnetic field into the ground, then detecting the secondary magnetic field produced by the electric currents that are induced in the ground. It exhibits relatively poor spatial resolution, but can respond to both metallic and nonmetallic waste deposits. The data produced by this instrument were digitized and recorded by a small data recorder carried by the operator. The data were subsequently transferred to a computer for scaling and display.

The metal detector was a Fisher M-Scope, Model TW-6. This instrument was originally marketed as a pipe and cable detector, but has proven to be effective in detecting buried metallic waste materials at depths of a few feet. The metal detector was carried by hand along the survey lines until a response was obtained. The location of the response was then recorded in a field notebook.

Results

Figures 2-6 show the radar data collected in this survey. Each of the small images in these photographs is called a radar profile and represents one survey line. The horizontal dimension in a given profile corresponds to the distance along the survey line. The vertical dimension corresponds to signal travel time or depth. Thus, a radar profile can be regarded as a vertical cross-sectional view of the ground under the survey line. The maximum penetration depth shown in these profiles is approximately 16 ft. The depth calibration is based on an estimate of the dielectric constant of the ground at this location, so may be in error by 10-15%. Excavation of an object detected by the radar and measurement of its depth would provide the ground truth needed to improve the accuracy of the depth scale.

Most of the survey lines were traversed twice with the GPR system, once in each direction. Thus, in Figures 2-6, two radar profiles are shown for each of these lines. A pair of profiles for a given line may not be identical because the two traverses were typically made with a lateral offset of a few feet to expand the area covered by the survey.

Our analysis of the radar data was based on a visual interpretation of the profiles. A small, isolated, reflective object in the ground can be identified by a characteristic hyperbolic reflection pattern like the one pointed out in Figure 2. A large deposit of waste material produces a complex reflection pattern consisting of many overlapping hyperbolas. A good example of this is shown in Figure 6, Line 27, where the south edge of the landfill is overlapped by relatively clean fill material. Another type of feature that is displayed in many of the profiles is a sedimentary interface. Good examples are shown in Figure 3 where strongly reflecting subsurface layers are present over most of the 1200-ft length of Line 7. (Note that Line 7 is displayed in two overlapping 1000-ft segments because its total length is too long to be displayed in a single image.)

Figure 4 contains two radar profiles that do not correspond to numbered survey lines. The first of these, labeled "Woods", corresponds to a sinuous path through the trees between the north ends of Lines 18 and 19 (see Figure 1). Scattered debris is present at several points along this line, and a dense landfill-type deposit is present at its west end, from the edge of the trees to the north end of Line 18. The profile labeled "Landfill" corresponds to a short northward traverse from the road spur near the end of Line 20. Waste materials, including blocks of concrete, are present along most of this line.

The three geophysical survey methods were applied along Line 4 on each of our two visits to the site. On the first visit, we surveyed a 200-ft line (the north half of the 400-ft line shown in Figure 1). The resulting radar and EMI profiles are labeled as Line 4 in Figures 2 and 7, respectively. We subsequently decided that the line should be extended to the north by an additional 200 ft. The resulting full-length profiles are labeled as Line 4+4X in Figures 5 and 13.

The EMI data are plotted in profile form in Figures 7-14. The scale of the vertical axes in these plots is such that the values 2047 and -2048 correspond to positive and negative full-scale responses of the EM31 sensor at an instrument range setting of 10 mmhos/m. However, we did not convert the plotted values to conductivity units because the presence of large amounts of metal in the waste deposits makes that conversion inaccurate, and our purpose was simply to detect the waste materials. For the same reason, we chose to truncate the high-amplitude response peaks in most of the profiles.

The EMI profiles give strong indications of trenches, pits, or waste boundaries on most of the survey lines. Lines 5, 6, 19, 23, and 30 are the only lines that do not seem to show compelling evidence of buried waste deposits. (The large peak at the east end of line 23 was produced by a small steel building.) The EMI profile along Line 7 is different from the others in that it exhibits a broad peak that extends over the entire length of the line. The most likely explanation for this result is that it reflects the distribution of metal boats, trailers, and other machinery inside the fenced motor pool area located only 15 ft to the northwest of the survey line. It might also be partly caused by an overhead power line that crosses the survey line at approximately the point where the profile's amplitude is a maximum. A less likely possibility is that the apparent conductivity high is produced by contamination of the groundwater which is probably present at a depth of approximately 25 ft in this area. This explanation is supported somewhat by the fact that the base levels of the profiles for Lines 11 and 12 are slightly elevated relative to the base levels of the profiles for other nearby lines.

The results of the metal detector, EMI, and ground-penetrating radar surveys are summarized on the site map of Figure 1. The broad, dark lines superimposed on the survey lines show the locations of buried waste materials as determined from all three sets of geophysical data. The metal detector and EMI responses were generally consistent with the indications of buried materials or ground disturbance provided by the radar system. However, the radar detected some buried waste materials that did not produce interpretable responses in the other instruments. An example of this is on Line 27 where the radar showed that the waste materials (landfill deposit) extend approximately 100 ft closer to the lake than was indicated by the metal detector and the EMI sensor.

A visual inspection of the ground surface at several locations at this site provided some insight into the nature of some of the waste materials. For example, the materials found at the ground surface along Line 4 and Lines 24-26 are concrete and asphalt blocks containing steel reinforcing rods. We also found this type of material near the lake on Lines 28 and 29 and, as mentioned above, to the north of Line 20 and to the east of Line 18. Domestic garbage is exposed at the edge of the cleared area at the north end of Line 18, and some industrial debris (e.g., steel cable and other pieces of metal) is present along and to the south of Line 21a.

Final Comments

Surface-based geophysical sensing methods of the types used in this reconnaissance are not normally able to identify the specific materials contained in a buried waste deposit or to determine their toxicity or threat to the environment. These types of information must be determined by sampling or excavation. In this case, our goal was to help in defining locations where groundwater sampling wells could be drilled close to the waste deposits but with a minimum risk of directly encountering buried hazardous waste materials. This goal was probably achieved even though some areas remain where the locations of the waste boundaries remain uncertain. The areas of greatest uncertainty appear to be: 1) the northeast edge of the landfill between Lines 16 and 21; 2) the cleared area to the west of the active gravel pit and to the south of Line 21; and 3) a small triangular area bounded by the mechanics training area, Line 3, and the highway.

GAS:klk

Attachments

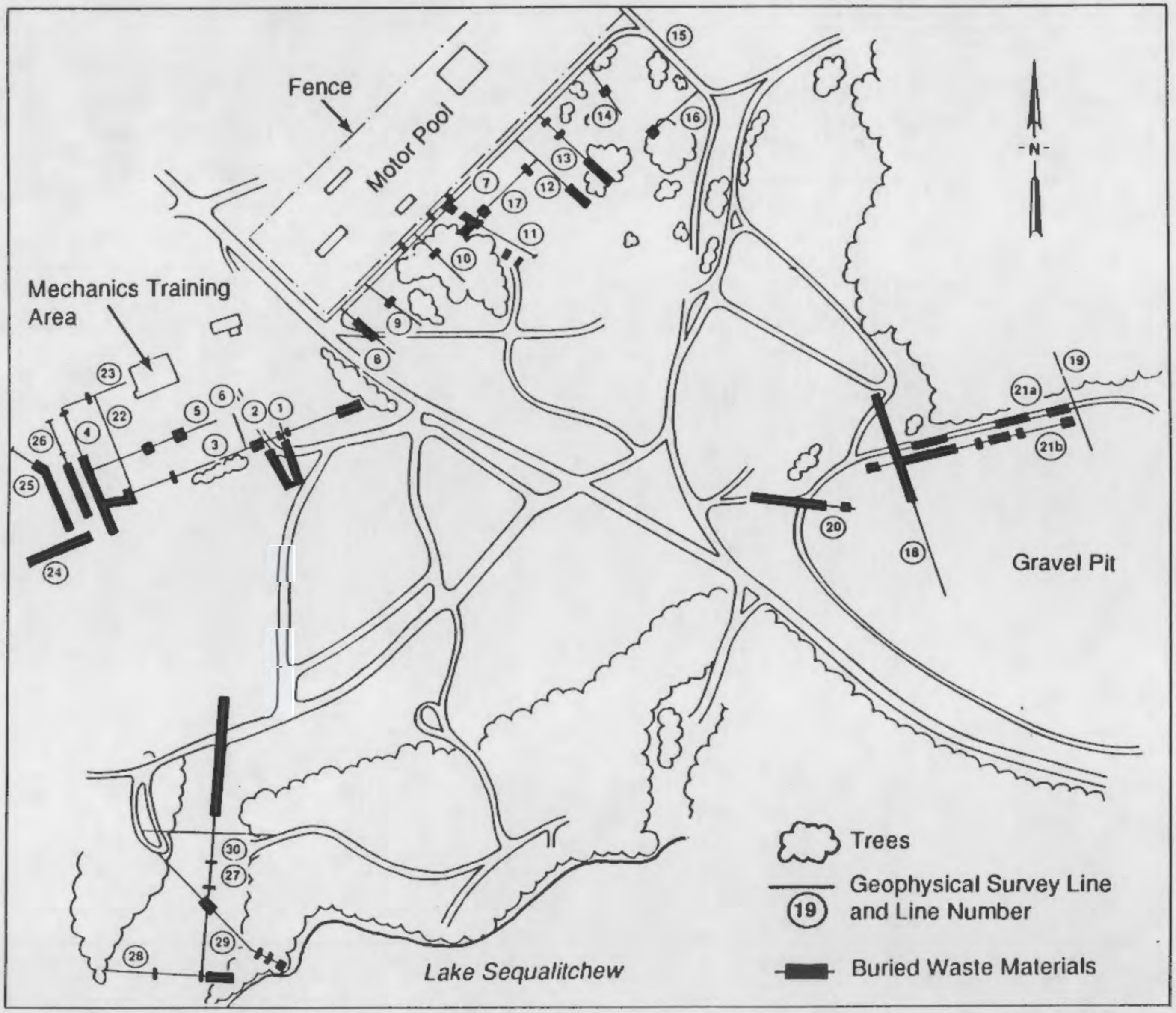
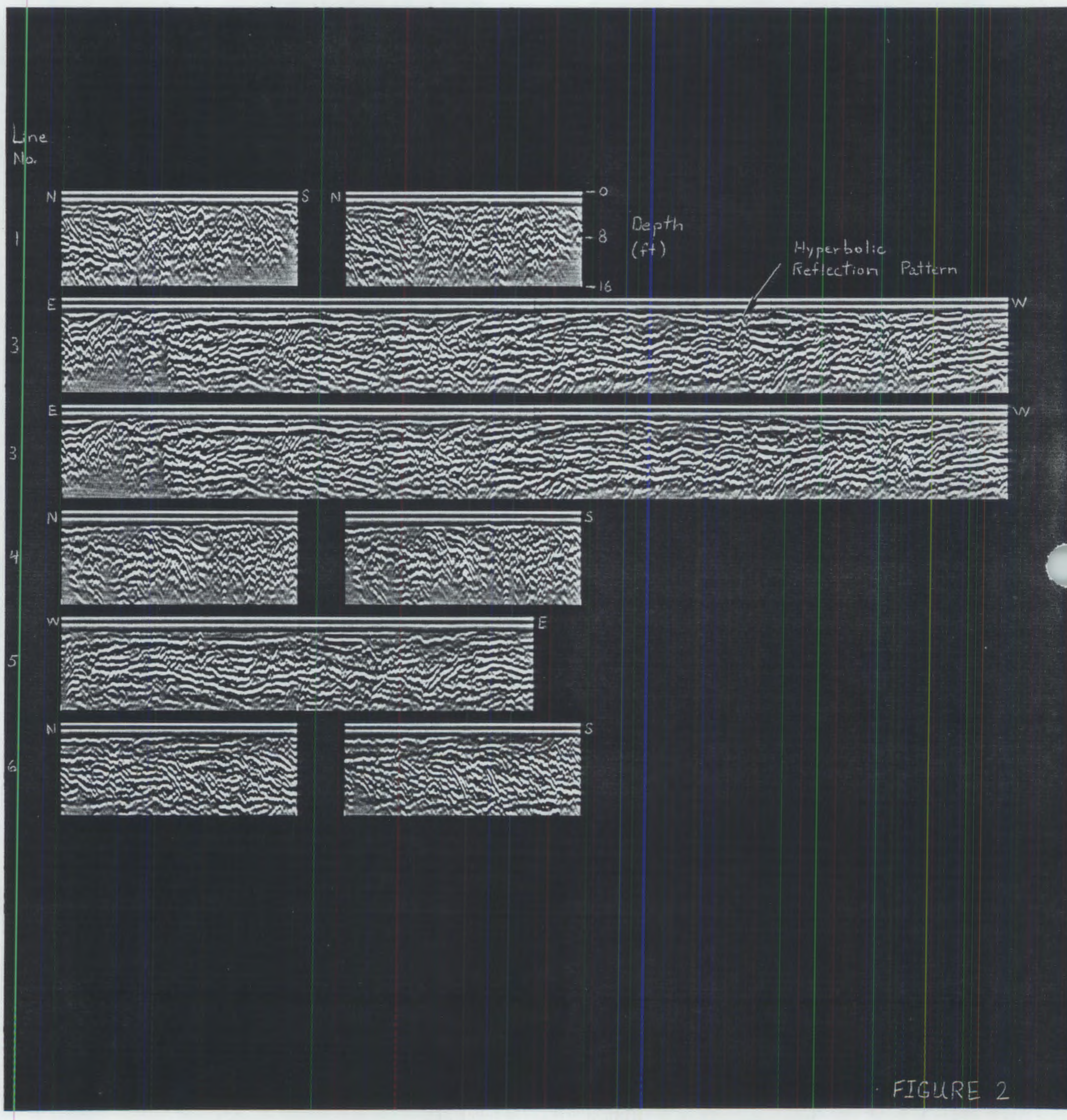
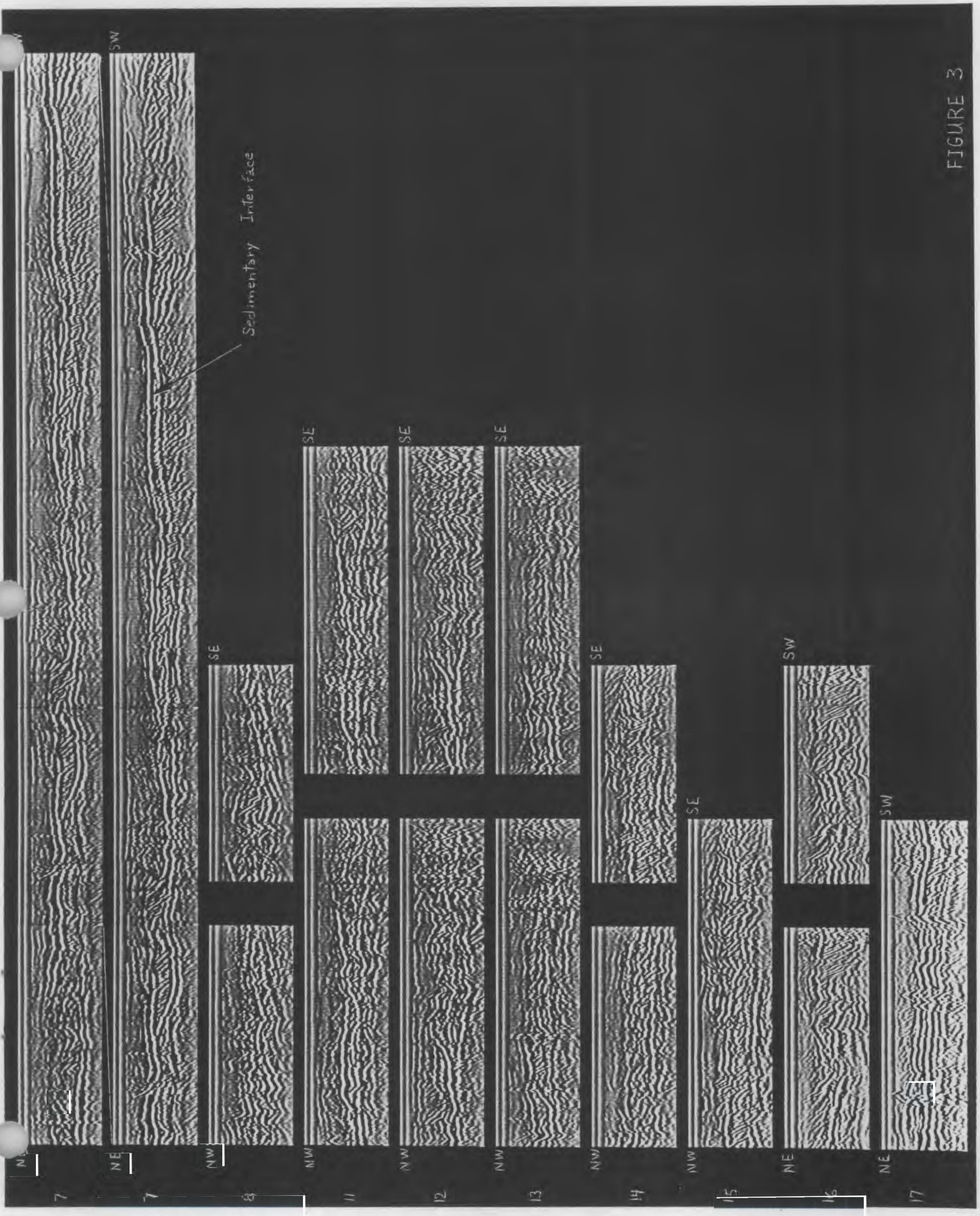

Fence
Motor Pool
Mechanics Training Area
N
Gravel Pit
Lake Sequalitchew
Trees
Geophysical Survey Line and Line Number
Buried Waste Materials

FIGURE 1



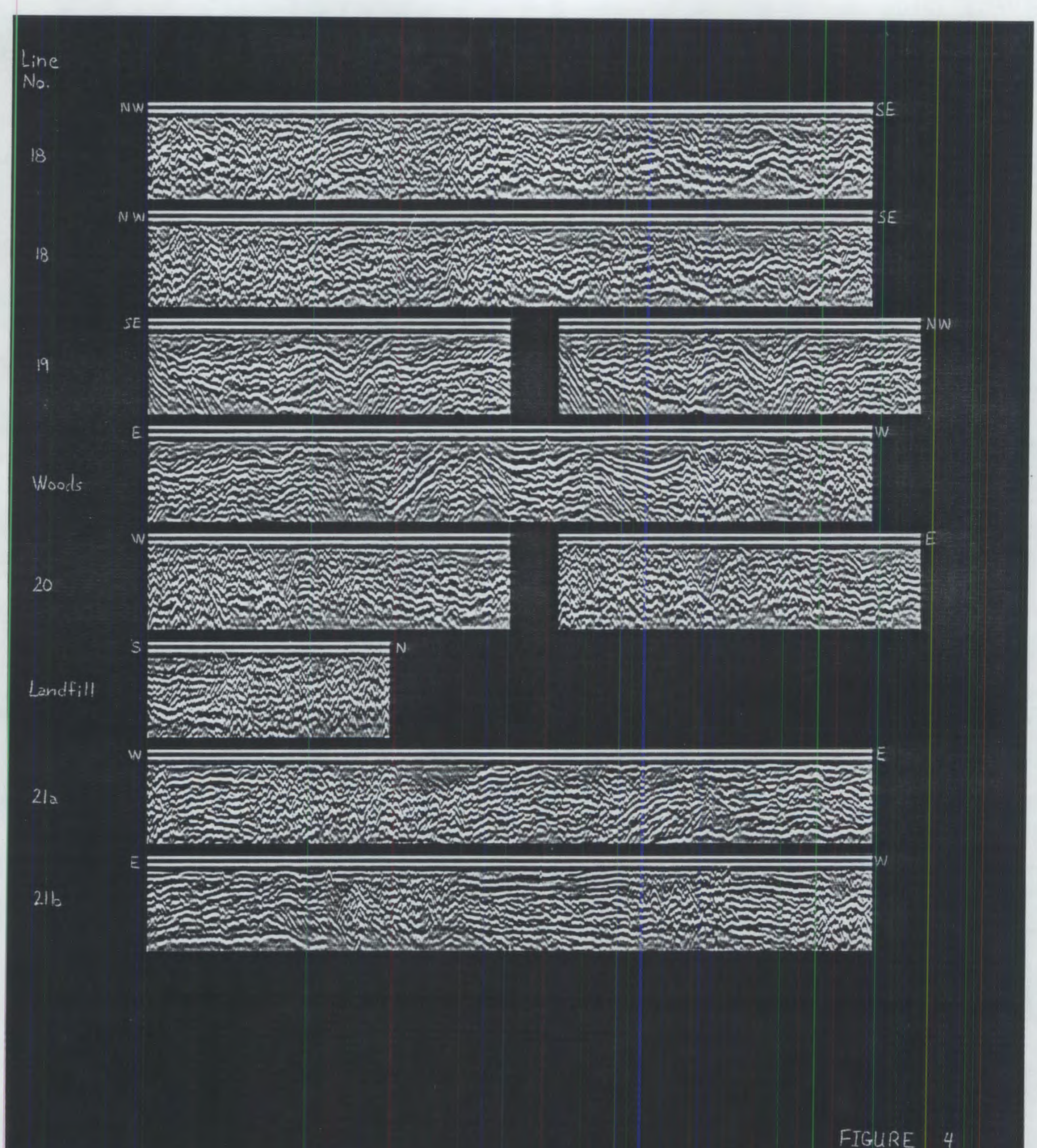
Line No.
N
S
N
1
0
8
16
Depth (ft)
Hyperbolic Reflection Pattern
E
W
3
E
W
3
N
S
4
W
E
5
N
S
6

FIGURE 2



Sedimentary Interface
SW
SE
SE
SE
SE
SE
SE
SW
SW
NE
NE
NW
NW
NW
NW
NW
NW
NE
NE
7
7
8
11
12
13
14
15
16
17

FIGURE 3



Line No.
NW
SE
18
NW
SE
18
SE
NW
19
E
W
Woods
W
E
20
S
N
Landfill
W
E
21a
E
W
21b

FIGURE 4

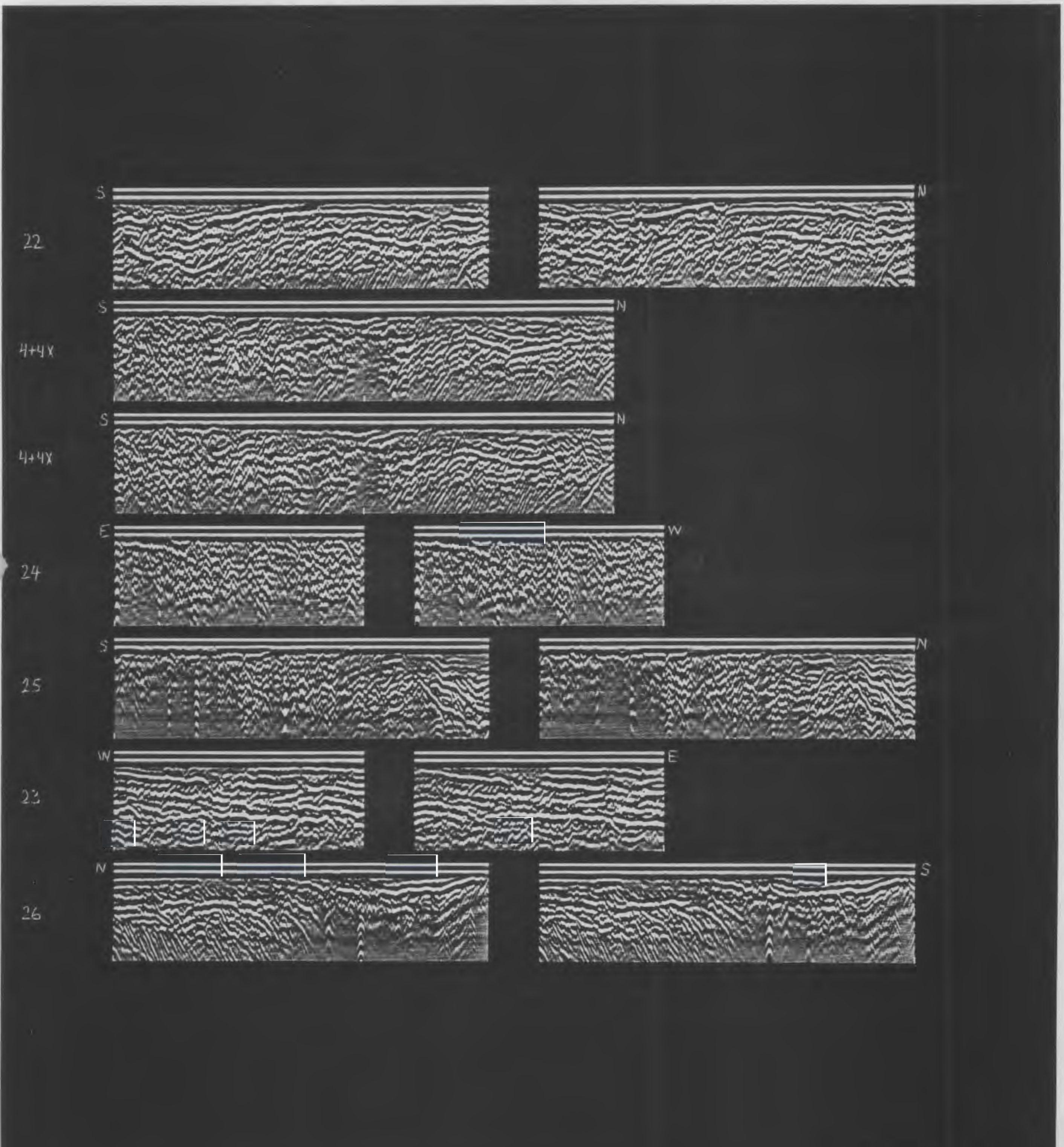


FIGURE 5

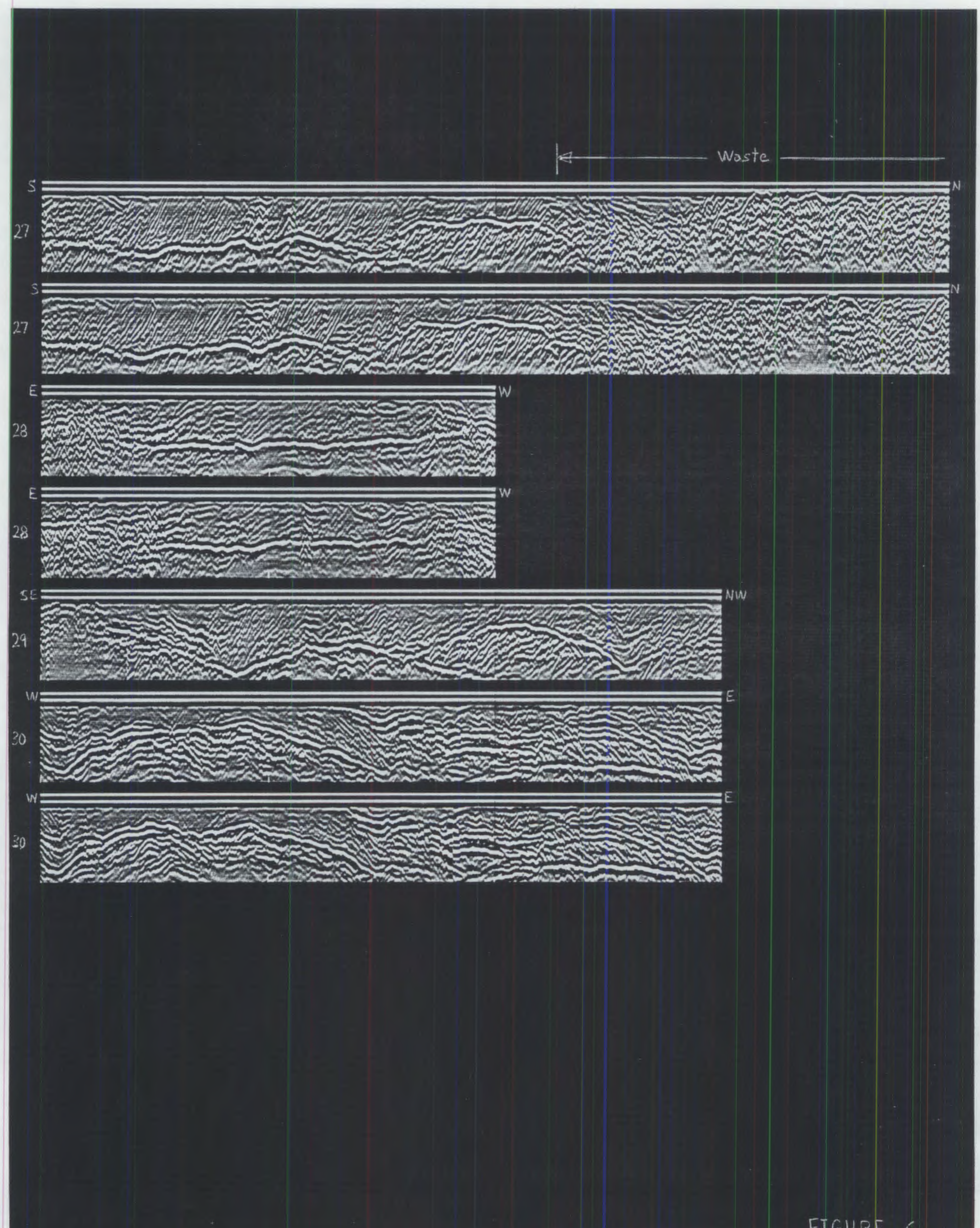


FIGURE 6

EM31 RESPONSE, LINES 1-6

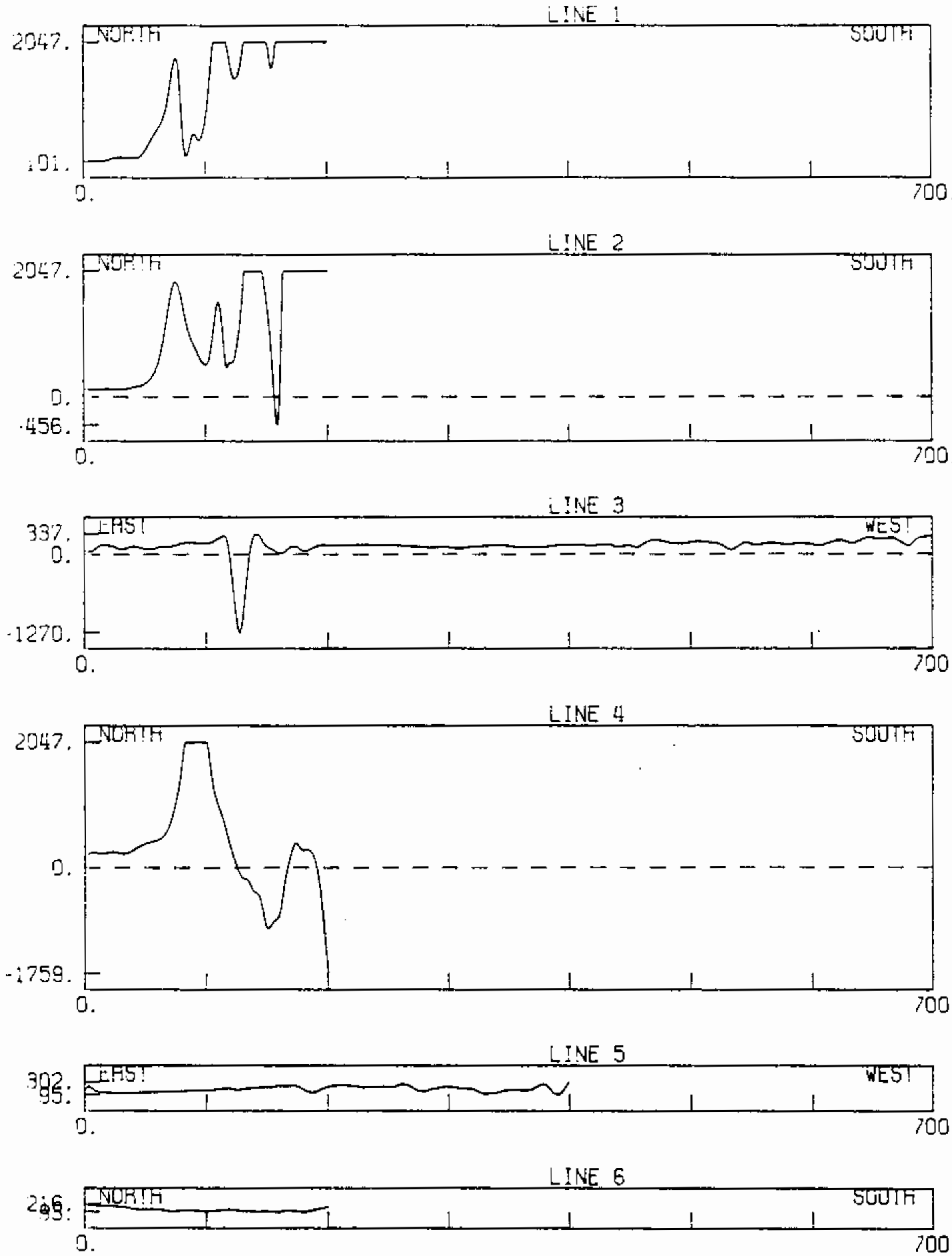


FIGURE 7

EM31 RESPONSE, LINES 1, 2, & 4

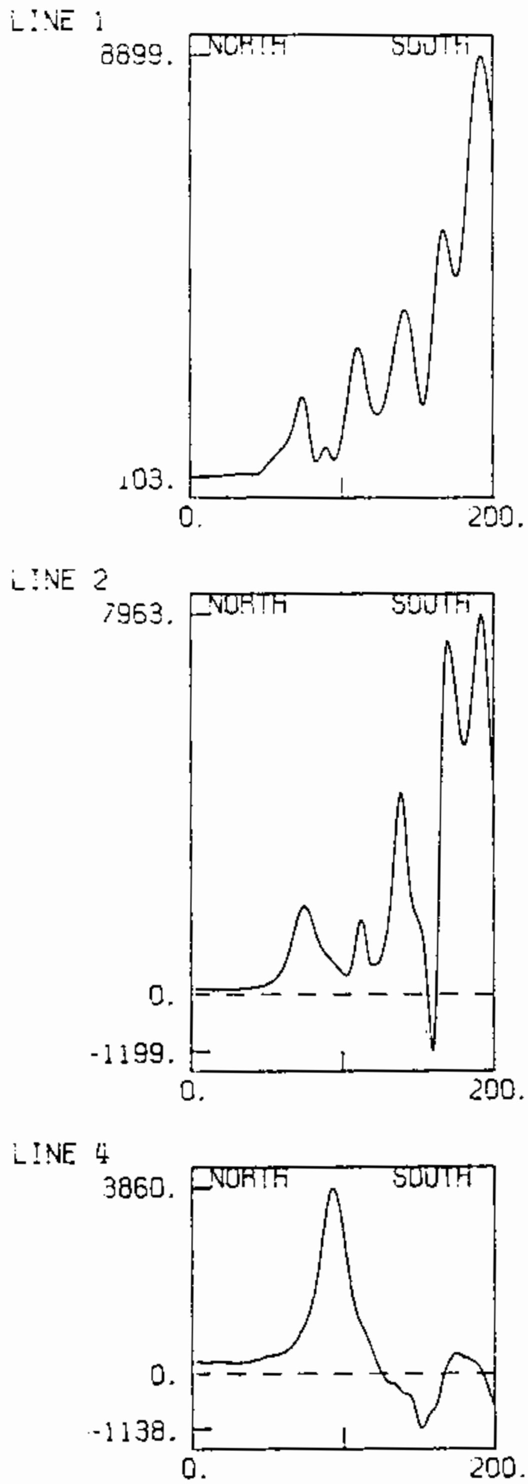


FIGURE 8

EM31 RESPONSE, LINES 8-11

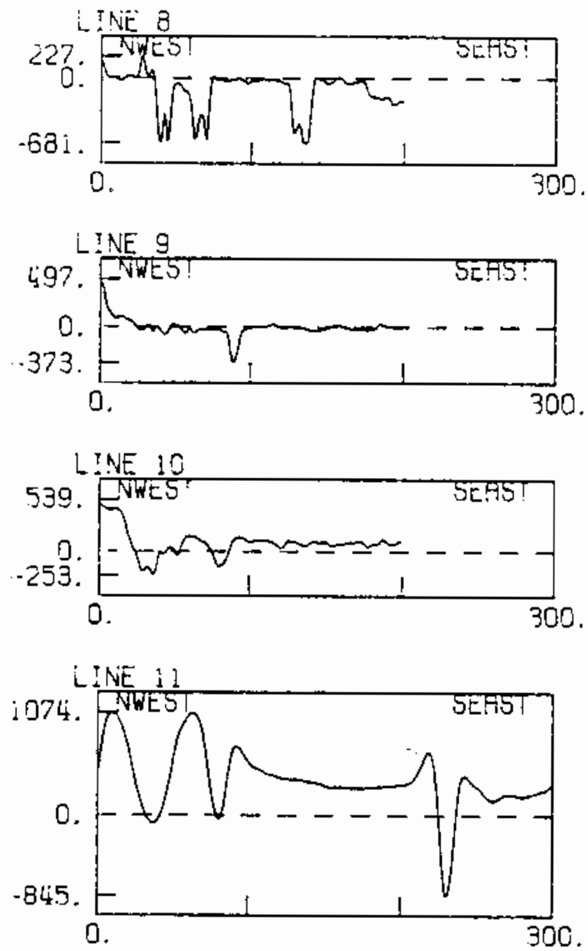


FIGURE 9

EM31 RESPONSE, LINES 12-15

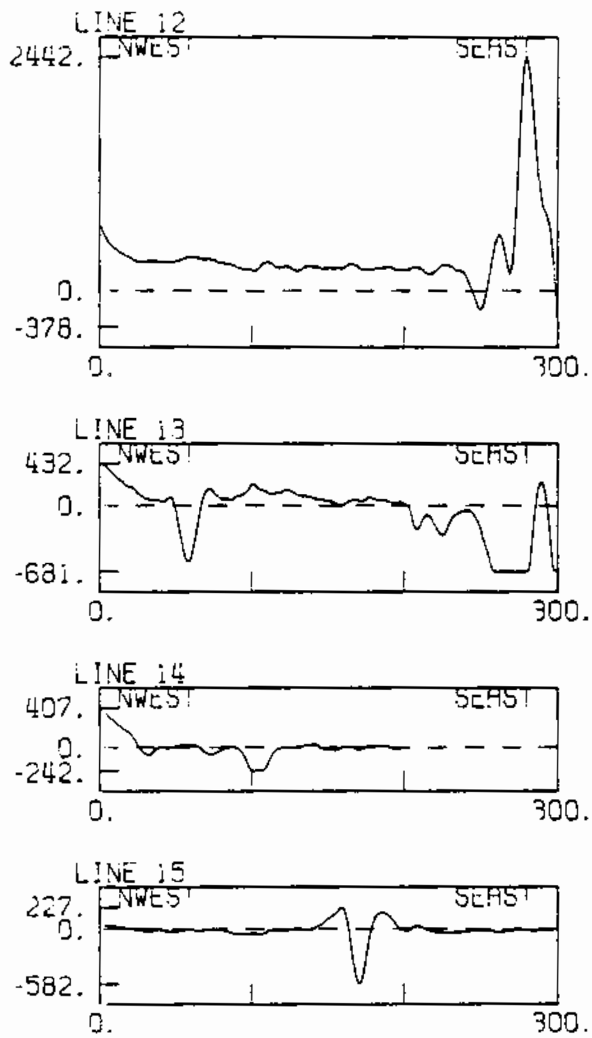


FIGURE 10

EM31 RESPONSE, LINES 7, 16, & 17

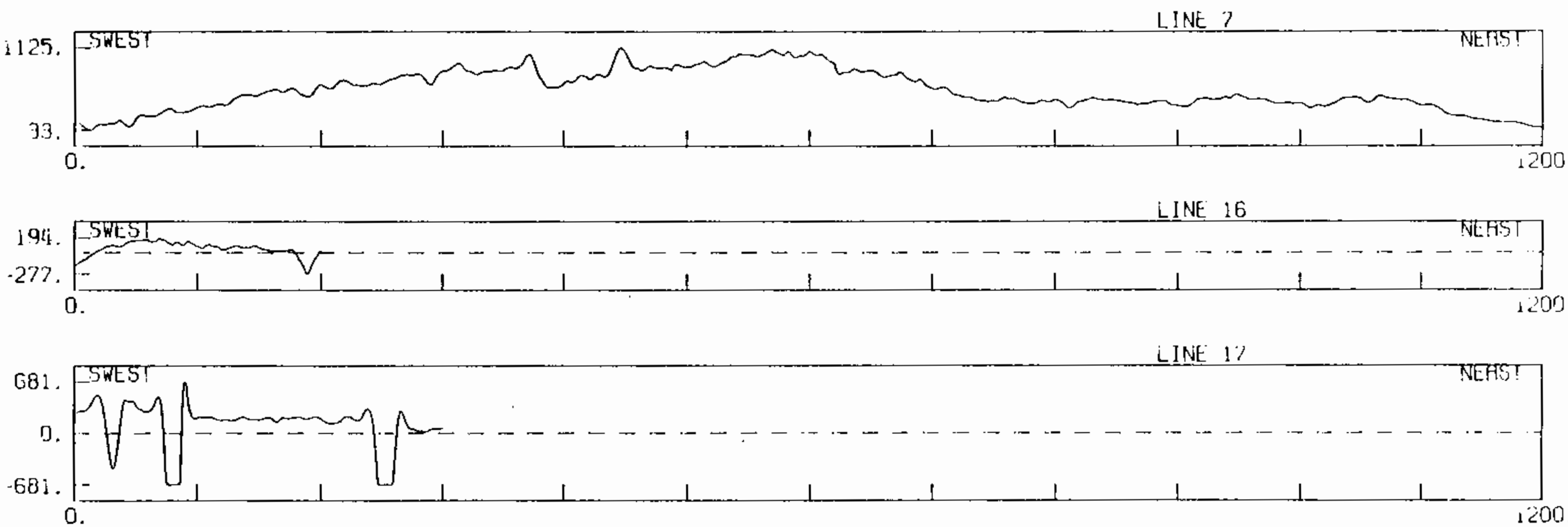


FIGURE 11

EM31 RESPONSE, LINES 18-21

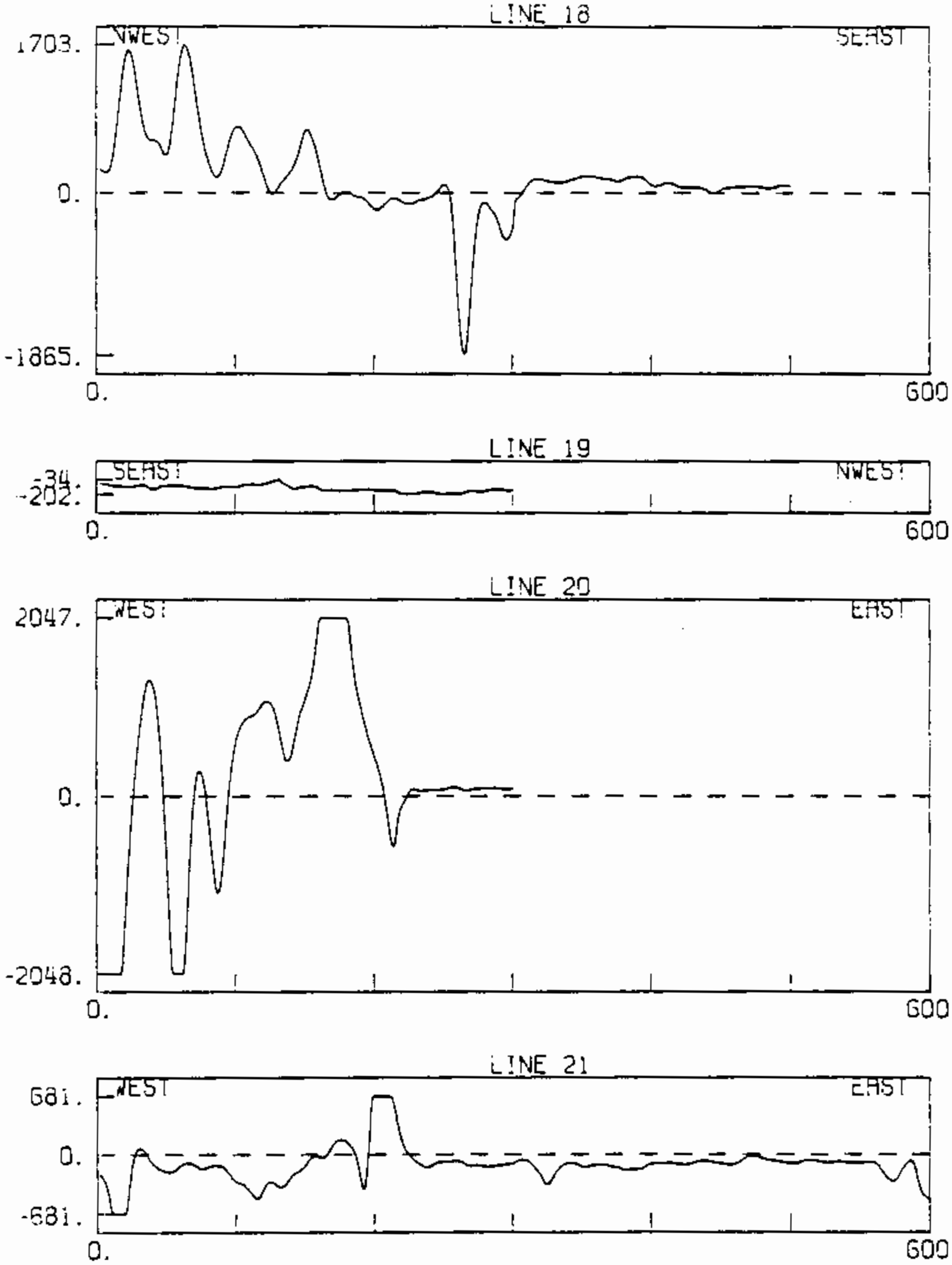


FIGURE 12

EM31 RESPONSE, LINES 4+4X, 22-25

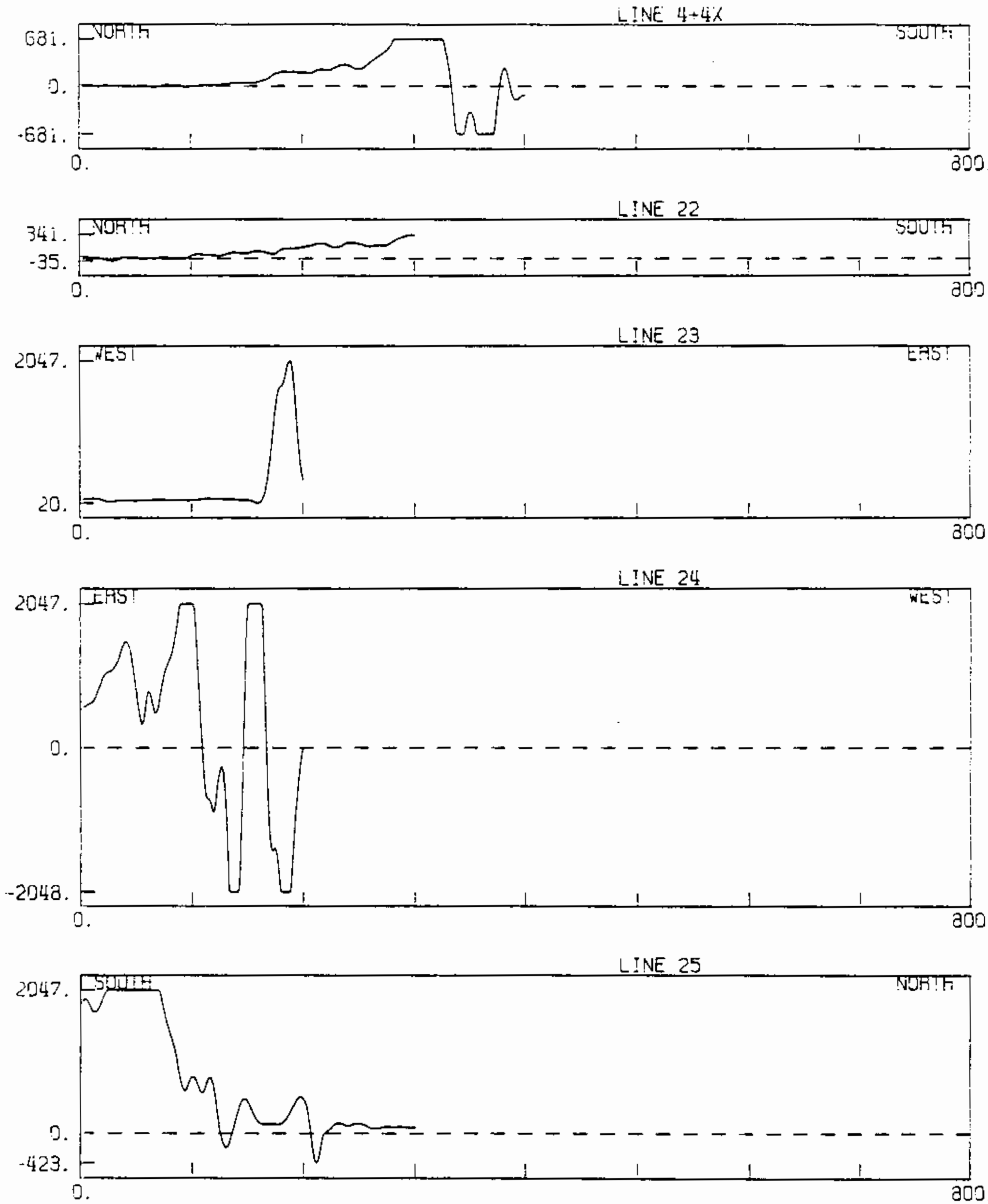


FIGURE 13

EM31 RESPONSE, LINES 26-30

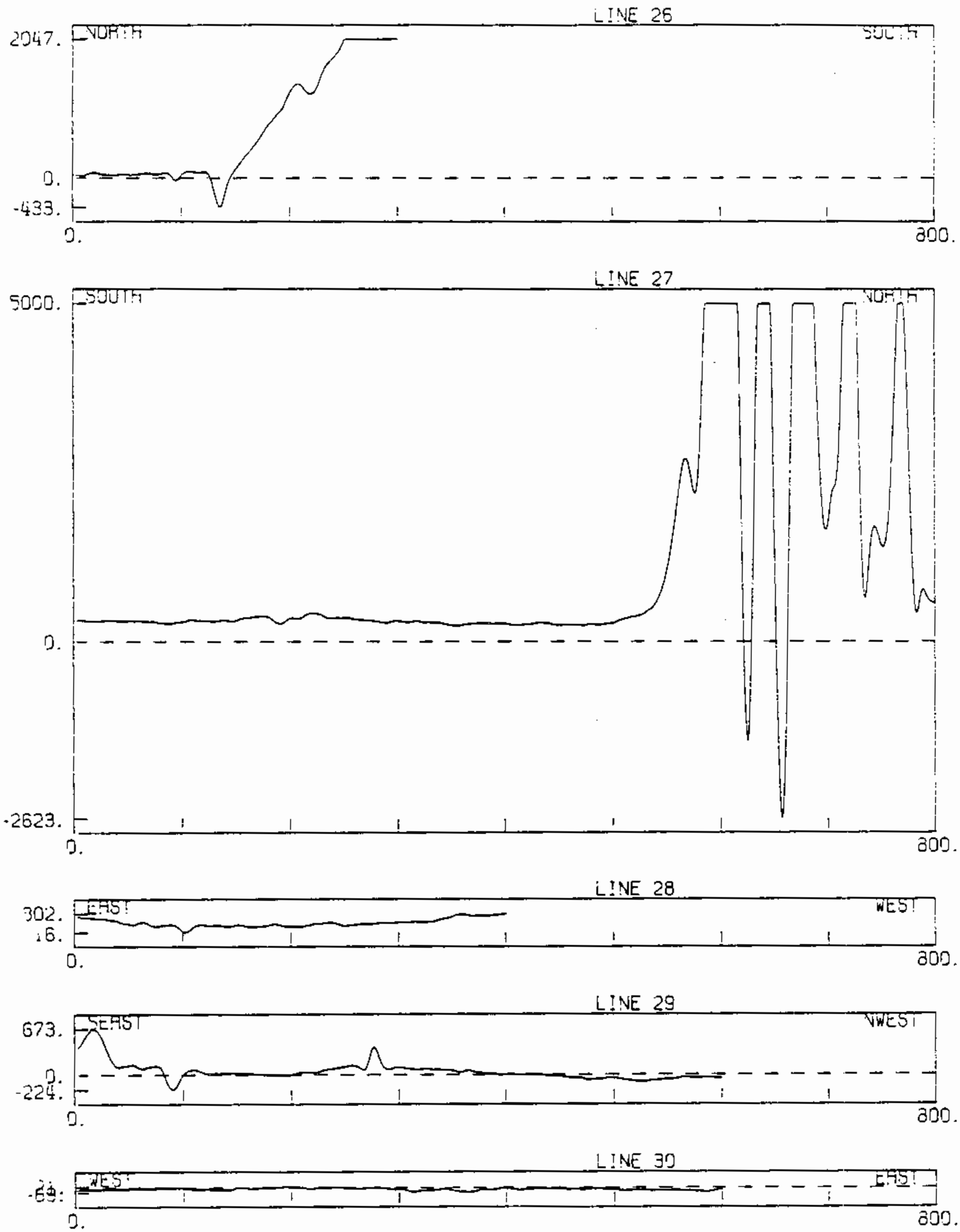


FIGURE 14

APPENDIX B

WELL SPECIFICATIONS

APPENDIX B

WELL SPECIFICATIONS

These specifications were excerpted from the drilling subcontract. References to other appendixes do not refer to the appendixes of this report.

DRILLING SPECIFICATION

1.00 General

1.01 Description:

A. Work Included:

The effort and materials required for this work include, but are not necessarily limited to:

1. Drilling, sampling, and installing and developing approximately 23 temporary test holes (TTH), 4 holes during Phase I, and up to 19 holes during Phase II.

2. Furnishing and placing grout, bentonite crumbles, bentonite pellets, and sand pack;

3. Furnishing and installing flush-threaded, Schedule 4D PVC casing, caps, protective steel cover with lockable cap and slotted PVC well screen; and

4. All other related items indicated in the figures, specified herein, or needed for a complete and proper installation in accordance with the intent of the specifications.

B. Work Location:

All the drilling sites are located at Fort Lewis, near Tacoma, WA. The location map is shown in Figure 1.

C. Site Access and Security:

The Contractor is responsible for familiarity with access routes for his equipment. Drill rigs may be left on the site overnight, but security and safety of rigs and equipment rests with the contractor.

Access to individual drilling sites is varied, ranging from open fields and parking lots to wooded areas.

D. Working Hours:

Drilling will be carried out during daylight hours, normally extending from 8:00 a.m. to approximately 5:00 p.m. Pacific Daylight time, although extended hours may be necessary to complete critical stages of work that are not planned. All work will be completed during the standard five day work week.

1.02 Qualifications and Compliance with Specifications:

A. Qualifications of Workmen:

Use sufficient journeyman drillers and a competent supervisor in the execution of this work to ensure proper and adequate installation of items throughout. Provide a complete list of workmen involved and enter those present in the daily log.

B. Compliance with Specifications:

1. Whenever required during progress of the work and after completion of construction, the contractor shall immediately furnish proof acceptable to Battelle that all items of the TTH's installed equal or exceed all requirements specified for this work.

2. In the event such proof is not available or is not acceptable to Battelle, the Contractor may be required to remove the item or items and replace with material meeting the specified requirements and to repair all damage caused in the removal and replacement, all to be accomplished at no additional cost to Battelle.

3. All TTH's shall be constructed and completed in accordance with the intent of Chapter 173-160 WAC, "Minimum Standards for Construction and Maintenance of Water Wells", and the specifications contained herein. In the event of a conflict, the technical specifications contained herein shall govern.

1.03 Drawings:

A. Intent of Figures:

The Contract figures, (Figures 2 and 3) do not attempt to show exact details of all piping and items to be installed. Diagrams are schematic and do not attempt to show all fittings, obstructions, flush couplings, or spacing required. Work measurements shall be verified from field measurements.

B. Shop Drawings:

No shop drawings are required.

C. As-Built Drawings:

During progress of the work, the Contractor will maintain an accurate record of all changes made, if any, in the specified installation layout and materials specified herein such as PVC casing, protective steel casing, welds, etc. The contractor will provide as-built drawings upon completion of the contract or provide as-built data to the Battelle Technical Administrator.

1.04 Material Handling:

A. Protection:

The contractor shall use all means necessary to protect well construction materials before, during, and after installation. All materials to be installed will be kept off the ground on stands, racks, or sawhorses to keep them clean. During vehicle transport all materials will be enclosed in the containers in which they were shipped to keep them clean and free from damage.

B. Damage and Repairs:

In the event of damage, the Contractor shall immediately make all repairs and replacements necessary to the approval of Battelle at no additional cost.

C. Cutting and Water Disposal:

Drill cuttings from the saturated (water bearing) and unsaturated zones shall be contained pending determination of their waste status. Containment shall consist of 7 mil plastic sheeting under and above the cuttings. Cuttings will be retained pending analytical results. It is not necessary to contain water for analysis.

D. Decontamination:

It is the contractor's responsibility to set up and use a decontamination station for cleaning the drill rig(s) and potentially contaminated equipment. All equipment in contact with earthen materials or borehole fluids shall be steam-cleaned between each borehole. The contractor shall supply the equipment necessary for this decontamination.

1.05 Site Conditions:

A. Site Geology:

The Contractor should anticipate drilling in unconsolidated materials, consisting of clay, silt, sand, gravel, cobbles, and boulders. These materials were deposited in former stream channels and glacial outwash. The distribution of these materials is highly variable.

2.00 Materials

A. General:

Equipment and materials necessary to complete the TTH's in all cases shall include, but are not necessarily limited to:

1. Drilling and completion equipment;

2. Protective steel covers, arc welding equipment, as needed and accessories;

3. PVC casing, well screen, top caps and bottom plugs;

4. Sand pack;

5. Steam cleaning equipment;

6. Cement and bentonite grouts;

7. Bentonite pellets or crumbles (TTH seal);

8. Approved A:B:C fire extinguisher capable of containing any fire excursion caused by drilling operations;

9. Concrete for TTH pad and steel protective posts; and

10. All other materials and supplies for completion of the work.

B. Compliance with Specifications:

When a separate item, which includes the furnishing of any material, is provided in the proposal schedule, the cost of furnishing, hauling, storing, and handling shall be included in the unit price for that item. When a separate item is not provided in the schedule for furnishing any material required to be furnished by the Contractor, the cost of furnishing, hauling storing, and handling shall be included in the unit price for the work for which the material is required. Materials furnished by the Contractor shall be of the type and quality described in these specifications. The Contractor shall make a diligent effort to procure the specified materials from any and all sources, but where materials required by the specifications become unavailable, substitute materials may be used, provided that no substitute materials shall be used without prior written approval of the Battelle Technical Administrator. Battelle's determination as to whether substitution shall be permitted, and as to what substitute materials may be used, shall be final and conclusive.

2.01 Drilling and Support Equipment

The use of one rig is necessary, such as a hollow-stem auger rig capable of drilling to the estimated depth of 40 to 60 feet, but not to exceed 100 feet. The hollow-stem auger type rig, if used, shall be capable of drilling through earthen materials (including clay, silt, sand and gravel) at the site to the estimated depths. The drilling machine for the TTH's must be capable of drilling to the required depth and allow for the collection of samples during drilling. The use of temporary casing will be allowed during the drilling. If methods other than hollow-stem auger are used, then the use of temporary casing during drilling is encouraged. The rig must be capable of removing any temporary casing while the permanent PVC casing is in the bore. Sand packing the well screen and sealing and grouting the permanent casing shall be accomplished while temporary casing is being removed. No additives may be used to facilitate lubrication. The contractor shall specify the size and capability of the equipment proposed for use.

Wherever possible, boreholes shall be drilled using hollow-stem auger flights having a minimum 3.75-in. I.D. and an 8-in. O.D. for installing nominal 2 in. diameter PVC. If 4 in. diameter PVC is used a minimum 6.0-in. I.D. and 10.5-in. O.D. flights will be required. The rigs shall be capable of collecting continuous core and split-spoon samples. If a split-spoon is used it shall be 2 or 2.5 in. diameter and samples should be taken every 5 feet or suspected change in lithology (sand to clay etc.). The lead flight of the augers will be equipped with an appropriate cutting bit to allow penetration into the type of material occurring at the site. Temporary steel casing set in the borehole shall have a minimum inside diameter of 8.0 inches.

2.02 PVC casing

Casing for the TTH's shall be new, white, 2-inch or 4-inch diameter, Schedule 40 PVC pipe having no painted surfaces. The 2-inch pipe will be used when drilling is done by auger and 4-inch will be used for other methods of drilling. Written documentation of the conformance to PS 2170, ASTM 1785 must be provided in the shipping manifest. The minimum pipe section length shall be 2 feet with Viton or Teflon "O" rings used at each flush-threaded connection. Dimension of the 2-inch PVC pipe shall be: outside diameter 2.375 inches, inside diameter 2.047 inches, and a wall thickness 0.164 inch. Dimensions of the 4-inch PVC pipe shall be: outside diameter 4.500 inches, inside diameter 4.026 inches, a wall thickness of 0.247 inch. The threading shall conform to ASTM F480 requirements for flush-threaded, thermoplastic well casing and pipe. All casing shall be cleaned and decontaminated after cutting and threading at the factory, using a mild detergent, then isopropyl alcohol or an approved equivalent cleaning procedure; then air dried and finally, hermetically sealed in plastic to minimize potential for contamination prior to installation in the borehole. Chlorinated solvents shall not be used for cleaning pipe or screen. The well casing shall be manufactured by UOP Johnson, St. Paul MN; Timco Manufacturing, Inc., Prairie du Sac, WI; Brainard-Kilman, Tucker, GA; Aardvark Corporation, Puyallup, WA; or an equal approved in advance by the Battelle Technical Administrator.

2.03 Screen, Casing Connection, End Caps and Plugs

A. Screen shall be provided in 5 and 10-ft lengths only and shall be 2-inch or 4-inch nominal inside diameter, Schedule 40 PVC with flush interior to permit passage of a 1.75 inch or 3.76 inch outside diameter bailer. The screen shall be of the continuous wrap or high flow slotted type in order to provide maximum inlet area consistent with strength requirements. At a minimum, the screen shall consist of 4 row, 100 slots per row, factory slotted PVC pipe. The screen shall be manufactured by UOP Johnson, St. Paul MN; Timco Manufacturing, Inc., Prairie du Sac, Wl; Brainard-Kilman, Tucker, GA; Aardvark Corporation, Puyallup, WA; or an equal approved in advance by the Battelle Technical Administrator.

B. PVC casing and screen shall have internal, flush-threaded ends requiring no glue or solvents and providing a smooth, uniform, outside diameter.

C. The overall screen length and slot size shall be selected so that the average velocity of water entering the screen is 0.1 ft/second. The screen shall provide a minimum of 10% open area with No. 0.020 slot openings.

D. All screens and casings shall be free of foreign matter (e.g. adhesive tape, labels, soil, grease, etc.) and cleaned and sealed in the same manner as the PVC casing. Screen and casing shall be kept in boxes or on racks until immediately prior to insertion in the TTH.

E. The bottom of the screen should be placed no more than 3 feet above the bottom of the TTH.

F. Schedule 40 PVC flush-threaded end caps or plugs to fit the bottom end of the screen and removable Schedule 40 vented, flush-threaded caps for the top of the casing shall be provided. All 10-foot screen bottoms shall be securely fitted at the factory with a flush-threaded bottom cap of the same composition as the screen. Five foot screen sections shall be of flush threaded couplings except for the 6 screens that will be placed in the 60 ft. TTH's. These 5-foot screens will have flush-threaded bottom caps similar to the 10-foot screens. The end cap shall be within 0.5 feet of the open portion in the bottom section of the screen.

G. Silt traps shall not be used.

H. Joints within and between the casing and screen shall be flush-threaded couplings. Heat-welded joints and/or gaskets shall not be used.

I. The tops of all PVC casings shall be installed with male threads upward so that slip caps placed on top can be <u>easily</u> removed by hand.

<u>2.04 Centering Guides</u>

Centralizers are required and shall be placed 2.0 feet above the sand pack.

<u>2.05 Filter (Sand) Pack:</u>

The Contractor shall provide and install filter pack below and around the screens. The filter pack around the screen shall consist of a size sufficient to be retained outside of the 0.020 slot screen while passing no more than 1.0% through the screen. Filter pack material shall consist of kiln dried, uniform, rounded and spherical grains of sand composed of at least 95% quartz. The filter pack sand shall have a uniformity coefficient (the quotient of the 60% passing, D_{60} size, divided by the 10% passing, D_{10} size) between 1.0 and 2.0. At least 90% of the particles shall have a Powers roundness of 4 to 6 (i.e., subrounded to well rounded). The filter pack material shall have a U.S. sieve size of 10 to 20 mesh (effective particle size of 1.0 to 1.2 mm or 0.039 to 0.047 in.). The sand materials shall be packaged in such a way as to prevent contamination and water damage. Each sack must be clearly labeled as to the mesh size of the sand contained. Approved supply sources are Colorado Silica Sand, Inc., Colorado Springs, Colorado and the Fountain Sand and Gravel Company, Pueblo, Colorado.

The use of any brand or variety of filter (sand) pack (other than the two approved sources noted above) must be approved by the Battelle Technical Administrator prior to the arrival on site of the drilling machinery. The following data shall be submitted in writing to the Battelle Technical Administrator as a part of the approval request:

1. Brand name(s)
2. Manufacturer(s)
3. Manufacturer(s) address(es) and telephone number(s)
4. Product description(s) from label(s) or brochure(s)

Allow six (6) working days from the time of receipt and information by Battelle for request evaluation and recommendations.

2.06 Bentonite Seal

A. Bentonite is the only sealant allowed. No organic additives shall be used. The use of any brand or variety of bentonite must be approved by the Battelle Technical Administrator prior to the arrival on-site of the drilling machinery. This includes bentonite powders, crumbles, pellets, etc., intended for grout, seals or hole abandonment. The following data shall be submitted in writing to the Battelle Technical Administrator as a part of the approval request:

   1. Brand name(s).
   2. Manufacturer(s).
   3. Manufacturer(s) address(es) and telephone number(s).
   4. Product description(s) from label(s) or brochure(s).

   Allow six working days from the time of receipt of information by Battelle for request evaluation and recommendation.

B. Bentonite for seals and boring abandonment shall be composed of commercially available pellets that are 1/4 to 3/8 inch in diameter or chunks, crumbles, or granules. Pellet seals shall be a minimum of 5-ft thick as measured immediately after placement, without allowance for swelling.

C. Bentonite grout, when used in TTH construction shall be a bentonite slurry grout or its equivalent. Such bentonite grout shall be mixed to approximately 100 pounds per 100 gallons of water, or in accordance with the manufacturers recommendations. Neither additives nor borehole cuttings shall be mixed with the grout.

2.07 Protective Steel Cover

A. The protective steel cover shall be, black plain-end welded steel pipe conforming to ASTM-53 or A-120 or an approved equal. The pipe section length shall be 5 feet with a locking cap. Size and wall thickness of base shall be 6-inch minimum inside diameter with a nominal 1/4 inch wall thickness. Steel caps shall have at least a 1/8 inch wall thickness. All welding must be performed in accordance with applicable portions of AWS D-1.1. A minimum 1/4 inch to a maximum 1/2 inch diameter hole located approximately 2.5 feet below the top of the steel cap shall serve as a drainage port.

B. Only the outside of the protective casing and covers/caps shall be painted safety yellow with a paint brush (not aerosol can) after installation. The yellow color for finish coats shall be as defined in ANSI Z53.1, Safety Color Code for Marking Physical hazards. Primer and paint materials shall conform to the following Federal Specifications:

o Primer for metal parts	TT-P-645
o Finish enamel	TT-E-489F, Class A

C. The painting of the TTH designation on the outside of the protective casing shall be performed using black paint and brush. This identification shall be done after the casing is painted as described above. Painting is required to be completed and dry prior to TTH development.

2.08 Surface TTH Protection

The final TTH shall be protected from damage by the following:

- A 4-foot by 4-foot by 4-inch thick concrete pad will be installed around the TTH's.
- Four metal posts shall be installed at the corners of the concrete pad. These posts shall be 4-inch in diameter schedule 40 carbon steel and shall be at least 6-feet in length of which 3.5-feet shall be above the pad. The post shall be painted safety yellow in the same manner as the TTH.
- A brass survey marker shall be placed in the surface of the pad. The surface of the survey marker shall be at least 3 in. in diameter to be of sufficient size to be stamped with the TTH number. The approved part number and material supply source is part number 01602 from Allen Precision Equipment, Atlanta, Georgia. Other brass markers may be used, if approved by the Battelle Technical Administrator.

2.09 Other Materials

All other materials, not specifically described but required for a complete and proper installation, shall be new and of first quality of their respective kinds, and subject to approval by the Battelle Technical Administrator.

2.10 Health and Safety Equipment

A. All individual protective clothing including coveralls, gloves, hard hats, steel-toed and shank boots, and related safety equipment shall be provided by the Contractor.

B. Monitoring of drill cuttings shall be carried out by Battelle. This monitoring will be done using an HNU organic vapor analyzer, an LEL 02 combustible gas indicator or similar devices. In the event that significant vapors are detected, work shall be suspended until the nature of the vapors is determined. It is estimated that most delays will be less than an hour, and any delays directed by Battelle will be considered standby time as documented by an approved Standby Order, Appendix C. Recommencement of work may require the use of half-face masks with organic vapor cartridges. All personnel must have had appropriate training in the use of such equipment prior to arrival on site.

3.00 Execution

3.01 Scope:

This section covers the complete construction and completion of TTH's.

A. Inspection:

The Battelle Technical Administrator shall verify that the TTH's have been constructed in strict accordance with all specifications presented herein.

B. Soil Description:

The Contractor should anticipate drilling in fine-to-coarse-grained material consisting of clay, silt, sand, gravels and cobbles to approximately 40 to 60 feet.

C. Warranty:

The information indicated in the technical section is to used by the contractor to assist him in properly evaluating the amount and character of the work that might be required. Such information is given, however, as being the best factual information available, without the assumption of responsibility as to its accuracy or for any conclusions that the Contractor might draw therefrom.

D. Notice:

The Contractor shall promptly, and before such conditions are disturbed, notify Battelle in writing of: 1) subsurface or latent physical conditions at the site differing materially from those indicated in this contract; or 2) unknown physical conditions at the site of an unusual nature, differing from those ordinarily encountered and from those generally recognized as inherent in the work of the character provided for in the contract. The

Battelle Technical Administrator shall promptly investigate the conditions and if he finds that such conditions do so materially differ and cause an increase or decrease in the cost of materials or the time required for the performance of this contract, he may recommend to the Battelle Contract Representative that an equitable adjustment be made and the contract modified accordingly.

E. Site of Work:

The Contractor is cautioned to visit the work site and by his own investigation satisfy himself as to the existing conditions affecting the work to be done under these specifications. If the Contractor chooses not to visit the site, he will never-the-less be charged with knowledge of conditions which a reasonable inspection would have disclosed.

3.02 Workmanship

Equipment used for drilling must be in good condition, of adequate size, with competent operators to insure satisfactory well construction within the time limits specified.

Drilling of the TTH's may be done by the hollow-stem auger or percussion tool method. TTH's shall be straight and a minimum of 8 inches in diameter to accommodate the installation of the permanent PVC casing specified, and allow the placement of grout by the tremie method.

3.03 Construction Record:

Written daily logs of construction progress shall be kept by the contractor, indicating size and length of casing installed; character, depth, and thickness of all changes in formation penetrated; water levels during the course of drilling; and any reasons for delays. Daily logs shall be made available to the Battelle Technical Administrator. All log entries shall be traceable to the date, time and workman making the entry. The Drilling Supervisor shall review daily logs and approve them by signature and date at the end of each working day.

3.04 Casing, Screen and Accessories

The PVC casing diameter, wall thickness, and other requirements are specified in Sections 2.02 and 2.03. Screen sections are to be joined to casing and each other by flush-threaded joints. Casing and screen shall be set round, plumb and true to line. Casings shall extend at least 24 inches above the concrete pad.

The screens will be ordered in writing by the Contractor in lengths specified in section 2.03. For each of the seventeen forty (40) foot deep TTH's the screen length shall be a total of 15 feet. The 6, 60 foot deep TTH's around landfill #1 will have a 5-foot screen installed at the bottom of each TTH. Screens shall be installed by setting them at the depth designated by the Battelle Technical Administrator. Use of other methods will not be permitted without specific approval, in writing, of the Battelle Technical Administrator.

3.05 Sand Pack:

After setting the screen in place, the sand pack, which meets the requirements of Section 2.05, shall be placed without a tremie to surround and extend 5 feet above the top of the screen. Where necessary, a loose fitting surge block or bailer will be used for 10 minutes to settle the sand pack; then additional sand may be added to satisfy the requirements illustrated in Figure 3. Temporary well casing or auger flights shall be withdrawn as the sand pack is being placed.

3.06 Bentonite Seal:

Approximately 100 lbs. of bentonite pellets shall be placed without using a tremie, immediately above the sand pack. Pellets are to be added slowly to prevent bridging in the annulus. Bentonite crumbles, chunks, granules, or grout slurry placed above the pellets may be installed immediately after pellets have settled to the bottom of the annulus. If grout is used it shall be placed by pumping through a tremie pipe. The tremie pipe shall extend to the bottom of the annular space. The tremie pipe is to remain submerged during the placement of all grout.

The Contractor shall place the bentonite seal around the TTH's as follows:

A. During removal of any drill casing, the annulus between the borehole and PVC casing shall be filled with bentonite to a point that is always at least two (2) feet above the bottom of the temporary casing, or auger flights.

B. Bentonite grout shall be placed through a tremie pipe (or hose) located just above the top of the seal.

C. After 24 hours the contractor shall check the site for grout settlement and that day pour the concrete well pad.

D. The protective steel casing and posts will then be installed while the concrete pad is being poured.

3.07 Protective Steel Cover

The Contractor shall protect the TTH at all times to prevent tampering or the entrance of foreign matter. After the concrete well pad has been placed and is reasonably firm, the specified protective steel cover (Section 2.07) shall be installed.

3.08 Well Development

Development of TTH's by pumping, bailing, and surging will be performed until the well water is clear, as determined by the Battelle Technical Administrator.

3.09 Cleaning and Decontamination of Equipment and Materials

Steam cleaning and rinsing of all drilling equipment including: rigs, water tanks (inside and out), augers, drill casings, rods, samplers, tools, recirculation tanks, etc., shall be done by the Contractor prior to arrival at the site. All equipment used in the borehole shall be cleaned between well sites. Prior to use on site, all casings, augers, and water tanks, etc., shall be devoid both inside and out of any asphaltic, bituminous, or other encrusting or coating materials, grease, grout, soil, etc. Paint, applied by the equipment manufacturer, need not be removed from the drilling equipment. All equipment or portions of equipment that come in contact with water or soil from the borehole must be cleaned between boreholes by brushing and steam cleaning. The residue from steam cleaning does not need to be contained for analysis. A separate steam cleaning site can be established, if appropriate, for each of the two drilling sites.

3.10 Abandonment of TTH's:

If, in the judgement of the Battelle Technical Administrator, a TTH should be abandoned for whatever reason, the Contractor will be ordered, in writing on a TTH Abandonment Form, see Appendix E, to abandon and fill the hole. If the TTH is to be abandoned, as a result of Contractor error or fault, the Contractor shall immediately make all repairs and work necessary for replacing the abandoned structure to the approval of the Battelle Technical Administrator at no additional cost. If the TTH is abandoned for reasons beyond the control of the Contractor, payment will be made for the actual depth drilled at the rate stated in the Payment Schedule, Appendix G.

The abandonment of any TTH's must be approved by the on-site Battelle Technical Administrator prior to any casing removal, sealing, or backfilling. Abandonment requests must be submitted in writing, see Appendix E, and include the following data:

A. Designation of TTH in question.

B. Current status (depth, contents of hole, stratigraphy, water level, etc.).

C. Reason for abandonment.

D. Recommendation.

Decisions on abandonment will be made within 4 hours of the request.

Once approved, the TTH to be abandoned shall be sealed by placing bentonite pellets and/or slurry from the bottom of the TTH to the surface. Grout shall be placed via the tremie method until undiluted grout flows from the TTH at the surface.

After 24 hrs., the Contractor shall check the abandoned site for grout settlement. That day, any settlement depression shall be filled with grout and rechecked 24 hrs later. This process shall be repeated until firm grout remains at the ground surface.

Normally an abandoned TTH shall be grouted with the well screen and casing in place. However, a lack of data concerning TTH construction or other factors may dictate the removal of the TTH materials and a partial or total hole redrilling prior to the sealing of the TTH site.

3.11 Site Cleanup and Restoration:

All structures, utilities and natural vegetation will be protected by the Contractor during the progress of the work. All debris, equipment and unused material will be removed from Fort Lewis by the Contractor. The property will be restored as near as possible to its original condition by the Contractor.

Disposal of any contaminated materials shall be the responsibility of the U.S. Army.

3.12 Standby (Delay) Time:

If it is necessary for the Contractor to stop drilling due to waiting for the Battelle Technical Administrator to complete other work, the Contractor will be placed on standby time, in writing, and removed from standby in writing, using the Standby Order form, Appendix C.

3.13 Special Work

Conditions at the Fort Lewis site may require special work. This work may include special perforating, setting special tools, special testing, minor exploratory drilling, unscheduled rehabilitation, abandonment of pre-existing Wells, or some unforeseen situation. Battelle may order special work using the Special Work Task Order (SWTO) form, Appendix D.

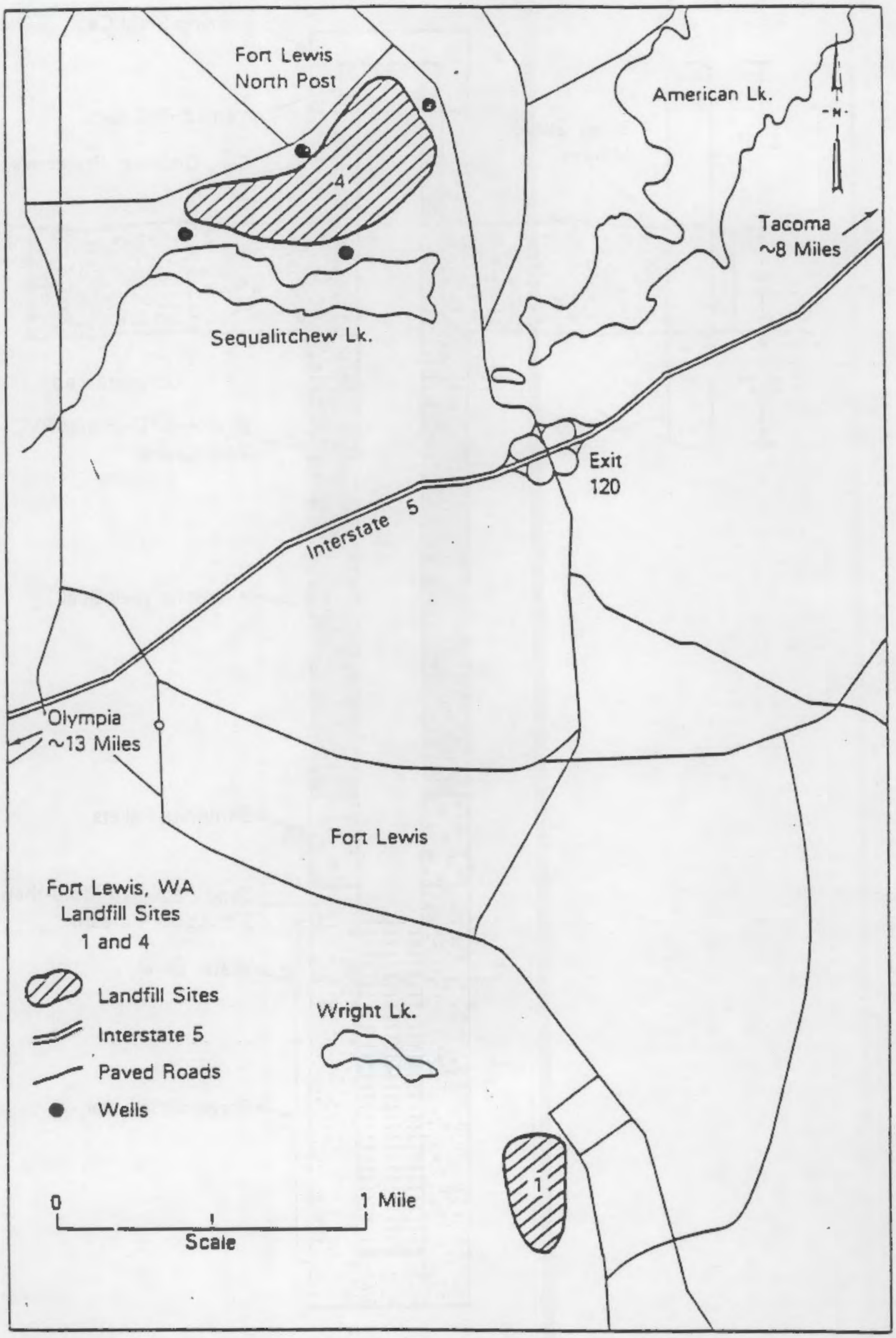


FIGURE 1. Fort Lewis, WA Landfill Sites

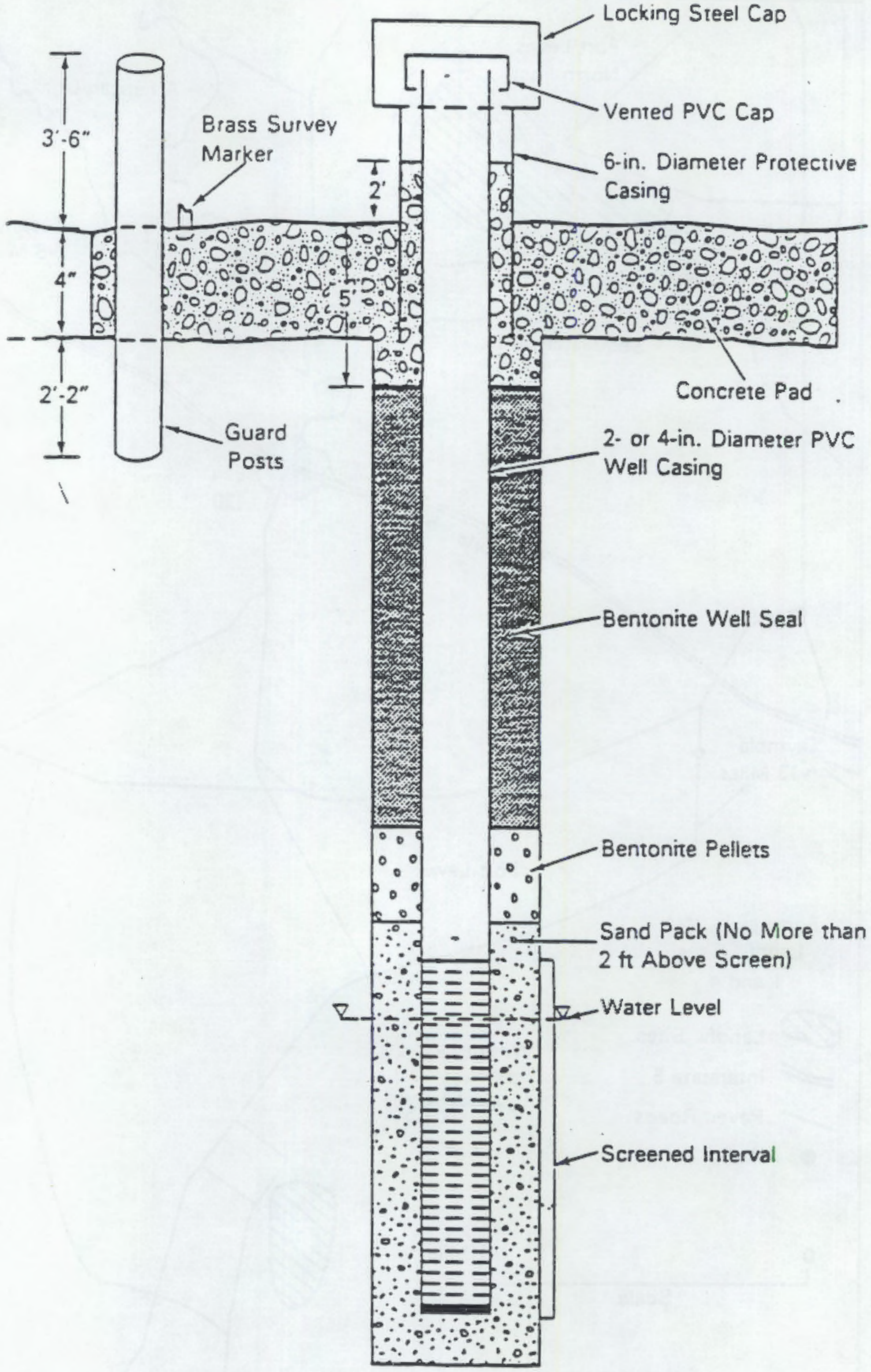


FIGURE 2. As-Built Well Diagram

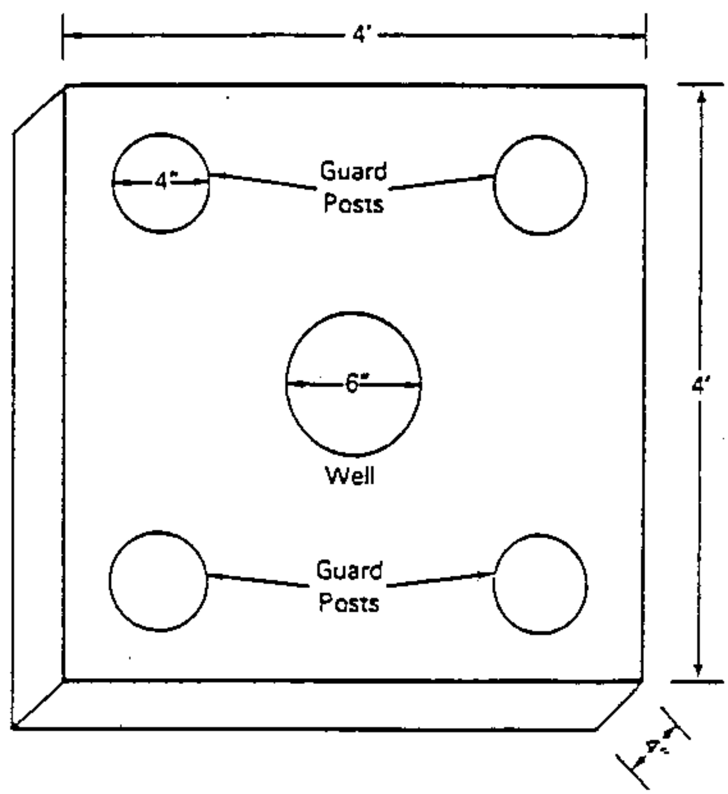


FIGURE 3. Surface Completion

<table>
<tr><td colspan="2">DESIGN FIELD CHANGE</td><td>DFC No.
FL-1</td></tr>
<tr><td>TASK NO.
11832
(Task 8802)</td><td>PROJECT TITLE
Ground-Water Investigation of Landfills 1 and 4, Fort Lewis, Washington (EES-25)</td><td>FINAL APPROVAL DATE
8-9-88</td></tr>
</table>

DOCUMENTS AFFECTED

Subcontract B-V5209-A-E, Appendix A, Drilling Specification, dated June 1988, Sections 2.06 (B) and 3.06

DESCRIPTION OF CHANGE

1. 2.06 (B): The last sentence should be changed to read, "Pellet seals shall be a minimum of 2-ft thick. If bentonite slurry will be used above the pellet seal the pellet seal shall be a minimum of 5-ft thick as measured immediately after placement, without allowance for swelling."
2. 3.06: The first sentence should be changed to read, "Approximately 50 lbs. of bentonite pellets shall be placed without using a tremie, immediately above the sand pack. If bentonite slurry is to be used above the pellets, approx. 100 lbs. of pellets shall be used."

DISTRIBUTION

SP Airhart
PA Eddy
DR Dahl
GV Last
Project File

JUSTIFICATION

The properties of bentonite chunks, crumbles, and granules are sufficiently similar to those of bentonite pellets to allow a bentonite pellet seal of less than 5-ft to be used. However, if a bentonite slurry seal is used above the bentonite pellet seal, the bentonite pellet seal must be a minimum of 5-ft to prevent penetration by the slurry.

REMARKS

None.

INITIATOR/AUTHOR	PHONE	ORGANIZATION	DATE
GV Last G.V. Last	6-8527	D7D34	8-9-88

APPROVALS

PROJECT MANAGER	QAD REPRESENTATIVE
Paul A Eddy 8-9-88	D.R. Dahl 8/9/88
	Peer Review 8-9-88

APPENDIX C

PROCEDURE FOR COLLECTION OF SEDIMENT SAMPLES USING HOLLOW STEM AUGER METHODS

TECHNICAL PROCEDURE

TITLE: TP-8, COLLECTION AND DOCUMENTATION OF SEDIMENT SAMPLES RECOVERED USING HOLLOW STEM AUGER METHODS.

1.0 APPLICABILITY

This procedure applies to work performed by well site geologists during collection and documentation of sediment samples recovered from boreholes drilled by hollow stem auger methods. This includes both the periodic and continuous sampling methods.

2.0 DEFINITIONS

Does not apply.

3.0 RESPONSIBLE STAFF

3.1 Project Manager

3.2 QAD Representative (Cognizant QE)

3.3 Principal Investigator and Cognizant Staff

3.4 Well Site Geologist

4.0 PROCEDURE

4.1 The driller shall advance the hollow stem auger flights to just above the required sample interval (every 5 ft and/or lithologic changes). If the continuous sampling method is being used, skip to step 4.4.

4.2 If a pilot bit is not being used while advancing the auger flights, then the driller shall remove any soil or residue that entered the flights during their advancement. The driller shall then lower a clean split-spoon sampler (also referred to as a split-barrel or split-tube sampler) through the hollow stem auger flights to the bottom of the clean borehole using solid drill rods.

Concurrence	Date	Approval	Date
J. R. Raymond	9/15/87	R L Skaggs	9/15/87
Prepared by G. V. Last	Date 9-15-87	QAD Concurrence R R LaBarge	Date 9/15/87
Procedure No. TP-8	Revision No. 0	Effective Date 5/01/87	Page 1 of 3

4.3 The driller shall then use an appropriate drive weight to hammer the sampler into the undisturbed materials (soil) below the borehole. The driller shall not drive the sampler a distance greater than the length of the sampler. The number of hammer blows should be counted and recorded by the well site geologist.

4.4 The driller shall remove the sampler from the auger flights, being careful not to knock the sample out of the sampler. The sampler shall then be carefully removed from the drill rod.

4.5 Carefully remove the drive shoe and the end cap from the sampler. Lay it flat and remove one side of the split-tube sampler.

4.6 With a knife or other suitable object, carefully scrape any smeared material (top 1/8 - 3/8 in.) off the top half of the sample. If this cannot be done without disturbing the sample, and/or if the sample can easily be described without exposing a fresher surface, then disregard this step.

4.7 Examine, physically describe, and photograph (optional) the sample. The physical description shall be recorded in the geologist's log or field notebook and shall include the borehole number, depth of the sampled interval, drill method, wet/dry sample, lithologic description, date and time the sample was collected, and any suitable comments regarding the representativeness of the sample. These descriptions shall be thorough, and all entries will be recorded chronologically. The geologist's log (or field notebook) shall be signed and dated at the end of each day.

4.8 Carefully remove selected subsamples from the sampler and place them in suitable containers (moisture can, canning jars, etc.). If more than one layer of material is present, then the subsamples shall be collected by partitioning the sample into lithologically similar subsamples. Care should be taken to exclude the top portion of the sample thought to be slough or not representative of the sampled interval. The sample containers shall be labeled with the borehole identification number, the depth interval of the sample or subsample, the date, and the geologist's initials.

4.9 The sampler shall then be scraped clean of all foreign matter and washed with water or a pre-approved detergent solution. The sampler shall then be rinsed clean, and reassembled.

4.10 Samples shall be labeled "Suspect" and/or discarded if the location and depth of the sample is lost or unknown, or if the representativeness of the sample is in question.

4.11 If physical analyses are to be performed by PNL's Soils Laboratory in the Sigma V building, the samples shall be hand delivered to the Soils Laboratory Coordinator or his representative. When the samples are received, the Soils Lab. Coordinator or his representative will log the samples into a controlled notebook, along with the date and time they were received. The samples will be logged in and always identified by the borehole number and depth as clearly labeled on the sample.

4.12 If chemical analyses are to be performed, then the appropriate sample handling and chain-of-custody procedures shall be followed as listed in PNL-MA-580, Environmental Monitoring Procedures.

APPENDIX D

GEOLOGIC SAMPLING AND WELL CONSTRUCTION DOCUMENTATION PROCEDURE

APPENDIX D

GEOLOGIC SAMPLING AND WELL CONSTRUCTION DOCUMENTATION PROCEDURE

This appendix contains the procedure for collecting and documenting drilling data that was in place during well drilling at the landfills.

Procedure for Collection and Documentation of Drilling Data, P-6 for RCRA Compliance/Hazardous Materials Monitoring

1.0 OBJECTIVE

This procedure provides standardized methods for the collection and documentation of sediment samples and well construction data, for wells drilled by the cable tool method.

2.0 APPLICABILITY

This procedure applies to work performed by well site geologists during well construction.

3.0 RESPONSIBILITIES

3.1 Well Site Geologist

- Collect and document drilling data

3.2 Senior Technical Reviewer

- Review and sign/date Well Completion Report/Title III Inspection List
- Review and sign/date As-Built Diagram
- Review and sign/date Drill Logs

4.0 PROCEDURE

4.1 Collection of Sediment Samples

Sediment samples shall be collected at 5-foot intervals and changes in formation by the well site geologist. All drill cuttings to be sampled shall be collected from the driller in a 5 gallon bucket.

Two pint jars shall then be filled from the bucket. One jar shall be submitted for laboratory analysis and the other retained for archiving.

A label indicating well number, depth, date, drilling method and initials of the geologist collecting the sample shall be placed on each sample jar. Well number, depth and date shall also be written on the lid of each jar.

Approvals: Project Manager 3/16/87		QA Rep. DR Dahl 3/16/87	
Procedure No: P-6	Revision No: 0	Date Issued: 3-16-87	Page 1 of 3

If the well is being drilled with a drive barrel above the water table, a moisture sample shall also be collected from the bucket. Each moisture sample shall be sealed with white identification tape. The well number, depth, date and initials of the geologist collecting the sample shall be recorded on the identification tape with indelible ink. Each moisture sample shall then be doubly wrapped in a plastic bag, and taped shut.

The remainder of the sample in the bucket shall be used for sediment sample description.

4.2 Documentation of Sediment Samples and Well Construction Data

Sediment sample descriptions and well construction data for each well shall be recorded on a Well Completion Report/Title III Inspection List (Attachment 1), As-Built Diagram (Attachment 2) and Drill Log (Attachment 3). These data shall be recorded daily by the well site geologist. Nonapplicable items shall be designated N/A.

The Well Completion Report/Title III Inspection List provides a complete summary of well construction and completion data. Data recorded on the Well Completion Report/Title III Inspection List shall include: general project and well information, drilling method, completion data, casing data, perforations, screen, annular seal, geophysical logging, aquifer testing and other applicable items. Casing data, perforations, screen, annular seal, geophysical logging, aquifer testing and other applicable items shall be approved by the well site geologist. After completion of the well, an overall review of the Well Completion Report/Title III Inspection List shall be performed by the Senior Technical Reviewer.

The As-Built Diagram is a graphical representation of the well construction, geologic and hydrologic data. Data recorded on the As-Built Diagram shall include: well number, geologist, page number, construction data, depth in feet, geologic and hydrologic data. After completion of the well, an overall review of the As-Built Diagram shall be performed by the Senior Technical Reviewer.

The Drill Log contains detailed descriptions of the sediment samples and well construction data. Data recorded on the Drill Log shall include: geologist name, date, rig, well number, depth at start, depth at finish, computer number, project number, subcontract number, total casing, depth, drill method, wet/dry sample, lithologic description including moisture sample data, time, drilling comments and remarks. A new Drill Log shall be used each day. After completion of the day's activities, the well site geologist shall sign and date the Drill Log. After completion of the well, an overall review of the Drill Logs shall be performed by the Senior Technical Reviewer.

4.3 <u>Description of Sediment Samples and Well Construction Data</u>

Detailed descriptions of the sediment samples and well construction data shall be recorded on the Drill Log under "Lithologic Description" by the well site geologist.

Sediment sample descriptions shall include the following information as a minimum: lithologic name, texture, sorting, gross mineralogy of the framework and matrix, roundness of the framework and matrix, wet/dry color, reaction in hydrochloric acid (HCl), consolidation and changes in lithology.

Well construction data shall include the following information as applicable: drill method, drill depth, completion depth, drill rate, casing (type, size, depth and lengths), perforations (type, depth and schedule), screen (type, length, slot size and depth), annular seal (type, interval and volume), packer (type, size and depth), well development and depth to water.

4.4 <u>Data Management</u>

After completion of the project, the original Well Completion Report/Title III Inspection List, As-Built Diagram and Drill Logs for each well shall be retained by V. L. McGhan of the PNL Geosciences Department. A copy of each completed form shall be retained by the PNL Records Retention Center.

Battelle

Well Completion Report/Title III Inspection List

Project ____________ Well Number ____________
Location ____________ Temporary Well Number ____________
Driller ____________ Coordinates ____________
Drilling Co. ____________ Casing Elevation ____________
Geologist ____________ Ground Elevation ____________

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D ______ H ______
Drilling Fluid ____________
Other ____________

COMPLETION DATA

Drilled Depth ____________
Completion Depth ____________
Date Started ______ Completed ______
Static Water Level/Date ____________

CASING DATA

Type	Size		
		to	
		to	
		to	

Approved By ______ Date ______

PERFORATIONS

Type ____________

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type ____________
Length ____________
Slot Size ____________
Depths ______-______
______-______

App. By ______ Date ______

ANNULAR SEAL

Type	Interval	Volume

App. By ______ Date ______

GEOPHYSICAL LOGGING

Sondes	Interval	Date
	-	
	-	
	-	
	-	
	-	
	-	
	-	

Approved By ______ Date ______

AQUIFER TESTING

Type of Test ____________
Length of Test ____________
Volume Pumped ____________
Drawdown ____________

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

___ Steam Cleaning
___ Storage of Const. Material
___ Tool Lubricants
___ Concrete Pad
___ Protective Steel Posts
___ Safety Paint
___ Straightness Test
___ Well Development
___ Downhole TV Inspection
___ Well Abandonment
___ Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By ____________ Date ____________

Reviewed By ____________ Date ____________

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number ____________ Geologist ____________ Page ____ of ____

Reviewed by ____________ Date ____________

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description

A-1800-186 (1/87)

DRILL LOG	By	Rig	Well Number	Computer Number	Project or Work Order No.
	Date		Depth To		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments

REMARKS:

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A 6000 021 (5 88)

APPENDIX E

WELL COMPLETION REPORT, AS BUILT DIAGRAM, NATURAL-GAMMA LOGS, AND DRILL LOGS OF THE NEW WELLS

APPENDIX E

WELL COMPLETION REPORT, AS BUILT DIAGRAM, NATURAL-GAMMA LOGS, AND DRILL LOGS OF THE NEW WELLS

This appendix contains field documentation compiled while drilling wells near Landfills 1 and 4. The wells described include

- for Landfill 1
  - LF1-PNL1
  - LF1-PNL2
  - LF1-PNL3
  - LFL-PNL4
- for Landfill 4
  - LF4-PNL1
  - LF4-PNL2
  - LF4-PNL3
  - LF4-PNL4
  - LF4-PNL5
  - LF4-PNL6

Note: no natural-gamma log is available for well LF4-PNL3 because no geophysical survey was conducted at that well.

WELL LF4-PNL1

Battelle Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832
Location FORT LEWIS
Driller LENNY BULTENA
Drilling Co. ONWEGO DRILLING CO., INC.
Geologist S.D AIRHART

Well Number
Temporary Well Number LF1-PNL1
Coordinates
Casing Elevation
Ground Elevation

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D ______ H ______
Drilling Fluid
Other 8" HOLLOW STEM AUGER + SPLIT-SPOON TO 48'

COMPLETION DATA

Drilled Depth 48'
Completion Depth 48.4'
Date Started 8-9-88 Completed 8-19-88
Static Water Level/Date 37.8' / 8-10-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	2" DIA. (SCH. 40)	33.1'

Approved By S.D. A Date 8-10-88

PERFORATIONS

Type
Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 2" DIA. SLOTTED PVC
Length 15.3'
Slot Size 20
Depths 33.1' - 48.4'

App. By S.D.A Date 8-10-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	28.9'- 48'	5.62 ft^3
1/4" PELLETS	23.3'- 28.9'	1.4 ft^3
BENT. CHUNKS	1.8'- 23.3'	5.36 ft^3
CONCRETE	0'- 1.8'	~.5 ft^3

App. By S.D.A Date 8-19-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NAT. GAMMA	2.3' - 44.3'	8-10-88

Approved By S.D.A Date 8-10-88

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

8-9 Steam Cleaning
8-9 Storage of Const. Material
8-9 Tool Lubricants
8-19 Concrete Pad
8-19 Protective Steel Posts
10/24 Safety Paint
NA Straightness Test
8/25 Well Development
NA Downhole TV Inspection
NA Well Abandonment
11/5 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By S D A Date 11-5-88

Reviewed By T.K. Mahlan Date 11-8-88

A-1800-187 (3/87)

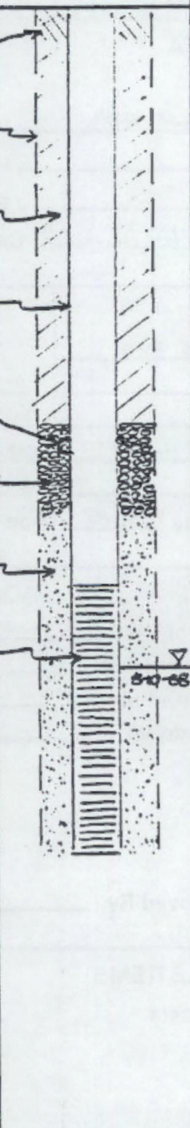
Battelle
Pacific Northwest Laboratories

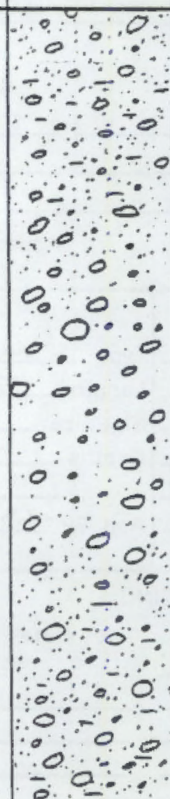
AS-BUILT DIAGRAM

Well Number LFI-PNL1 Geologist S.P. AIRHART Page 1 of 1

Reviewed by [signature] Date 11-8-88

Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Geologic/Hydrologic Data: Lithologic Description
CONCRETE				
		5		MUDDY SANDY GRAVEL
BOREHOLE DRILLED W/ 8" AUGER				
		10		MUDDY SANDY GRAVEL
BENTONITE CHUNKS				
		15		GRAVEL
2" DIA. PVC CASING				
		20		NO SAMPLE (ASSUME GRAVEL)
CENTRALIZER				
		25		GRAVEL
1/4" ENVIROPLUG PELLETS				
		30		GRAVEL
10-20 COL. SILICA SAND				
		35		MUDDY SANDY GRAVEL
2" DIA. SLOTTED PVC (20 SLOT)	8-10-88			
		40		MUDDY SANDY GRAVEL
		45		MUDDY SANDY GRAVEL
DEPTH DRILLED = 48'				





A-1800-186 (3/87)

Well: LFI-PNLI Drilled Depth 48' Interval Logged 2.3'-44.3'

Log Type: NAT. GAMMA Date 8-10-88 Casing Size 4" HOLLOW STEM AUGER FLIGHTS

Logged By: S.P. AIRHART Water Level Depth 36.8'

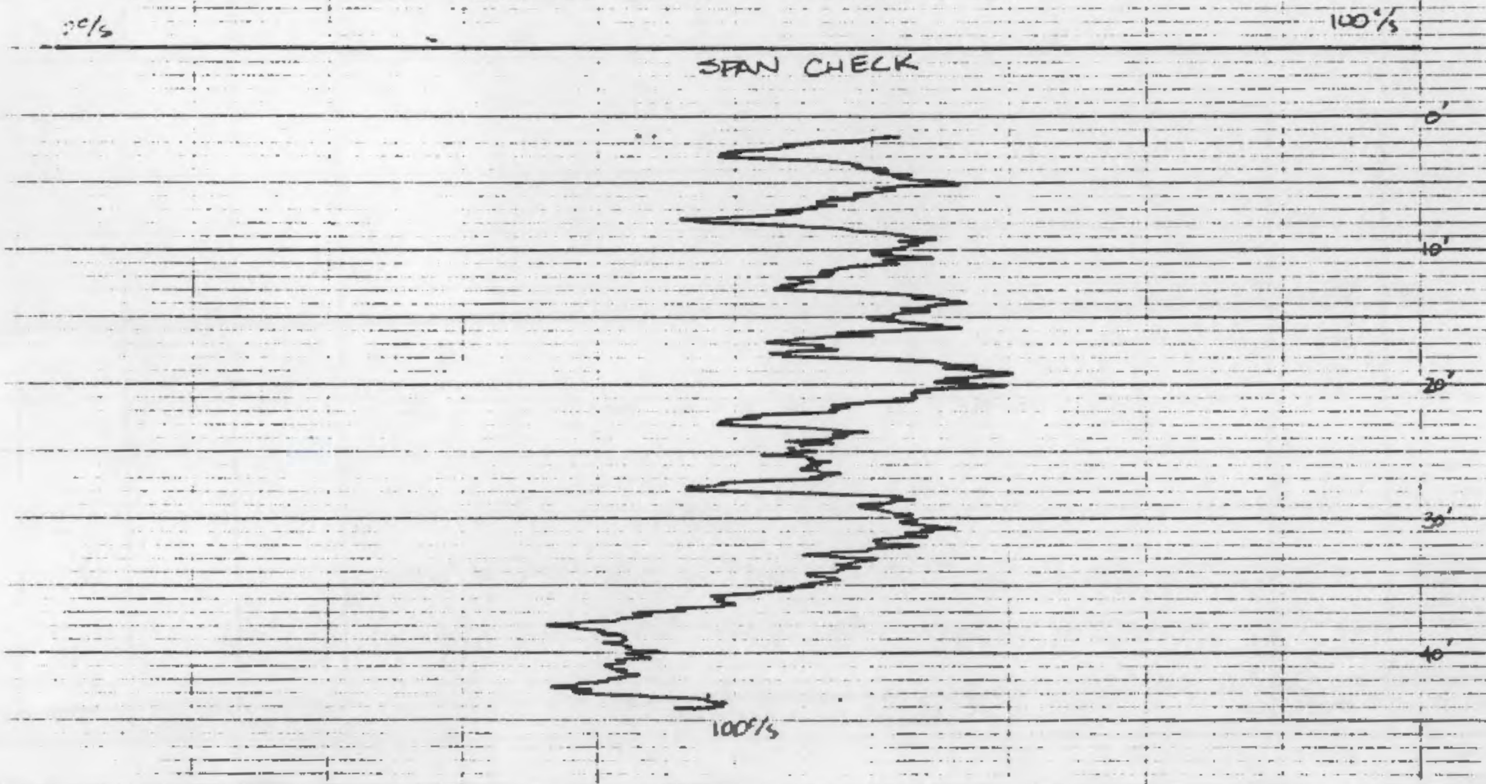
Logging Scales: Sensitivity 100 c/s Time Constant 3

Vertical Scale 10'/in. Logging Speed 15'/min.

Source Strength NA Spacer Length NA.

Remarks: Reference Procedure GW-6 Rev. 2

Probe Serial # NG-001



DRILL LOG	By: AIRHART	Rig: SCHRAMM T64 ONWEGO	Well Number: LF1-PNL1	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-9-88		Depth: 0' To 5'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Moved drill rig and equipment to hole	16:00	
				Using Rotary Rig as an auger; 4" ID & 8" OD	16:30	Started drilling.
				Hollow stem flights.		
				0'-3' Fine-to-med pebble gravels. Rounded		
				clasts.		
					16:45	Will take 5' sample
						in morning.

REMARKS:

S.D. Airhart
8-9-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64 ONWELD	Well Number: LFI - PNL1	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-10-88		Depth: 5' To 20'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	5'-6.5'	SS	M	MUDDY SANDY GRAVEL: 75% gravel, 20% sand,	0735	Drove 17" recovered
				5% silt: Gravels are SA-R, very fine		6".
	Took	Photograph →		pebble to very coarse pebble, dominantly		Blows/5" = 15, 46, 50
	of	sample		med pebble. Variable lithologies - mostly	Took 1 sed. & 1 moist sample.	
				igneous: moist color olive brown 2.5Y4/4;	No rxn	w/ 10% HCl
	10'	SS	W	MUDDY SANDY GRAVEL: 75% gravel, 20% sand,	07:55	Drove 6" - 100 blows
				5% silt: Gravels are SA-R. VFP-SC -		only 3" recovered
				wet color olive brown 2.5Y4/4 - no rxn w/		small cobble ~70 mm
				10% HCl; Took photograph;		stuck in bottom of
				Note only ½ jar of sample was collected -		split spoon
				seds are wet - checked w/ HNU no response.	Took 1	sed & 1 moist sample
	15'-16'	SS	W	GRAVEL: 90% gravel 3% sand 7% mud - VFP-SC SP-R	0820	Blows/5.5" = 7, 11, 50
				sample is wet. Wet color light olive brown		Drove 18" - recovered ~8"
				2.5Y 5/4 - No rxn w/ 10% HCl - Took 1 sed. &	1 moist	sample
				Took photograph. Checked hole w/ HNU - no response.		
	20'			NO SAMPLE RECOVERY @ 20'. Sediments are	0835	
				gravel - too large to fit in sampler.		

REMARKS:

St. D. Airhart
8-10-88

E.7

D - Dense Hard H - Hard T... L - Loose M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig SCHRAMM T64 ONWEGO	Well Number LFI-PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 8-10-88		Depth 20' To 28'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Based on sediments returning to surface		
				while augering - sediments are mod.-to-		
				well sorted MP-VCP. >90% gravels.		
						Note: Drillers using
						small dabs of
						Chevron Poly FM
						grease on sampling
						Flight threads
	25'-25.5'	SS	VM	GRAVEL: 85% gravel (VFP-VCP [up to 40mm]) 5% sand	05:10	100 blows / ~5"
				(VFS-VCS) 10% silt/clay: Clasts are SA-SR; Moist		5" sample recovered
				color olive brown 2.5Y 4/4 : No rxn. w/ 10% HCl;		
				unconsolidated : Took moisture sample +		
				1 jar sediment sample : Took photograph : No		
				response w/ 11.7 HNU.		
	25'-28'			Very gravelly - augering more slowly	→	Wood frags returning
	28'			Hit obstruction - probably cobble or boulder - auger		to surface Collected
				will not advance. Pulled auger out and moved		and jarred Not

REMARKS:

certain of depth. Probably 5'-15'.

St. P A [signature]
8-10-88

E.8

DRILL LOG	By AIRHART	Rig SCHRAMM	Well Number LEI-PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 8-10-88	T64	Depth 28' To 35'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				rig ~ 2' - Resumed drilling new hole will		
				not sample until 30'.		
	30'	SS	VM	GRAVEL: 85% gravel (VFP-VCP up to 50mm - dom.	11:15	blows/4½" = 50
				MP-CP) 3% sand 12% clay/silt - No sed.		Drove sampler 4½"
				structure evident: Moist color: olive 5Y5/4:		Recovered 3"
				No rxn. w/ 10% HCl: unconsolidated - Note		
				presence of clay: Only enough sample for		
				moisture sample: No photograph taken		
	35'-35.5'	SS	M	MUDDY SANDY GRAVEL: 65% gravel, 25% sand, 10%	12:00	blows/5½" - 50
			5Y4/2	clay/silt: 10% CP (up to 25mm) 15% MP, 20% FP,		Drove sampler 7"
				20% VFP, 10% VCS, 10% CS, 3% MS, 1% FS, 1% VFS, 10% clay/		Recovered 6"
				silt: very poorly sorted: (gravel) SA-SR,		
				lithologies include: basalt, yellow qtzite, ign.		
				(sand) A-SA grains: unconsolidated:		
				Moist color olive gray 5Y4/2; No rxn w/ 10% HCl		
				Note increase in sand Took 1 sed. sample		
				& moisture sample & photograph.		

REMARKS:

St. P. Airhart
8-10-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standard Work

E.9

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64 ONWEGO	Well Number: LFI-PNL1	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-10-88		Depth: 35' To 45'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Hit water. Checked w/ steel tape: D/W: 34.9'	13:30	
				below land surface		
				(VFP-CP < 30mm) (dom. MS-CS)		
	40'-41'	SS	W	MUDDY SANDY GRAVEL: 60% gravel, 30% sand, 10%	13:40	blows/5" = 18
				silt/clay: clasts are SA-SR, granite, porphyritic,		blows/6" = 50
				basalt, qtzite & other: grains Ang- primarily		Drove sampler - 1'1"
				rock frags: wet color olive 5Y5/3: no rxn.		Recovered 1'
				w/ 10% HCl; unconsolidated. 2 sed. samples		
				taken. ; photograph taken		
	45'-46'	SS	W	MUDDY SANDY GRAVEL: 55% gravel (VFP-VCP largest	14:40	blows/5" = 13,50
				is 30 mm) 40% sand (VFS-VCS) 5% silt/clay. Clasts		
				are SA-SR; sand grains are A-SA: Formation is		Drove sampler 10"
				unconsolidated: wet color olive 5Y5/3: No rxn. w/		recovered
				10% HCl; took 2 sed. samples.		
				Measured D/W @ 36.76' below land (S-tape # L30001)		
				Instructed driller to drill to 47'	1500	
				Stopped drilling @ ~48' below land	1515	

REMARKS:

S.P. Airhart
8-10-88

D Drive Barrel H Hard Tool L Large M Medium S Small VC Very Coarse C Coarse F Fine VF Very Fine Standing Water

E.10

DRILL LOG	By AIRHART	Rig SCHRAMM T64	Well Number LF1-PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 8-10-88		Depth 45' To 48'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Checked D/B = 46'6" below land (s-tape L30001)	15:45	
				Checked hole w/ HNU (11.7 lamp) no response	15:46	
				Geophysically logged hole: (2.25' - 44.8')	16:00 -	17:00
				w/ Nat. γ probe		
				Drillers steam-cleaning PVC		
				Added the following 2" dia. PVC to hole:	17:15 -	
				15'4½" of slotted screen (20 slot) w/ bottom cap		
				1 10' section casing w/ hoop centralizer (4'5" above screen)		
				2 9'11" sections casing = 19'10"		
				1 5'6" section		
				Total PVC = 50'7½"		
				D/B inside PVC = 46'9" below land ∴ top		
				of screen = 31'4½" or ~ 31'.		
				Added ¾ 100 lb. bag of 10-20 Col. Silica Sand to 43	17:40	
				Pulled auger flights to 44'	17:45	

REMARKS:

StD Airhart
8-10-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

DRILL LOG	By AIRHART	Rig SCHRAMM T64	Well Number LFI-PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 8-11-88		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/w : 37' below land (E-tape # A150-04)	0735	
				D/B inside PVC = 48'2" (s-tape # L3000-1)		
				D/sand = 43'3" below land (s-tape # L3000-1)	0740	
				Added 4 1/2 bags (100 lb) of Colorado Silica	0835	
				sand 10-20 mesh. D/sand = 28'11" below		
				land.		
				Surged hole to settle sand. None settled	08:58	
				∴ Final D/sand = 28'11" below land		
				Added 2 1/4 5 gal buckets of Enviroplug 1/4" pellets	08:50	
				D/pellets = 23'4" below land (final depth)		
				Added 7 1/2 50 lb bags of Enviroplug (Medium)	10:30	
				bentonite chips.		
				D/bentonite = 1'10" below land (final depth)		
				Moved rig off hole	11:00	

REMARKS:

StP. Airhart
8-11-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

(FORT LEWIS - LANDFILL 1)

DRILL LOG	By: AIRHART Date: 8-19-88	Rig: NO RIG CUBBY	Well Number: LF1 - PNL1 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed 1 sack of Columbia I & P cement (1 part)		
				w/ sand & gravel (4 parts) (~ 4:1 mixture) to		
				fill remaining annulus, surface pad,		
				surface protective casing, & 4 protective posts		
				Set brass marker		
				Distance from pad to top of protective casing = 34¼"		= 2'10¼"
				Distance from pad to top of PVC = 26¼" = 2'2¼"		
				Distance from pad to concrete inside protective casing = 13" = 1'1"		

REMARKS:

STP Airhart
8-19-88

E.13

(FORT LEWIS- LANDFILL 1)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF1- PNLH	Computer Number NA	Project or Work Order No. 11832
	Date 9-1-88		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixing cement - pouring surface pad	0900	10:45
				Mixed 1 bag Portland cement w/ gravel		
				+ sand and poured surface pad and		
				base around protective posts.		
				set brass cap	10:45	
						95
						2.49
				Top of pad to top of 6" protective casing = 2.49'		.67
				Top of pad to inside protective casing = -0.46'	below pad	1.82
				Top of pad to top of PVC = 1.82'		

REMARKS:

SLP Airhart
9-1-88

E.14

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	NO RIG	LFI-PNLI		11B32

Date	Depth	To	Subcontract No.
			NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Painted posts during week of 10/17-10/21		

REMARKS:

11/5/88 St P Airhart

WELL LF4-PNL2

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 118.32
Location FORT LEWIS
Driller LENNY BULTENA
Drilling Co. OWEGO DRILLING CO., INC.
Geologist S. P. AIRHART

Well Number
Temporary Well Number LFI-PNL2
Coordinates
Casing Elevation
Ground Elevation

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D ______ H ______
Drilling Fluid
Other 8" HOLLOW STEM AUGER W/ SPLIT-SPOON

COMPLETION DATA

Drilled Depth 33'
Completion Depth 32.5'
Date Started 8-11-88 Completed 8-19-88
Static Water Level/Date 21.7' below land / 8-16-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	4" DIA (SCH. 40)	to 17.1'
		to
		to

Approved By StP. A[illegible] Date 8-16-88

PERFORATIONS

Type NA

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 4" DIA. SLOTTED PVC
Length 15.4'
Slot Size 20
Depths 17.1' - 32.5'

App. By StP A[illegible] Date 8-16-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	13' - 33'	4.82 ft³
1/4" PELLETS	8.7' - 13'	0.93 ft³
BENT. CHUNKS	2' - 8.7'	1.43 ft³
CONCRETE	0' - 1'	~.4 ft³

App. By StP. A[illegible] Date 8-19-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NAT. GAMMA	2' - 31'	8-16-88
	-	
	-	
	-	
	-	
	-	
	-	

Approved By StP A[illegible] Date 8-16-88

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

.03

OTHER APPLICABLE ITEMS

8-11 Steam Cleaning
8-11 Storage of Const. Material
8-11 Tool Lubricants
8-19 Concrete Pad
8-19 Protective Steel Posts
10/24 Safety Paint
NA Straightness Test
9/8 Well Development
NA Downhole TV Inspection
NA Well Abandonment
11/5 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By StP A[illegible] Date 11-5-88

Reviewed By V.L. Marshall Date 11-8-88

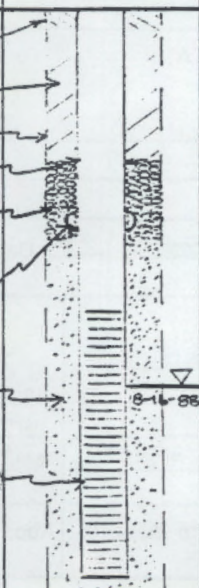
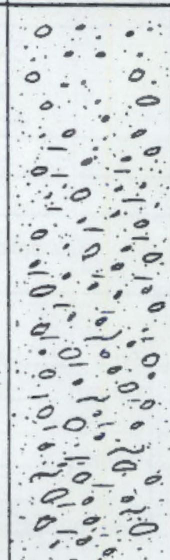
A-1600-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LFI-PNL2 Geologist S.D. AIRHART Page 1 of 1

Reviewed by [signature] Date 11-8-88

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
CONCRETE				
BENTONITE CHUNKS		5		NO SAMPLE (ASSUME SANDY GRAVEL)
BOREHOLE DRILLED w/ 9" AUGER				
2" DIA. PVC CASING		10		SILTY SANDY GRAVEL
1/4" ENVIROPLUG PELLETS				
		15		SILTY SANDY GRAVEL
CENTRALIZER				
		20		SILTY/CLAYEY SANDY GRAVEL
10-20 COL. SILICA SAND				
		25		SILTY SANDY GRAVEL
2" DIA. SLOTTED PVC (20 SLOT)				
		30		SILTY/CLAYEY SANDY GRAVEL
DEPTH DRILLED = 33'		35		
		40		

A-1800-186 (3/87)

Well LFI-PNL2 Drilled Depth 33' Interval Logged 2'-31'

Log Type NAT. GAMMA Date 8-16-88 Casing Size 4" HOLLOW STEM AUGER FLIGHTS

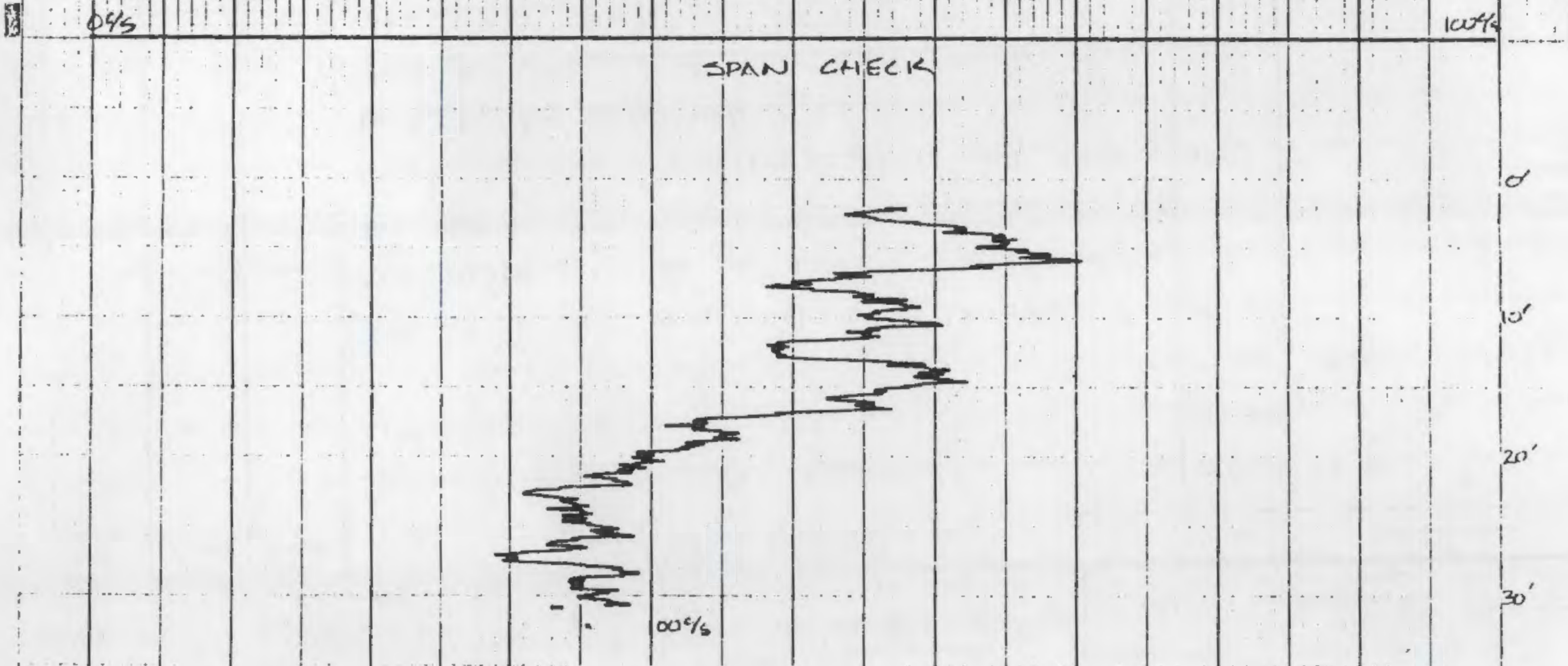
Logged By S.P. AIRHART Water Level Depth 21.7'

Logging Scales: Sensitivity 100 c/s Time Constant 3

Vertical Scale 10'/in Logging Speed 15'/min

Source Strength NA Spacer Length NA

Remarks: REFERENCE PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



DRILL LOG	By: AIRHART (LENNY BULTENA)	Rig: SCHRAMM T64 ONWEGO	Well Number: LF1-PN2 (FORT LEWIS LANDFILL #1)	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-11-88		Depth: 0' To 5'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Steam cleaned rig & equipment	12:00	13:30
				Moved rig to well site	14:00	
					14:15	Began Drilling
				Appears to be large cobble or boulder @	15:05	
				3.5' depth ∴ no split-spoon sample will		
				be taken.		
				Unable to make progress @ this spot Moving	15:15	
				back to try new hole.		
				Still no progress at new spot. Moving again	15:30	
				Drilled to ~ 5'	17:00	Shut Down

REMARKS:

St P. Airhart
8-11-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse

E.20

(FORT LEWIS - LANDFILL #1)

DRILL LOG	By: AIRHART Date: 8-16-88	Rig: SCHRAMM T64 ODWEGO [illegible]	Well Number: LF1-PNL2 Depth: 5' To 15'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0745	Drillers arrived
					0810	Taking 5' split
						spoon sample
						150 blows/4" w/
						150 lb. hammer.
				Unable to obtain 5' split-spoon sample-	0815	
				formation is too coarse.		
					0840	Taking split spoon
						blows/4": 28,41,50
						Drove 12"
						recovered 6"
	10'-10.5'	SS	VM	SILTY SANDY GRAVEL: 60% gravel (VFP-CP) 30% sand	0845	
				(VFS-VCS) 10% silt/clay : moist color - olive		NOTE: Large gravels
				brown 2.5Y 4/4 : unconsolidated : Took 1 jar		@ these depths
				sample + moisture sample : Photograph taken		10-15'.
	15'	SS	VM	SILTY SANDY GRAVEL: 60% gravel 20% sand	0905	Took split-spoon
				20% silt/clay : moist color - dark grayish brown		blows/4": 90,150,200
				2.5Y 4/2 : unconsolidated: Took moisture sample and	photo.	Drove 12"

REMARKS:

recovered 2"

S.P. Airhart 8-16-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

— Raining —

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64	Well Number: LFI-PNL2	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-16-88	LENNY BULTENA	Depth: 15' To 30'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	20-20.8'	SS.	VM-W	SILTY/CLAYEY SANDY GRAVEL: 70% gravel (VFP-CP) 15%	10:20	
				sand (VFS-CS) 15% clay/silt : Moist/wet color		
				olive brown 2.5Y4/4 : unconsolidated : Took		
				moisture sample and 1 jar sample - NOTE:		
				High moisture content in sediment - No photograph		
				was taken.		
	25-26.5'	SS	W	SILTY SANDY GRAVEL : 50% gravel (VFP-CP pred VFP-FP)	11:05	Blows/5" = 50
				40% sand (VFS-VCS pred. MS-CS) 10% silt/clay :		Drove
				gravels are M-W sorted : clasts are subang. - to -		
				rounded : clasts are weathered a rusty brown		
				color : wet color light olive brown 2.5Y 5/4 :		
				unconsolidated : 2 jar sed samples were taken		
				(1@ 25-26' & 1@ 26-26.5') : photo was taken.		
				Noticeably less fines @ this depth compared to		
				20' interval.		
				D/W ~ 21.5' (E-tape # 12175)	11:25	
	30'-31'	SS	W	SILTY/CLAYEY SANDY GRAVEL : 45% gravel, 45% sand,	12:15	
				10% silt/clay : sample is very unusual color →		

REMARKS:

SLP. Airhart
8-16-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64 LENNY BULTENA	Well Number: LFI-PNL2	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-16-88		Depth: 30' To 33'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				wet color is dark yellowish brown 10YR4/6.		
				clasts are mod.-to-well sorted (VFP-MP). Clasts		
				weathered dark brown-to-rust. -unconsolidated.		
				2 sediment samples taken. Too rainy for photo.		
				D/W = 21.5' below land surface	12:20	
				Instructed driller to drill to 32.5-33' below	12:25	
				land surface		
				Geophysically logged hole (Nat. 8 probe) 2'-31'	13:30-	14:05
				Installed the following sections of 2" dia. PVC	14:00-	14:15
				casing & screen		PVC specs —
				15'4½" 20-slot slotted PVC screen w/ bottom cap		2", sched 40, 280 PSI
				9'10½" section PVC casing w/ centralizer set		PVC 1120, meets
				5' above top of screen.		ASTM 1785.
				9'9½" section PVC casing		
				Total 35'½"		
				D/W = 21'8" below land	14:35	
				Bottom of PVC = 33' below land		

REMARKS:

StP. Airhart
8-16-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ Standing Water

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64	Well Number: LFI-PNLZ	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-16-88	L BULTENA	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 4½ 100 lb bags of 10-20 mesh Col. Silica		
				sand.		
				D/sand = 13' below land (final depth)		
				Added 1½ buckets Enviroplug ¼" pellets	14:40	
				D/pellets: 8'8" below land		
				Added 2 50 lb. bags Enviroplug med bentonite	15:50	
				D/bentonite = 3' below land		
				Tearing down rig	16:00	
				Moved rig and equipment to yard for steam	16:30	
				cleaning.		

REMARKS:

S.D. Airhart
8-16-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   ___ Standing Water

A-6000-021 (5-85)

DRILL LOG	By: AIRHART Date: 8-17-88	Rig: No Rig	Well Number: LFI-PNL2 Depth: DEVELOPMENT To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Set up pump rented from Instrumentation		
				Northwest. Pump is similar to a Hydrostar		
				however instead of a rod inside the riser		
				pipe, this pump has a ball valve on		
				the bottom and riser pipe plunges up		
				and down.		
				Started pump	13:15	
				Measured ~ 10 gals pumped in 1 hour	14:10-	15:10
				Pumped for ~ 1 more hour. Pumped 20-30		
				gals. Water is very turbid. Yellowish-brown		
				color. Appears to be clayey.		

REMARKS:

StP. Airhart
8-17-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By AIRHART Date 8-18-88	Rig NO RIG	Well Number LFI-PNL2 Depth COMPLETION To	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Set 4'x4' Form for surface pad Dug	13:00-14:45	
				holes for protective posts		

REMARKS:

J.E.P. Airhart
8-18-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

(FORT LEWIS LANDFILL 1)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LFI- PNL2	Computer Number	Project or Work Order No. 11832
	Date 8-19-88	CUBBY	Depth COMPLETION To	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed 1 sack of Columbia I+P [1 part]		
				cement w/ sand + gravel [4 parts] (~ 4:1 mixture)		
				to fill remaining annulus, surface pad,		
				and 4 protective posts, + surface protective casing.		
				set brass marker		
				Distance from pad to top of protective casing = 28 5/8"		
				Distance from pad to top of PVC = 18 7/8"	9 1/16"	
				Distance from pad to concrete inside protective casing = 1/2"		

REMARKS:

StP. [signature]
8-19-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000 021 (6.85)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF1-PNL2	Computer Number NA	Project or Work Order No. 11852
	Date 8-23-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Began hand bailing w/ 1.5" dia. x 10' long	10:50	– ~ 15:00
				dart bailer. Bailing ~ .5-to-1.5 gal/min		
				Needs further development.		

REMARKS:

SDA [signature]
8/23/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-86)

DRILL LOG	By: AIRHART	Rig: PNL SAMPLING TRUCK	Well Number: LFI-PNL2	Computer Number: NA	Project or Work Order No.: 11832
	Date: 9-8-88		Depth: DEVELOPMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 24.09' below top of 6" protective casing	10:38	
				D/W = 24.09' " " (@ notch)	10:39	
				D/B = 35.11" below top of 6" prot. casing	10:43	
				set HYDROSTAR pump @ 35' below top of 6"	11:25	
				casing		
				started pumping well @ ~ 3.5 gals/min.	11:27	
				water is very turbid (orangish color)		
				Took photo of water after 5 min. of		
				development.		
				stepped up pumping to ~ 5.4 gals/min (~60 strokes/min w/ hydrostar)	11:33	
				Took photo of water after 15 min development		
				Took photo of water after 35 min development		
				" " " " " 60 min "	12:27	water slightly turbid
						water will produce > 6 gal/min
				sampled water for chemical analysis to be	12:30-12:55	
				performed by AM-TEST		

REMARKS:

Disassembling HYDROSTAR 13:10

moved off well 13:20

[signature] 9/8/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LFI-PNL2	Computer Number NA	Project or Work Order No. 11832
	Date		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Painted posts during week of 10/17-10/21		

REMARKS:

St P Airhart
11/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

<u>WELL LF1-PNL3</u>

Battelle Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832	Well Number
Location FORT LEWIS	Temporary Well Number LFI-PNL3
Driller LENNY BULTENA	Coordinates
Drilling Co. ONWEGO DRILLING CO., INC.	Casing Elevation
Geologist S.P. AIRHART	Ground Elevation

DRILLING METHOD	COMPLETION DATA
Rotary Air ____ Mud ____	Drilled Depth 40.4'
Cable Tool D ____ H 0'-40.4'	Completion Depth 39.6'
Drilling Fluid	Date Started 8-17-88 Completed 8-25-88
Other TRIED W/ 8" AUGER TO 17' - UNSUCCESSFUL; TOO MUCH GRAVEL	Static Water Level/Date 28.65' / 8-24-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	4" DIA (SCH. 40)	to 24'
		to
		to

Approved By S.P.A. Date 8-24-88

PERFORATIONS	SCREEN	ANNULAR SEAL
Type NA	Type 4" DIA. SLOTTED PVC	Type / Interval / Volume
Depth / Schedule	Length 15.6'	10-20 SAND / 19.5'-40' / 9.1 ft^3
	Slot Size 20	1/4" PELLETS / 15.5'-19.5' / 1.6 ft^3
	Depths 24.0' - 39.6'	BENT. CHUNKS / 2'-15.5' / 4.62 ft^3
		CONCRETE / 0'-2' / ~.6 ft^3
App. By ____ Date ____	App. By S.P.A. Date 8-24-88	App. By S.P.A. Date 8-24-88

GEOPHYSICAL LOGGING			AQUIFER TESTING
Sondes	Interval	Date	Type of Test NA
NAT. GAMMA	0' - 38.2'	8-24-88	Length of Test
			Volume Pumped
			Drawdown
Approved By S.P.A.		Date 8-24-88	Approved By ____ Date ____

OTHER APPLICABLE ITEMS

8-17 Steam Cleaning	8-25 Protective Steel Posts	NA Downhole TV Inspection
8-17 Storage of Const. Material	10/24 Safety Paint	NA Well Abandonment
8-17 Tool Lubricants	NA Straightness Test	11/5 Complete As-Built Diagram, Driller's and Geologist's Logs
8-25 Concrete Pad	9/8 Well Development	

Approved By S.P.A. Date 11-5-88

Reviewed By V.L. McGhan Date 11-8-88

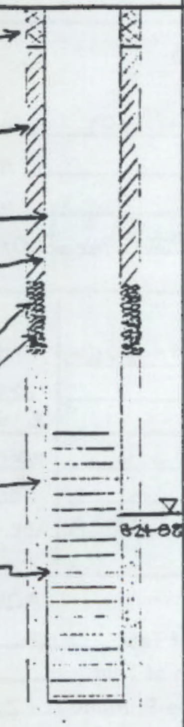
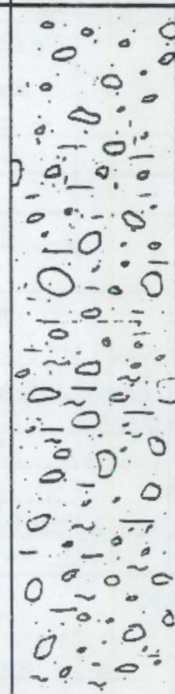
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LFI-PNL3 Geologist S.P. AIRHART Page 1 of 1

Reviewed by [signature] Date 11-8-88

Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Geologic/Hydrologic Data: Lithologic Description
CONCRETE				
		5		SANDY GRAVEL (lots of organic matter)
8" DIA. CARBON STEEL CASING (REMOVED)				
		10		SILTY SANDY GRAVEL
4" DIA. PVC CASING				
BENTONITE CHUNKS		15		SILTY SANDY GRAVEL (large gravel)
1/4" ENVIROPLUG PELLETS		20		SANDY MUDDY GRAVEL
CENTRALIZER				
		25		SANDY MUDDY GRAVEL
10-20 COL. SILICA SAND				
	8-24-88	30		MUDDY SANDY GRAVEL
4" DIA SLOTTED PVC (20 SLOT)				
		35		MUDDY SANDY GRAVEL
		40		
DRILLED DEPTH = 40.4'				

A-1800-186 (3/87)

Well LFT-PNL3 Drilled Depth 40.4' Interval Logged 0'- 38.2'

Log Type NAT. GAMMA Date 8-24-88 Casing Size 8" CARBON STEEL

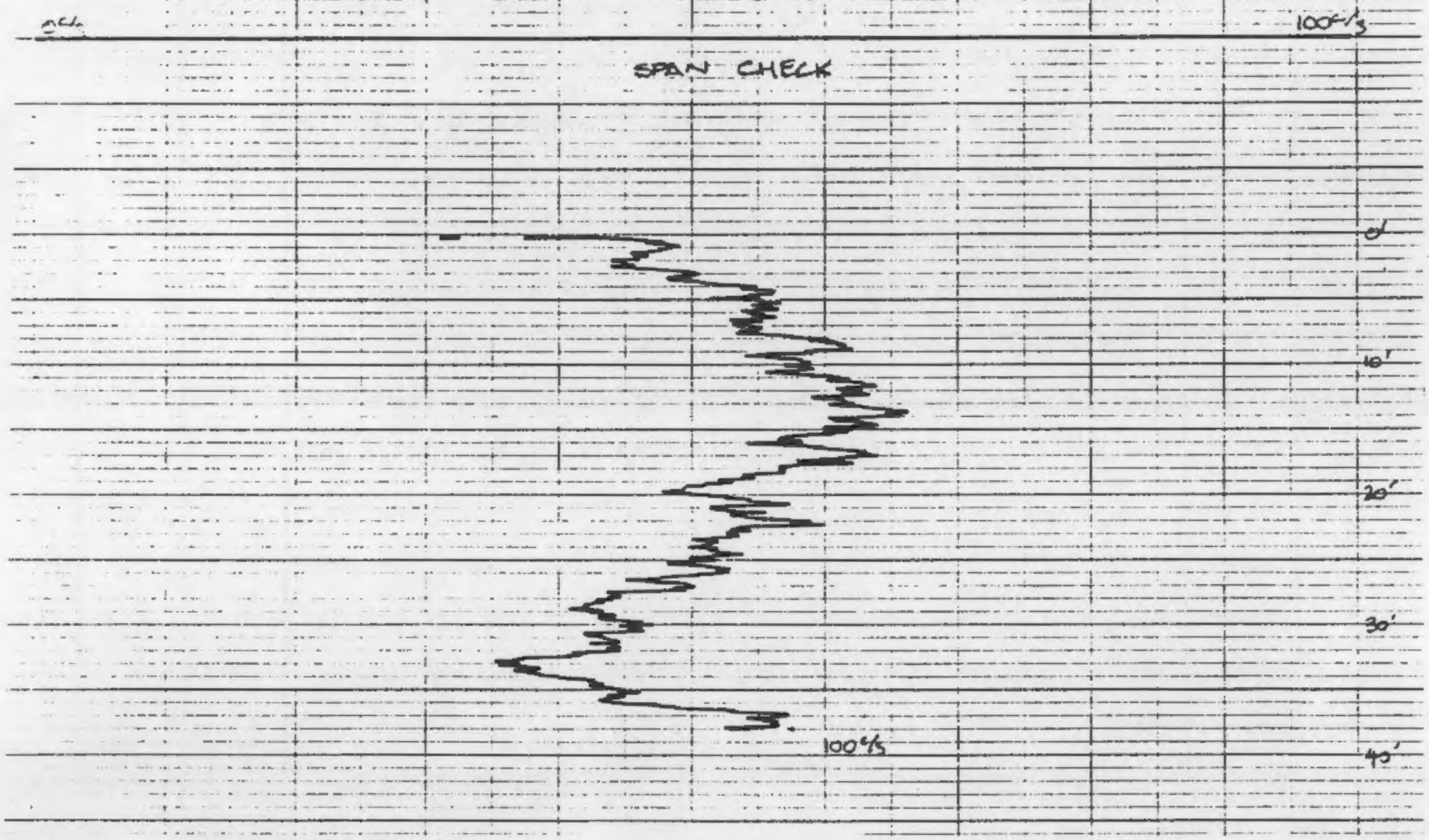
Logged By S.P. AIRHART Water Level Depth 28.7'

Logging Scales: Sensitivity 100c/s Time Constant 3

Vertical Scale 10'/in. Logging Speed 15'/min.

Source Strength NA Spacer Length NA.

Remarks: REFERENCE PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



(FORT LEWIS - LANDFILL #1)

DRILL LOG	By: AIRHART	Rig: SCHRAMM T64 ONWEGO - LENNY BULTENA	Well Number: LF1-PNL3	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-17-88		Depth: 0' To 14'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Steam cleaned drilling rig and equipment	07:00-	08:15
				Moved drilling rig to proposed well location	08:20	
				Setting up rig	09:00	
	5'	SS	SM	SANDY GRAVEL : 60% gravel 37% sand 3% silt :	09:15	Started Drilling
				moist color dark grayish brown 10YR 4/2 : No rxn.	09:25	140 blows - only
				w/ 10% HCl : clasts in sampler are VFP-FP -		recovered 2-3" of
				clasts around auger are VFP-VCP, ∴ sample		sample in sampler
				is not representative : Took moisture sample :		shoe.
				No jar sample or photograph taken.		
	10'-10.5'	SS	SM	SILTY SANDY GRAVEL : 50% gravel, 45% sand, 5% silt	10:10	blows/6" : 50, 50 for 3"
				sample very similar to previous sample. moist color		3" sample recovered.
				dark grayish brown 10YR 4/2 ; No rxn. w/ 10% HCl :		
				Clasts in sample are VFP - FP w/ a 50 mm		
				VCP stuck in shoe: Took moisture sample and		
				1 jar sample and photograph.		
	10 - 14'					
				Large gravels @ 10-14' interval. Bit is wandering		
				and drilling is slow. Pulled inner-bit out of		

REMARKS:

S.P. Airhart
8/17/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000-021 (5-85)

DRILL LOG	By: AIRHART Date: 8-17-88	Rig: SCHRAMM T64 KELLY OLSON	Well Number: LFI- PNL3 Depth: 14' To 14'	Computer Number: NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				hole. It is very hot due to friction. Also a		
				lot of moisture on tool which evaporates		
				quickly.		
				Unable to take 14-15' sample. No sed.	11:20	100 blows / 1 inch
				in split-spoon. Noted split-spoon very		
				warm & moist.		
				checked hole w/ HNU. Checked w/ 10.2 eV lamp		
				- had a 10 unit response six-inches inside		
				hole and ~ 5 unit response @ well head -		
				11.7 eV lamp - had an 8-unit response inside		
				hole and ~ 5 unit response @ well head.		
				Noted that on both probes - when placing		
				probe inside auger recieved a reading then		
				the meter fell swiftly back to zero. This		
				did not occur @ well head. Perhaps low O_2		
				environment affecting response. No smell apparent.		
				Decided to continue drilling and monitor hole		

REMARKS:

frequently.

[signature] 8/17/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A 6000-021 (5-85)

DRILL LOG	By AIRHART	Rig SCHRAMM T64	Well Number LF1-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-17-88	KELLY OLSON	Depth 14' To 16'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Drilled 1' to 15'. Checked a port in the top auger flight w/ HNU. 10.2 eV - ~30 unit response 11.7 eV - ~25 unit response.		
				Checked port in auger again. 10.2 eV - ~60 unit response 11.7 eV ~30 unit response.	12:35	
				Checked port again after letting sit open for 1.5 hrs. 10.2 eV - ~100 unit response 11.7 eV ~60 unit response	14:00	
				Decided to continue drilling - Contamination only escapes when auger flights are taken apart.		
				Tried to continue drilling. Auger would not advance. Pulled auger flights back. Bit is worn almost completely off (took photo). Bit very hot. Probably was drilling through boulder. HNU readings were probably due to excess heat from bit.	14:00	

REMARKS:

Tearing rig down - moving off hole 15:00

S+P Airhart
8/17/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-85)

(FORT LEWIS-LANDFILL 1)

DRILL LOG	By AIRHART	Rig OWWEGO BUCYRUS ERIE 22W	Well Number LFI-PNL3	Computer Number	Project or Work Order No. 11832
	Date 8-18-88	LENNY BILTEMA	Depth 0' To 16'	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				steam cleaning cable tool rig and casing	11:30 –	12:30
				and tools.		
				moved rig & equipment to well site.	12:40	
				Set up rig	12:50	
				Began drilling. Note: started drilling ~	13:10	
				3' away from hole started w/ auger bit		
				yesterday (8-18). Will not take samples		
				until 20' depth, since sample were		
				taken to 14' yesterday.		
21'2½"	of 8"	casing			13:15	Added 21'2½" of
						8" casing & shoe
				0-5' sample from bailer – very deep dark brown		
				color comprised of ~ 50% wood, organics ~50%		
				sand, gravel – assume since we are drilling near		
				trees the wood probably is from root systems.		
				Took 1 jar sample of mud.		
				Took 1 jar sample of both 10' & 15' cuttings		

REMARKS:

Will describe tomorrow.

17:45 shut Down.

St P. Airhart 8-18-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (6-85)

(FORT LEWIS - LANDFILL 1)

DRILL LOG	By: AIRHART Date: 6-19-88	Rig: ONWEGO BUCYRUS ERIE 22W (FANK PUFENA)	Well Number: LFI - PNL3 Depth: 16' To 16'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Descriptions of yesterdays 10' + 15' samples.		
	10'	H	W	SILTY SANDY GRAVEL : 50% gravel 40% sand	8-18-88	
				10% silt : poorly sorted : (gravels) VFP-MP		
				Many fragmented, preserved clasts are A-SR,		
				composition highly variable - predominantly		
				porphyry and metam. ; (sand) VFS-VCS		
				dom. FS-MS ; comp. highly variable ; wet		
				color olive gray 5Y 4/2 : unconsolidated :		
	15'	H	W	SILTY SANDY GRAVEL : 45% gravel 40% sand	8-18-88	
				15% silt : poorly sorted : (gravel) VFP-MP		
				dom. VFP-FP - highly fragmented - composed		
				of basalt, qtzite, porphyry, metam., and others -		
				(sand) VFS-VCS, comp. variable, grains		
				A-SA : wet color : olive gray 5Y 5/2 : unconsolidated		
				NOTE: lighter color than prev. sample - more fines		
					0900	started drilling
						8-19-88

REMARKS:

S.D. Airhart
8-19-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A 6000 021 (5-86)

DRILL LOG	By	Rig	Well Number	Computer Number	Project or Work Order No.
	AIRHART	Bucyrus Erie 22W	LFI-PNL3	NA	11832
	Date	L. Bultena	Depth		Subcontract No.
	8-19-88		16' To 20'		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				checked hole w/ HNU 10.2 & 11.7 lamps	11:05	
				- nothing detected (20' depth)		
					11:10	Taking 4" split-spoon
						150 blows / 8"
						Drove 8"
						Recovered 2.4" -
						16" of cuttings
	20-20.6	SS	W	SANDY MUDDY GRAVEL: 65% gravel, 15% sand,	11:20	
				20% clay/silt : 10% VCP, 15% CP, 20% MP,		Took 2 sed. jar
				10% FP, 10% VFP, 2% VCS, 3% CS, 7% MS, 3% FS-VFS,		samples, & photograph
				20% clay/silt (mostly clay) : very poorly		1 photo of split-spoon
				sorted : (gravel) SA-R. clasts composed of		1 photo of washed sample
				quartzite, basalt, other ign. & metam. (sand)		No Moisture sample
				A-SR, pred. Si-rich : wet color : Dark		taken - sed. wet from
				grayish brown 10YR 4/2 - clay color is		drilling water.
				pale yellow 2.5Y 7/4 : unconsolidated but		
				compacted : No rxn. w/ 10% HCl - formation		
				is a clay/sand supported gravel		

REMARKS:

St. P. Airhart
8-19-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ Standing Water

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LFI-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-19-88	L. Bultena	Depth 20' To 26'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
21'2½"					11:45	Cut off 2½" of 8"
					11	casing - Added
31'½" of 8" casing						10'6" of 8" casing
						21'2½" - 2½" + 10'6" = 31'6"
					12:00-12:10	Driving casing
					12:10	Drilling.
					13:40	Tried driving casing -
						casing would not drive
					13:45	continued drilling
						Hard drilling @ ~24'
					14:25	Taking split-spoon
						Drove 14" / 200 blows
						Recovered 14"
	25-26'	SS	W	SANDY MUDDY GRAVEL: 65% gravel, 15% sand,	14:30	
				20% clay/silt (mostly clay): 7% VCP, 15% CP,		Took 2 sed. jar
				15% MP, 18% FP, 10% VFP; 2% VCS, 3% CS, 5% MS,		samples. Took 2
				5% FS-VFS, 20% clay/silt; very poorly sorted		photos. of split-spoon
				(gravel) mafic-rich clasts SA-R (sand) predominantly		& washed sample.

REMARKS:

St. D. Airhart
8-19-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	B.E. 22W	LFI-PNL3	NA	11832
Date: 8-19-88	L. Beltema	Depth: 26' To 29'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
31'6"				mafic rock frags. A-SA ; wet color: olive		
				gray 5Y5/2 - clay color olive 5Y5/4 :		
				no rxn. w/ 10% HCl ; unconsolidated but		
				compacted - hard drilling - As per previous		
				sample formation is gravel w/ interstitial		
				sand + clay.		
					16:10	Quit Drilling

REMARKS:

St P. Airhart
8-19-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

(FORT LEWIS - LANDFILL 1)

DRILL LOG	By: AIRHART Date: 8-23-88	Rig: OHWEGO Bucyrus Erie 22W LENNY BULTENA	Well Number: LFI-PNL3 Depth: 29' To 31'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
31'6"					11:20	started drilling
					11:45	Adding water.
						Water source: Fire
						Hydrant on base
					11:57	Putting on split-spoon.
	30'-31.5'	SS	W	MUDDY SANDY GRAVEL; 70% gravel (largest a	12:25	Took split-spoon
				broken cobble ~.3' dia.) 20% sand, 10% gravel:		blows/6": 75,90,66
				very poorly sorted. Gravels much larger than		Drove 18"
				previous samples - much less silt/clay.		Recovered 18"
				Wet color: olive 5Y4/3: Formation is matrix-to-		
				clast supported pebble/cobble gravel. Clast		
				appear mostly SR-R. Took 2 sed samples		
				(30-30.5' & 30.5-31'). Took photo of split-spoon.		
31'4½"						Cut off 1½" of 8" casing
						31'6" - 1½" = 31'4½"
						Added 10'6" of 8" casing
40'10½"	of 8"	casing				31'4½" + 10'6" = 41'10½"

REMARKS:

S.P. Airhart
8-23-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5 86)

DRILL LOG	By: AIRHART Date: 8-23-88	Rig: OAWEGO B.E. 22W L. Bulleua	Well Number: LFI-PNL3 Depth: 31' To 40'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	35-36'	SS	W	MUDDY SANDY GRAVEL: 70% gravel (largest is ~50mm	15:35	Took split-spoon
				dia.) 15% sand 15% silt/clay: very poorly sorted;		Blows/6": 60, 50, 70
				Formation seems quite compacted based on		Drove 18"
				split-spoon. Gravel w/ tightly pand sand/clay		Recovered 15"
				matrix Some clasts are highly weathered and		
				friable. Very similar to previous sample but		
				slightly smaller gravels. Took 2 sed. samples -		
				Took 2 photos - split spoon sample & washed		
				sample.		
				Hit water while taking sample	15:40	
				D/W = 30.95' below land (E-tape # 12175)	16:15	
				Will drill to 41'		
					16:30	continued drilling
					19:00	Quit drilling

REMARKS:

Stephen Airhart
8-23-88

E.43

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

(FORT LEWIS- LANDFILL #1)

DRILL LOG	By: AIRHART Date: 8-24-88	Rig: GNWEGO B.E. 22W L. Bultena	Well Number: LF1-PNL3 Depth: 40' To 40'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 28.65 below land surface (E-tape #	07:15	
				D/B = 40.4 below land surface	07:30	
				Geophysically logged hole (0'-38.2') w/	08:30-	09:15
				Nat. γ probe		
				Added the following sections of 4" dia. PVC	09:30	
				casing & screen.		
				15'7" of slotted 20 slot PVC and end cap		
				20'1/2" of casing w/ centralizer 5' above top	of screen	
				10' of casing		
				Cut off 4'7 1/2" of top casing		
				∴ Total PVC = 41'		
				Added 1 100 lb. bag of 10-20 mesh Colorado	09:40	
				Silica sand to adjust bottom of PVC @ 39' below	land	
				Pulled 8" casing to 38' below land - pulling hard	10:05	
				D/sand = 35'6" below land	10:08	
				Pulled 8" casing to 37.5'. D/Sand = 35'	10:10	

REMARKS:

SEP Airhart
8-24-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   ____ Standing Water

A 6000-021 (5-86)

E.44

DRILL LOG	By: AIRHART Date: 8-24-88	Rig: BE-22W L. Bultena	Well Number: LF1-PNL3 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 1 bag 10-20 Col. silica sand to 32'	10:20	
				Pulled 8" casing to 34'6" land	10:35	
				D/sand = 34' below land	10:40	
				Added 2½ bags Col. sand to 24' below land	10:50	
				Pulled 8" casing to 31' below land	11:05	
				D/sand = ~~26'~~ below land	11:10	
				Added 1 bag Col Silica sand to 22' below	11:15	
				land.		
				Pulled 8" casing to 28'4" below land	11:25	
				D/sand = 24.5' below land	11:35	
				Added 1¾ bags Col. silica sand to 17.5' below	12:20	
				land		
				Pulled 8" casing to 23'	12:25	
				D/sand = 21'		
				Added ¼ bag sand to 20.5' below land	12:35	
				Pulled 8" casing to 21.5' below land	12:50	
				D/sand = 21' below land		
				Added 1 bag sand to 17.5' below land	13:00	

REMARKS.

StP Airhart
8-24-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine __ Standing Water

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LFI-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-24-88	L. Bulteng	Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 19' below land surface	13:10	
				D/sand = 19.5' below land (Final Sand Depth)	13:15	
				Added 1/2 bucket Enviroplug 1/4" pellets	13:17	
				D/pellets = 18.5' below land	13:20	
				Pulled 8" casing to 18.5' below land	13:22	
				D/pellets = 18.5' below land	13:30	
				Added 1 1/2 buckets of Enviroplug 1/4" pellets	13:34	
				D/pellets = 14.5' below land	13:34	
				Pulled 8" casing to 15.5'		
				D/pellets = 16.5'		
				Added 1/2 bucket of pellet to 15.5' (final depth)	13:50	
				Added 1 1/2 50 lb. bags Enviroplug Medium	13:54	
				bent. chunks to 9' below land	13:56	
				Pulled 8" casing to 13'8" below land	14:22	
				D/chunks = 10.75' below land	14:25	
				Added 2 bags bent chunks to 4.5' below land	14:27	
				Pulled 8" casing to 8 1/2' below land		
				D/chunks = 8 1/2' below land	15:00	

REMARKS:

StP Airhart
8-24-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF1-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-24-88	L. Bultena	Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 2 bags bent chunks to 1' below land	15:05	
				Pulled 8" casing to 6.5' below land	15:14	
				D/chunks = 4' below land		
				Added 1 bag bent chunks to 1' below land	15:20	
				Pulled remaining 8" casing out of hole		
				D/chunks = 2' below land (final depth)	15:23	
				Dropped 6" dia. surface protective casing in	15:26	
				remaining hole		
				Set 3½" dia. ⅛ h.p. submersible pump		
				– Berkley Magnum pump –		
				Started pumping water. Drew water down to	16:00	
				intake w/in 3 min of pumping @ ~ 3 gpm.		
				Water which was discharged is very turbid		
				Very slow recovery. Turned pump on a couple		
				more times. Immediate drawdown to intake		
					17:00	Shut Down

REMARKS:

STP [signature]
8-24-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine __ Standing Water

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	ONWEGO B.F. 22W	LFI - PNL3	NA	11832
Date: 8-25-88	L-Beltena	Depth: DEVELOPMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Bailed hole w/ 3" clast bailer. Bailed ~	09:10-	09:15
				8 gals and well went dry		
					11:00	Tore rig down
						and moved off.
				Mixed 1 bag Portland type I & II cement w/	13:00-	17:00
				gravel to pour remaining annular seal.		
				4' x 4' surface pad and base around		
				protective posts - Also set brass marker		

REMARKS:

JEP Airhart
8-25-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

E.48

DRILL LOG	By AIRHART / Date 9-1-88	Rig NO RIG	Well Number LF1-PNL3 / Depth COMPLETION To	Computer Number NA	Project or Work Order No. 11632 / Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Measured:		
				Height from pad to top of 6" surface protection casing = 2.15'		
				pad to top of 4" PVC = 1.41'		
				pad to top of concrete inside protective casing = -0.84' below pad.		

REMARKS:

St P. Airhart
9-1-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig PNL SAMPLING TRUCK	Well Number LFI-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 9-8-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 30.48' below top of 6" protective casing (@ notch in casing)	14:47	Measurements
				D/W = 30.47' " " " " " "	14:48	taken w/ steel
				D/B = 41'7" " " " " " "	14:49	tape # L30001
				set HYDROSTAR pump @ 41' below top of 6" casing	15:20	
				Started pumping well	15:40	
				Pumped @ ~ 3-4 gpm - well pumped to		
				intake @ ~ 10-15 gals		
				Turned off - watched recovery - very slow -		
				~ 1"/30 sec.		
				Poured 4 gals - STEAM DISTILLED WATER USP -	15:50	
				PURE WATER CORPORATION - in hole -		
				Pumped water out	15:55	
				Letting recover -	16:00	- 17:00
				Not fully recovered after 1 hr. - 3' short		
				Pumped water out	17:05	

REMARKS:

StP Airhart
9/8/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (6-86)

DRILL LOG	By AIRHART	Rig PNL SAMPLING TRUCK	Well Number LEI-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 9-9-88		Depth SAMPLING / DEVELOPMENT		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Arrived @ well –	0700	
				Pumped 13 gals. water – to intake –	0705-	0715
				Failed to take static D/water before		
				pumping – will allow well to recover.		
				This pumping is considered a "purge" – will		
				sample after well recovers.		
				Returned to well site – checked D/W –	0910	
				water is still recovering, but is w/in ½"		
				of fully recovering		
				Measured time required to recover 1"	0930	
				1st meas. = 2 min 27 secs 2nd meas = 2 min. 38 secs. 3rd meas	: 2 min. 47 secs.	
				D/W @ time of sampling = 32'11" below top of	0944	
				6" casing (checked w/ E-tape)		
				Taking samples for chemical analysis which	0945-	0955
				will be performed by AM TEST		
				Disassembling HYDROSTAR	1000 –	1015
				Moved off hole	1020	

REMARKS:

[signature] 9/9/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ Standing Water

DRILL LOG	By: AIRHART	Rig: North	Well Number: LFI-PNL3	Computer Number: NA	Project or Work Order No.: 11832
	Date		Depth To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
"	"			Painted posts during week of 10/17-10/21		

REMARKS:

StP Airhart
11/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing W...

WELL LF4-PNL4

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832	Well Number
Location FORT LEWIS	Temporary Well Number LFI-PNL4
Driller LENNY BULTENA	Coordinates
Drilling Co. ONWEGO DRILLING CO., INC.	Casing Elevation
Geologist S.D. AIRHART	Ground Elevation

DRILLING METHOD	COMPLETION DATA
Rotary Air TRIED TO 7' Mud	Drilled Depth 44.2'
Cable Tool D H 0'-44.2'	Completion Depth 44.6'
Drilling Fluid	Date Started 8-23-88 Completed 9-1-88
Other	Static Water Level/Date 34' / 8-30-88

CASING DATA

Type	Size	to
PVC	4" DIA. (SCH. 40)	29'

Approved By S.D.A. Date 8-30-88

PERFORATIONS	SCREEN	ANNULAR SEAL
Type NA	Type 4" DIA. SLOTTED PVC	Type / Interval / Volume
Depth / Schedule	Length 15.60'	10-20 SAND 23.5'-44' 8.56 ft³
	Slot Size 20	1/4" PELLETS 20'-23.5' 1.24 ft³
	Depths 29' - 44.6'	BENT. CHUNKS 15'-20' 6.39 ft³
		CONCRETE 0'-1.5' ~.4 ft³
App. By Date	App. By S.D.A. Date 8-30-88	App. By S.D.A. Date 8-31-88

GEOPHYSICAL LOGGING			AQUIFER TESTING
Sondes	Interval	Date	Type of Test NA
NAT. GAMMA	2' - 42.2'	8-30-88	Length of Test
			Volume Pumped
			Drawdown
Approved By S.D.A.		Date 8-30-88	Approved By Date

OTHER APPLICABLE ITEMS

8-23 Steam Cleaning	9-1 Protective Steel Posts	NA Downhole TV Inspection
8-23 Storage of Const. Material	10/24 Safety Paint	NA Well Abandonment
8-23 Tool Lubricants	NA Straightness Test	11/5 Complete As-Built Diagram, Driller's and Geologist's Logs
9-1 Concrete Pad	9-1 Well Development	

Approved By S.D.A. Date 11-5-88

Reviewed By M. McElhaney Date 11-8-88

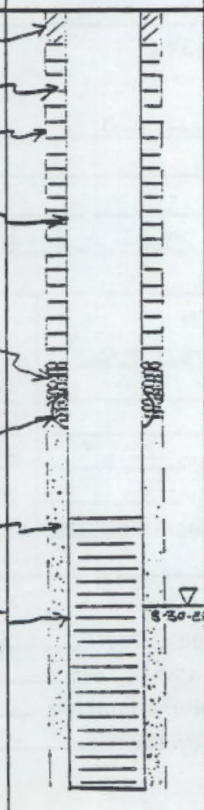
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LFI-PNL4 Geologist S.P. AIRHART Page 1 of 1

Reviewed by V.C. McAllen Date 11-8-88

Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Geologic/Hydrologic Data: Lithologic Description
CONCRETE				
BENTONITE CHUNKS		5		POOR SAMPLE -
8" DIA. CARBON STEEL				PROBABLY SANDY GRAVEL
CASING (REMOVED)		10		MUDDY SANDY GRAVEL
4" DIA. PVC CASING				
		15		MUDDY SANDY GRAVEL
1/4" BENTONITE PELLETS		20		MUDDY SANDY GRAVEL
CENTRALIZER		25		MUDDY SANDY GRAVEL
10-20 COL. SILICA SAND		30		MUDDY SANDY GRAVEL
4" DIA. SLOTTED PVC (20 SLOT)		35		MUDDY SANDY GRAVEL
		40		SANDY GRAVEL
DEPTH DRILLED = 44.2'		45		

A-1800-186 (3/87)

Well LFI PNL4 Drilled Depth 44.2' Logged Interval 2'-42.2'

Log Type NAT. GAMMA Date 8-30-88 Casing 8" CARBON STEEL

Logged By S.P. AIRHART Water Level Depth 34'

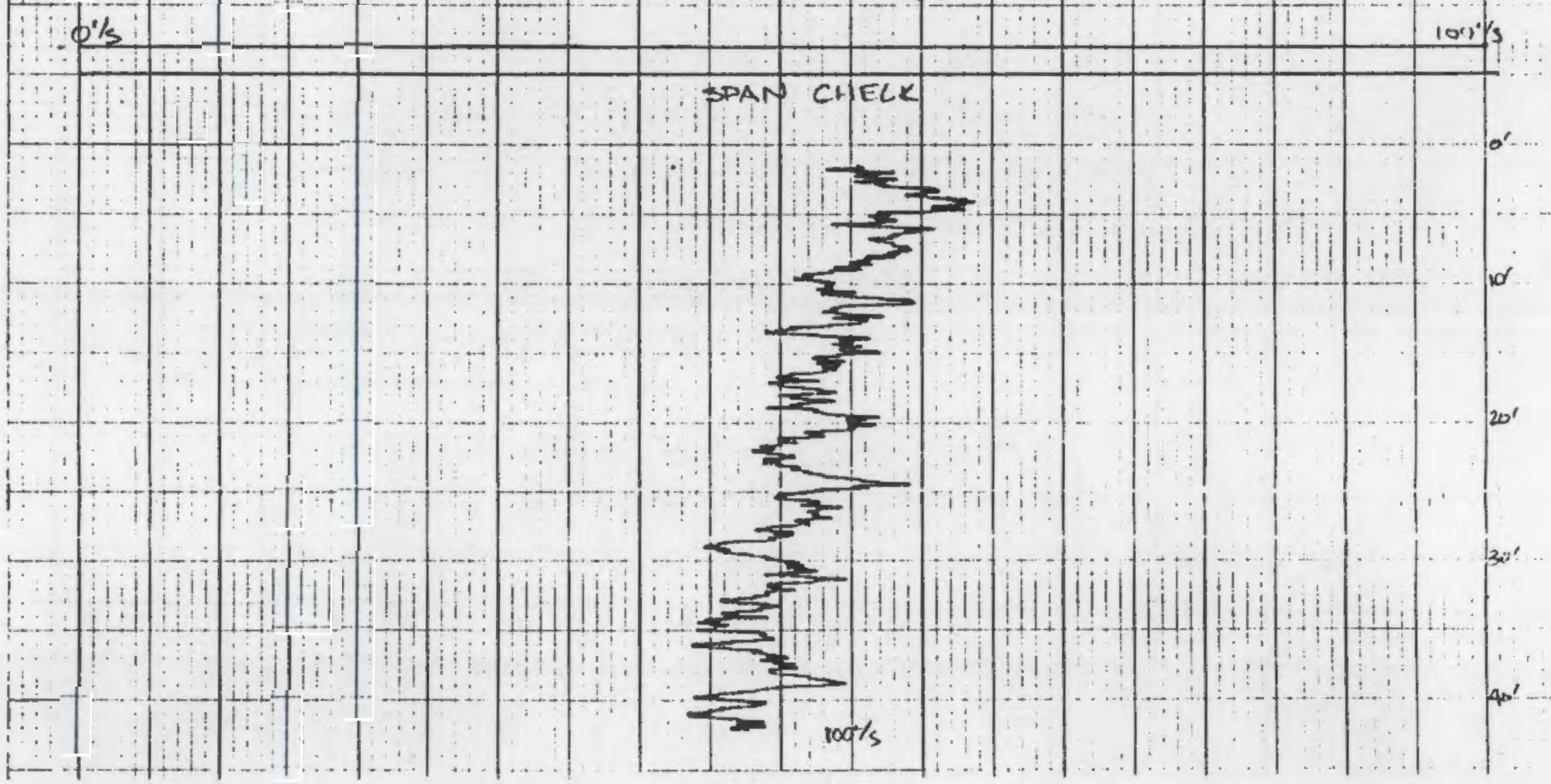
Logging Scales: Sensitivity 100 c/s Time Constant 3

Vertical Scale 10'/in. Logging Speed 15'/min

Source Strength NA Spacer Length NA

Remarks: REFERENCE PROCEDURES GW-6 REV. 2

PROBE SERIAL # NG-001



(FORT LEWIS - LANDFILL #1)

DRILL LOG	By: AIRHART	Rig: OSWEGO SCHRAMM T64 KELLY OLSON	Well Number: LF1-PNL4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-23-88		Depth: 0' To 0'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				steam cleaning rig & equip. –	0700 –	0800
				Note: Using a pressure wash chemical		
				while steam cleaning to aid in degreasing:		
				Specs on chemical:		
				Manufacturer: Dayton Electric MFg. Co.		
				Chicago Illinois 60648		
				Product Name: Pressure Washer Chemical No. 5W132		
				Description: A non-flammable, biodegradable and		
				U.S.D.A. approved detergent for cleaning heavy		
				accumulations of grease and oil. Accepted for		
				use in kitchens, food processing equipment, etc		
				Contents: Complex Sodium Phosphates, Alkaline		
				Builders and surfactants.		
				– It was O.K'd to use this product as long		
				as equipment was rinsed w/ non-detergent		
				water after cleaning.		
				Moved rig to hole.	11:00	
				Setting up rig (Schramm T64 Air Rotary w/ Tricone bit)	11:00 –	12:30

REMARKS:

StP. Airhart
8-23-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine — Standing Water

E.56

DRILL LOG	By: AICHART	Rig: [illegible] SCHRAMM [illegible] T64 [illegible]	Well Number: LFI-[illegible]	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-23-88		Depth: 0′ To 5′		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Welding drive shoe to 8″ casing	12:45 –	15:20
					15:45	Set 20′10″ of 8″ casing
					15:50	Began Drilling
	5′	AIR ROTARY	D	collected 5′ sample by catching air hose		
				exhaust. sample is composed of very small		
				pebble to sand size rock frags and		
				rock flour. Very poorly representative.		
					1700	Casing Hammer
						not working. Unable
						to drive casing.
						Must repair.
					17:30	Took off casing
						hammer for
						repair

REMARKS:

StP Aichart
8-23-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

(FORT LEWIS - LANDFILL # 1)

DRILL LOG	By: AIRHART Date: 8-25-88	Rig: ONWELLO BUCYRUS ERIE 22W L. BULTENA	Well Number: LFI-PNL 4 Depth: 5' To 15'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
20'10"				Steam cleaned cable tool rig and equip.		
				Moved rig to hole and set up	13:10	
					13:30	Started Drilling
						Hole is drilled to
						~8' w/ rotary.
					14:50	Put on split spoon
	10-11'	SS	W	MUDDY SANDY GRAVEL: 65% gravel, 20% sand, 15%	14:55	Taking split spoon
				silt: 5% CP, 15% MP, 20% FP, 25% VFP, 5% VCS, 5% CS,		blows/6" = 46, 50, 66
				7% MS, 3% FS-VFS, 15% clay/silt: very poorly	15:15	Drove 18"
				sorted (gravel) A-SR, dominantly mafic ign.		Recovered 12-18"
				(sand) A-SA, dom. ign. rock frags: wet		
				color: olive gray 5Y5/2: No rxn. w/ 10% HCl;		
				sediment is compacted, not consolidated -		
				gravel supported in sand/mud matrix.	15:30	Drove casing ~4'
				Took 2 sed. samples & 2 photos	15:45	Resumed drilling
				Note: slight color change - more brown - appears	16:30	
				siltier between 12'-13'		
					17:00	Put on split-spoon

REMARKS:

Sgt P. Airhart
8-25-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   ____ Standing Water

E.58

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LFI-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 8-25-88	L. Bultena	Depth 15' To 17'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					17:10	Took split-spoon
						blows/6": 30, 60
						& 80 for 4"
						drove 16"
						recovered 16"
	15-16'	SS	W	MUDDY SANDY GRAVEL : 70% gravel, 20% sand,	17:15	
				10% mud - 2% SC (largest = 3" broken piece)		
				5% VCP, 7% CP, 20% MP, 15% FP, 21% VFP, 3% VCS,		
				2% CS, 10% MS, 5% FS-VFS, 10% mud : very		
				poorly sorted : (gravel) larger than previous		
				sample - A-R - mostly SR - again dominantly		
				porphyry, igneous (sand) A-SA grains		
				varied composition : wet color : olive gray		
				5Y 5/2 : No rxn. w/ 10% HCl : Took 2 sed.		
				samples and 2 photos (split-spoon & washed		
				sample)		
					17:30	Shut Down

REMARKS:

St P. Airhart
8-25-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A 6000 021 (5 86)

E.59

(FORT LEWIS- LANDFILL 1)

DRILL LOG	By: AIRHART Date: 8-26-88	Rig: ONWEGO BUCYRUS ERIE 22W LENNY ELLIOTT NA	Well Number: LF1- PNL4 Depth: 17' To 20'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0700	started Drilling
					0800	Building up bit
					0800	Resumed drilling
					0840	Putting on split-spoon
	20'	SS	W	MUDDY SANDY GRAVEL: 65% gravel 20% sand 15%	0950	50 blows / 2"
				mud. - sample is poorly rep. of 20' interval -		Drove 2"
				mostly cuttings from 15'-20' interval - sample		Recovered mostly
				is same in lithologic composition as prev.		cuttings - driller
				2 samples - NO A color, driller indicated that		did not bail
				large gravels may be present since split-spoon		before taking
				did not want to drive. Took 1 sed sample		split-spoon
				and photograph of split-spoon.		
20'7½"					1000	Cut off 2½" of 8" casing
						20'10" - 2½" = 20'7½"
30'½"					1010	Adding 9'5" of 8" casing
						20'7½" + 9'5" = 30'½"
					11:30	Drove casing
					11:45	Resumed Drilling

REMARKS:

SLP.A[illegible]
8-26-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-071 (5-85)

E.60

DRILL LOG	By AIRHART Date 8-26-88	Rig B.E. 22W L. Bultena	Well Number LFI-PNL-4 Depth 20' To 30'	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					13:25	Taking split-spoon
						100 blows/6"
	25-26'	SS	W	MUDDY SANDY GRAVEL: 65% gravel, 20% sand, 15% silt:	13:30	80 blows/6"
				2% VCP, 3% CP, 15% MP, 20% FP, 25% VFP, 10% VCS,		50 blows/1½"
				5% CS, 3% MS, 2% FS-VFS, 15% silt; very poorly sorted;		Drove 13½"
				(gravel) A-SR clasts - dominantly porphyry, ign.		Recovered 13½"
				(sand) A-SA grains - wide assortment of liths;		
				wet color: olive gray 5Y5/2; no rxn. w/ 10%		
				HCl; compacted formation.		
					13:45	Resumed drilling
						Able to drill ~2'
						open - either more
						fines or more consol.
					14:30	Checked hole w/
						HNU 10.7 & 11.3 lamps -
						No reading -
					14:50	Putting on split-spoon

REMARKS:

St P. Airhart
8-26-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

cut off 1" added 10'2½"

DRILL LOG	By: AIRHART Date: 8-26-88	Rig: B.E. 22W L. Bullena	Well Number: LFI-PNL4 Depth: 30' To 31'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					14:55	Note: increased
						drill rate in
						last 5' interval.
					15:00	Taking split-spoon
						blows/6" = 28, 56 ;
	30-31'	SS	W	MUDDY SANDY GRAVEL: 60% gravel 30% sand, 10%	15:05	60 blows for 3".
				silt - more sand in 30.5-31' interval than in		Drove 15"
				30-30.5' interval - 7% CP, 10% MP, 25% FP, 18% VCP,		Recovered 17"
				15% VCS, 5% CS, 7% MS, 3% VFS, 10% silt : very poorly		
				sorted (gravel) A-SR mostly SA-SR - more		
				mafic (sand) A-SA grains : wet color olive		
				gray 5Y5/2 ; No rxn. w/ 10% HCl : slightly		
				faster drilling ∴ less compacted than prev. sample		
				More sand less fines than prev. sample.		
					15:20	cut off 1" 8" casing
29'11½"						30'½" - 1" = 29'11½"
						Added 10'2½" of 8" casing
40'2"						29'11½" + 10'2½" = 40'2"

REMARKS:

St R Airhart
8-26-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART Date 8-26-88	Rig B.E. 22W L Bultena	Well Number LFI-PNL4 Depth 31' To 31'	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					15.45	Driving casing
					16:00	Shut Down

REMARKS:

St P. Airhart
8-26-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

(FORT LEWIS LANDFILL 1)

DRILL LOG	By AIRHART	Rig ONWEGO Bucyrus Erie 22W Lenny Beltema	Well Number LF1-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 8-30-88		Depth 31' To 37'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0755	Started Drilling
					1020	Putting on split-spoon
					1025	Took split-spoon
						blows/6": 50, 42, 45
	35'-36.5'	SS	W	MUDDY SANDY GRAVEL: 60% gravel, 30% sand,	1030	drove 18"
				10% mud: 10% VCP, 10% CP, 10% MP, 15% FP, 15% VFP,		recovered
				5% VCS, 5% CS, 10% MS, 10% FS-VFS, 10% mud:		
				very poorly sorted: clasts are A-SR,		
				sand grains A-SA - many different metam.,		
				ign lithologies represented - wet color		
				olive gray 5Y4/2: no rxn w/ 10% HCl -		
				drills hard - consolidated (?) - Took 2 sed.		
				samples and 2 photos (split-spoon & washed		
				sample) No sed structure evident.	10:45	Driving casing
					11:00	Resumed drilling
				Encountered water: D/W ~ 34' below land	12:22	

REMARKS:

S.P. Airhart
8-30-88

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF1-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 8-30-88	L. Bultena	Depth 37' To 44'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					12:25	Putting on split-spoon
					12:30	Taking split-spoon
						blows/6" = 32,25,48
	40-41'	SS	W	SANDY GRAVEL: 50% gravel 45% sand 5% silt	12:40	Drove 18"
				2% SC, 5% VCP, 7% CP, 10% MP, 14% FP, 12% VFP,		Recovered 16"
				5% VCS, 5% CS, 20% MS, 15% FS-VFS - 5% silt poorly		
				sorted - clasts A-SR, sand grains A-SA		
				- wide range of lithologies - wet color		
				olive gray 5Y 4/2 - Took 2 sed samples -		
				2 photos (split-spoon & washed sample)		
40'½"					12:50	Cut off 1½" of 8" cas.
						40'2" - 1½" = 40'½"
45'½"	of 8" casing				13:20	Added 5' of 8" casing
						40'½" + 5' = 45'½"
					13:25	Driving casing
					13:35	Resumed Drilling
					14:50	Stopped Drilling

REMARKS:

JtP Airhart
8-30-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LFI-PNL4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-30-88	L. Bultena	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/B: 44.2' below land surface		
				Geophysically logged hole w/ Nat. γ probe	15:00 —	15:30
				(2' - 42.2')		
				Checked hole w/ HNU (10.7 & 11.3 probes)	15:45	
				No response.		
				Added the following sections of 4" dia.	16:40	
				PVC:		
				15.60' slotted (20 slot) screen		
				20.07' casing w/ centralizer 5' above screen		
				10.00' casing		
				Total PVC = 45.67' →		
				Added .75' of PVC casing (8-31-88) ∴ Total PVC =	46.42'	
				Bottom of screen @ 44.37' below land		
				∴ top of screen @ 28.77'		
				Added 2 100 lb. bags of 10-20 Col. silica sand	17:00	
				D/sand = 35' below land	17:05	

REMARKS:

StPAirhart
8-30-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ Standing Water

E.66

DRILL LOG	By AIRHART Date 8-30-88	Rig B.E. 22W L. Bultena	Well Number LFI-PNL4 Depth COMPLETION TO	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 42' below land	17:25	
				D/sand : 37' below land	17:27	
				Pulled 8" casing to 41' below land	17:30	
				D/sand : 38' below land	17:35	
				Added 2 bags 10-20 Col silica sand to 29'	17:44	
				Pulled 8" casing to 38' below land	17:57	

REMARKS:

StP Airhart
8-30-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

DRILL LOG	By AIRHART	Rig Buyrus Erie 22W	Well Number LFI-PNL4	Computer Number NA	Project or Work Order No. 11632
	Date 8-31-88		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				8" casing @ 38' below land	0725	
				D/sand = 32.5' below land	0730	
				Pulled 8" casing to 35.5' below land	0810	
				D/sand = 33' below land	0814	
				Added 2½ bags 10-20 Col silica sand to 23'	0819	
				Pulled 8" casing to 30.8' below land	0835	
				D/sand = 26' below land	0837	
				Pulled 8" casing to 30' -	08:45	
				Added ½ bag 10-20 Col. silica sand	08:46	
				Pulled 8" casing to 27.5' below land	08:55	
				D/sand = 25.5' below land	09:03	
				Added 1 bag 10-20 Col silica sand to 22'	09:08	
				pulled 8" casing to 24' below land	10:05	
				D/sand = 23.5' below land (final sand depth)	10:06	
				Added 2 5 gal buckets Enviroplug ¼" pellets	10:10	
				D/pellets = 18.3' below land	10:12	
				Pulled 8" casing to 22.4' below land	10:20	
				D/pellets = 19.1' below land	10:25	

REMARKS:

StP Airhart
8-31-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ - Standing Water

DRILL LOG	By: AIRHART Date: 8-31-88	Rig: B.E. 22W L. Bultena	Well Number: LFI-PNL4 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 20.3' below land	11:08	
				D/pellets = 20' below land (final pellet	11:10	
				depth)		
				Added 2 50 lb. bags of Enviroplug Med bent.	11:15	
				D/bent = 14.5' below land	11:17	
				Pulled 8" casing to 18' below land	11:27	
				D/bent = 16.5' below land	11:38	
				Added 3 bags Enviroplug bent. to 7.5' below land	11:42	
				Pulled 8" casing to 12.5' below land	12:15	
				D/bent = 9.5' below land	12:20	
				Pulled 8" casing to 10' below land	12:26	
				Added 3 bags Enviroplug bent to .5' below land	12:43	
				Pulled 8" casing to 6' below land	12:55	
				D/bent = 2' below land	12:58	
				Added 1 bag Enviroplug bent to +.5' above land	13:00	
				Pulled remaining 8" casing out of hole	13:20	
				D/bent = 1.5' below land (final bent. depth)	13:25	
				Started bailing w/ 3" dart bailer	13:26	- 13:45

REMARKS:

[signature]
8-31-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By: AIRHART Date: 8-31-88	Rig: NO RIG	Well Number: LFI-PNL4 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				set 3" 1/3 h.p. submersible pump in	13:50	
				hole - began development.		
				Ran pump intermintently from 13:50 -to-	17:15	
				Pumped ~ 150-200 gals from hole. Water		
				cleaned up. Can see bottom of 5 gallon		
				bucket when filled w/ pumped water.		
				Little turbidity. Saw a small amount		
				of white film floating in pumped water.		
				Could be PVC shavings or bentonite powder		
				from 5 gallon buckets.		
				Well produced ~ 3 gpm @ end of development.		
				Dug post holes and set surface pad	15:00 -	17:50
				frame. Note: Noticed that sediment		
				is very consolidated w/ lots of gravel		
				when digging post holes (1½' deep)		

REMARKS:

St P Airhart
8-31-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By: AIRHART Date: 9-8-88	Rig: PNL SAMPLING TRUCK	Well Number: LFI-PNL4 Depth: SAMPLING To	Computer Number: NA	Project or Work Order No.: 11B32 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 36.80′ below top of 6″ protective casing (at notch)	16:16	
				D/W = 36.80′ " " " " " "	16:17	
				D/B = 46′ 9½″ " " " " " "	16:19	
				set HYDROSTAR pump @ 44′ below top of 6″ casing	16:50	
				Began pumping (NOTE: well was already	17:18	
				developed w/ submersible pump i.e. we will		
				just purge well then sample - 1 well volume ~ 6.5 gals)		
				Pumped well @ ~ 3-4 gpm for 20 min.	1745	
				Took samples for chemical analysis which	1745	
				will be performed by AM TEST		
				Took a duplicate set of samples.	1755	
				Disassembling HYDROSTAR —	1830	
					1900	Went home —
				Painted Posts Week of 10/17 - 10/21		
				StP Airhart 11/5/88		

REMARKS:

StP Airhart
9/8/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

WELL LF4-PNL1

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832
Location FORT LEWIS
Driller LENNY BULTENA
Drilling Co. ONWEGO DRILLING CO., INC.
Geologist S.P. AIRHART

Well Number
Temporary Well Number LF4-PNL1
Coordinates
Casing Elevation
Ground Elevation

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D ______ H 0'-41'
Drilling Fluid
Other TOOK SPLIT-SPOON SAMPLES AT 5' INTERVALS

COMPLETION DATA

Drilled Depth 41'
Completion Depth 37.4'
Date Started 7-27-88 Completed 8-9-88
Static Water Level/Date 26.6' / 7-29-88

CASING DATA

Type	Size		
PVC (ASTM 1785)	4" DIA (SCH. 40)	to	21.8'
		to	
		to	

Approved By SPA Date 7-29-88

PERFORATIONS

Type NA

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 4" DIA. SLOTTED PVC
Length 15.6'
Slot Size 20
Depths 21.8' - 37.4'
-
App. By SPA Date 7-29-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	17.5'-40'	9.63 ft³
1/4" PELLETS	14-17.5'	1.24 ft³
BENT. CHUNKS	2.8'-14'	5.01 ft³
PRE-MIX	0'-2.8'	~.8 ft³

App. By SPA Date 8-9-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NAT. GAMMA	0' - 40'	8-2-88
	-	
	-	
	-	
	-	
	-	
	-	

Approved By SPA Date 8-2-88

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

7-27 Steam Cleaning
7-27 Storage of Const. Material
7-27 Tool Lubricants
8-9 Concrete Pad
8-25 Protective Steel Posts
10-24 Safety Paint
NA Straightness Test
9-1 Well Development
NA Downhole TV Inspection
NA Well Abandonment
10/24 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By SPA Date 10-24-88

Reviewed By D.L. McGhan Date 11-8-88

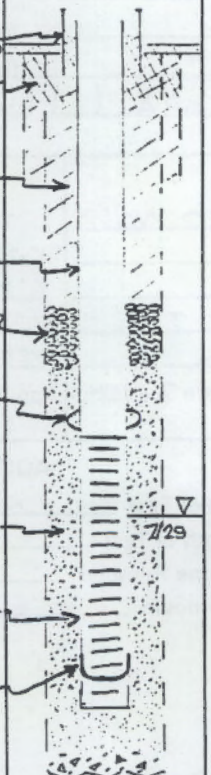
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LF4-PNL1 Geologist S.P. AIRHART Page 1 of 1

Reviewed by D.L. McElhan Date 11-8-88



Construction Data: Description	Depth in Feet	Geologic/Hydrologic Data: Lithologic Description
6" DIA. CARBON STEEL CASING	0'	
PRE-MIX CONCRETE		
	5'	SILTY SANDY GRAVEL
BENTONITE CHUNKS		
	10'	SILTY SANDY GRAVEL
4" DIA. PVC CASING		
1/4" ENVIROPLUG PELLETS	15'	SANDY GRAVEL
CENTRALIZER	20'	SILTY SANDY GRAVEL
	25'	GRAVEL
10-20 MESH COL. SILICA SAND		
	30'	SILTY SANDY GRAVEL
4" DIA. SLOTTED PVC (20 SLOT)	35'	SANDY GRAVEL
4" DIA. ABS CAP PLACED IN BOTTOM OF SCREEN	40'	SILTY SANDY GRAVEL
DEPTH DRILLED = 41'		
	45'	
	50'	

A-1800-186 (3/87)

Well LEH-1 Drilled Depth 36' Interval Logged 0' - 34'

Log Type Nat Gamma Date 8-2-88 Casing Size 4" PVC

Logged By EJ [illegible] [illegible] ~26.6'

Logging Scale: Sensitivity 500 c/s Time Constant 3

Vertical Scale 10'/in Logging Speed 15'/min

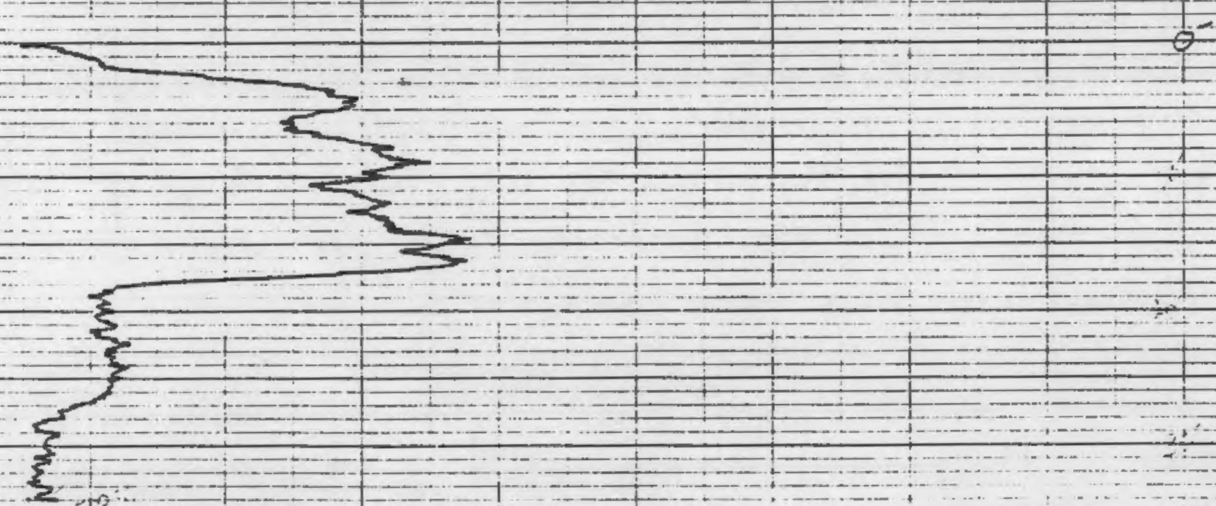
Source Strength NA [illegible] NA

Remarks: Ref Procedure GW-6 Rev. 2

Probe Ser # NG-001

- LOGGED AFTER COMPLETION -

0 c/s SPAN CHECK 100 c/s



E.76

DRILL LOG	By: AIRHART	Rig: BUCYRUS-ERIE 22W	Well Number: LF4-PNL1	Computer Number	Project or Work Order No.: FORT LEWIS
	Date: 7-27-88	ONWEGO	Depth: 0' To 6'	NA	Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Steam cleaning 8" carbon steel casing, 4" PVC casing	09:30 – 11:30	
				& screen, and drill rig		
				Setting up rig. Pins on drill string were	11:30 – 12:30	
				lubricated w/ Chevron Poly FM grease		
				Driller: Lenny Bultena, ONWEGO Drilling Co, Inc.		
					12:50	Began drilling
						(hardtool)
					13:05	Added ~2 gals H_2O
7' of	starter	casing		Set 7' of 10" dia. starter casing		
				Driller is hard-tool drilling then switching		
				over to 4" dia. split spoon @ sample interval		
	5-6'	SPLIT SPOON	W	SILTY SANDY GRAVEL: 65% gravel, 30% sand, 5% silt;	14:55	
				10% CP, 20% MP, 15% FP, 20% VFP, 5% VCS, 3% CS, 10% MS,		
				7% FS, 5% VFS, 5% silt: poorly sorted: (gravel)		
				SA-SR, 25% basalt, 60% porphyritic rx., 15% qtzite &		
				other metam: (sand) Angular grains, 15% basalt, 85%		
				qtz & other qtz-rich rock frags: color (wet) dark olive		
				gray 5Y3/2 (dry) light gray 5Y7/2: No rxn. w/		

REMARKS:

St P. Airhart
7-27-88

DRILL LOG	By AIRHART	Rig BE. 22W	Well Number LF4 - PNL1	Computer Number NA	Project or Work Order No. FORT LEWIS
	Date 7-27-88	ONWEGO	Depth 6' To 8'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				10% HCl ; unconsolidated ; No sedimentary structure		
				evident, Moisture sample was taken, however,		
				seds were wet from drilling water (driller		
				did not bail before taking split-spoon sample.		
					16:30	Welding 8" drive
						shoe
21'5¾" of 8" casing					17:00	Added 21'5¾" of
						8" casing w/ shoe
					17:30	Shut Down

REMARKS:

StP. Airhart
7-27-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse ...

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL1	Computer Number	Project or Work Order No. FORT LEWIS
	Date 7-28-88	ONWEGO	Depth 8' To 10'	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
21 3/4"					09:30	Started Drilling
					10:30	Driller indicated
						formation is hard -
						not consolidated
						however - loosing
						mud
					11:05	Driving casing
						Has Added ~ 5 gals H_2O
				Color change @ 9'-10' : Wet color was dark olive	11:30	
				gray 5Y 3/2 now is light olive gray 5Y 6/2	11:33	Bailed
				Formation appears much siltier.	11:35	Putting on split-spoon
				Monitored hole w/ HNU Photoionizer 10.2 ev &	11:45	
				11.7 ev probes. Nothing detected.		
					12:05	Taking split-spoon
						23 blows / 6"
						20 blows / 6"
						20 blows / 6"

REMARKS:

— 18" sample —

S.P. A[illegible] 7-28-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine [illegible]

E.78

15 ... 22 porph 6 fine ... 7 chert, qtz   45   30 44 12 14

DRILL LOG	By: AIRHART	Rig: B.E-22W	Well Number: LF4-PNLI	Computer Number: NA	Project or Work Order No.: FORT LEWIS
	Date: 7-28-88	ONWEGO	Depth: 10' To 15'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
21'5 3/4"	10.5-11.5'	SPLIT SPOON	W	SILTY SANDY GRAVEL: 75% gravel, 15% sand, 10% silt/clay	12:22	
				2% SC, 3% VCP, 15% CP, 15% MP, 20% FP, 20% VFP, 5% VCS		
				2% CS, 3% MS, 3% FS, 2% VFS, 10% silt/clay; very poorly		
				sorted: (gravel) Ang.-SubRound, 30% basalt, 44%		
				igneous (including porphyry, rhyolite, metaigneous)		
				12% sandstone & metaseds 14% quartz & chert		
				(sand) Ang-SubAng., 30% basaltic, 50% qtz, chert,		
				quartzite 20% ign rock frags; color (wet) olive		
				gray 5Y5/2 (dry) light gray 5Y7/2: NO rxn. w/		
				10% HCl; unconsolidated. No sedimentary structure		
				preserved; MOISTURE SAMPLE NOT TAKEN - TOO MUCH		
				DRILLING WATER.		
				Driller indicated drill rate increased @ 12.5-13'	13:15	
				probably a sandy lense.		
					13:40	Putting on split-spoon

REMARKS:

SEP Airhart
7-28-88

E.79

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A-6000-021 (5-85)

40 20 10 25

8 ign, 4 basalt, 2 chert/qtz, 5 meta...

DRILL LOG	By: AIRHART Date: 7-28-88	Rig: B.E. 22W ONWEGO	Well Number: LF4-PNL1 Depth: 15' To 20'	Computer Number: NA	Project or Work Order No.: FORT LEWIS Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					13:50	Taking split-spoon
						11 blows / 6"
						30 blows / 6"
						19 blows / 6"
						— Total 18" sample —
				Driller thinks we encountered water during		(15'-16.5')
				split spoon sampling.		
	16'	SPLIT SPOON	W	SANDY GRAVEL: 40% gravel, 55% sand, 5% silt -	13:55	
				2% VCP, 3% CP, 10% MP, 10% FS, 15% VFP, 5% VCS, 10% CS,		
				20% MS 15% FS, 5% VFS, 5% silt : very poorly sorted:		
				(gravel) SA - SR ; 45% ign. & porphyry 20% basalt,		
				25% breccia, & metasedimentary 10% chert, qtz. (sand)		
				A-SA, 50% qtz, chert 10% basalt, 40% metam & ign.		
				rock frags. ; color (wet) olive brown 2.5Y 4/4		
				(dry) white 2.5Y 8/2 ; No rxn. w/ 10% HCl ;		
				unconsolidated. Appears to be thinly interbedded		
				sand-rich & gravel rich layers.		

REMARKS:

St. P. Airhart
7-28-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - ...

E.80

DRILL LOG	By: AIRHART	Rig: B.E. 22W ONWEGO	Well Number: LF4-PNL1	Computer Number: NA	Project or Work Order No.: FORT LEWIS
	Date: 7-28-88		Depth: 20' To 22'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
21' 5¾"					14:50	Putting on split-spoon
					15:00	Took split-spoon sample
						12 blows / 6"
						10 blows / 6"
						10 blows / 6"
						9 blows / 6"
						— Total 24" sample —
						20' - 22'
	21'	SPLIT SPOON	W	SILTY SANDY GRAVEL - 70% gravel, 20% sand, 10% silt:	15:10	
				3% VCS, 7% CS, 5% MS, 3% FS, 2% VFS		
				1% SC, 2% VCP, 5% CP, 15% MP, 25% FP, 22% VFP, 10% silt;		
				very poorly sorted : (gravel) A-R, 58% ign.		
				porphyry, metaign, 30% basalt, 16% qtz & cht 16%		
				sedimentary, metasedimentary (qtzite) ; (sand)		
				A-SA ~~12% VCS, 5% CS, 2% MS, 1% FS-VFS, 10% silt~~ SPA 7/29 ;		
				color (wet) olive gray 5Y4/2 (dry) light gray		
				2.5Y 7/2 ; No rxn. w/ 10% HCl ; semi-compacted		
				(gravel in a silty matrix) - unconsolidated ;		
				No sed. structure preserved. No moisture sample.		

REMARKS:

S.P. Airhart
7-28-88

D - Drive Barrel H - Hard Tool

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LFA-PNL1	Computer Number: NA	Project or Work Order No.: FORT LEWIS
	Date: 7-28-88	ONWEGO	Depth: 22' To 25'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
21'5 3/4"					15:40	Cut off 1 3/4" 8" casing
21'4"						21'5 3/4" - 1 3/4" = 21'4"
31'10"	of 8" casing				16:00	Added 10'6" of 8" casing
						21'4" + 10'6" = 31'10"
					17:30	Shut Down

REMARKS:

St. P. Airhart
7-28-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL1	Computer Number NA	Project or Work Order No. FORT LEWIS
	Date 7-29-88	ONWEGO	Depth 25' To 27'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
31'10"					0715	Putting on split-
						spoon.
					0735	Took split-spoon sample
						11 blows / 6"
						11 blows / 6"
						18 blows / 6"
						27 blows / 6"
						— Total 24" sample —
						(26'-28')
				Driller notified me that sample was 1 ft past 25'		
				∴ 26'-28'. Photograph of sample was taken		
				prior to knowing this ∴ photograph depth		
				interval should be corrected.		
	26-27	SPLIT SPOON	W	GRAVEL : 81% gravel, 14% sand, 5% silt:	07:40	
				2% VCP, 5% CP, 21% MP, 25% FP, 28% VFP, 6% VCS, 3% MS,		
				3% MS, 1% FS, 1% VFS, 5% silt ∴ very poorly sorted:		
				(gravel) A-SA, 47% qtzites & metasedimentary 37% igneous,		
				porphyry, 8% basalt, 6% metamorphic, 2% chert		

REMARKS:

St P. Airhart
7-29-88

E.83

D - Drive Barrel H - Hard Tool ...

DRILL LOG	By: AIRHART Date: 7-29-88	Rig: B-E-22W ONWEGO	Well Number: LF4-PNLI Depth: 27' To 31'	Computer Number: NA	Project or Work Order No.: FORT LEWIS Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
31'10"				(sand) A-SA, 70% qtz & qtzite, 10% basalt, 20%		
				ign. & metam. rock frags ; color (wet) olive		
				5Y5/3 (dry) light gray 5Y7/2 ; No rxn. w/ 10% HCl;		
				unconsolidated : No sed. structure preserved. No		
				moisture sample taken. NOTE: coarsening		
				evident @ end of sample interval (28').	08:30	Putting on split-spoon
					08:40	Took split spoon sample
						7 blows/6"
						8 blows/6"
						9 blows/6"
						8 blows/6"
						– 24" sample –
						30' – 32'
	31'	SPLIT SPOON	W	SILTY SANDY GRAVEL : 70% gravel, 25% sand, 5% silt :	08:50	
				1% VCP (50 mm), 3% CP, 5% MP, 26% FP, 35% VFP, 10% VCS,		
				7% CS, 5% MS, 2% FS, 1% VFS, 5% silt ; very poorly		
				sorted : (gravel) A-SR, 40% qtzite, 40% igneous, metam.		
				porphyry, 10% qtz, cht, 10% basalt (sand) A-SA		

REMARKS:

S.P. Airhart
7-29-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig BE. 22W	Well Number LF4-PNL1	Computer Number	Project or Work Order No. FORT LEWIS
	Date 7-29-88	ONWEGO	Depth 31' To 35'	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
31'10"				65% qtzite, qtz, 30% igneous & metam. 5% basalt;		
				color (wet) olive 5Y5/3 (dry) light gray 2.5Y 7/2;		
				No rxn. w/ 10% HCl; unconsolidated; No sed.		
				structure evident; No moisture sample		
42'5" of 8" casing					0930	Added 10'7" of 8" casing
						31'10" + 10'7" = 42'5"
					0935	Drilling
					10:20	Putting on split-spoon
						Took split-spoon sample
						3 blows/6"
						9 blows/6"
						52 blows/6"
						— 18" sample —
						— 35'-36.5' —
				Split-spoon would not drive past 18"-20". Sample		
				has a sand plug (see photograph) which is		
				probably due to wash-in when water entered casing.		
				D/W = 29' below land (E-tape # A150-04)	10:25	

REMARKS:

S. P. Airhart
7-29-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-0

E.86

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LF4-PNL1	Computer Number: NA	Project or Work Order No.: FORT LEWIS
	Date: 7-29-88	ONWEGO	Depth: 35' To 36'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	36'	SPLIT SPOON	W	NOTE: This sample appears to have settled out inside the split-spoon. Fine on top, coarse @ bottom of spoon. There is ~6' of water in the hole ∴ this is likely. Took sample out of middle of spoon. Appears most fine have been washed out.	10:30	
				SANDY GRAVEL: 70% gravel, 30% sand: 15% MP, 25% FP, 30% VFP, 17% VCS, 8% CS, 5% MS: mod. sorted: (gravel) A-SR, 50% ign., porphyry, metaign. 40% quartzite & other metam. 10% basalt (sand) A-SA: 40% qtz, clf 20% basalt, 40% ign, metam, rock frags. color (wet) olive 5Y5/3 (dry) light gray 5Y7/2; No rxn w/ 10% HCl; unconsolidated. No sed. structure evident, slightly finer than previous sample.		
						Put on split-spoon
						Took split spoon sample

REMARKS:

S.P. Airhart
7-29-88

15'7" bottom cap to top of screen 21'1½" 10'0" 26'7" 26'½" 12:40

DRILL LOG	By AIRHART / Date 7-29-88	Rig B.E. 22W ONWEGO	Well Number LF4-PNL1 / Depth 36' To 40'	Computer Number NA	Project or Work Order No. FORT LEWIS / Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
						14 blows/6"
						17 blows/6"
						11 blows/6"
						13 blows/6"
						– 24" sample –
						40'-42'
	41'	SPLIT SPOON	W	SILTY SANDY GRAVEL: 65% gravel, 30% sand, 5% silt:	11:55	
				5% VCP (biggest 42mm), 5% CP, 10% MP, 20% FP, 25% VFP,		
				3% VCS, 2% CS, 12% MS, 8% FS, 5% VFS, 5% silt: very poorly		
				sorted: (gravel) A-SR, 35% igneous, porphyry 35% metam.		
				30% basalt (sand) A-SA, 60% qtz, qtzite 30% ign. & metam		
				rock frags 10% basalt; color (wet) olive gray 5Y 4/2		
				(dry) white 2.5Y 8/2; No rxn. w/ 10% HCl;		
				Unconsolidated: No sed. structure evident.		
					12:00	Stopped Drilling
				D/B = 40' below land (steel tape)		
				D/W = 26'7½" below land (E-tape # A150-04)	12:50	

REMARKS:

S.P. Airhart
7-29-88

O - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

NOTE: 40' = Total depth drilled w/ hard tool
42' = Total depth sampled w/ split spoon

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LF4-PWH	Computer Number	Project or Work Order No.
	Date: 7-29-88	ONWEGO	Depth: 40' To 37'		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Adding 4" PVC casing & screen (20-slot)	12:50	
				screen w/ bottom cap = 15'7"		
				casing = 10' section		
				(centralizer directly above screen)		
				casing = 21'1½" section		
				Total casing and screen = 46'8½"		
				Want to set bottom of screen @ 37'.		
				Adding 10-20 mesh silica sand (pulling		
				up on PVC as sand is added.)		
				Added 2 100 lb bags 10-20 mesh Col. silica sand	13:10	
				D/sand: 34' below land (∴ 3' of sand on bottom + 2' above bottom of screen)		
				Cut off 7'2½" of PVC. ∴ Total length = 39'6"		
				(Allowing for 2'6" of stickup).		
				Pulled 8" casing to 36' below land		
				D/sand = 35.5' below land		
				Added 1 100 lb bag 10-20 sand to 32'		
				Pulled 8" casing to 33'10" below land		
				Added 1 100 lb bag 10-20 sand to 28' below land	14:15	

REMARKS:

S.P. Airhart
7-29-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small ...

DRILL LOG	By AIRHART	Rig B.E.-22W	Well Number LF4-PNL1	Computer Number	Project or Work Order No. FORT LEWIS
	Date 7-29-88	ONWEGO	Depth COMPLETION To	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 31'		
				D/sand • 29' below land		
				Added 1 100 lb bag 10-20 sand to 25' below land		
				Pulled 8" casing to 28'11" below land		
				D/sand = 26.5' below land		
				Added 2 100 lb bags 10-20 sand to 18.5' below land	14:35	
				Pulled 8" casing to 24'5" below land		
				D/sand = 21' below land		
				Added 1 100 lb bag 10-20 sand to 17' below land		
				Pulled 8" casing to 21'10" (Appears that PVC has come up)		
				D/sand = 19'		
				Pulled 8" casing to 20'4"		
				D/sand : 20'		
				Added 1 100 lb bag 10-20 sand to 16' below land	15:00	
				Pulled 8" casing to 17'6" below land		
				D/sand = 17.5' below land	15:10	
				Started bailing w/ 3" dart bailer to settle sand	15:15	
				D/sand = 17.5' below land did not settle	15:30	

REMARKS:

NOTE: Did not perform straightness test.

S.P. Airhart
7-29-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine __ Standing Water

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL1	Computer Number	Project or Work Order No. FORT LEWIS
	Date 7-29-88	ONWEGO	Depth COMPLETION To	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/B inside PVC = 36'9" from land		
				Added 2 5 gal buckets 1/4" Enviroplug Pellets	15:45	
				D/pellets: 12.5' below land		
				Pulled 8" casing to 13.5' below land		
				D/pellets: 14' below - small amount of cave		
				material @ this point.		
				Added 4 50 lbs bags of Med. Enviroplug bentonite		
				D/bentonite = 2' below land		
				Pulled remaining 8" casing out of hole	16:45	
				D/bentonite = 7' below land - small amount of		
				cave material @ this point		
				Added 3 bags of Enviroplug bentonite		
				D/bentonite = 2' below land		
				Pulled 10" casing to 3' below land		
				D/bentonite = 2'10" below land	16:55	
					17:00	Shut Down

REMARKS:

S.R. Airhart
7-29-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

DRILL LOG	By: EJ JENSEN Date: 8-2-88	Rig: B.E. 22W ONWEGO	Well Number: LF4-PNL1 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: FORT LEWIS Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Geophysically logged hole using Natural		
				Gamma, probe.		

REMARKS:

SEP. [illegible]
8-2-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   ____ Standing Water   A 6000 021 (5 85)

E.92

DRILL LOG	By: AIRHART	Rig: B.E. 22W ANWEGO	Well Number: LF4-PNL1	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-8-88		Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 5'3" of 6" carbon steel casing	16:00	
				Mixed & poured 3 90 lb sacks (.66 ft^3/sack)		
				to fill remaining borehole to surface and		
				inside of protective casing to 8" above		
				land surface.		
				Began bailing w/ 3" dia. 20' long dart	16:35	
				bailer. Water is very silty / turbid.		
				Bailing rate ~ 5 gpm		
				Stopped bailing - water still turbid	1700	
				D/B inside PVC = 35'9" below land ∴		
				appears to be ~ 1' of sediment on		
				bottom of screen.		

REMARKS:

St. P. Airhart
8-8-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000.021 (5-85)

DRILL LOG	By: AIRHART	Rig: B.E.-22W	Well Number: LF4-PNL1	Computer Number: NA	Project or Work Order No.: FORT LEWIS
	Date: 8-9-88	ONWEGO	Depth: COMPLETION TO		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Resumed bailing well w/ 3" dart bailer	07:10	
				Quit bailing. Water still turbid, however	09:30	
				getting cleaner. Some Col. silica sand and		
				misc. rock frags remain @ bottom of		
				screen.		
				Mixing concrete & pouring surface pad.	09:50	
				Mixed and poured 9 90 lb bags of Pre-mix		
				concrete and 1/2 bag of Portland cement		
				For 4'x4' surface pad		
				Cut "weep" hole in protective casing		
				Set brass marker		

REMARKS:

StPAirhart
8-9-88

E.93

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small

(FORT LEWIS- LANDFILL 4)

DRILL LOG	By AIRHART	Rig Bucyrus Erie 22W	Well Number LF4- PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 8-18-88	OWNED	Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Started bailing on well w/ 3" dia.	08:30 -	09:30
				dart bailer. Sandpack and formation		
				gravels are coming up w/ bailer.		
				Appears that bottom cap has come		
				off (?). D/B inside PVC = 35'6" below		
				land. Approx. 1' of fill in bottom.		

REMARKS:

[signature]
8-18-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _Standing Water

DRILL LOG	By: AIRHART	Rig: NO RIG	Well Number: LF4-PNL1	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-24-88		Depth: DEVELOPMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Khris Olson and Dave Dahl (PNL) took water		
				samples for chemical analysis		

REMARKS:

S. P. Airhart
8-25-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

(FORT LEWIS-LANDFILL 4)

DRILL LOG	By	Rig	Well Number	Computer Number	Project or Work Order No.
	AIRHART	NO RIG	LF4-PNL1	NA	11832
	Date		Depth		Subcontract No.
	8-25-88		COMPLETION To		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed 1/3 bag Portland cement w/ gravel to set 4 protective posts around surface pad.		

REMARKS:

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000 021 (5-85)

DRILL LOG	By AIRHART	Rig no rig	Well Number LF4 - PNL1	Computer Number NA	Project or Work Order No. 11832
	Date 9-1-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				set 3" dia. ABS cap in bottom of well		
				to provide bottom since PVC bottom		
				was damaged w/ bailer.		
				New D/B = 35.52' below top of PVC		
				← Add length of weight		
				placed 3" dia 1/3 hp submersible pump	12:30-	13:00
				in hole. Pumped hole @ ~ 10 gpm.		
				water cleaned up clear. Very little if		
				any turbidity.		
				Note: pump was cleaned in local car wash		
				(steam cleaner not available) using no soap -		
				before placing in hole.		

REMARKS:

St P. Airhart
9-1-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-PNL1	Computer Number NA	Project or Work Order No. 11832
	Date		Depth To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				painted posts during week of 10/17-10/21		

REMARKS:

S.P. Airhart
11-5-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine — Standing Water

WELL LF4-PNL2

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project	Well Number
Location FT. Lewis	Temporary Well Number LF4-PNL2
Driller Lenny Buttens	Coordinates
Drilling Co. ONWEGO	Casing Elevation
Geologist G V Last	Ground Elevation

DRILLING METHOD	COMPLETION DATA
Rotary Air ___ Mud ___	Drilled Depth 40'
Cable Tool D ___ H ___	Completion Depth 38'
Drilling Fluid ___	Date Started 8-3-88 Completed 8-9-88
Other 8" Hollow stem Auger + split-spoon to 40'	Static Water Level/Date 29' / 8-4-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	2" (sch. 40)	to 23'
		to
		to

Approved By G V Last Date 8-5-88

PERFORATIONS	SCREEN	ANNULAR SEAL
Type NA	Type PVC slotted	Type / Interval / Volume
Depth / Schedule	Length 15'	Bent. Chunks / 2'-18' / 200 lbs.
	Slot Size 20	Bent. Pellets / 18'-20' / .62 ft^3
	Depths 23' - 38'	Pre-Mix / 0'-2' / .7 ft^3
App. By ___ Date ___	App. By G V Last Date 8-5-88	App. By G V Last Date 8-5-88

GEOPHYSICAL LOGGING			AQUIFER TESTING
Sondes	Interval	Date	Type of Test NA
Nat. Gamma	2' - 36'	8-4-88	Length of Test
			Volume Pumped
			Drawdown
Approved By G V Last		Date 8-5-88	Approved By ___ Date ___

OTHER APPLICABLE ITEMS

8/2 Steam Cleaning
8/5 Storage of Const. Material
8/5 Tool Lubricants
8/9 Concrete Pad
8/25 Protective Steel Posts
10/24 Safety Paint
NA Straightness Test
9/7 Well Development
NA Downhole TV Inspection
NA Well Abandonment
10/24 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By S P A [illegible] Date 10-24-88

Reviewed By [illegible] McElhinney Date 11-8-88

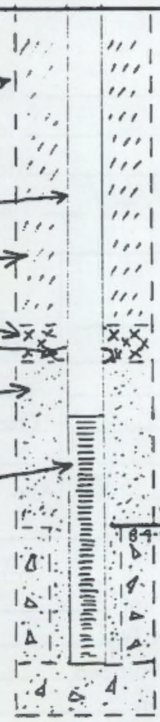
A-1800-187 (3/87)

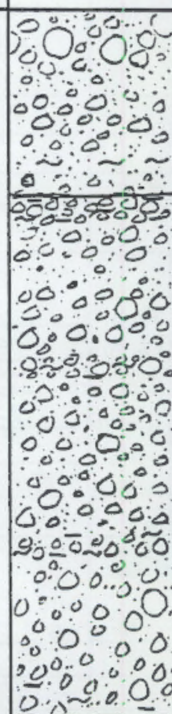
Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LF4-PNL2 Geologist GV Last Page 1 of 1

Reviewed by V.L. McGhan Date 11-8-88





Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Geologic/Hydrologic Data: Lithologic Description
8" Borehole via Auger		5		GRAVELLY SAND
Flights				
		10		SLIGHTLY PEBBLY COARSE SAND
2" PVC casing				MUDDY MEDIUM TO FINE PEBBLE
Bentonite Chunks		15		VERY COARSE TO COARSE SAND (WET)
Bentonite Pellets				
Centralizer		20		MUDDY SANDY GRAVEL (WET)
Silica Sand Pack				
		25		SANDY GRAVEL (WET)
2" PVC (20 slot) slotted				
screen		30		MUDDY SANDY GRAVEL (SATURATED)
		35		
		40		SLIGHTLY MUDDY SANDY GRAVEL

A-1800-186 (3/87)

Well LF4-2 Drilled Depth [illegible] Interval Logged 2' - [illegible]

Log Type [illegible] Gamma Date 8-4-83 Casing Size 4" ID, [illegible]

Logged By EJ [illegible] - PNL Water Level Depth 30'

Logging Scales: Sensitivity 100 c/s Time Constant 3

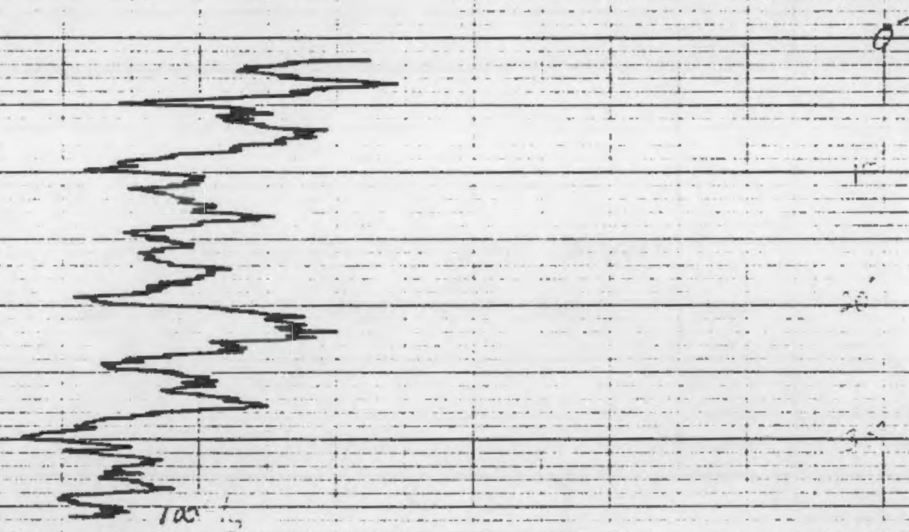
Vertical Scale 10'/in Logging Speed 15'/min

Source Strength NA Spacer Length NA

Comments Ref. Procedure GW-6 Rev. 2

Probe SER. # GG NG-001

0 c/s SPAN CHECK 100 c/s



E.101

DRILL LOG

By	FJ Jensen
Date	8/2/88
Rig	SCHRAMM RotoDrill
Well Number	LF4 - PNL2
Depth	0' To 5'
Computer Number	
Project or Work Order No.	
Subcontract No.	

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				steam cleaned rotary rig.	0900	
				AUGERED TO 5'. DRILLER SAYS VERY LARGE PEBBLE	1300	
				TO COBBLE (0.25' IN DIA.) TO APPROX. 3'. THEN MEDIUM		
				PEBBLE (0.1' IN DIA.) TO 5'.		

E.102

REMARKS:

[illegible] 8/3/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By: GV Last Date: 8-3-88	Rig: ONWEGO SCHRAMM	Well Number: LF4 - PNL2 Depth: 5' To 15'	Computer Number	Project or Work Order No. Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				SPLIT TUBE SAMPLING WITH 140 lb. Hammer.	07:27	19, 50+, 50+ (Blow
	5-6'	A-SS	SM	GRAVELLY SAND, NO OBSERVED SEDIMENTARY STRUCTURES.	07:32	BLOW COUNTS/6"
				20% GRAVEL UP TO .16' IN DIA. SAND IS PREDOMINANTLY		19, 50+, 50+
				COARSE. 1 SILTY AREA NOTED. MOISTURE SAMPLE		
				TAKEN FROM SHOE, PICTURE TAKEN. 2 JAR SAMPLES. FIRST		
				JAR FROM BOTTOM 6" OF SPLIT TUBE. SECOND FROM		
				TOP AND CONTAINS SAME STUFF. NO RESPONCE ON		
				HNU WITH 10.2 eV PROBE.		
	7-8.5	A		DRILLING [illegible] THROUGH A SILTY SAND [illegible]	07:50	
	10-11.5	SS	SM	10-10.5' SLIGHTLY PEBBLY COARSE SAND GRADING DOWNWARD	08:00	Blow counts/6"
				TO MEDIUM SAND (1 JAR SAMPLE)		17, 49, 50
				10.5-11.5' MATRIX SUPPORTED MEDIUM TO VERY FINE PEBBLE (MAX SIZE		PICTURES TAKEN.
				0.18'). MATRIX IS MUDDY (SILT + CLAY) COARSE SAND.		
				(MOISTURE SAMPLE & 1 JAR SAMPLE)		
	15'	SS	WET	Very Coarse to Coarse Sand. Not enough to sample	08:41	Blow counts = >50/4"
				except for moisture sample only. No picture.		
				Checked Well head. No responce on HNU with 10.2 eV probe.	08:55	

REMARKS: A = auger
SS = split spoon

GV Last 8-3-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

DRILL LOG	By: GV Last Date: 8-3-88	Rig: ONWEAD SCHRAMM	Well Number: LF4-PNL2 Depth: 15' To 30'	Computer Number	Project or Work Order No. Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	15-20'	A			09:00	much Harder Drilling.
						RIG SMOKES SOME (DIESEL).
	20-21'	SS	WET	MUDDY SANDY GRAVEL. INCREASED CLAY CONTENT.	09:15	BLOW COUNTS = 50+/6"
				65% VERY FINE TO MEDIUM PEBBLE (0.07' max). 35% VERY		BEYOND 6" OF SAMPLING.
				FINE TO V. Coarse Sand mostly C-M. LOTS OF LITHIC FRAGMENTS.		HAD WET MUD ON IT.
				GRAVELS ARE WELL ROUNDED. 20% BASALTIC, 10%		MOISTURE SAMPLE
				GRANITIC, 70% OTHER. WET COLOR IS OLIVE BROWN (2.5YR 4/4)		FROM SHOE. 1 JAR SAMPLE.
				NO REACTION IN 10% HCl. NO RESPONSE ON HNU (10.2)		
	25'	SS	Wet	SANDY GRAVEL, less mud. No sedimentary Structures.	10:08	BLOW COUNTS = 130/3.5"
				60% Very Fine to Medium Pebble (0.06' in Dia.-max), 35%		
				Coarse to Medium Sand, 5% silt & clay in nodules. Gravel		
				is rounded to well rounded, Sand is subangular and		
				mostly lithic fragments. Gravels are multiple lithologies		
				mostly porphyritic. Color (Dry) is light brownish grey (2.5YR 7/2).		
				No reaction to 10% HCl. Took moisture sample from shoe &		
				1 small jar sample.		
	30'	A		Driller says material is all about the same. Gravels with	10:30	
				some lens of muddier or sandier materials. Drills rough & smooth		

REMARKS: back and forth.

GV Last 8-3-88

E.104

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By: GV Last	Rig: ONWEGO	Well Number: LF4-PNL2	Computer Number	Project or Work Order No.
	Date: 8-3-88	Schramm	Depth: 30' To 40'		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	30-31'	SS	(Saturated) Wet	Muddy Sandy Gravel. Sample is saturated. No sedimentary	10:39	Blow counts = 48/6"
				Features. Sample is 60% very fine to fine pebble, 40% Non-		and 130/4". Driller
				descript sand (more very fine to fine sand than previous sample).		thinks we hit water
				Gravels are subrounded to subangular and multiple lithologies. Sands are		at ~28'.
				mostly lithic fragments. Dry color is lt. brownish gray (2.5Y 6/2)		No Response on HNU (10.2)
				No reaction to 10% HCl. No moisture sample taken. 2 jar samples.		
	31-35'	A		Materials coming to surface around auger flights, is primarily	11:17	
				Medium to Very Coarse Pebble. Above samples may indicate		
				the material is finer than it actually is. Picture taken.		
	35-36.5'	SS	(Saturated) Wet	Slightly muddy MEDIUM TO FINE SAND grading downward to a clean	11:43	Blow counts 7, 20 & 50
				Very Coarse to Medium SAND. Less muddy at 35.3'.		per 6" intervals
				Driller thinks we hit sand at ~34 ft. "Hard to say."		No Response on HNU (10.2
				95% Sand, predominantly coarse to medium. 5% very fine		or 11.7).
				pebble which is subangular. Sand is mostly lithic fragments.		
				Took 2 jar samples (35.5-36 and 36-36.5). Dry color of mud		
				is lt. yellowish brown (2.5Y 6/4). No reaction to 10% HCl.		
	40	A		LAST SAMPLE THOUGHT TO BE SAND THAT HEAVED UP	1320	SAND Heaving - pilot
				HOLE — NOT REPRESENTATIVE OF FORMATION		bit stuck in flights

REMARKS: Pulled flights up 5' to 35'.

GV Last 8-3-88

E.105

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse ...

DRILL LOG	By GV Last Date 8-3-88	Rig ONWEGO Schramm	Well Number LF4-PNL2 Depth 40' To 40'	Computer Number	Project or Work Order No. Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				REDRILLED TO 40'. PILOT BIT DOWN ONLY TO ~35'.	13:48	
				PULLED PILOT BIT OUT - LOTS OF SAND ON TOP OF IT	15:56	D/B = 36' BELOW (BLS)
				CAUSING TROUBLE. PULLED FLIGHTS TO 37' BLS.		LAND SURFACE. D/W
						= 29' BLS. STEEL TAPE
						No. L30001
				REDRILLED TO 40'. PULLED PILOT BIT. FLIGHTS PULLED	16:30	D/B = 36' BLS
				BACK TO 36'.		D/W = 29' BLS
						STEEL TAPE No. L30001

REMARKS: BLS = Below land surface

GV Last 8-3-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-85)

E.106

DRILL LOG	By: GV Last Date: 8-4-88	Rig: ONWEGO Schramm	Well Number: LF4-PNL2 Depth: 40' To 40'	Computer Number	Project or Work Order No. Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					07:12	D/B = 34' BLS
						D/W = 29' BLS
						300' steel tape # L30001
	30-40'	A		REDRILLED TO 40' USING SAMPLER INSTEAD OF PILOT BIT TO	07:55	
				KEEP HOLE OPEN		
	40'	SS	(Saturated) Wet	SLIGHTLY MUDDY SANDY GRAVEL. 60% Very Coarse to Very Fine	08:05	Blow counts = >50/4"
				Pebble; 35% Coarse to Medium Sand (some Very Coarse to Very		No response on HNU
				Fine); and 5% Silt and Clay. Gravels are subrounded		(10.2 probe).
				to subangular (very fine pebbles), and mixed lithologies.		
				Sand is angular to subround and mostly lithic fragments.		
				Only bottom 4" of sample is representative. Took 1 jar		
				sample. Dry color of mud is lt. brownish gray (2.5Y 6/2). No reaction		
				to 10% HCl.		
					09:16	D/B = 38' BLS
						D/W = 30' BLS
						steel tape No. L30001
				Run natural gamma log from 2' to 36'.	09:40 –	
					10:30	

REMARKS: SS = splitspoon
BLS = below land surface

GV Last 8-4-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse

E.107

DRILL LOG	By: GV Last Date: 8-4-88	Rig: ONWEGO Schwamm	Well Number: LF4-PNL2 Depth: 40' To 38'	Computer Number	Project or Work Order No. Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				set 15' of 2" slotted (20 slot) PVC screen and 25' of PVC	11:15	Western Plastics Corp PVC
				pipe. Bottom set at 39.5'. Centralizer 5' above screen.		meets ASTM 1785 (sch. 40)
				Added ~1.5 gal. of 10-20 mesh Colorado Silica sand. Measured	11:30	
				top of sand at 36'.		
				Pulled flights up to 37'. PVC trying to come up. Sand pack at 37'	11:40	
				Added ~1.5 gal. of 10-20 sand pack. Sand pack at 34'.		
				Pulled flights back some. Added 1.5 gal. sand.	11:54	
				Pulled flights to 35'. Sand at 34'.	11:55	
				Added 2.0 gal. of sand. Sand pack at 31'.	11:57	
				Pulled flights back to 32'. Sand pack at 28.5'	12:00	Driller thinks bad measure above.
				Added 1 gal of sand. Sand pack at 27'.	12:10	
				Pulled flights back to 29.5'. Sand pack at 25'. (Bridged?)	12:20	
				Rotated flights to loosen bridging. PVC came up to 38.0'. Sand	12:35	
				pack still at 25'.		
				Worked flights up & down. Got Bridge out. Flights at 29'.	1327	Bottom of screen still at
				Sand at 32'. Added 2 gal. of sand. Pulled flights to 26'		~38'.
				Sand at 27.5'		
				Added 1 gal. of sand. Sand at 24'.	1332	

REMARKS: 8.5 to 9 gal. of sand / 1-100 lb. sack.

GV Last 8-4-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

0.33183 0.325' R OUSIDE AUGER
0.09621 0.175'
0.03142 0.10' R PVC

DRILL LOG	By: GV Last	Rig: ONWEGO	Well Number: LF4 - PNL2	Computer Number	Project or Work Order No.
	Date: 8-4-88	Schramm	Depth: 38' To 38'		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled flights to 25'. Sand at 25'.	1337	
				Added ~ 1.5 gal. Sand at 23'. Pulled 6", added 1 gal.	1343	
				of sand. Pulled flights to 23'. Sand at 23.5'		
				Added 2.0 gal of sand. Pulled flights to 22.5'. Sand at	1348	used 2 100 lb bags
				22'. Added 1.5 gal. sand. Sand at 19.5'.		of sand so far.
				Pulled flights up to 22.5'. Sand at 22.5'.	1400	
				Built surge block and surged well for 10 min.	1630	
				Sand pack measured at 22.5'.	1650	
				Added 6 gal (3/4 100 lb sack) of silica sand. Pulled	1713	used a total of 2.75
				flights to 20'. Measured sand pack at 20'.		100 lb sacks of colorado
						silica sand. Estimate
						1" sand pack thickness
						below water table &
				16.0 (Above)		3" sand pack thickness
				4.5		above water table. Total
				20.5 g		estimated volume 20.5 g.
						we used ≈ 22 gal. of
						sand.

REMARKS: ~0.065 cu. ft/ft A hole between 2" PVC & 4" ID AUGERS. (0.5 gal.)
~0.235 cu. ft/ft (1.76 gal) between 2" PVC & 8" OD AUGER.

GV Last. 8-4-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000 021 (5-85)

E.109

DRILL LOG	By: GV Last Date: 8-4-88	Rig: ONWEGO Schramm	Well Number: LF 4-PNL2 Depth: 38' To 38'	Computer Number	Project or Work Order No.: 11832 Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 1 50 lb. bucket of Enviroplug Pellets 1/4 inch.	17:30	PELLET SEAL 18-20'
				Pulled flights to 18'. Pellet Seal at 18-20'.		
				Added 1 50 lb. sack of Enviroplug Medium Bentonite	17:39	
				Chunks. Pulled flights to 15'. Chunks measured to		
				15'.		
				Added 1 50 lb. sack of Enviroplug chunks. Pulled	18:04	
				flights back to 10'. Chunks at 9'.		
				Added 1 50 lb. sack of Enviroplug chunks. Pulled	18:29	
				flights all the way out. Chunks are at 2'.		

REMARKS:

GV Last 8-5-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

DRILL LOG	By GV LAST	Rig ONWEGO	Well Number LF4-PNL2	Computer Number	Project or Work Order No. 11832
	Date 8-5-88	Schramm	Depth 38' To 38'		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				MOVED RIG OFF HOLE	0155	D/B = 35.5' BLS
				BOTTOM OF HOLE IS SOFT, ACTS LIKE 3' OF MUD		D/W = 35-6' = 29' BLS
				IN HOLE.		STEEL TAPE L30001

REMARKS:

G.V. Last 8-5-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-DNL2	Computer Number NA	Project or Work Order No. 11832
	Date 8-9-88		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed & poured 10 90 lb bags of Pre-mix		
				concrete and bags of Portland cement		
				for remaining annulus, and 4'x4'		
				surface pad.		
				Set 5' section of 6" dia. carbon steel		
				casing for protective casing around PVC.		
				Set brass marker	12:45	

REMARKS:

S.D. Airhart
8-9-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A 6000.021 (5-85)

DRILL LOG	By: AIRHART Date: 8-24-88	Rig: NO RIG	Well Number: LF4-PNL2 Depth: DEVELOPMENT To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Khris Olson and Dave Dahl (PNL) attempted		
				to take water samples for chemical		
				analysis, however water was too muddy.		
				NOTE: cubby (ONWEGO) bailed a few times		
				w/ a 1½" dia dart bailer on 8-23 -		
				he stated that well was very muddy.		
				needs more development.		

REMARKS:

StP Airhart
8-24-88

E.113

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

(FORT LEWIS- LANDFILL 4)

DRILL LOG	By: AIRHART Date: 8-25-88	Rig: NO RIG	Well Number: LF4-PNL2 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed 1/3 bag Portland cement w/ gravel		
				to set 4 protective posts around		
				surface pad.		

REMARKS:

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small

E.114

DRILL LOG	By: AIRHART Date: 9-1-88	Rig: NO RIG	Well Number: LF4-PNL2 Depth: DEVELOPMENT To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				bailed hole w/ 2" dart bailer to		
				remove mud from hole. Mud cleaned		
				out of hole after ~ 15-20 bails -		
				- well also ran out of water -		
				NOTE. bailer was cleaned @ local		
				car wash (no steam cleaner available)		
				using no soap - before placing in well.		

REMARKS:

STP Airhart
9-1-88

E.115

DRILL LOG	By: AIRHART Date: 9-7-88	Rig: SAMPLING TRUCK - PNL -	Well Number: LF4-PNL2 Depth: DEVELOPMENT To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Don Glover & myself arrived @ wellsite	12:40	
				D/W from top of 6" protective casing ≈ 33'		
				D/B " " " " " " ~ 41.5'		
				(Both depths checked w/ a SOILTEST DR-759		
				Water Level indicator)		
				Set Hydrostar pump @ 88' below top of		
				6" casing.		
				Started pumping	13:45	
				Pumped for 2 min 20 sec. - well ran out of		
				water - pumped ~ 1.5 gals. Letting recover.		
				Pumped ~ 1 gal: 2 min 6 sec 13:58 - 14:00		
				Pumped ~ 1 gal 1 min 30 sec 14:26 - 14:27		
				Pumped ~ 3 gals 10 min 00 sec 14:56 - 15:06		
				Calculated 0.16 gal/lin. linear ft inside 2" PVC		
				Turned pump on @ 15:22 to run while we	15:20 - 17:20	
				surveyed well elevations. Pump off 17:20 - water		
				is clean.		

REMARKS:

JHP Airhart
9/7/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.116

DRILL LOG	By AIRHART	Rig SAMPLING TRUCK - PNL-	Well Number LF4-PNL2	Computer Number NA	Project or Work Order No. 11B32
	Date 9-7-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Let well recover 5 min then pumped		
				again. for 2 min.		
				Let well recover 15 min then pumped	17:50	
				again. A little more turbidity when well.		
				is allowed to fully recover		

REMARKS:

St P Airhart
9/7/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

E.118

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	SAMPLING TRUCK - PNL -	LF4-PNL2	NA	11832
Date		**Depth**		**Subcontract No.**
9-8-88		DEVELOPMENT/SAMPLING		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Don Glover & myself arrived @ wellsite	0750	
				Pumped ~ 1 gal. H_2O - took pH, cond., temp°	0815	
					0815-0830	Letting well recover
				Pumped ~ 1 gal H_2O - took pH, cond., temp°	0830	
				Not much change in readings ∴ will sample		
				during next pumping.		
				sampled water for chemical analysis -	0845	
				AM-TEST will do analysis		
				Disassembling 'HYDROSTAR pump assembly	0920-0940	
				Moved off well	09:45	

REMARKS:

St P. Airhart
9/8/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (6-85)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-PNL2	Computer Number NA	Project or Work Order No. 11832
	Date		Depth To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				painted posts during week of 10/17-10/24		

REMARKS:

S.P. Airhart
11/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.119

WELL LF4-PNL3

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832	Well Number
Location Fort Lewis	Temporary Well Number LF4-PNL3
Driller Lenny Bultena	Coordinates
Drilling Co. ONWEGO	Casing Elevation
Geologist GV Last	Ground Elevation

DRILLING METHOD	COMPLETION DATA
Rotary Air ______ Mud ______	Drilled Depth 46.5'
Cable Tool D ______ H ______	Completion Depth 43'
Drilling Fluid	Date Started 8-5-88 Completed 8-9-88
Other 8" HOLLOW STEM AUGER & SPLIT-SPOON 0'-46.5'	Static Water Level/Date 34.7' / 8-8-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	2" DIA. (SCH. 40)	27.6'

Approved By SDA Date 8-8-88

PERFORATIONS

Type NA

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 2" DIA. SLOTTED PVC
Length 15.4'
Slot Size 20
Depths 27.6' - 43'

App. By SDA Date 8-8-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	25.4'-43'	3.46 ft³
¼" PELLETS	23.3'-25.4'	1.03 ft³
BENT. CHUNKS	3'-23.3'	5.33 ft³
CONCRETE	0'-3'	~.6 ft³

App. By SDA Date 8-9-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NOT LOGGED	-	

Approved By ______ Date ______

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

8/5 Steam Cleaning
8/5 Storage of Const. Material
8/5 Tool Lubricants
8/9 Concrete Pad
8/25 Protective Steel Posts.
10/24 Safety Paint
NA Straightness Test
8/24 Well Development
NA Downhole TV Inspection
NA Well Abandonment
10/24 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By SDA Date 10-24-88

Reviewed By J.L. McGlaun Date 11-8-88

A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LF4-PNL3 Geologist GV Last Page 1 of 1

Reviewed by V.L. McGhan Date 11-8-88

Construction Data: Description	Depth in Feet	Geologic/Hydrologic Data: Lithologic Description
CONCRETE		
	5	Gravel Backfill
BOREHOLE DRILLED W/ 8" AUGER		
	10	Muddy Sandy Gravel
BENTONITE CHUNKS		
	15	Slightly Muddy Sandy Gravel
2" DIA. PVC CASING		
	20	Slightly Muddy Sandy Gravel
CENTRALIZER		
	25	Slightly Muddy Sandy Gravel
1/4" ENVIROPLUG PELLETS		
	30	Slightly Muddy Sandy Gravel
10-20 COL. SILICA SAND		
	35	Slightly Muddy Sandy Gravel
2" DIA. SLOTTED PVC (20 SLOT)		
	40	Sandy Gravel
	45	Sandy Gravel
DEPTH DRILLED = 46.5'		

Construction Diagram:

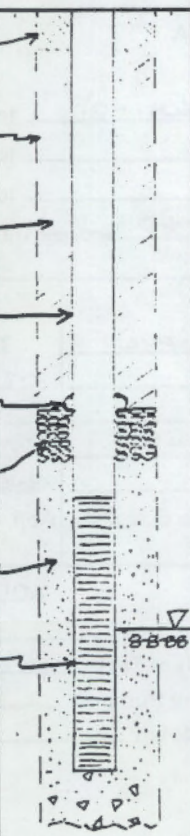
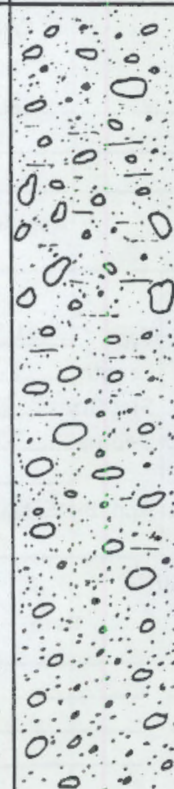


Diagram Litho.:



A-1800-186 (3/87)

DRILL LOG	By: GV Last Date: 8-5-88	Rig: ONWEGO Schramm T64	Well Number: LF4-PNL3 Depth: 0' To 16.5'	Computer Number	Project or Work Order No.: 11832 Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					08:00-	STEAM CLEAN RIG &
					09:00	AUGER FLIGHTS.
					09:43	SET UP RIG OVER HOLE.
				Using Rotary Rig as an auger; 4" ID hollow stem flights; 8" OD.	09:48	STARTED DRILLING.
	0-5'	A	Sm	Large Gravel backfill (up to 0.3' DIA).	10:34	GOT WORD THAT HOLE
						IS ~ 3' FROM 12" WATER
						main). No HNU responce.
	5'	SS	Wet.	MUDDY SANDY GRAVEL. Very little recovery. Probably not	11:27	21, 50/3" (BLOW COUNT.)
				very representative. Took picture. 1 jar sample.		[~30 min. after sampled.]
	10-11'	SS	V. Moist	SLIGHTLY MUDDY SANDY GRAVEL. 60% medium (0.1' DIA) TO Very	11:33	23, 37, 50/3" (BLOW
				fine pebble, 35% sand (mostly c-m) 5% mud (silt & clay).		COUNTS /6".
				Pebbles are subrounded and mixed lithologies. Took pictures;		No responce on HNU (11.7)
				Moisture sample at 11; 1 Jar sample at 10-11'. Moist color		
				is lt. olive brown (2.5 Y 5/4). No reaction to 10% HCl.		
	15-16.5	SS	WET	Slightly MUDDY SANDY GRAVEL; 70% M-VF Pebble, 25% Sand (VC-C)	1203	Blow counts = 13, 24 & 27/6"
				and 5% mud. Lots more VC sand to VF Pebble. largest clasts		
				are ~ 0.1' DIA. large clasts are subrounded, small ones are angular.		
				Took picture, moisture sample & 1 jar samples. Dry color is lt. gray (2.5Y 7/2).		

REMARKS:
No reaction to 10% HCl.

GV Last 8-5-88

E.123

DRILL LOG	By: GV Last Date: 8-5-88	Rig: ONWEGO Schramm T64	Well Number: LF4-PNL3 Depth: 16.5' To 31'	Computer Number	Project or Work Order No.: 11832 Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	20-21.5	SS	Wet	SLIGHTLY MUDDY GRAVEL; 65% VF-M Pebble (mostly Fine-pea size) 30% sand (medium-Very Coarse) and 5% mud. Gravel is mostly subangular, larger ones (up to 0.1') are subrounded. Sand is subangular and mostly lithic fragments. No sedimentary structures observed, although material is coarser between 20-20.5'. Took picture; moisture sample & 2 jar samples. Dry color is lt. gray (2.5Y 7/2). No reaction to 10% HCl.	1300	16-26-26 (BLOW COUNTS)
	25-26.5	SS	Wet	SLIGHTLY MUDDY SANDY GRAVEL; 70% M-VF Pebble (more M-F Pebbles than last sample); 25% Sand (mostly VC-M); 5% Mud. Gravels are subrounded except VF pebble; mixed lithologies including porphyry, diorites, granite & basalt. Took picture; moisture sample & 1 jar sample.	1326	Blow counts/6" = 12, 30 & 33. Drove sampler 18" but recovered only 0.8' of core.
	25-30'	A		Material coming up with flights is mostly F-M pebble.	1344	No response on HNU (10.2)
	30-31'	SS	Wet	SLIGHTLY MUDDY SANDY GRAVEL; 70% VF-M pebble (mostly F-VF; 25% Sand (mostly VC-M); 5% mud. Gravels are subround to subangular, mixed lithologies. Sand is angular to subangular & mostly lithic fragments. No sed. structures. Took picture; moisture sample from shoe, and 1 jar sample.	1420	Blows/6" = 45 & 96. Drove 1'. Got 0.5' of core.

REMARKS: SOME UNIDENTIFIED FLUID LEAKING ON GROUND 2' FROM WELL. 4 in dia. spot.

GV Last 8-5-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.124

DRILL LOG	By: GV Last Date: 8-5-88	Rig: ONWEGO Schramm T64	Well Number: LF4-PNL3 Depth: 31' To 41.5'	Computer Number	Project or Work Order No. 11832 Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	35-36.5	SS	(Saturated) Wet	SLIGHTLY MUDDY SANDY GRAVEL. Sample coarsens from silts at top to predominantly sand and then to clean Gravels at bottom. Top part Probably hydraulically sorted while driving sampler. Sample is 70% M-VF pebble (mostly M-F); 25% Sand (mostly Coarse), and 5% mud. Gravels are subrounded and mixed lithology. Sand is angular to subrounded and mostly lithic fragments. Some rounded quartz grains. Some M-C pebbles (0.15' DIA). Poorly sorted between 35-35.7'. Took picture; 2 jar samples. Top 0.1' of core discarded as not representative.	1455	Blows/6" = 25,18 & 28. Drove sampler 18". Recovered 1.1' of core. Hit water ~ 34'.
					1530	D/B = 40' BLS D/W = 34.5' BLS steel tape no. L30001.
	40-41.5'	SS	Wet	40-40.3' basaltic coarse sand. 40.3-40.6' upward fining coarse to fine brownish sand. sharp contacts with overlying coarse black sand, underlying gravels. 40.6-41.1' clean fine pebbles; mixed lithologies. well sorted. grades to poorly sorted slightly muddy sandy gravel (med. pebble). at 41.1-41.5'.	1540	Blows/6" = 4,13,27 Drove Sampler 18".

REMARKS:

E.125

E.126

DRILL LOG	By: GV Last	Rig: ONWEGO Schramm T64	Well Number: LF4-PNL3	Computer Number	Project or Work Order No.: 11832
	Date: 8-5-88		Depth: 41.5 To 46.5'		Subcontract No.

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	40-41.5'	(CONTINUED)		TOOK PICTURE; 2 jar samples, 1 of brown sand (40.3-40.6')		
				1 of clean f. pebble to slightly muddy sandy gravel (40.8-41.5')		
	45'	A			1640	D/B=45' BLS
						D/W=34.5' BLS
						STEEL TAPE No. L30001
	45-46.5'	SS	Wet	45-46' coarse to medium (brown) sand	1650	BLOWS/6" = 12/22/22/35
				46-46.5' sandy medium to Fine Gravel.		DROVE SAMPLER 24", BUT
				TOOK PICTURE, 2 jar samples; 1 of [C-M] sand. (45-45.5')		DRILLER SAYS TOP 6" IS SLUFF.
				1 of gravel (46-46.5').		Recovered 18" of core.
						Top 6" IS NOT REPRESENTATIVE

REMARKS:

GV Last 8-5-88

DRILL LOG	By: AIRHART	Rig: CNWEGO SCHRAMM T64	Well Number: LF4-PNL3	Computer Number: NA	Project or Work Order No.: 11832
	Date: 8-8-88		Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 34'8" below land surface (E-tape #	08:30	
				D/B = 44'7½" below land surface (steel tape #	08:40	
				Installed the following 2" dia. PVC casing &	09:10	
				screen:		
				+ 15'5" of slotted (20 slot) PVC screen		
				+ 3 - 10' sections of PVC casing - Centralizer	5' above screen	
				Total length (measured w/ steel tape		
				= 45'3" (including bottom cap).		
				Adding ~¼ 100 lb bag 10-20 mesh Col. silica		
				sand. D/sand = 40'6" below land.		
				Driller is pulling auger flights w/ straight		
				up w/out rotating in order to help		
				prevent PVC from pulling up w/ auger		
				flights. The depth to the construction		
				materials (sandpack bent., etc.) is being		
				checked continuously w/ steel tape in order		

REMARKS:

S R Airhart
8-8-88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small

E.127

DRILL LOG	By AIRHART	Rig ONWEGO SCHRAMM T64	Well Number LF4-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-8-88		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				to maintain an overlap between the		
				materials & the bottom of the auger		
				flights.		
				Added 1/4 bag 10-20 Col. Silica sand to 37' b.l.s.	09:40	
				Added 2½ bags 10-20 Col. silica sand to 26'2"	10:20	
				b.l.s. while pulling auger flights.		
				swabbed hole w/ ½-inch black pipe &	10:20 -	10:30
				1½-in. weight - swabbed for ~ 10 min.		
				D/sand = 26' b.l.s.	10:35	
				Added 1/4 bag 10-20 Col. Silica sand		
				Final D/sand = 25'5" b.l.s.	10:45	
				Added 1¾ 5 gal buckets of Enviroplug ¼"	11:05	
				pellets - Final D/pellets = 23'4" b.l.s.		
				Added 5½ 50 lb. bags of Medium Enviroplug	11:55	
				bentonite crumbles. Final D/crumbles = 3' b.l.s.		
				Top of hole caved. Dug down 2' for surface	12:00	
				seal.		

REMARKS:

SLP. Airhart
8-8-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Circulating Water

E.128

DRILL LOG

DRILL LOG	By: AIRHART Date: 8-8-88	Rig: ONWEGO SCHRAMM T64	Well Number: LF4-PNL3 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added a 30" extension on to PVC casing in order	13:00	
				to provide 30" stickup from land surface		
				Tried blowing water out of well w/ high pressure		
				air for development. Unsuccessful.		
				Tore down rig and moved off hole	1345	

REMARKS:

S. D. Airhart
8-8-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000.021 (5-85)

DRILL LOG	By: AIRHART Date: 8-9-88	Rig	Well Number: LF4- PNL3 Depth: COMPLETION TO	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed gravel from around well-site w/		
				Columbia Type I & II cement. Used		
				bags cement. Set 5' section		
				Set 5' section of 6" dia. carbon steel		
				casing.		
				Poured cement to fill remaining		
				annulus and 4'x4' pad.		

REMARKS:

StD Airhart
8-8-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.130

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LFH-PNL3	Computer Number NA	Project or Work Order No. 11832
	Date 8-24-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Khris Olson and Dave Dahl (PNL) took		
				water samples w/ teflon bailer for		
				chemical analysis. Dropped bailer in		
				well - need to fish out.		
				NOTE: Cubby (ONWEGO) bailed well w/		
				1½" dart bailer on 8-24. Geologist was		
				not present. Further development is necessary.		

REMARKS:

StRAirhart
8-24-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

page 1 of 1

(FORT LEWIS- LANDFILL 4)

DRILL LOG	By: AIRHART Date: 8-25-88	Rig: NO RIG	Well Number: LF4-PNL3 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Mixed 1/3 bag Portland cement w/ gravel		
				to set 4 protective posts around		
				surface pad.		

REMARKS:

S. D Airhart
8/25/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing W...

DRILL LOG	By: AIRHART Date: 9-8-87	Rig: NO RIG	Well Number: LF4-PNL3 Depth: FISHING To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Successfully fished out teflon bailer	0950	09:55
				which was dropped in well during last		
				sampling. Used a treble hook and lead		
				sinker. No bait was necessary.		

REMARKS:

St P. [signature]
9/8/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	NO RIG	LF4-PNL3	NA	11832
Date		Depth To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Painted posts during week of 10/17-10/21		

REMARKS:

St D Airhart
11/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

E.134

WELL LF4-PNL4

Battelle Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832
Location FORT LEWIS
Driller DARREL LUDTKE
Drilling Co. ONWEGO DRILLING CO., INC.
Geologist S.P. AIRHART

Well Number
Temporary Well Number LF4-PNL4
Coordinates
Casing Elevation
Ground Elevation

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D ______ H 0'-39'
Drilling Fluid
Other TOOK SPLIT-SPOON SAMPLES AT 5' INTERVALS

COMPLETION DATA

Drilled Depth 39'
Completion Depth 33.7'
Date Started 9-29-88 Completed 10-5-88
Static Water Level/Date 26.8' / 10-3-88

CASING DATA

Type	Size		
PVC (ASTM 1785)	4" DIA (SCH. 40)	to	23.2'
		to	
		to	

Approved By SPA Date 10-4-88

PERFORATIONS

Type NA

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 4" DIA. SLOTTED PVC
Length 10.5'
Slot Size 20'
Depths 23.2' - 33.7'
App. By SPA Date 10-4-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	18.7'-33.7'	6.96 ft^3
¼" PELLETS	33.7-39' / 14.2-18.7'	1.86 ft^3 / 1.86 ft^3
BENT. CHUNKS	1'-14.2'	5.68 ft^3
CONCRETE	0'-1'	~.66 ft^3

App. By SPA Date 10-5-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NAT. GAMMA	2.7' - 37.1'	10/4/88
	-	
	-	
	-	
	-	
	-	
	-	

Approved By SPA Date 10-4-88

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

9/29 Steam Cleaning
9/29 Storage of Const. Material
9/29 Tool Lubricants
10/24 Concrete Pad
10/24 Protective Steel Posts
10/24 Safety Paint
NA Straightness Test
10/6 Well Development
NA Downhole TV Inspection
NA Well Abandonment
10/24 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By SDA Date 10-24-88

Reviewed By D.L. McElhaney Date 11-8-88

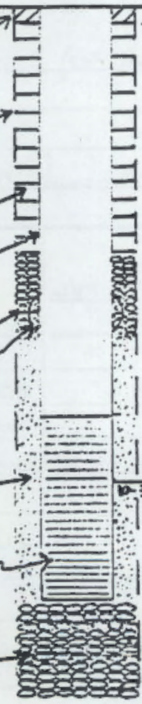
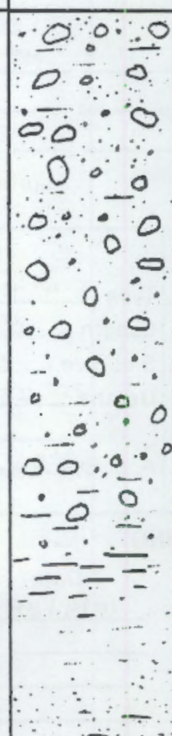
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

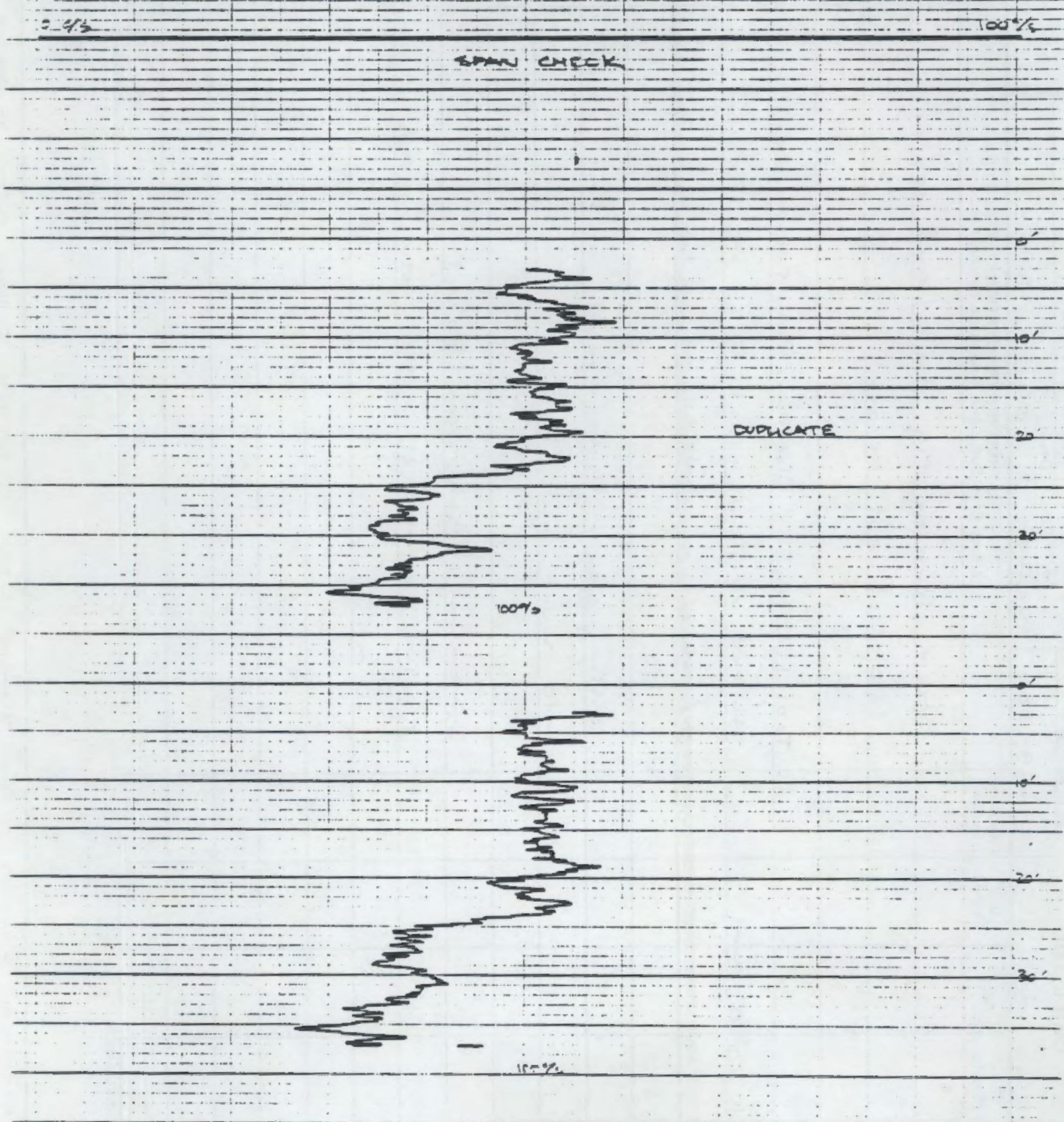
Well Number LF4-PNL4 Geologist S.P. AIRHART Page 1 of 1

Reviewed by [signature] Date 11-8-88

Construction Data		Depth in Feet	Geologic/Hydrologic Data	
Description	Diagram		Diagram Litho.	Lithologic Description
CONCRETE				
		5		MUDDY SANDY GRAVEL
8" DIA. CARBON STEEL				
CASING (REMOVED)		10		MUDDY SANDY GRAVEL
BENTONITE CHUNKS				
4" DIA. PVC CASING		15		MUDDY SANDY GRAVEL
1/4" BENTONITE PELLETS		20		MUDDY SANDY GRAVEL
CENTRALIZER				
		25		MUDDY SANDY GRAVEL
10-20 COL. SILICA SAND				
		30		MUDDY GRAVEL
4" DIA. SLOTTED PVC (20 SLOT)				
		35		CLAY / SILT (CONTACT AT ~30-31')
1/4" BENTONITE PELLETS				
		40		MUDDY SAND
DRILLED DEPTH = 39'				

A-1800-186 (3/87)

Well LFH-PNL4 Total Depth 39′ 27′-37.1′
Log Type NAT-GAMMA Date 10-4-88 8″ CARBON STEEL
Logged By S.P. AIRHART 24′
Sensitivity 100 c/s 3
Vertical Scale 10′/in. 15′/min
Source Strength NA NA
Remarks: REF. PROCEDURE GN-6 REV. 2
PROBE SERIAL # NGr001



DRILL LOG	By AIRHART Date 9-29-88	Darrel Ludtke Rig Bucyrus Erie 22W ONWEGO	Well Number LF4-PNL4 Depth 0' To 5'	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Steam cleaning rig, tools, and casing	0700-	0900
				(geologist not present)		
					0900	Moved to site
				Tool Lubricant = Chevron Poly FM grease	1000	set up rig
10'2½"	8" casing			started drilling - set 10'2" of 8" casing	1050	Began drilling
				w/ shoe - Added ~ 3 gals H_2O.		
				Drilling slow - large gravels - has added	12:30	
				~10 more gals H_2O.		
				Dimension of split-spoon barrel	13:00	Putting on split-spoon
				Total barrel length = 26" shoe = 5½"	13:20	Bailed hole
				I.D ~4".		Taking split spoon
						Blows/6" = 23, 28, 23
						Drove 18"
						Recovered 20"

REMARKS:

St. A. Airhart
9/29/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

E.138

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 9-29-88	ONWEGO	Depth 5' To 6.5'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	5-6.5'	SPLIT SPOON	W	MUDDY SANDY GRAVEL: 75% gravel, 15% sand,	1830	Took 2 photographs
				10% clay/silt : 5% VCP, 20% CP, 25% MP, 10% FP,		1: of split-spoon
				15% VFP, 2% VCS, 3% CS, 7% MS, 3% FS-VFS, 10%		1 of washed sample
				clay/silt (interstitial clay/silt between		
				clasts) : very poorly sorted ; (gravel)		
				SA-R clasts dominantly porphyritic ign.,		
				w/ some metam and meta-sedimentary		
				(sand) A-SA grains, wide mixture of		
				lithologies ; wet color: olive gray 5Y5/2;		
				No rxn. w/ 10% HCl ; unconsolidated: no		
				sed structure evident in split-spoon -		
				sediment becomes more sandy @ 6.5' (@ end	14:50	Checked hole
				of split-spoon)		(drilled ~ 8') w/
						10.7 & 11.3 HNU lamps
						Slight response (1-3 pts)
						on both lamps (more
						apparent on 11.3 however)
						Possibly exhaust from

REMARKS:

St P. Airhart
9/29/88

rig - will check again after more drilling

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

E.139

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 9-29-88	ONWEGO	Depth 6.5′ To 12.5′		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
10′2½″				6-10′ - cuttings more sandy - drilling		
				easier		
	10′-11.5′	SPLIT SPOON	M	MUDDY SANDY GRAVEL: 65% gravel 28% sand	15:50	Took split-spoon
				7% silt/clay: 5% VCP, 10% CP, 25% MP, 15% FP,		blows/6″ = 29, 35, 26
				10% VFP, 3% VCS, 5% CS, 15% MS, 5% FS-VFS, 7%		Drove 18″
				silt/clay: poorly sorted: (gravel) SA-R -		Recovered 19″
				dominantly ign. (porphyritic & aphanitic)	16:00	Checked hole w/ 11.3eV
				(sand) A-SA - wide variety rock frags:		HNU - slight response
				slightly browner than prev. sample -		probably from drill
				surface of clasts appears weathered		rig exhaust
				(rusty): No rxn. w/ 10% HCl; unconsolidated		
20′5″ of 8″ casing.					1700	Adding 10′2½″ of 8″ casing
						10′2½″ + 10′2½″ = 20′5″
					1730	resumed drilling
				Added ~ 30-50 gals H_2O today while	1855	Shut Down
				drilling		

REMARKS:

St P. Airhart
9/29/88

E.140

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A-6000-021 (5-86)

Darrel Ludtke

DRILL LOG	By: AIRHART	Rig: Bucyrus Erie 22W	Well Number: LF4 - PNL4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 9-30-88	ONWEGO	Depth: 12.5' To 16.5'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0700	resumed drilling
				Hard drilling. Drilling is driving pipe		
				then drilling out plug - only able		
				to drive casing ~ 2'.		
					1000	checked hole (@ 15')
						w/ 11.7 eV probe HNU
						Nothing Detected
					1005	Putting on split-spoon
	15-16.5	W	SPLIT SPOON	MUDDY SANDY GRAVEL: 78% gravel, 14% sand,	1010	Taking split-spoon
				8% silt/clay: 8% VCP (largest ~60 mm), 10% CP,		blows/6" = 18, 35, 43
				25% MP, 20% FP, 15% VFP, 2% VCS, 3% CS, 6% MS,		Drove 18"
				3% FS-VFS, 8% silt/clay: poorly sorted: (gravel)		Recovered 18"
				A-SR clasts, dominantly aphanetic & porphyritic		
				ign. (incl. basalt), some meta & meta-sedim		Took 2 photographs
				(sand) A-SA grains - mixed composition;		- 1 of split-spoon
				wet color olive 5Y5/3: No rxn w/ 10% HCl;		& 1 of washed
				unconsolidated		sample

REMARKS:

StP. [signature]
9/30/88

E.141

D - Drive Barrel H - Hand Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 9/30/88	ANWTCO	Depth 16.5' To 26.5'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	20-21.5	SPLIT SPOON	W	MUDDY SANDY GRAVEL: 70% gravel 20% sand 10% silt/	1300	Took split spoon
				clay: 5% SC (~100 mm largest) 3% VCP, 20% CP,		blows/6" - 25, 32, 52
				15% MP, 15% FP, 12% VFP, 7% VCS, 3% CS, 8% MS,		drove 18"
				2% FS-VFS, 10% silt/clay: poorly sorted:		recovered 18"
				(gravel) clasts A-R - mostly SR - composed		Took 2 photos
				of basalt, quartzite, porphyritic ign		1 of split-spoon
				(sand) A-SA - mixture of rock frags -		1 of washed sample
				domnantly mafic (no change from prev.		
				sample except for larger gravels) -		
				wet color: olive 5Y 5/3 ; No rxn w/ 10%		
28'6"	of 8" casing			HCl ; unconsolidated	14:00	Added 8'1" of 8" casing
						20'5" + 8'1" = 28'6"
				Driller thinks we've hit water	14:20	Resumed drilling
	25-26.5	SPLIT-SPOON		MUDDY SANDY GRAVEL: Finer grained,	16:55	Taking split-spoon
				better sorted than prev. sample. 70% gravel		Blows/6" 45, 31, 53
				20% sand 10% silt/clay: 15% CP, 30% MP, 15% FP,		Drove 18"
				10% VFP, 3% VCS, 1% CS, 5% MS, 11% FS-VFS, 10% silt/clay:		Recovered 18"
				poor-mod sorted. (gravel) A-R - mostly SR	17:00	Checked hole w/

REMARKS:

St P. [signature]
9/30/88

11.3 lamp HNU
nothing detected

O - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

E.142

DRILL LOG	By AIRHART Date 9/30/88	Rig B.E. 22W ONWEGO	Well Number LF4-PNL4 Depth 26.5' To 28'	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				clasts are dominantly igneous & metam. -		Took 2 photos
				more quartz than prev. (sand) finer		1 of split-spoon
				than previous A-SR, 60% si-vicl 40% mafic		1 of washed sample
				: wet color 5Y5/3 olive : NO rxn. w/ 10%		
				HCl ; unconsolidated		
				Checked D/W @ 24'8" below land - do	1730	
				not think this represents true static		
					1740	Resumed drilling
					1820	Quit Drilling
						Bailed
				Checked D/W @ 25'0" below land - will		
				check on Monday to see if this is		
				true static - I don't believe it is		
					19:00	Shut Down
				Added ~ 60-70 gals H_2O to hole today		

REMARKS:

St A Airhart
9/30/88

E.143

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine __ Standing Water A-6000-021 (5-85)

DRILL LOG	By AIRHART	Rig Darryl Ludtke Bucyrus Erie 22W ONWEAD	Well Number LF4-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 10-3-88		Depth 28' To 31.5'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0700	Drillers arrived
				Checked D/W @ 27'2" below top of casing	0750	
				which is same as Friday p.m. ∴ this		
				probably is not true static		
					0930	Adding 9'8½" of 8" casing
38'2½" of 8" casing						28'6" + 9'8½" = 38'2½"
					0950	Driving casing
					1000	Resumed drilling
						Added ~5 gals H2O
				Easy drilling (~6") @ 28' - probably sand lense		
				Hit water - checked D/W @ 26'9½" below land	1100	
				Will drill to 37' below land.		
	30-31.5	SPLIT-SPOON	W	MUDDY GRAVEL: 60% gravel; 10% sand, 30% clay/silt:	11:20	Taking split-spoon
				Dominantly MP-CP - SA-R - formation is		Blows/6": 29, 59, 74
				tightly compacted w/ brown (olive brown 2.5Y 4/4) clay/silt - thin		Drove 18"
				layer (~3") of bluish clay/silt @ ~30.5' -		Recovered 18"
				Looks like an effective aquitard.		Took 3 photo
						1 of split-spoon

REMARKS:

StP Airhart
10/3/88

1 of clay/silt
1 of washed sample

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.145

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	B.L. 22W	LF4-PNL4	NA	11832
Date		**Depth**		**Subcontract No.**
10-3-88	ONWFRO	31.5' To 33'		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Drilled to 32' w/ 2" of open hole.		
				Water is shut off. Concerned whether		
				the clay/silt (described in prev. sample)		
				is an aquitard - if so - do not want		
				to continue drilling and risk		
				intercommunication between seperate		
				aquifers. Instructed drillers to take		
				split spoon	13:30	Taking split-spoon
						160 blows / 8"
						very tight!
				Appearance of split-spoon 32-33' split-spoon		
				sample same as 30' sample. Matrix		
				supported gravels. matrix is primarily silt		
				w/ some clay (brown).		
				Checked D/W @ 26'8½" below ∴ static	13:50	
				returned. Instructed drillers to continue		
				drilling.		
				Changed over to larger bit	14:00	

REMARKS:

S.A. Airhart
10-3-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By AIRHART	Rig B.F.77W	Well Number LF4-PAIL1	Computer Number	Project or Work Order No. 11852
	Date 10-3-88	ONWEGO	Depth 33' To 35'	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					1405	Resumed drilling
				Not drilling ahead of pipe very easily	1430	
				∴ driller decided to drive casing		
				ahead which is what he's been		
				doing -		
				while driving casing - noticeable change		
				@ ~34' ∴ driller believes we are		
				out of formation @ 34'.		
					14:36	Resumed drilling
				Drilling rate faster		
				Pulled bit out of hole. dark blue/gray	15:05	Stopped drilling
				clay on bit! Bailed thick blue/gray		
				mud. Checked hole w/ 11.7 probe of		
				HNU - no reading -		
					15:15	Putting on split-spoon
					15:30	Taking split-spoon
						Blows/6": 12,18,21

REMARKS:

S.P. [signature]
10/3/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine

E.146

E.147

DRILL LOG	By: AIRHART	Rig: [illegible]	Well Number: [illegible]	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-3-88		Depth: 35' To 39'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	35-36.5'	SPLIT SPOON	W	BLUE/GREY CLAY/SILT - 100% CLAY/SILT	15:35	Drove 18"
						Recovered 12"
				checked D/W @ 37'4" below ground -	15:45	
				water is probably shut off since		
				drive-shoe is in clay		
				will continue drilling to further characterize	1600	Resumed drilling
				clay layer		
				Stopped drilling @ 40' - Drilling fast	16:20	Quit drilling
				still appears to be in clay - checked		
				D/W - noticed that water was still		
				coming in hole - probably around		
				bottom of shoe which is @ 34'10" - Bailed		
				~ 4 times w/ 4" dia. flat-bottom bailer -		
				noticed that fine-to-med. black sand		
				was coming in - again probably around shoe -		
				-Driving casing to shut off water - Drove	17:00	
				casing to 36'2½" below land -		
				Redrilling to 40'	17:05	

REMARKS:

St P. [illegible]
10/3/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine [illegible]

E.148

DRILL LOG	By: AIRHART	Rig: Bucyrus Erie 22W	Well Number: LF4-PNL4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-3-88	ONWEGO	Depth: 39' To 39'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					1730	Bailed 2 or 3 times
				checked D/B @ 39'3" below land	1740	
				D/W = 37' below land		
					1750	Taking split-spoon
						blows/6" = 23, 22, 29
	40-41'	SPLIT-SPOON	W	SAND: 100% VFS-FS : sand is very well sorted	1800	
				- composed of 60% qtz & qtz-rich 40% mafic grains		
				Sand is slightly coarser than previous		
				silt/clay sample - appears to be same		
				lithology (dark gray-to-black color) w/		
				coarsening w/ depth. Formation appears to		
				be water bearing.		

REMARKS:

St P Airhart
10/4/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

Gravel backfill

DRILL LOG	By AIRHART	Rig Bucyrus Erie 22W	Well Number LF4-PNL4	Computer Number	Project or Work Order No. 11857
	Date 10-4-88		Depth 39 To 39	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 26'4¾" below land surface (E-tape #1)	0810	
				Note: this is ~5" higher than yesterday's		
				measured static (26'9½") There are 3 possible		
				explanations for a difference in static.		
				1. Yesterday's measurement was taken too		
				close to drilling & the water table was		
				not fully recovered		
				2. We are in a confined zone which		
				is possible due to clay layer @ ~34'		
				3. Normal water table fluctuation account		
				for difference.		
				Drillers went to Aardvark corp. in Puyallup	0830 –	1145
				to pick up bentonite pellets & viton O-rings		
				Measured D/B inside borehole = 38.5' below land	1150	
				Geophysically logged hole w/ Nat. γ probe	13:20 –	13:50

REMARKS:

S4P [signature]
10/4/88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   Standing Water

E.149

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LF4-PNL4	Computer Number: N/A	Project or Work Order No.: 11832
	Date: 10-4-88	OWNED	Depth: 39 To 39		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/B = 38'5" below land	13:57	
				Pulled 8" casing to 34'7½" below land	14:22	
				D/B = 38'4" below land		
				Bailed hole to see if there is any black		
				sand in bottom of hole (if so the		
				sand is coming around the shoe from		
				above the clay) - no sand in bailer -		
				just a few clumps of clay ∴ black sand		
				as noted in 35-40' interval is from that		
				interval. D/B: 38'4" below land	14:30	
				Added 1 bucket of ¼" Enviroplug pellets to 37'2"	14:35	
				Added 1 bucket of ¼" Enviroplug pellets to 36'2"	14:40	
				Added 1 bucket of ¼" Baroid bentonite pellets to 33'8½"		
				Pulled 8" casing to 33'9" below land -	15:00	
				D/pellets = 33'8" below land	15:03	
				Added ¼ bag 10-20 Colorado silica sand to 32'10" below land	15:10	
				Pulled 8" casing to 33'2" below land		
				D/sand = 33'2" below land		

REMARKS:

3 buckets ¼" pellets
¼ bag 10-20 sand

SAP [signature]
10/4/88

E.150

page 3 of 4

DRILL LOG	By: AIRHART Date: 10-4-88	Rig: D.E. 22W ONWEGO	Well Number: LF4-PWL4 Depth: COMPLETION To	Computer Number: NA.	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added the following sections of 4" dia PVC	15:40	
				(sch. 40) casing and screen		
				10'6" of slotted PVC screen (20 slot)		
				20'3/4" of PVC casing w/ attachable centralizer		
				(R.G. Ray Corp Buffalo Grove Ill. # H-J2 2026-71)		
				located 5' above top of screen		
				5' of PVC casing		
				∴ Total 4" PVC = 35'6 3/4"		
				Added 1 100 lb. bag of 10-20 Col. silica sand to 29'	15:15	
				Pulled 8" casing to 29'11"		
				D/sand = 29'8" below land	16:10	
				Added 1 100 lb bag of 10-20 sand to 26'6"	16:13	
				Pulled 8" casing to 28'5½" below land		
				D/sand = 28'2" below land	16:20	
				Added 1½ bags of 10-20 sand to 20'8"		
				Pulled 8" casing to 25'3" below land	16:40	
				D/sand = 22' below land	16:50	

REMARKS:

3½ bags 10-20 sand

S P Airhart
10/4/88

D - Drive Barrel H - Hard Tool L - Large M - Medium ...

E.151

E.152

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LLA-PN-4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-4-88	ONWEGO	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 3/4 bag 10-20 sand to 21'	1700	
				Pulled 8" casing to 22.5' below land		
				D/sand = 21'3" below land	17:15	
				Pulled 8" casing to 22'2" below land	17:20	
				D/sand = 21'4" below land	17:22	
				Pulled 8" casing to 21'6" below land	17:25	
				D/sand = 21'6" below land	17:30	
				Added 3/4 bag 10-20 Col. silica sand to 19'	17:37	
				Pulled 8" casing to 20'3" below land		
				D/sand = 19.5' below land	17:44	
				Pulled 8" casing to 20' below land	18:20	
				D/sand = 20' below land	18:25	
				Added 1/4 bag 10-20 sand to 19.5'	18:50	
				Pulled 8" casing to 19'1" below land		
				D/sand = 19'9" below land		
				Added 1/4 bag 10-20 sand to 18'9" below land	1854	
					1855	Shut Down

REMARKS:

2 bags 10-20 sand

S.A. D. [illegible]
10/4/88

D - Drive Barrel H - Hard Tool L - Large M - M[illegible] ...

DRILL LOG	By: AIRHART Date: 10-5-88	Rig: B-F 22W Oswego	Well Number: LF4-PWL4 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 18'3" below land	0730	
				D/sand = 18'8¼" below land (final depth)	0750	
				Began bailing w/ 2" bailer to settle sand	0757 - 0810	
				sand did not settle.		
					0830	welding puller head
				Added ½ bucket of Baroid ¼" bentonite pellets	0845	
				D/pellets = 17'6" below land		
					0847	[illegible] pellets
				Pulled 8" casing to 17'6" below land		
				D/pellets = 17'9" below land		
				Added ½ bucket Baroid ¼" pellets		
				Added ½ bucket Baroid ⅜" pellets		
				D/pellets = 16'2"		
				Pulled 8" casing to 16'6" below land	0900	
				D/pellets = 16'5' below land		
				Added ½ bucket Baroid ⅜" pellets to 15'4"		
				Added 1 bucket Baroid ¼" pellets to 13'1"	0905	
				Pulled 8" casing to 14'2" below land	0910	

REMARKS:

3 buckets ¼" pellets

[signature]
10/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ...

DRILL LOG	By: AIRHART	Rig: B.F. 22W	Well Number: LF4-PNE4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-5-88	ONWEGO	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/pellets = 14'2" below land (final depth)	0911	
				Added 3 50 lb. bags of Enviroplug Med. bentonite		
				D/bentonite = 6'3" below land	0920	
				Pulled 3" casing to 12'3" below land	0922	
				Added 1 50 lb bag Enviroplug bent to 4'1"	0925	
				Pulled 8" casing to 7'4½" below land	0930	
				D/bentonites = 7' below land	0939	
				Added 3 50 lb bags Enviroplug bent to +2.5 above ground	0940	
				Pulled 8" casing to 3'5½"		
				D/bent = 2' below land	1015	
				Added 1 50 lb. bag Enviroplug bent to +1'8" above ground	1020	
				Pulled remaining 8" casing out of hole	1040	
				D/bent = 0' - ground surface	1041	
				Dug out 1' of bent. ∴ D/bent = 1' below land (final depth)	1046	
				Top of PVC = 27½" above land		
				Set 6" protective casing - Top @ 38½" above land	1100	
				Tore down rig - moved to steam clean	1200	

REMARKS:

St P. Airhart
10/5/88

E.154

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-PNL4	Computer Number NA	Project or Work Order No. 11832
	Date 10-6-88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Set 1/3 h.p. 4" dia. submersible pump		
					0712	Pump on
				After pumping 8 min. D/W = 26'6½" below	0720	
				land. Pump rate = 12.5 gpm		
				After pumping 18 min D/W = 26'6½" below	0730	Water clean
				land (no change) Pump rate = 12.5 gpm.		
				After pumping 30 min D/W = 26'6½" below	0742	Water clean
				land (no change) -	0742	Pump off
				Allowed to recover 20 min. D/W = 26'5½"	0802	
				below land		
				Pumped 375 gallons H_2O		

REMARKS:

St. A. [illegible]
10/6/88

O - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A-6000-021 (5-85)

E.155

E.156

DRILL LOG	By: AIRHART Date: 11-4-88	Rig: NO RIG	Well Number: LFH-PNL4 Depth: COMPLETION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Concrete surface seal, concrete pad, 4 protective posts, brass marker, painting - all performed by onwego drilling during week of 10/17 - 10/21		

REMARKS:

StD Airhart
11-4-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

WELL LF4-PNL5

Battelle Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832	Well Number
Location FORT LEWIS	Temporary Well Number LF4-PNL5
Driller DARREL LUDTKE	Coordinates
Drilling Co. ONWEGO DRILLING. CO., INC.	Casing Elevation
Geologist S.P. AIRHART	Ground Elevation

DRILLING METHOD	COMPLETION DATA
Rotary Air ______ Mud ______	Drilled Depth 36'
Cable Tool D 0'-35' H 35'-36'	Completion Depth 35.7'
Drilling Fluid	Date Started 10-5-88 Completed 10-14-88
Other	Static Water Level/Date 26.4' / 10-6-88

CASING DATA

Type	Size	to
PVC (ASTM 1785)	4" DIA.	to 20.2'
		to
		to

Approved By SP Airhart Date 10-6-88

PERFORATIONS	SCREEN	ANNULAR SEAL
Type NA	Type 4" DIA. SLOTTED PVC	Type / Interval / Volume
Depth / Schedule	Length 15.5'	10-20 SAND / 16.1-35.7' / 6.96 ft^3
	Slot Size 20	1/4" BENT. PELLETS / 11.4-16.1' / 1.86 ft^3
	Depths 20.2' - 35.7'	BENT. CHUNKS / 1'-11.4' / 5.65 ft^3
		CONCRETE / 0'-1' / ~.66 ft^3
App. By ______ Date ______	App. By SPAirhart Date 10-6-88	App. By SPAirhart Date 10-7-88

GEOPHYSICAL LOGGING			AQUIFER TESTING
Sondes	Interval	Date	Type of Test NA
NAT. GAMMA	1' - 33.6'	10-6-88	Length of Test
			Volume Pumped
			Drawdown
Approved By SPAirhart		Date 10-6-88	Approved By ______ Date ______

OTHER APPLICABLE ITEMS

10/5 Steam Cleaning	10/21 Protective Steel Posts	NA Downhole TV Inspection
10/5 Storage of Const. Material	10/21 Safety Paint	NA Well Abandonment
10/5 Tool Lubricants	NA Straightness Test	10/21 Complete As-Built Diagram, Driller's and Geologist's Logs
10/21 Concrete Pad	10/14 Well Development	

Approved By SPAirhart Date 10-21-88

Reviewed By D.C. McShane Date 11-8-88

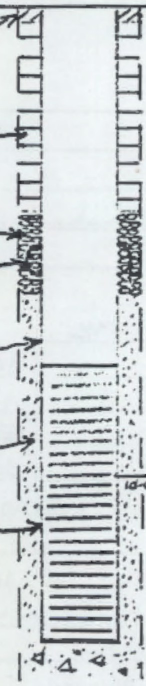
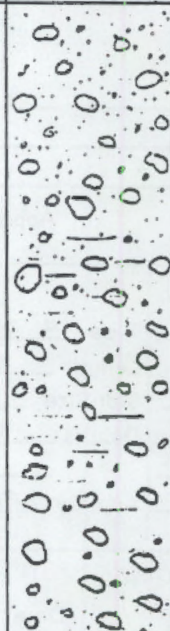
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LF4-PNLS Geologist S.P AIRHART Page 1 of 1

Reviewed by V.L. McGhan Date 11-8-88

Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Lithologic Description
				
CONCRETE				
		5		SANDY GRAVEL
BENTONITE CHUNKS				
		10		SANDY GRAVEL
BENTONITE PELLETS				
CENTRALIZER		15		MUDDY SANDY GRAVEL
4'DIA. PVC CASING		20		SANDY GRAVEL
10-20 COL. SILICA SAND		25		MUDDY SANDY GRAVEL
4" DIA SLOTTED PVC (20 SLOT)		30		MUDDY GRAVEL
		35		MUDDY SANDY GRAVEL
DRILLED DEPTH = 36'				
		40		

A-1800-186 (3/87)

Well: LF4-PNL5 — Drilled Depth: 36' — Interval Logged: 1'-33.6'

Log Type: NAT. GAMMA — Date: 10-6-89 — Casing Size: 6" CARBON STEEL

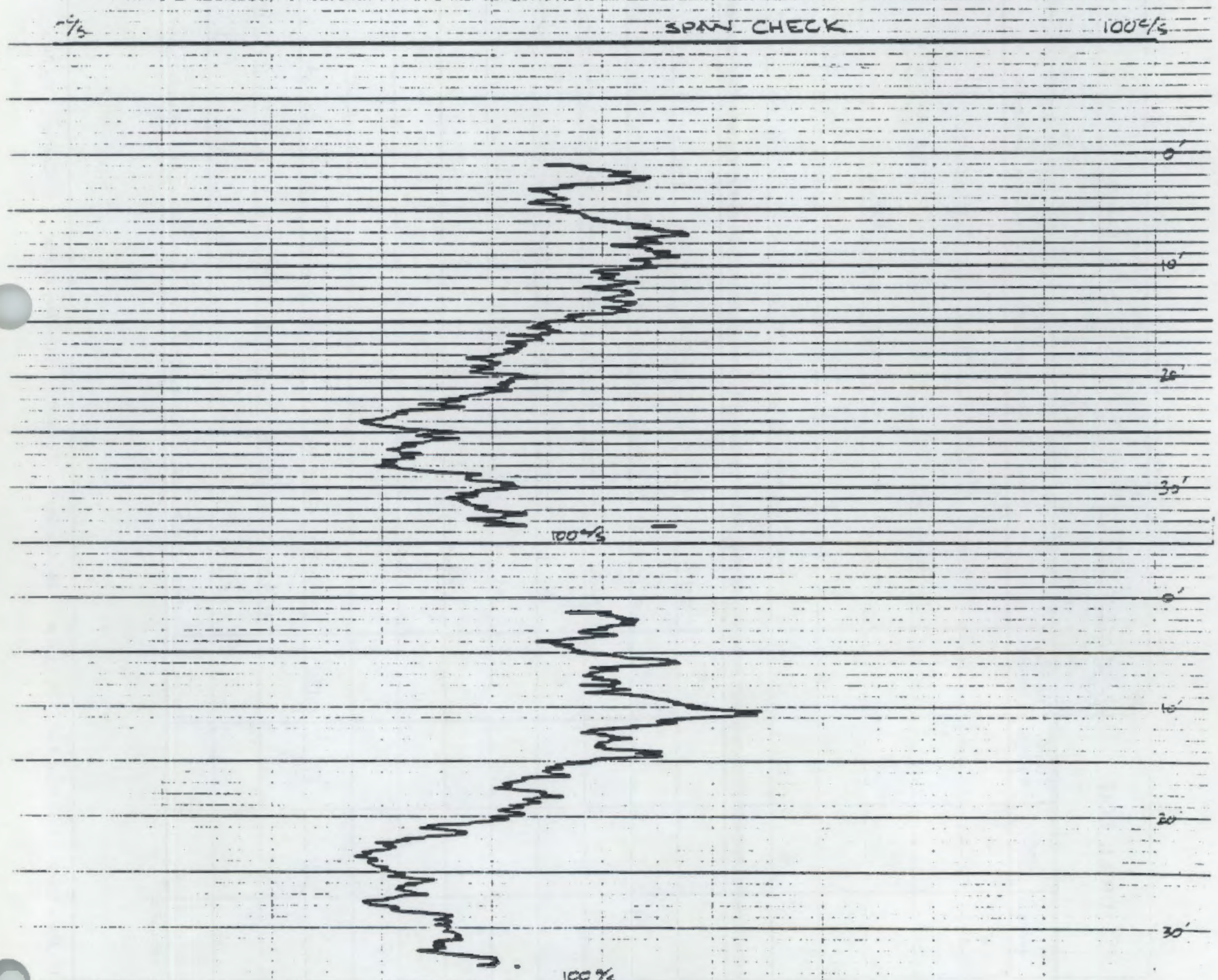
Logged By: S.P. AIRHART — Water Level Depth: 26.4'

Logging Scales: Sensitivity: 100 c/s — Time Constant: 3

Vertical Scale: 10'/in. — Logging Speed: 15'/min.

Source Strength: NA. — Spacer Length: NA.

Remarks: REF. PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



DRILL LOG	By AIRHART	Rig Becker Drill [illegible]	Well Number LF4-PNLS	Computer Number NA	Project or Work Order No. 11852
	Date 10-5-88		Depth 0' To 10'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				steam cleaned rig & equipment	12:00-	12:45
				Setting up rig - used Chevron Poly FM	12:45-	14:00
				grease for making up tools		
				Started Drilling w/ 7¼" Drive barrel	14:00	
	5'	D	D	SANDY GRAVEL: 70% gravel, 27% sand, 3% silt:	14:10	Took Moisture sample
				2% SC (largest 110 mm) 5% VCP, 8% CP, 20% MP,		
				35% FP-VFP, 2% VCS, 5% CS, 10% MS, 10% FS-VFS,		
				3% silt: poorly sorted: clasts are SR-R,		
				composition dom. ign. : sand grains		
				A-SA ~50% qtz-rich 50% mafic : dry color		
				olive brown 2.5Y 4/4 : NO rxn w/ 10% HCl ;		
				unconsolidated.		
9'3" of 8"					14:45	Added 9'3" of 8" casing
						w/ shoe.
	10'	D	D	SANDY GRAVEL: 60% gravel, 37% sand, 3% silt:	15:50	Moisture sample
				10% VCP, 15% CP, 15% MP, 13% FP, 7% VFP, 3% VCS, 2% CS,		taken
				20% MS, 12% FS-VFS, 3% silt poorly sorted: clasts		
				are SA-SR, dom ign, sand grains		

REMARKS:

[signature]
10/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

E.160

ORILL LOG	By: AIRHART Date: 10-5-88	Rig: B.E.-22W GNWFLU	Well Number: LF4-PNLS Depth: 10' To 15'	Computer Number: NA	Project or Work Order No.: 11852 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				(10' cont.)		
				... A-SA - 50% qtz-rich 50% mafic : color (dry)		
				olive brown 2.5Y 4/4 ; no rxn w/ 10% HCl ;		
				unconsolidated - gravels slightly smaller		
				& more sand than prev. sample.		
15'6" of	8" casing				16:20	Adding 6'3" of 8" casing
						9'3" + 6'3" = 15'6"
				Formation becomes moister @ ~ 13' - also		
				muddier (more silt/clay)		
	15'	D	M	MUDDY SANDY GRAVEL: 60% gravel, 30% sand,	17:30	Moisture sample
				10% silt/clay : 1% SC (~70 mm) 5% VCP, 10% CP,		taken
				15% MP, 10% FP, 19% VFP, 2% VCS, 15% CS, 10% MS,		
				3% FS-VFS, 10% silt/clay : poorly sorted. clasts		
				SA-SR - surfaces coated w/ moist silt : comp.		
				primarily igneous - noted rotten granite - sand		
				A-SA grains ~60% qtz-rich 40% mafic - grains		
				sticking together w/ moist silt : moist color		
				olive brown 2.5Y 4/4 : unconsolidated - able to		
				drill ~ 1' out of pipe.		

REMARKS:

St P. [signature]
10/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.161

DRILL LOG	By: AIRHART	Rig: BE.22W	Well Number: LF4-PMLS	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-5-88	ONUST G.D	Depth: 15' To 20'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
20'6" of 8" casing					1800	Adding 5' of 8" casing 15'6" + 5' = 20'6"
				Formation becoming sandier (less gravel) @ ~ 18' below land.		
	20	D	M	SANDY GRAVEL: 55% gravel, 42% sand, 3% silt: 2% VCP, 3% CP, 15% MP, 15% FP, 20% VFP, 2% VCS, 3% CS, 30% MS, 7% FS-VFS, 3% silt: mod-to-poorly sorted; (GRAVEL) A-SR clasts mostly porphyritic igneous (sand) SA-SR grains 65% qtz. & qtz.-vick 35% mafic: moist color olive (5Y5/4): NO rxn. w/ 10% HCl; unconsolidated - driller able to get ~ 2-5 ft. open hole.	1900	Moisture sample
					1910	Shut Down

REMARKS:

St. A. [illegible] 10/5/88

E.162

PARCEL LUSTRE

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNLS	Computer Number	Project or Work Order No. 11852
	Date 10-6-88	ONWFHO	Depth 20' To 25'	NA	Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0815	Drilling
25' of	8"				0830	Added 4'6" of 8" casing
						20'6" + 4'6" = 25'
					0900	Drilling
				Formation not staying in drive barrel ∴		
				must add casing before taking 25' sample		
29'2"	of 8"				1000	Adding 4'2" of 8" casing
						25' + 4'2" = 29'2"
				Checked hole w/ 11.7 eV probe (HNU meter)		
				no response		
				sediment is not staying in drive-barrel -	1100	
				appears to be saturated @ ~25'.		
				Building-up inside of drive barrel.		
	25'	D	VM	MUDDY SANDY GRAVEL: 30% gravel, 65% sand,	11:35	Moisture sample
				5% silt: 2% VCP, 5% CP, 3% MP, 10% FP, 10% VFP,		taken
				10% MS, 40% FS, 15% VFS, 5% silt: mod. sorted:		
				(gravel) A-SR no Δ composition		
	–			(sand) SA-SR - 90% qtz-rich 10% mafic.		

REMARKS:

St P Airhart
10/6/88

E.163

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

26'3½"

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL5	Computer Number NA	Project or Work Order No. 11832
	Date 10-6-88	ONWEGO	Depth 25' To 30'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				(25' cont.) moist color olive 5Y 4/3; unconsolidated		
				note: less gravel than previous		
				sample - finer sand, Δ composition of		
				sand.		
	30'	D	M	MUDDY GRAVEL: 40% gravel, 25% sand,	11:50	moisture sample
				35% silt/clay: 5% VCP, 10% CP, 15% MP, 10% FP-VFP		taken
				5% MS, 10% FS, 10% VFS, 35% silt/clay; poorly sorted		
				(gravel) A-SR - same composition		
				(sand) SA-SR - dom qtz-rich ≥80%, moist		
				color: olive 5Y 5/3 - unconsolidated - note:		
34'11" of 8" casing				much finer than prev. sample.	12:00	Added 5'9" of 8" casing
					12:30	water came in
						casing @ ~32'
				Measured D/W: 26'3½" below land (E-tape)	12:45	

REMARKS:

St P Airhart
10/6/88

E.164

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VF - Very Fine

DRILL LOG	By AIRHART	Rig B.E. 22W OWWEGO	Well Number LF4-PNL5	Computer Number NA	Project or Work Order No. 11832
	Date 10-6-88		Depth 30' To 36'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	35'	D	W	MUDDY SANDY GRAVEL: 70% gravel, 27% sand	13:05	
				3% silt: 2% VCP, 15% CP, 20% MP, 15% FP, 18% VFP,		
				15% VCS, 8% CS, 3% MS, 1% FS-VFS, 3% silt:		
				poorly sorted: (GRAVEL) SA-SR clasts composed		
				primarily of porphyritic ign. & metam. rxs.		
				(sand) A-SA grains composed of 50% qtz-rich		
				50% mafic & other rock frags: wet color:		
				light olive brown 2.5Y 5/4: unconsolidated		
				NOTE: Formation coarsens considerably.		
				Measured D/W @ 26'5" below land (E-tape)	13:30	
39'10" of 8"					14:30	Added 4'11" of 8" casing
						34'11" + 4'11" = 39'10"
				Driller must change over to hard tool -		
				suction from drive barrel keeps sucking		
				sand up inside casing		
				Stopped drilling - check D/B @ 35'11" below land	1549	

REMARKS:

[illegible]
10/6/88

E.165

sand 16' pellets 11-12'

DRILL LOG	By AIRHART	Rig B.E. 22W ONWFGO	Well Number LF4-PNL5	Computer Number NA	Project or Work Order No. 11832
	Date 10-6-88		Depth 36' To 36'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Geophysically logged hole w/ Nat. 8 (1'-33.6')	16:00-	16:30
				Added the following section of 4" dia.	16:50	
				sch. 40 PVC casing & screen.		
			5.52	5'1/4" +6" slotted PVC screen (20-slot) w/ 6" bottom cap		
			10.00 20.03	10'0" slotted PVC screen (20-slot)		
			4.99 40.54	20'3/8" casing w/ attachable centralizer attached		
				5' above screen.		
				4'11 7/8" casing (Put 2.5' of casing back on)		
				Total PVC casing & screen = 40'6 3/8" = 40.54'		
				Removed 4'11 7/8" section temporarily during completion = 35.55 + 2.5' = 38.05' PVC		
				∴ Top of screen @ 19.95' below land		
				Bottom of PVC @ 35.47' below land		
				Added 2 100 lb bags 10-20 Col. silica sand		
				D/sand = 26'10 1/2" below land	17:45	
					17:50	Began pulling 8" casing

REMARKS:

2 bags sand

[signature]

10-6-88

E.166

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF4-PNL5	Computer Number NA	Project or Work Order No. 11832
	Date 10-6-88	OSWEGO	Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 32'4" below land	18:00	
				D/sand = 29'5" below land	18:00	
				Pulled 8" casing to 30'10" below land		
				D/sand = 29'3" below land		
				Added 2 bags 10-20 sand to 21'6" below land	18:15	
				Pulled 8" casing to 26' below land	18:25	
				D/sand = 24.5' below land	18:30	
Added	2 100 10-20	lb bags sand to	of 16'	→ Pulled 8" casing to 22'1" below land	18:53	
				D/sand = 19' below land	18:59	
				Added 1 bag 10-20 sand to 14'7" below land	19:00	
					19:10	Shut Down

REMARKS:

4 bags sand

S. P. Airhart
10/6/88

E.167

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse ...

DARREL LUDTKE

DRILL LOG

By	Rig	Well Number	Computer Number	Project or Work Order No.
AIRHART	B.E. 22W	LF4-PWL5	NA	11632
Date		**Depth**		**Subcontract No.**
10-7-88	ONWEGO	completion To		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added ½ bag 10-20 silica sand while pulling casing	0830	Pulling casing
				Pulled 8" casing to 16'1" below land	0910	
				D/sand = 14'1" below land (final sand depth)		Used 7½ 100 lb bags
						of Col. silica sand
				Added 2 5 gal. buckets of Baroid ¼" bentonite	0921	
				pellets to 11'4" below land		
				Added 1 more bucket of Baroid ¼ pellets		
				while pulling		
				Pulled 8" casing to 11'8" below land	0944	
				D/pellets = 11'5" below land (final pellet depth)	0950	Used 3 5 gal buckets
				Added 2 50 lb. bags of Enviroplug Med bentonite	0951	of Baroid ¼" bentonite
				chunks to 5'9" below land		pellets
				Pulled 8" casing to 8'2" below land	1006	
				D/chunks = 7'3" below land		
				Added 1 50 lb. bag Enviroplug Med bent. to 4'	1008	
				Pulled 8" casing to 6' below land	1011	
				D/chunks = 5'[illegible] below land	1015	
				Added 2 bags Enviroplug Med bent to .5' below land	1025	

REMARKS:
5 bags Bent. chips
½ bag sand
3 buckets pellets

[illegible signature]
10/7/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine _ Standing Water

E.168

DRILL LOG	By: AIRHART	Rig: IEC 7200 / Air Wel No	Well Number: LF4 · PWL5	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-7-88		Depth: Completion To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 1 bag Enviroplug bentonite while pulling	11:00	
				Pulled remaining 8' casing out of hole	11:05	
				D/chunks = 25' below land (no cave) big		
				void @ top.		
				Added 2 bags Enviroplug bentonite to 1' below land		Used 8 50 lb bags
				Final D/bentonite chunks = 1' below land		of Enviroplug Med
				Placed 6" carbon steel protective casing to	11:10	bentonite
				42" above land		
				Bailed w/ 2½" O.D. Dart bailer - water	11:15-	12:00
				very turbid - not bailing down however.		
				Took VOA samples	12:00	
					12:05	Shut Down
				Will development well next week using		
				submersible pump.		

REMARKS:

3 bags Bent. chips

S.P. Airhart
10/7/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

DRILL LOG	By AIRHART	Rig Bucyrus Erie 22-W	Well Number LF4-PNL5	Computer Number NA	Project or Work Order No. 11832
	Date 10-11-88	ONWEGO	Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Tore down rig - moved off hole		

REMARKS:

StP Airhart
10/11/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse

E.170

DRILL LOG	By: AIRHART Date: 10-14-88	Rig: No RIG	Well Number: LF4-PNL5 Depth: DEVELOPMENT To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Static D/W = 29'1" below top of 6" casing	14:20	
				which is 42" above land (E-tape)		
				Set 1/3 h.p. submersible pump	14:22	
				Measured static - no displacement	14:23	
					14:24	Pump on
				D/W = 29'6½" below top of 6" casing (1 min)	14:25	
				D/W = 29'6½" " " " " " (3 min 30 sec)	14:28:30	
				Initially water was orange-brown color -		
				very turbid - Noticeable clean-up @ 5 min.		
				Discharge rate = 10-11 gpm	14:31	
				D/W = 29'6¾" " " " " " (8 min)	14:32	
				Surged well by moving pump up and down	14:33	
				by hand - water orange-brown color and		
				turbid again		
				Surged well again @ 14:40, 14:47, 14:53, 14:57,		
				15:05,		
				D/W = 29'7¼" below top of 6" casing (46 min)	15:10	

REMARKS:

St P. Airhart
10/14/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.171

DRILL LOG	By: AIRHART	Rig: ONWEGO DRILLING	Well Number: LF4-PNL5	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-14-88		Depth: DEVELOPMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Filled 5 gal. bucket w/ water - clear - can	1553	
				see bottom of bucket clearly through		
				water		
				D/W = 29'7 3/4" below top of 6" casing (92 min)	1554	
				Pump off	1558	
				Total pumping time = 94 min @ 10-11 gpm		
				∴ 940 - 1054 gallons of water pumped		

REMARKS:

St P. [signature]
10/14/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.172

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4 - PNLS	Computer Number NA	Project or Work Order No. 11832
	Date		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				concrete surface seal, concrete surface		
				pad, brass marker, protective posts,		
				and painting was performed by onwego		
				drilling during the week of 10/17-10/21		

REMARKS:

[signature]
11-4-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

E.173

WELL LF4-PNL6

Battelle
Pacific Northwest Laboratories

Well Completion Report/Title III Inspection List

Project 11832
Location FORT LEWIS
Driller DARREL LUDTKE
Drilling Co. ONWEGO DRILLING CO., INC.
Geologist S.P. AIRHART

Well Number
Temporary Well Number LF4-DNL6
Coordinates
Casing Elevation
Ground Elevation

DRILLING METHOD

Rotary Air ______ Mud ______
Cable Tool D 0'-20' H 20'-30'
Drilling Fluid
Other

COMPLETION DATA

Drilled Depth 32'
Completion Depth 30.1'
Date Started 10-11-88 Completed 10-21-88
Static Water Level/Date 20.0' / 10-12-88

CASING DATA

Type	Size		
PVC (ASTM 1785)	4" DIA.	0' to	14.5'
		to	
		to	

Approved By SD Airhart Date 10-12-88

PERFORATIONS

Type NA

Depth	Schedule
-	
-	
-	

App. By ______ Date ______

SCREEN

Type 4" DIA. SLOTTED PVC
Length 15.6'
Slot Size 20
Depths 14.5' - 30.1'
App. By SD Airhart Date 10-12-88

ANNULAR SEAL

Type	Interval	Volume
10-20 SAND	11.6'-30'	8.56 ft^3
1/4" PELLETS	6.8'-11.6'	1.86 ft^3
BENT. CHUNKS	1.3'-6.8'	2.84 ft^3
CEMENT	0'-1.3'	~1 ft^3

App. By SPA Airhart Date 10-24-88

GEOPHYSICAL LOGGING

Sondes	Interval	Date
NAT. GAMMA	2' - 28'	10-12-88
	-	
	-	
	-	
	-	
	-	
	-	

Approved By SP Airhart Date 10-12-88

AQUIFER TESTING

Type of Test NA
Length of Test
Volume Pumped
Drawdown

Approved By ______ Date ______

OTHER APPLICABLE ITEMS

10/11 Steam Cleaning
10/11 Storage of Const. Material
10/11 Tool Lubricants
10/24 Concrete Pad
10/24 Protective Steel Posts
10/21 Safety Paint
NA Straightness Test
10/14 Well Development
NA Downhole TV Inspection
NA Well Abandonment
10/24 Complete As-Built Diagram, Driller's and Geologist's Logs

Approved By S.D. Airhart Date 10-24-88

Reviewed By D.L. McGlam Date 11-8-88

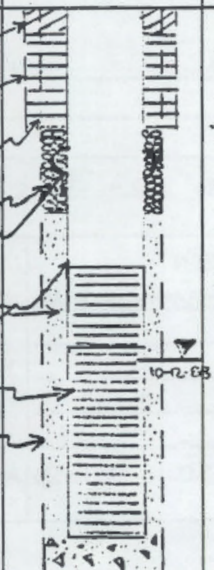
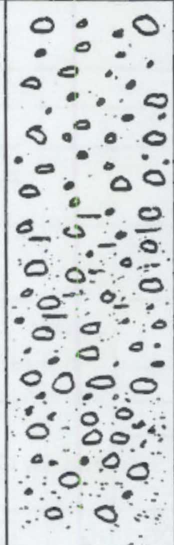
A-1800-187 (3/87)

Battelle
Pacific Northwest Laboratories

AS-BUILT DIAGRAM

Well Number LF4-PNL6 Geologist S.P. AIRHART Page 1 of 1

Reviewed by V. L. McGhan Date 11-8-88

Construction Data: Description	Construction Data: Diagram	Depth in Feet	Geologic/Hydrologic Data: Diagram Litho.	Geologic/Hydrologic Data: Lithologic Description
CONCRETE				
10" DIA. CARBON STEEL CASING (REMOVED)		5		GRAVEL (BACKFILL)
BENTONITE CHUNKS		10		GRAVEL
1/4" BENTONITE PELLETS				
CENTRALIZER		15		MUDDY SANDY GRAVEL
10-20 COLORADO SILICA SAND				
4" DIA. PVC CASING	10-12-88	20		GRAVEL
4" DIA. SLOTTED PVC				
8" DIA. CARBON STEEL CASING (REMOVED)		25		SANDY GRAVEL
		30		GRAVELLY SAND
DEPTH DRILLED = 32'				
		35		

A-1800-186 (3/87)

Well LF4-PNL6 Drilled Depth 32' Interval Logged 2'-28'

Log Type NAT. GAMMA Date 10-12-88 Casing Size 8" CARBON STEEL

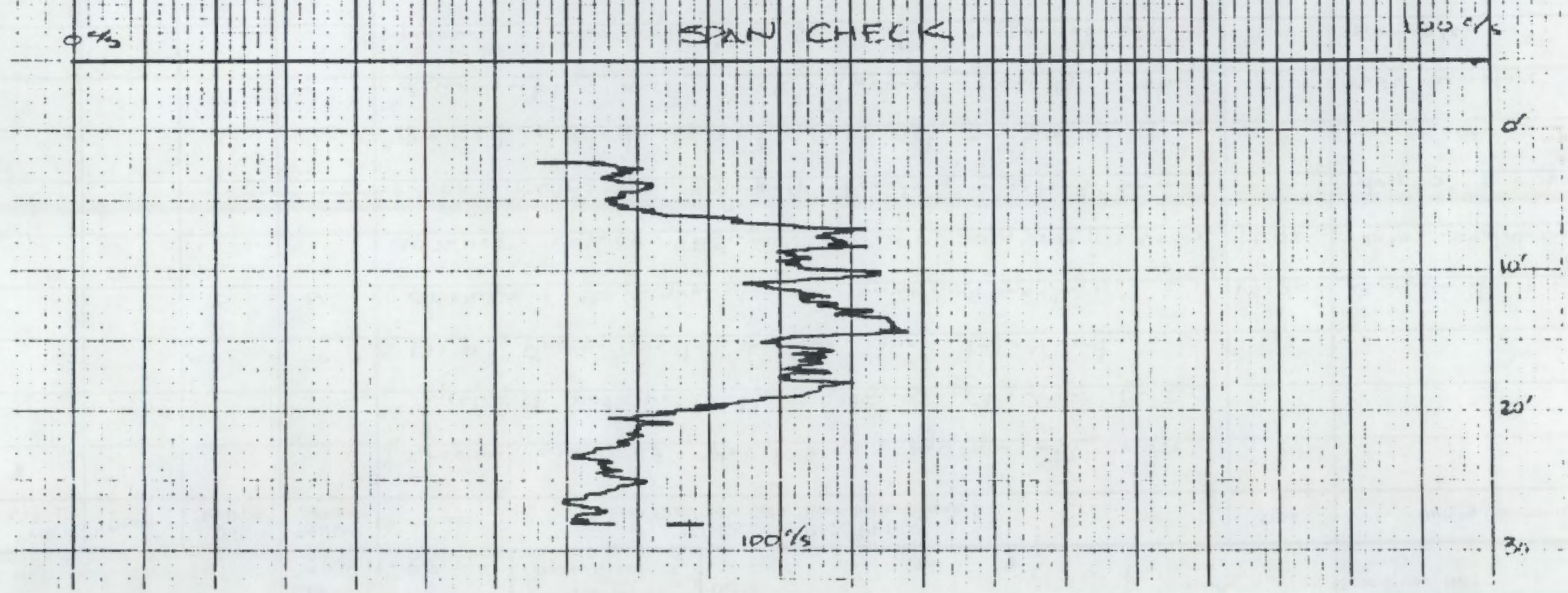
Logged By S.P. AIRHART Water Level Depth 20.1'

Logging Scales Sensitivity 100c/s Time Constant 3

Vertical Scale 10'/in Logging Speed 15'/min

Source Strength NA. Spacer Length NA.

Remarks: REF. PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



E.177

E.178

DRILL LOG	By: AIRHART	Rig: DARRYL LUDTKE Bucyrus Erie 22W ONWEGO	Well Number: LF4-PNL6	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-11-88		Depth: 0' To 7'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Steam cleaned drill rig, equipment, pipe		
				(geologist not present). Using Chevron Poly		
				FM II Food grade grease for lubricant.		
	5'	D	M	GRAVEL: 90% gravel, 5% sand, 5% silt:	13:00	Began drilling
				10% VCP, 15% CP, 15% MP, 30% FP, 20% VFP, 3% VCS,	13:05	Note: sediment
				1% CS, 1% MS-VFS, 5% silt (coating clasts & sand		dry 0'-3' - became
				grains) - Mod. sorted (GRAVEL) SA-SR clasts		moist @ 3'.
				dominantly mafic-rich igneous (sand) A-SA		Took moisture
				grains ~50% qtz-rich 50% mafic : moist color		sample
				olive 5Y 4/3; No rxn w/ 10% HCl; unconsolidated		
				Hole keeps caving @ ~6' - adding casing →	13:15	Added 9'3" of 8" casing
						w/ shoe.
				Interesting: Found CPebble size chunk of coal	13:20	
				@ ~6' below land		
				Not getting much footage - gravels are too loose -	14:15	
				Removed 8" casing - will set 10" surface casing		

REMARKS:

StP [signature]
10/11/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small ...

E.179

DRILL LOG	By: AIRHART	Rig: B.E-22W	Well Number: LTU-PNL6	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-11-88	ONWEGO	Depth: 7' To 15'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
	10'	D	M	GRAVEL: 80% gravel 15% sand 5% silt:	1515	Moisture
				3% SC (greatest ~120 mm) 10% VCP, 15% CP, 15% MP,		sample taken
				20% FP, 17% VFP, 3% VCS, 5% CS, 5% MS, 2% FS-VFS,		
				5% silt : (poorly sorted) (GRAVEL)		
				clasts are SR-R ; predom. mafic-rich igneous.		
				(SAND) A-SR grains ~70% qtz-rich 30% mafic ;		
				moist color olive 5Y 4/3 ; no rxn w/ 10%		
				HCl ; unconsolidated		
15'4" of 8"					1600	Added 9'3" + 6'1" of
						8" casing = 15'4"
					1610	Resumed Drilling
				Large cobble (25-30 cm. dia.) @ ~ 12-13'	1630	
				Checked hole w/ 10.2 + 11.7 eV probes HNU	1645	
				no response - approx depth 13'		
	15	D	D	SILTY SANDY GRAVEL: 60% gravel, 30% sand,	17:20	Moisture
				10% silt : 5% CP, 15% MP, 25% FP, 15% VFP, 1% VCS,		sample taken
				1% CS, 3% MS, 10% FS, 15% VFS, 10% silt : poorly sorted		

REMARKS:

SP Airhart
10/11/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By: AIRHART Date: 10-11-88	Rig: B.E. 22W UNWEGO	Well Number: LF4-PNLL Depth: 15' To 19'	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				(15' cont....) (GRAVEL) SA-SR clasts - no Δ composition		
				(SAND) Too Fine to distinguish detail;		
				slight moist- to dry color: olive 5Y 4/3 : No rxn. w/ 10%		
				HCl ; unconsolidated		
20'1" of 8" casing					17:50	Added 4'9" of 8" casing
						15'4" + 4'9" = 20'1"
					17:55	Resumed Drilling
24'11" of 8" casing					18:30	Adding 4'10" of 8"
						20'1" + 4'10" = 24'11"
					19:00	Shut Down

REMARKS:

St P. Airhart
10/11/88

E.180

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ...

DRILL LOG	By AIRHART	Rig Bucyrus Erie 22-W	Well Number [illegible]	Computer Number NA	Project or Work Order No. 11852
	Date 10-12-88	[illegible]	Depth 19' To 20'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0700	started Drilling
	20'	D	VM	GRAVEL: 80% gravel, 15% sand, 5% silt : 2% SC	0710	Took moisture
				(largest ~ 100 mm dia.), 10% VCP, 15% CP, 20% MP,		sample
				20% FP, 13% VFP, 3% VCS, 8% CS, 2% MS, 2% FS-VFS,		
				5% silt : poorly sorted : (GRAVEL) dom. SR -		
				dom. mafic-rich ign. No Δ in lithology (SAND)		
				A-SA grains dom. mafic lithology : Moist		
				color olive 5Y5/3, no rxn w/ 10% HCl ;		
				unconsolidated		
					0715	last sample is
						moist-to-wet-
						suspect water
				Encountered water immediately when	0725	
				drilling resumed		
				D/W: 19'11½" below land (E-tape)	0740	
					0800	Changed over to
						hard tool

REMARKS:

[signature]
10/12/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine

E.181

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: 1F4-PNL6	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-12-88	ONWE(W	Depth: 20' To 25'		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					0930	Adding 5'7" of 8" casing
30'6"	of 8"					24'11" + 5'7" = 30'6"
					0943	Drove casing
					0946	Resumed drilling
					1015	Putting on split-spoon
	25'	SPLIT SPOON	W	SANDY GRAVEL: 65% gravel, 32% sand, 3% silt:	1020	Taking split-spoon
				5% VCP, 15% CP, 15% MP, 30% FP-VFP, 15% VCS,		Blows/6" - 10, 17, 30
				10% CS, 5% MS, 2% FS-VFS, 3% silt: (poorly sorted)		Drove 18'
				(GRAVEL) SA-R clasts dom. mafic (sand) A-SA		Recovered ~10" + cuttings
				50% qtz-rich 50% mafic; wet color olive 5Y 4/3;		Some of sample fell
				unconsolidated - NOTE: Driller indicated		out of shoe.
				fm. seems very loose - should produce a lot of		
				water - most of actual intact sample dropped out		
				of split-spoon ∴ a lot of cuttings in sample.		
					10:40	Resumed Drilling
34'6" of 8"					10:55	Adding 4' of 8" casing
						30'6" + 4' = 34'6"

REMARKS:

S.P. Airhart
10/12/88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine

E.182

DRILL LOG	By AIRHART	Rig B.E. 22W ONWEGO	Well Number LF4-PNL6	Computer Number NA	Project or Work Order No. 11832
	Date 10-12-88		Depth 25' To 30'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					1105	Resumed Drilling
				Driller indicated that Fm. keeps heaving in	1150	
				hole. The formation consists of pea-size		
				gravels & sand w/ very little silt. The		
				driller will drive the pipe and try and		
				drill the plug down to 30'.		
					11:55	Resumed Drilling
				Drilled & bailed.		
				D/B = 29'11" below land	12:45	
				D/W = 20'1 3/4" below land (E-tape)		
				Had to take sample from bailer - not representative	12:55	
				since there is a plug in the pipe. Could not drill		
				to end of pipe - sediment kept heaving.		
				Geophysically logged hole w/ Nat. γ probe	13:00 - 13:30	
				(2'-28')		

REMARKS:

S D Airhart
10/12/88

E.183

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small

DRILL LOG	By AIRHART	Rig B.E. 22W ONWEGO	Well Number LFW-PNL6	Computer Number NA	Project or Work Order No. 11852
	Date 10/12/88		Depth 30' To 20'		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added the following sections of 4" dia sch. 40		
				PVC (flush-joint threaded) casing and screen		
				Bottom cap = 6¾" 7¼"		
				10' section slotted (10 slot) screen		
				5'¼" section slotted (10 slot) screen		
				20'¼" casing		
				cut off 2'6" of casing		
				Total 4" PVC = 33'1¼" (-4" cut off later)		
				= 32'9¼" Total PVC		
				After setting PVC in hole. Noted that bottom		
				of hole heaved up 6" to 29'6". Geologist		
				O.K.'d this depth. Started straight-lining 8"		
				casing out of hole - PVC coming up w/ casing		
				because of plug in 8" casing.		
				Removed PVC from hole. Began redrilling	14:00	

REMARKS:

[signature]
10/12/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small

E.184

E.185

DRILL LOG	By AIRHART / Date 10-12-88	Rig B.E. 22W ONWF60	Well Number LF-1-PAILL / Depth 30' To 30'	Computer Number N/A	Project or Work Order No. 11832 / Subcontract No. N/A

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Description of 30' sample taken @ 12:55		
	30'	H	W	GRAVELLY SAND: 29% gravel 70% sand 1% silt:		
				1% MP, 6% FP, 22% VFP, 1.0% VCS, 20% CS, 30% MS,		
				10% FS-VFS, 1% silt; mod-to-poorly sorted.		
				(GRAVEL) - Dom A-SA clasts dom. mafic ign.		
				No Δ lith. (sand) A-SA mixed liths -		
				- very clean hard to distinguish color,		
				unconsolidated (heaving)		
				NOTE This sample may not be representative		
				of 30' interval since it was taken from		
				sed which had heaved up 8" casing.		
				Stopped drilling - pulled 8" casing to 30'1"	14:50	
				D/B = 29'9½" below land		
				Reset PVC @ 29'10" below land	15:23	

REMARKS:

St P Airhart
10/12/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water A-6000-021 (5-85)

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: LF4-PNL6	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-12-88	ONWEGO	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 3 100 lb bags of 10-20 mesh Col.	1530	
				silica sand to 15'6" below land.		
				Pulled 8' casing to 23'3" below land		
				D/sand - 21' below land		
				Added 1 bag 10-20 Col silica sand to 18'	1550	
				Pulled 8" casing to 20'5" below land	1557	
				D/ sand : 18.5' below land	1600	
				Added 1 bag 10-20 Col. silica sand to 14'	1610	
				Pulled 8" casing to 15'10" below land	1620'	
				D/ sand = 16'1" below land - mud on end of	1622	
				tape indicates some cave occurred		
				Added 3 bags 10-20 Col. silica sand while	1640	
				pulling 8" casing		
				Pulled 8" casing to 12'6" below land	1655	
				D/sand = 11' below land	1700	
				Pulled 8" casing to 11'8" below land		
				D/sand : 11'7" below land (Final sand depth)	1730	
				Added 2 5 gal buckets of 1/4" Baroid bentonite	1736	

REMARKS: pellets to 6.5' below land
2 buckets 1/4" pellets
8 100 lb bags 10-20 sand

StP. Airhart
10/12/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small ...

E.186

E.187

DRILL LOG	By: AIRHART	Rig: B.E. 22w (?)	Well Number: [illegible]	Computer Number: NA	Project or Work Order No.: [illegible]
	Date: 10-12-88	OWEGO (?)	Depth: [illegible] To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled 8" casing to 8'6" below land	17:42	
				D/pellets = 8'3" below land	17:44	
				Added 1 bucket 1/4" Baroid bent pellets to 6'	17:53	
				Pulled 8" casing to 5'8" below land		
				D/pellets = 6'9" below land (final D/pellets)	1800	
				Added 1 50 lb bag of Enviroplug Med bent		
				chunks		
				Pulled 8" casing to 5'7" below land	[illegible]	
				D/chunks = 4'10" below land	[illegible]	
				Added 2 50 lb bags of Enviroplug Med bent	1813	
				chunks to +6" above land		
				Pulled 10" surface casing out of hole - 8"	1815	
				shoe would not pull through it		
				Added 1 50 lb bag of Enviroplug Med. bent		
				chunks to +3' above land		
				Pulled remaining 8" casing out of hole		
				D/chunks = 1'4" below land (final depth)	1822	
				Bailing w/ 2" dart bailer - water is turbid	1823 -	1828

REMARKS:

1 bucket 1/4" pellets — but not much if any sand

4 bags Bent. chunks — Will finish development w/ pump

S.P. Airhart
10/12/88

D - Drive Barrel   H - Hand Tool   L - Large   M - Medium   S - Small ...

DRILL LOG	By AIRHART	Rig B.E. 22W	Well Number LF41-PNL6	Computer Number NA	Project or Work Order No. 11832
	Date 10-12-88	ONWEGO	Depth COMPLETION TO		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Cut off 4" of PVC - PVC = 36" above level		
				Added 6" dia. carbon steel surface casing		
				to 41" above level.		
				Put on protective cap and lock	1840	
					1850	Shut Down

REMARKS:
8 100 lb. bags 10-20 mesh Colorado silica sand
3 buckets 1/4" Baroid bentonite pellets
4 50 lb. bags of Enviroplug Med. Bentonite chunks.

[signature] 10/12/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.188

E.189

DRILL LOG	By: AIRHART	Rig: Bucyrus Erie 22W	Well Number: LF4-PNLL	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-13-88	ONWEGO	Depth: COMPLETION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Tore down rig - picked up equipment	0700 -	0830
				around well site		
				Moved off to afram clean	0830	

REMARKS:

S.P. Airhart
10/13/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-PNL6	Computer Number NA	Project or Work Order No. 11932
	Date 10/14/88		Depth DEVELOPMENT To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				D/W = 23'7¼" below top of 6" casing (41"	12:57	
				above land) - set ⅓ h.p. submersible	12:58	Pump on
				pump	13:43	Pump off
				No drawdown after 45 mins pumping		
				- Discharge rate = 10 gpm -		
				surged pump up and down to try		
				and develop out silt. Well cleaned		
				up clear - Filled 5 gal. bucket - could		
				see bottom of bucket clearly through water		
				Total pumping time = 45 minutes		
				@ 10 gpm = 450 gallons pumped		

REMARKS:

St P. [illegible]
10/14/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine Standing Water

E.190

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LF4-PNL6	Computer Number NA	Project or Work Order No. 11832
	Date		Depth COMPLETION To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				concrete surface seal, concrete pad,		
				brass marker, protective posts, safety		
				yellow painting all was performed by		
				OSWEGO drilling during week of		
				10/17 - 10/21		

REMARKS:

St P Airhart
11/5/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

E.191

APPENDIX F

MOISTURE CONTENT OF SEDIMENT SAMPLES

APPENDIX F

MOISTURE CONTENT OF SEDIMENT SAMPLES

The information below shows moisture content data for selected wells at Landfills 1 and 4.

Well Number	Depth, feet Below Land Surface	Moisture Content, wt.%
LF1-PNL1	6.0	2.42
	10.0	5.93
	15.0	4.63
	25.0	6.98
	30.0	5.69
	33.5	7.87
LF1-PNL2	10.5	4.58
	15.0	5.73
	20.8	8.75
LF1-PNL3	5.0	8.24
	10.5	5.68
LF4-PNL2	6.0	2.22
	11.5	3.37
	15.0	6.44
	21.0	8.40
	25.0	6.88
LF4-PNL3	11.0	5.00
	16.5	5.57
	21.5	5.35
	26.5	5.43
	31.0	4.01
LF4-PNL5	5.0	3.87
	10.0	3.25
	15.0	3.27
	20.0	4.79
	25.0	13.27
	30.0	12.75
LF4-PNL6	5.0	3.61
	10.0	2.58
	15.0	3.00
	20.0	4.77

APPENDIX G

<u>WATER-LEVEL MEASUREMENT PROCEDURE</u>

APPENDIX G

WATER-LEVEL MEASUREMENT PROCEDURE

This appendix contains the procedure used to measure water levels at the new wells near Landfills 1 and 4.

Introduction

Water-level measurements are taken each time a well is sampled, before it is purged. These measurements are taken as depth-to-water from the top of the well casing. They must be subtracted from the surveyed elevation of the casing given in Hanford Wells to obtain the elevation of the water table. The water-table elevations obtained for all wells in the sampling network during a particular sampling episode can be used to produce a contour map showing the ground-water surface at the time that the measurements were made. These contour maps can be used to help characterize the ground-water flow system and to ensure that the sampling network is adequate.

Graduated steel measuring tapes are more accurate than electrical tapes and so should be used for official measurements. However, an electrical tape can be used to determine the approximate depth to water.

Equipment

The following equipment will be needed:

- steel measuring tape with attached weight
- blue carpenter's chalk
- a copy of Hanford Wells (PNL-5397)
- electrical tape
- engineer's measuring tape
- field record forms.

Graduated Steel Tape Method

Chalk the 1-ft section of steel tape below the zero reading point.

Find the elevation of the measuring point and the estimated water level in Hanford Wells, or use an electric tape to find the approximate depth to water.

Lower the steel tape from the well's measuring point (marked with paint on the top of the casing) to the estimated water level. Note the amount of tape that is in the well by reading the tape at the measuring point. This value is referred to as the "hold point."

Remove the steel tape and check the wetted portion below the zero reading point.

NOTE: If the chalked portion is not wet, repeat the procedure, but allow more of the tape to go down the well (i.e., use a greater hold point).

Add the unwetted length of the chalked portion of the tape to the hold point value to obtain the depth-to-water measurement.

G.2

If the chalked portion is not wet, repeat until the water level is marked on the chalked portion of the tape.

Repeat the procedure until two steel tape measurements agree within ±0.05 ft.

Record the depth-to-water measurements, time of measurements, measuring device, and the name of the person taking the measurements on the field record form.

Electric Tape Method

Lower the electric tape from the measuring point into the borehole until the buzzer and the light indicate contact with the water.

Mark the electric tape at the measuring point and identify the nearest graduation on the electric tape.

If the water level is deeper than the nearest graduation marked on the tape, add the difference to the depth identified to obtain the true depth to water.

If the water level is shallower than the nearest graduation marked on the tape, subtract the difference from the depth identified to obtain the true depth to water.

Record the depth-to-water measurements, time of measurements, measuring device, and the name of the person taking the measurements on the field record form.

NOTE: This measurement should be used only as an approximate depth to water, because the electric tape is less reliable than the steel tape.

APPENDIX H

WELL LOCATION AND ELEVATION SURVEY DATA

APPENDIX H

WELL LOCATION AND ELEVATION SURVEY DATA

This appendix includes

- results of the 1988 and 1982 surveys of the existing (1981 and 1984) monitoring wells at Landfills 1 and 4
- results of the 1989 survey of both the new (1988) and the existing (1981 and 1984) monitoring wells at Landfills 1 and 4.

DEPARTMENT OF THE ARMY
SEATTLE DISTRICT, CORPS OF ENGINEERS
P.O. BOX C-3755
SEATTLE, WASHINGTON 98124-2255

REPLY TO ATTENTION OF

March 7, 1988

Geotechnical Branch

SUBJECT: Ft. Lewis, Washington Landfills 1 and 4, Horizontal and Vertical Control for Existing Borings

Mr. Paul Eddy
Battelle Pacific Northwest Labs
Battelle Blvd.
Richland, Washington 99352

Dear Mr. Eddy:

Seattle District has completed the survey of existing ground water monitoring wells located at landfills 1 & 4, Ft. Lewis, Washington. The survey information is provided herein.

In reviewing existing information, our survey personnel disclosed a 1982 survey of the wells located at landfill 4. Information from the earlier survey is being provided here; the wells were not resurveyed. Landfill 1 required a new survey, that information is also attached. The well casings associated with landfill 1 are in very poor condition, consequently all elevations are on 2x2 hubs placed approximately 2-feet from the casings. It was also discovered that wells 1 & 2 at landfill 4 were incorrectly identified (numbers reversed) on the map provided to you in our meeting of February 11.

If you any questions, or if we can be of further assistance, please contact Mr. Mike Bowlus/NPS-EG-H, telephone (206) 764-6744.

E.T. Bailey

Enclosure

E.T. Bailey
Chief, Hazardous Waste Mgmnt. Sect.

Copies furnished:

Randy Hanna/DEH AFZHEHQ
Fort Lewis, Washington

LANDFILLS 1 & 4

FT. LEWIS, WASHINGTON

WELL SURVEY

LANDFILL 1
(1988 survey, elevations are top of 2x2 hub, coordinates are casing center)

WELL #	ELEV. 1/	LATITUDE	LONGITUDE	NORTHING	EASTING 2/
LF-1	302.46	47.4.11.24535	122.35.18.85152	640125.080	1479594.900
LF-2	302.14	47.4.02.80571	122.35.18.83797	639270.330	1479573.200
LF-3	296.77	47.3.52.69644	122.35.16.21592	638241.710	1479727.540
LF-4	311.46	47.4.01.82937	122.35.11.32028	639157.680	1480090.810

LANDFILL 4
(1982 survey, elevations are top of casing, coordinates are casing center)

WELL #	ELEV.	LATITUDE	LONGITUDE	NORTHING	EASTING
1	224.69	47.6.49.98508	122.36.05.55298	656287.351	1476791.728
2	219.19	47.6.53.18160	122.36.28.23885	656652.944	1475231.875
3	238.79	47.7.06.21637	122.36.06.17757	657932.344	1476792.355
4	235.93	47.7.09.37644	122.35.44.09606	658211.757	1478327.455
11	234.79	47.7.00.66870	122.36.04.44537	657367.306	1476897.139

1/ NGVD 27
2/ STATE PLANE COORDINATES ZONE 2

ROUTING AND TRANSMITTAL SLIP

Date 6-1-89

TO: (Name, office symbol, room number, building, Agency/Post)	Initials	Date
1. George		
2.		
3.		
4.		
5.		

	Action		File		Note and Return
	Approval		For Clearance		Per Conversation
	As Requested		For Correction		Prepare Reply
	Circulate		For Your Information		See Me
	Comment		Investigate		Signature
	Coordination		Justify		

REMARKS

Attached are the results of the survey of Ft Lewis Landfills 1 & 4. I've sent a copy to Randy Hanna, also. If you have any questions please call me.

DO NOT use this form as a RECORD of approvals, concurrences, disposals, clearances, and similar actions

FROM: (Name, org. symbol, Agency/Post)	Room No.—Bldg.
Joan Shafer Corps · Seattle	Phone No. (206) 764-6744

5041-102 ☆ U.S. GPO: 1986—491-247/40002

OPTIONAL FORM 41 (Rev. 7-76)
Prescribed by GSA
FPMR (41 CFR) 101-11.206

Port Lewis, WA
Well Location Survey
Landfills No. 1 & No. 4
Seattle District Corps of Engineers

For: The Department of Army
Seattle District Corps of Engineers
Contract DACA67-89-D-0003
Work Order No. 2

Horton Dennis and Associates, Inc.
May 22, 1989
HDA Job No. 8371.02

FORT LEWIS WELL LOCATION SURVEY

Horizontal Control: Washington coordinate system, south zone. Established from United States Army Corps of Engineers published control for 1987 aerial mapping project.

Vertical Control: National Geodetic Vertical Datum 1929 (NGVD 1929). Also established from USA COE 1987 published mapping control.

Explanation: Horizontal and vertical values were established for the center of existing brass caps at well locations. Vertical values were established for the North Rim of the existing PVC well pipe inside well casing.

May 22, 1989
RMA

SEATTLE DISTRICT CORPS OF ENGINEERS
WORK ORDER NO. 2 CONTRACT DACA67-89-D-0003
HDA JOB NO. 8371.02

FORT LEWIS, WASHINGTON
WELL LOCATIONS LANDFILL 1 & 4

LANDFILL NO. 1

WELL NO	COMPUTER NO	ELEVATION	NORTHING	EASTING	REMARKS
PNL-1	136	306.47	640370.6733	1480403.3561	BRASS CAP
		308.66			TOP PVC
LFI-4	139	311.45	639158.6144	1480090.8904	BRASS CAP
		312.59			TOP PVC
LFI-3	142	296.90	638242.6336	1479727.4028	BRASS CAP
		297.69			TOP PVC
PNL-2	143	296.82	638284.9083	1479184.6580	BRASS CAP
		298.37			TOP PVC
PNL-3	144	306.30	638634.4298	1478887.6439	BRASS CAP
		307.74			TOP PVC
LFI-2	146	302.11	639271.3857	1479573.5343	BRASS CAP
		303.48			TOP PVC
LFI-1	148	302.63	640126.0797	1479594.9728	BRASS CAP
		303.64			TOP PVC
PNL-4	150	303.19	640611.7514	1480157.4493	BRASS CAP
		305.00			TOP PVC

NOTE: BRASS CAP IS A PRESET MONUMENT AT THE WELL SITE. ALL ELEVATIONS ON PVCS ARE TO THE NORTH RIM.

WELL NO.	CUMPUTER NO	ELEVATION	NORTHING	EASTING	REMARKS
LF4-PNL-4		233.86	658162.3213	1476174.4060	BRASS CAP
		235.72			TOP PVC
LF4-PLN-1	103	236.22	657439.0119	1476136.1599	BRASS CAP
		237.82			TOP PVC
LF4-11	105	232.06	657397.1543	1476813.5658	BRASS CAP
		234.05			TOP PVC
LF4-PNL-2	107	238.22	658639.2226	1477139.2425	BRASS CAP
		240.48			TOP PVC
LF4-4	110	233.96	658201.8046	1478294.0279	BRASS CAP
		235.41			TOP PVC
LF4-PNL-6	114	229.55	656714.1107	1478619.1314	BRASS CAP
		232.19			TOP PVC
LF4-PNL5	120	235.12	657661.29 ~~657574.6377~~	1475354.80 ~~1475681.3245~~	BRASS CAP
		237.46			TOP PVC
LF4-~~1~~ 2	124	217.32	656696.7986	1475242.6186	BRASS CAP
		218.27			TOP PVC
LF4-~~2~~ 1	129	223.31	656276.4394	1476795.1897	BRASS CAP
		225.37			TOP PVC
LF4-PNL-3	132	244.37	656576.2839	1477954.7651	BRASS CAP
		246.59			TOP PVC

NOTE: CORRECTIONS MADE PER VERBLE COMMUNICATION WITH JOAN SHAFER, U.S. ARMY CORPS OF ENGINEERS, JUNE 13, 1989.

APPENDIX I

DRILL LOGS OF EXISTING WELLS AT LANDFILL SITES 1 AND 4

APPENDIX I

DRILL LOGS OF EXISTING WELLS AT LANDFILL SITES 1 AND 4

This appendix contains drilling information for older wells at Landfills 1 and 4, including

- for Landfill 1
  - well 84-CD-LF 1
  - well 84-CD-LF-2
  - well 84-CD-LF-3
  - well 84-CD-LF-4
- for Landfill 4
  - well Fort Lewis #1
  - well Fort Lewis #2
  - well Fort Lewis #3
  - well Fort Lewis #4
  - well Fort Lewis #11.

DRILL LOG	By: AIRHART Date: Week 10/17-10/22/88	Rig: NO RIG	Well Number: LANDFILL NO. 1 EXISTING WELLS Depth: RESTORATION TO	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				The following is the record for restoration		
				of existing wells 84-CD-LF-1, 84-CD-LF-2,		
				84-CD-LF-3, 84-CD-LF-4 near landfill		
				No. 1. This work was performed by		
				Owego Drilling, Inc. during week of		
				10/17-10/22/88.		
				— Well 84-CD-LF-1 —		
				Removed existing surface casing - replaced		
				w/ 6" dia. carbon steel casing - Added		
				cement to ground surface between		
				6" casing and PVC casing (on top of		
				existing bentonite seal - No D/top of seal		
				taken) -		
				Poured 4'x4' concrete pad, installed		
				and painted four protective posts		
				around pad, installed brass marker		
				in pad, placed PVC cap on PVC and		
				6" aluminum locking cap w/ lock on 6" surface casing -		

REMARKS: painted protective posts and surface casing.

St P. A[illegible] 10/26/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A 6000 021 (5 85)

1.2

DRILL LOG	By	Rig	Well Number	Computer Number	Project or Work Order No.
	AIRHART	NO RIG	LANDFILL NO. 4 EXISTING WELLS	NA	11B32
	Date		Depth		Subcontract No.
	10/30 - 10/31/88		RESTORATION TO		NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				The following finishing work was performed		
				on existing wells during 10/25 - 10/31/88.		
				This work was started after restoration		
				of well (removal of existing casing and		
				emplacement of annular seal) was completed.		
			–	cement surface seal poured above bentonite		
				seal - 1' @ well No. 11, 1' @ well No. 1,		
				1' @ well No. 2, 0.5' @ well No. 4		
			–	poured 4'x4' surface pad (only		
				used 2'x2' surface pad @ well No. 1		
				because of its proximity to road)		
			–	placed 6" protective surface casing		
				around PVC w/ locking cap		
			–	placed 4 protective posts around		
				surface pad (painted yellow)		
			–	placed cap on PVC casing.		

REMARKS:

St P. Airhart 10/31/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

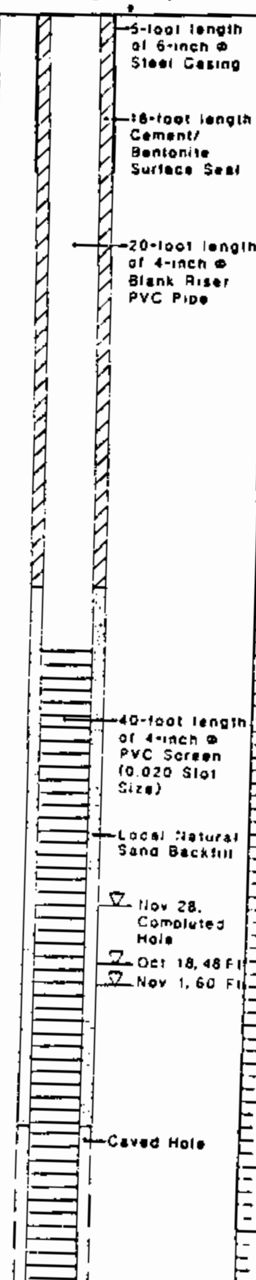
A 6000 021 (5-85)

WELL 84-CD-LF 1

Hole No. [illegible]

DRILLING LOG	DIVISION	INSTALLATION	
1. PROJECT J-1345-05 Gray Field Landfill		10. SIZE AND TYPE OF BIT	
2. LOCATION (Coordinates or Station)		11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
3. DRILLING AGENCY Richardson Drilling		12. MANUFACTURER'S DESIGNATION OF DRILL SPEEDSTAR 71 Cable Tool Churn Drill	
4. HOLE NO. (As shown on drawing title and file number) 84-CD-LF 1		13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED 12 / UNDISTURBED
5. NAME OF DRILLER Larry Gustin		14. TOTAL NUMBER CORE BOXES NA	
6. DIRECTION OF HOLE [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.		15. ELEVATION GROUND WATER	
		16. DATE HOLE	STARTED 10/12/84 / COMPLETED 11/5/84
7. THICKNESS OF OVERBURDEN		17. ELEVATION TOP OF HOLE	
8. DEPTH DRILLED INTO ROCK NA		18. TOTAL CORE RECOVERY FOR BORING NA %	
9. TOTAL DEPTH OF HOLE 60 FT		19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		(Loose to very dense), damp to saturated, sandy to very sandy GRAVEL, locally slightly silty. Color of fines is yellowish brown (10 YR 3/2 to 5/4) above water table (30 feet) and olive gray (5Y 5/2 to 6/3) below.		S-1	
	10				S-2	
					S-3	
	20				S-4	
					S-5	
	30				S-6	
					S-7	
	40					

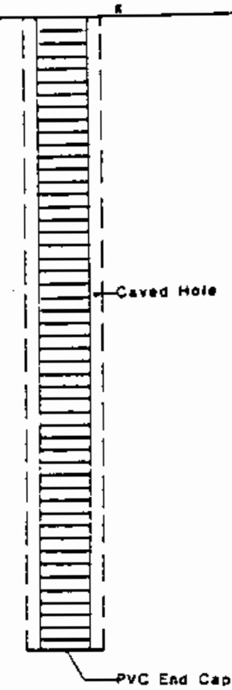


ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. | PROJECT | HOLE NO.

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No.

PROJECT | INSTALLATION | SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40		(Loose to very dense), damp to saturated, sandy to very sandy GRAVEL, locally slightly silty. Color of fines is yellowish brown (10 YR 3/2 to 5/4) above water table (30 feet) and olive gray (5Y 5/2 to 6/3) below.	S-8		
				S-9		
	50			S-10		
			(Medium dense to dense), saturated, slightly silty, sandy to very sandy GRAVEL. Interstratified beds of silty SAND and sandy GRAVEL at 55 feet. Color of fines varies from brown (7.5 YR 5/8) to yellow-brown (2.5 Y 6/4).	S-11		
	60			S-12		
			Bottom of Casing at 60.0 Ft. Sampled to 61.0 Ft. Completed 5 November 84. Note: 6-inch ∅ steel casing was advanced during drilling to a total depth of 60.0 feet. Water levels are for date specified with casing at depth indicated. Upon completion of hole and after installation of PVC screen, casing was pulled leaving 5-foot length in place below ground surface.			
	70					
	80					



ENG FORM 1836-A (ER 1110-1-1801) | PROJECT | HOLE NO.

WELL 84-CD-LF-2

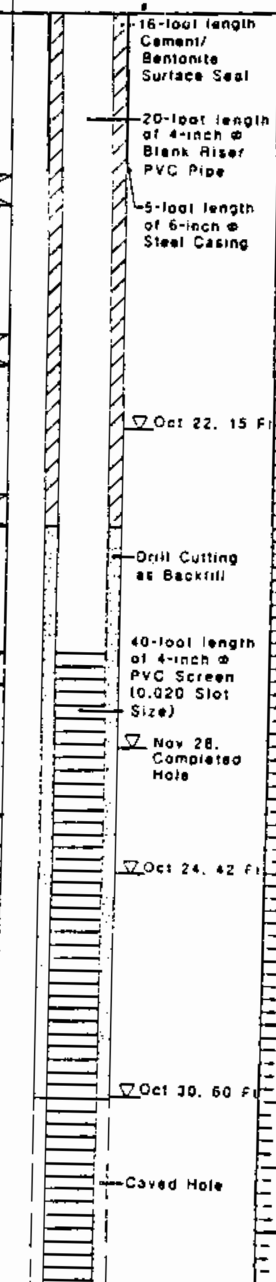
Hole

DRILLING LOG | DIVISION | INSTALLATION

1. PROJECT: Gray Field Landfill - J1345-05
2. LOCATION (Coordinates or Station):
3. DRILLING AGENCY: Richardson Drilling
4. HOLE NO. (As shown on drawing title and file number): 84-CD-LF-2
5. NAME OF DRILLER: Larry Gustin
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN:
8. DEPTH DRILLED INTO ROCK: NA
9. TOTAL DEPTH OF HOLE: 60 FT

10. SIZE AND TYPE OF BIT:
11. DATUM FOR ELEVATION SHOWN (TBM or MSL):
12. MANUFACTURER'S DESIGNATION OF DRILL: SPEEDSTAR 71 Cable Tool Churn Drill
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 12 | UNDISTURBED
14. TOTAL NUMBER CORE BOXES:
15. ELEVATION GROUND WATER:
16. DATE HOLE: STARTED 19 Oct 84 | COMPLETED 31 Oct 84
17. ELEVATION TOP OF HOLE:
18. TOTAL CORE RECOVERY FOR BORING: %
19. SIGNATURE OF INSPECTOR:

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		(Loose to very dense), wet to saturated, sandy GRAVEL to very gravelly SAND. Locally slightly silty or slightly cobbly. Color of fines changes from dark grayish brown (2.5Y 4/2) shallower than 5 feet depth to pale olive (5Y 6/3) below five feet.		S-1	
	10				S-2	
					S-3	
	20				S-4	
					S-5	
	30				S-6	
					S-7	
	40					

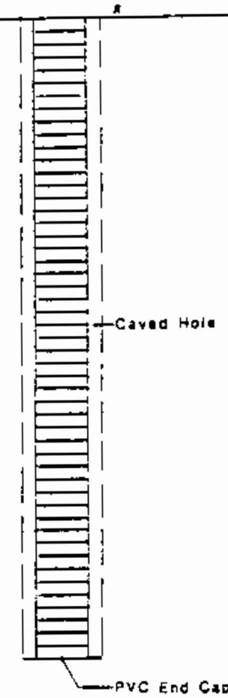


ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. | PROJECT | HOLE NO.

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 84-CD-LF-2

PROJECT | INSTALLATION | SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40		(Loose to very dense), wet to saturated, sandy GRAVEL to very gravelly SAND. Locally slightly silty or slightly cobbly.	S-8		
			(Soft), wet to saturated, slightly cobbly SILT grading downward to (soft to medium stiff) interbedded PEAT, SILT and very silty, fine SAND. Color of peat is reddish brown (5YR 2.5/2) and color of fines is very dark gray (N 3/)	S-9		Caved Hole
	50			S-10		
			Interbedded (loose), saturated, slightly silty, gravelly SAND and (medium stiff) SILT grading downward to interbedded clean, fine to medium SAND and sandy GRAVEL. Color of fines varies from greenish gray (5 BG 5/1) to dark greenish gray (5 G 5/1).	S-11		
	60			S-12		PVC End Cap
			Bottom of Casing at 60.0 Feet Sampled to 61.0 Feet Completed 31 October 84 Note: 6-inch Ø steel casing was advanced during drilling to a total depth of 60.0 feet. Water levels are for date specified with casing at depth indicated. Upon completion of hole and after installation of PVC screen, casing was pulled leaving 5-foot length in place below ground surface.			
	70					
	80					



ENG FORM 1836-A (ER 1110-1-1801) GPO 1968 OF -625-103 | PROJECT | HOLE NO

DRILL LOG	By AIRHART	Rig NO RIG	Well Number LANDFILL NO. 1 EXISTING WELLS	Computer Number N/A	Project or Work Order No. 11832
	Date Week 10/17-10/22/88		Depth RESTORATION TO		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
		→	Wells	84-CD-LF-2, 84-CD-LF-3, 84-CD-LF-4 –		
				Added concrete to ground surface		
				above existing bentonite seal		
				(1.8' @ well LF-3, 2.3' @ well LF-4		
				removed ~ 1' of bentonite from		
				well LF-2 and replaced w/ 1' of concrete)		
				Poured 4'x4' concrete surface pad,		
				emplaced brass survey marker		
				Placed 4 protective posts around pad,		
				Placed PVC caps and 6" aluminum		
				locking caps on wells		
				Painted surface casing & protective posts.		

REMARKS:

St. D. Airhart 10/26/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

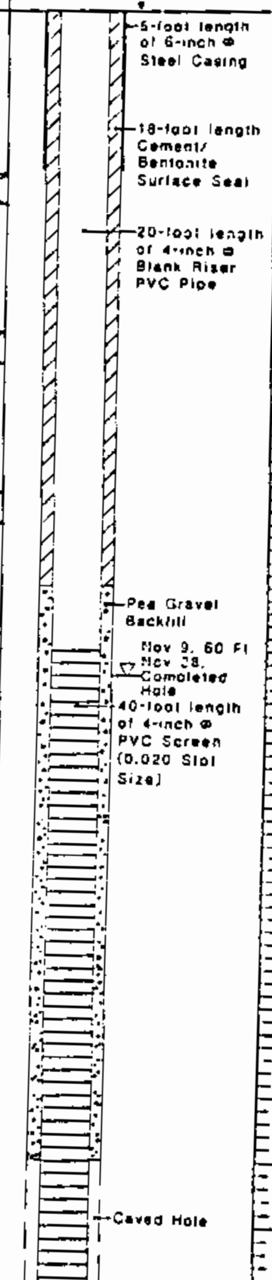
I.9

WELL 84-CD-LF-3

DRILLING LOG

Field	Entry
DIVISION	
INSTALLATION	
1. PROJECT	Gray Field Landfill - J1345-05
2. LOCATION (Coordinates or Station)	
3. DRILLING AGENCY	Richardson Drilling
4. HOLE NO. (As shown on drawing title and file number)	84-CD-LF-3
5. NAME OF DRILLER	Larry Gustin
6. DIRECTION OF HOLE	☑ VERTICAL ☐ INCLINED ______ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN	
8. DEPTH DRILLED INTO ROCK	NA
9. TOTAL DEPTH OF HOLE	60 FT
10. SIZE AND TYPE OF BIT	
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)	
12. MANUFACTURER'S DESIGNATION OF DRILL	SPEEDSTAR 71 Cable Tool Churn Drill
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN	DISTURBED: 12 / UNDISTURBED:
14. TOTAL NUMBER CORE BOXES	
15. ELEVATION GROUND WATER	
16. DATE HOLE	STARTED: 6 Nov 84 / COMPLETED: 9 Nov 84
17. ELEVATION TOP OF HOLE	
18. TOTAL CORE RECOVERY FOR BORING	%
19. SIGNATURE OF INSPECTOR	

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		(Medium dense to very dense), moist to saturated sandy GRAVEL to very gravelly SAND with scattered cobbles. Color of fines is olive (5Y 5/3).			
					S-1	
	10				S-2	
					S-3	
	20				S-4	
			(Very stiff), saturated, gravelly SILT (dark gray N4/) grading downward to, and probably interstratified with (dense), wet, slightly gravelly, fine SAND, silty SAND, and slightly silty, gravelly SAND. Color of fines is greenish gray (5 G 5/1).		S-5	
	30				S-6	
					S-7	
	40		(Very dense), saturated, slightly silty, gravelly to very gravelly SAND and slightly silty, very sandy GRAVEL.			

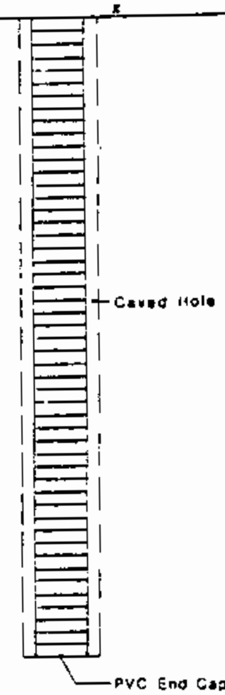


ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. PROJECT HOLE NO.

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE | Hole No. 84-CD-LF-3

PROJECT | INSTALLATION | SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40		(Very dense), saturated, slightly silty, gravelly to very gravelly SAND and slightly silty, very sandy GRAVEL. Sand is fine to medium in 45-50 ft interval and fine to coarse elsewhere. Color of fines grades from olive (5Y 5/3) with yellowish brown (10 YR 5/8) mottling at top of interval to light olive brown (2.5Y 5/6) to strong brown (7.5YR 4/6) at bottom of interval.	S-8		
				S-9		
	50			S-10		
				S-11		
	60			S-12		
			Bottom of Casing at 60.0 Feet Sampled to 61.0 Feet Completed 9 November 84 Note: 6-inch ø steel casing was advanced during drilling to a total depth of 60.0 feet. Water levels are for date specified with casing at depth indicated. Upon completion of hole and after installation of PVC screen, casing was pulled leaving 5-foot length in place below ground surface.			
	70					
	80					



ENG FORM 1836-A JUN 67 (ER 1110-1-1801) GPO 1960 OF-420-503 | PROJECT | HOLE NO.

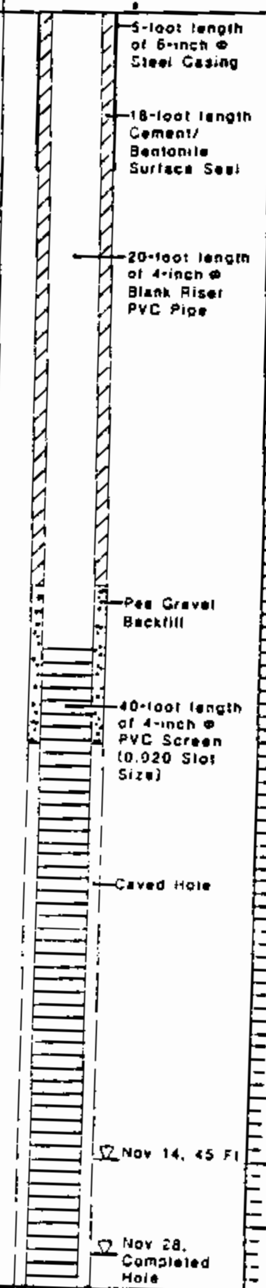
<u>WELL 84-CD-LF-3</u>

DRILLING LOG | DIVISION | INSTALLATION

1. PROJECT: Gray Field Landfill - J1345-05
2. LOCATION (Coordinates or Station)
3. DRILLING AGENCY: Richardson Drilling
4. HOLE NO. (As shown on drawing title and file number): 84-CD-LF-3
5. NAME OF DRILLER
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN
8. DEPTH DRILLED INTO ROCK: NA
9. TOTAL DEPTH OF HOLE: 60 FT

10. SIZE AND TYPE OF BIT
11. DATUM FOR ELEVATION SHOWN (TBM or MSL)
12. MANUFACTURER'S DESIGNATION OF DRILL: SPEEDSTAR 71 Cable Tool Churn Drill
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 12 | UNDISTURBED
14. TOTAL NUMBER CORE BOXES
15. ELEVATION GROUND WATER
16. DATE HOLE: STARTED 12 Nov 84 | COMPLETED 15 Nov 84
17. ELEVATION TOP OF HOLE
18. TOTAL CORE RECOVERY FOR BORING %
19. SIGNATURE OF INSPECTOR

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	0		(Medium dense to dense), moist to saturated, very sandy GRAVEL and very gravelly SAND, locally cobbly and/or slightly silty. Color of fines is very dark grayish brown (10YR 3/2) near surface grading to olive (5 Y 5/3) at 15 feet depth. Olive from 15 to 36 feet where a slightly redder hue (4Y 5/3) is perceptable and continues to 58 feet.			
					S-1	
	10				S-2	
					S-3	
	20				S-4	
					S-5	
	30				S-6	
					S-7	
	40					

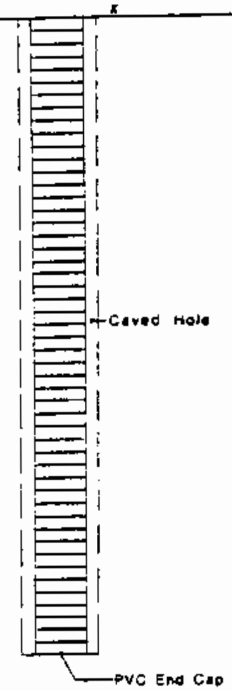


ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. | PROJECT | HOLE NO.

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE

PROJECT | INSTALLATION | SHEET 2 OF 2 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	40		(Medium dense to dense), moist to saturated, very sandy GRAVEL and very gravelly SAND, locally cobbly and/or slightly silty. Color of fines is very dark grayish brown (10YR 3/2) near surface grading to olive (5 Y 5/3) at 15 feet depth. Olive from 15 to 36 feet where a slightly redder hue (4Y 5/3) is perceptable and continues to 58 feet.	S-8		
				S-9		
	50			S-10		
				S-11		
			(Medium dense), saturated, slightly silty, sandy GRAVEL. Sand is fine to medium. Color of fines is brown (7.5 YR 5/4) with mottling of reddish brown (2.5 YR 4/4).			
	60			S-12		
			Bottom of Casing at 60.0 Feet. Sampled to 61.0 Feet. Completed 15 November 84 Note: 6-inch ø steel casing was advanced during drilling to a total depth of 60.0 feet. Water levels are for date specified with casing at depth indicated. Upon completion of hole and after installation of PVC screen, casing was pulled leaving 5-foot length in place below ground surface.			
	70					
	80					



ENG FORM 1836-A JUN 67 (ER 1110-1-1801) | PROJECT | HOLE NO.

WELL FORT LEWIS #1

WELL LOG

BY

Tacoma Pump and Drilling Co., Inc.

30316 MOUNTAIN HIGHWAY
GRAHAM, WASHINGTON 98338
PHONE 847 – 6087

DATE STARTED APRIL 28, 81
DATE COMPLETED APRIL 28, 81
Depth 38' Ground Level
Size of Casing 8"
RIG - CABLE ☐ ROTARY ☒
STATIC LEVEL 10' PUMPING LEVEL —
GPM 150 DRAWDOWN —
SCREEN 4" PVC PERF.
PERFORATIONS

Drilled for FORT LEWIS # 1
Address SOUTH SIDE LANDFILL 1/LAKE
SE 1/4, SW 1/4, 19, T19N, R2E

MATERIALS PENETRATED	CASING USED	START	STOP
TOPSOIL		0	3
GRAVEL, SOIL		3	14
SAND, GRAVEL (DRY)		14	24
SAND, GRAVEL (WET)		24	38

Other information: 38' OF 4" PERF PVC. INSTALLED BOTTOM/16'
PULLED 8" CASING TO 10' G.L.

DRILLER [signature] 0193

DAILY CONTRACT INSPECTION REPORT

NOTE: Contractor fill in Blocks 1, 3, 4a, 5b, 7, 8, 9, and 10 daily or not less than once each week when no work is proceeding. Fill in 4b and 6d each Thursday and more often when appropriate. The Government will fill in the balance of the blanks.

1. Description of Work Being Done Including Location of Work.

INSTALLATION OF MONITORING WELL, SITE #1, FT. LEWIS - WELL DEPTH 38'.

Workmen on Job 2 Name of Contractor's Representative on Job RON HANSEN / CURT COOTS

2. Government Representative's Instructions to Contractor:

24' HIT WATER, DRILLED TO 38', STATIC WATER LEVEL 10'.
PUT IN PVC TO 38', PULLED CASING TO 10', SEALED WITH BENTONITE.

3. Contractor's Remarks: Include difficulties encountered, delays, description of work not installed in accordance with contract requirements and corrective action being taken or planned and future coordination with using agency required.

4a. HOURS:	0800	1200	1500	4b. Percent Complete
Weather	—	CLOUDY, DRIZZLE, COOL	—	
Temperature:				

5a. Inspector's Signature	5b. Signature of Contractor
[signature]	[signature]
Checked by Contract Administrator (Date)	Reviewed by Engineer (Initial) [initials] (Date) 29 [illegible]

6a. Date of Notice to Proceed	6b. Date Started	COMPLETION DATE 6c. ROR BY CONTRACTOR	6d. ESTIMATED
27 APRIL 1981	28 APRIL 1981		

7. Abbreviated Contract Name	8. Contractor
GROUNDWATER MONITORING WELL	TACOMA PUMP & DRILLING

9. Contract No.	Reference No. (if applicable)	Specification No.
DACW-57-81-D-0[illegible]		3744

10. Above report is for DATE:	Report Serial No. 1
28 APRIL 1981	

HFL FORM 1235-FEE
1 Dec 74

Well Ft. Lewis # 1 Drilled Depth ______ Interval Logged 3' – 35.6'

Log Type NAT GAMMA Date 10-25-89 Casing Size 8" carbon steel

Logged By S.P. AIRHART Water Level Depth 13.7'

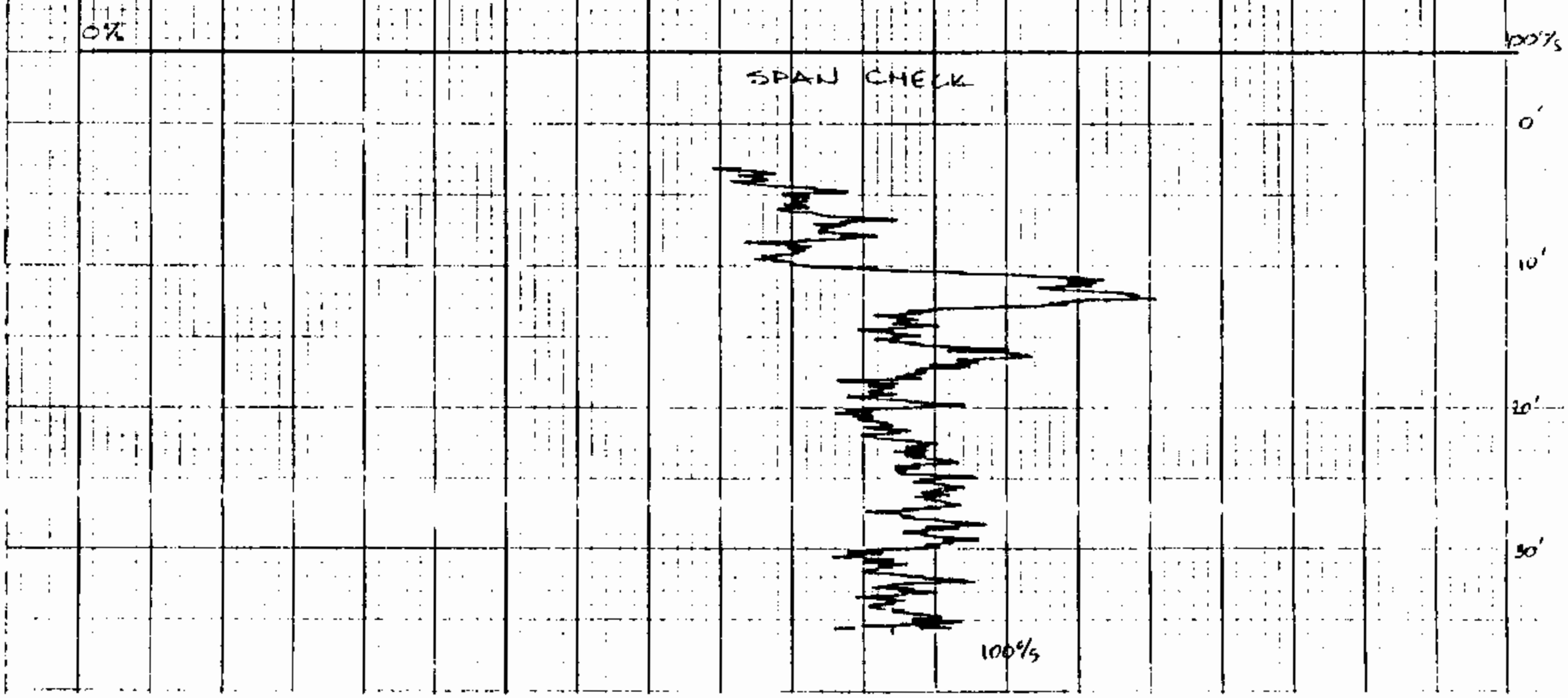
Logging Scales: Sensitivity 100%s Time Constant 9

Vertical Scale 10'/in Logging Speed 15'/min

Source Length NA Spacer Length NA

REF. PROCEDURE GWL REV. 2

PROBE SERIAL # NG-001



DRILL LOG	By: AIRHART Date: 10-27-88	Rig: Bucyrus Erie 22W Denver	Well Number: Well No. 1 Depth: Restoration To	Computer Number: NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled steam-cleaned rig to well - set up	0850	
				D/B inside PVC = 38.45' below land	0900	
				D/B outside PVC = 7.55' below land		
				D/W = 14.30' (E-tape) below land		
				Pulled 8" casing gradually 1.9' - sediment	0950	
				just started caving under shoe - D/B =		
				8.7' below land		
				Added 2/3 bag (50 lb bags) of Med	1030	
				Enviroplug bentonite chips to 7.3' below		
				land. Started pulling casing - noted		
				plug forming		
				Quit pulling casing - trying to break plug	1245	
				out w/ pole - very tight. Managed to		
				penetrate a few holes in plug		
				Cut off 4' of 8" casing. D/B = 8' below	1250	
				land		
				Mixed bentonite slurry - used #8 Enviroplug	1258	
				bentonite w/ water - Mixed a good thick		

REMARKS:

SEP [signature]
10/27/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-85)

DRILL LOG	By: AIRHART Date: 10-27-88	Rig: BE 22W Darrel	Well Number: Well No. 1 Depth: Restoration To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				oatmeal textured batch w/ lots of		
				unhydrated pieces in slurry. Added		
				slurry while pulling casing. Watched		
				level from top of casing w/ light.		
				Added ~ 20 gallons slurry.		
				Pulled remaining 8" casing out of hole.	1340	
				D/slurry = 4' below land. Added 2		
				50 lb bags of Med. Enviroplug bentonite		
				to 1' below land. Set 6" protective		
				casing.		
				Tearing down rig.	1350	

REMARKS:

St P. Airhart
10/27/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A 6000 021 (5 85)

I.19

WELL FORT LEWIS #2

WELL LOG

BY

Tacoma Pump and Drilling Co., Inc.

30316 MOUNTAIN HIGHWAY
GRAHAM, WASHINGTON 98338
PHONE 847 – 6087

DATE STARTED APRIL 29, 81

DATE COMPLETED APRIL 29, 81

Depth 36' Ground Level

Size of Casing 8"

RIG - CABLE ☐ ROTARY ☒

STATIC LEVEL 5' PUMPING LEVEL —

GPM 100+ DRAWDOWN —

SCREEN 4" PVC. PERF.

PERFORATIONS

Drilled for FORT LEWIS # 2

Address

SE 1/4, SE 1/4, SEC 19, T19, R2E

MATERIALS PENETRATED	CASING USED	START	STOP
TOPSOIL		0	3
GRAVEL, CLAY		3	12
GRAVEL, CLAY, (SEEPAGE)		12	16
HARDPAN (SEEPAGE)		16	24
GRAVEL, SAND, WATER		24	36

Other information: 38' OF 4" PERF PVC INSTALLED BOTTOM/16'
PULLED 8" CASING TO 10' G.L.

DRILLER [signature] 0193

DAILY CONTRACT INSPECTION REPORT

NOTE: Contractor fill in Blocks 1, 3, 4a., 5b, 7, 8, 9, and 10 daily or not less than once each week when no work is proceeding. Fill in 4b and 6d each Thursday and more often when appropriate. The Government will fill in the balance of the blanks.

1. Description of Work Being Done Including Location of Work.

INSTALLATION OF MONITORING WELL, SITE #2, FT. LEWIS. -WELL DEPTH 36'.

\# Workmen on Job 2 Name of Contractor's Representative on Job RON HANSEN / GUS COSTS

2. Government Representative's Instructions to Contractor:

DRILLED TO 13', PULLED BIT-WATER AT 6' (SURFACE WATER), ±16' HIT WATER, DRILLED TO 36', STATIC WATER LEVEL 5'+.
PUT IN PVC TO 36', PULLED CASING TO 10', SEALED WITH BENTONITE.

3. Contractor's Remarks: Include difficulties encountered, delays, description of work not installed in accordance with contract requirements and corrective action being taken or planned and future coordination with using agency required.

4a. HOURS:	0800	1200	1500	4b. Percent Complete
Weather / Temperature:	COOL, CLOUDY →	→	SAME THU	

5a. Inspector's Signature	5b. Signature of Contractor
[illegible]	[illegible]
Checked by Contract Administrator (Date)	Reviewed by Engineer (Initial) [illegible] (Date) 30 APR 81

6a. Date of Notice to Proceed	6b. Date Started	COMPLETION DATE 6c. ROR BY CONTRACTOR	COMPLETION DATE 6d. ESTIMATED
22 APRIL 1981	28 APRIL 1981		

7. Abbreviated Contract Name	8. Contractor
GROUNDWATER MONITORING WELLS	TACOMA PUMP & DRILLING

9. Contract No.	Reference No. (if applicable)	Specification No.
DAKF 57-81-D-0BB		3744

10. Above report is for DATE:	Report Serial No.
29 APRIL 1981	2

HFL FORM 1235-FEE
1 Dec 74

Well Ft Lewis Well #2 Drilled Depth ______ Interval Logged 2.6'-33.5'

Log Type NAT GAMMA Date 10-25-88 16:18 Casing Size 8" CARBON STEEL

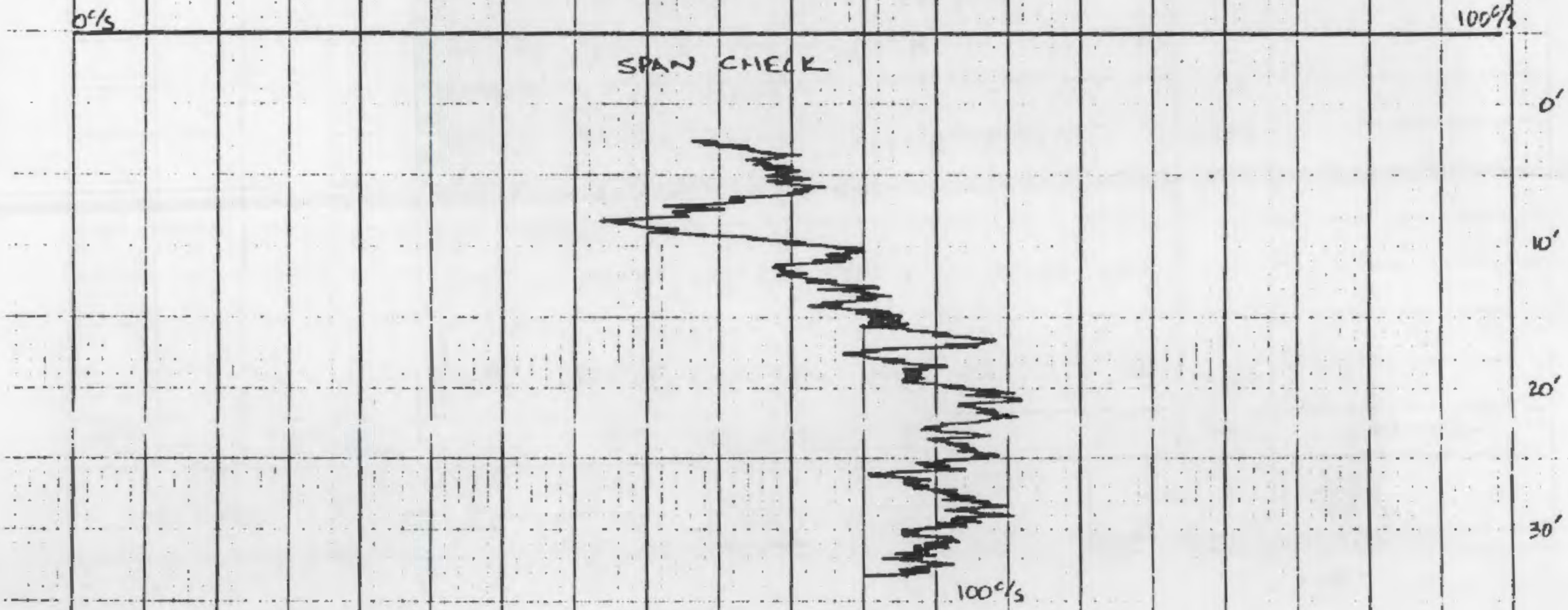
Logged By S.P. AIRHART Water Level Depth 7.8'

Logging Scales: Sensitivity 100 c/s Time Constant 3

Vertical Scale 10'/in. Logging Speed 15'/min.

Source Strength NA. Spacer Length NA

Remarks: REF. PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



page 1 of 1

DRILL LOG	By: AIRHART Date: 10-27-88	Rig: B.E. 22W Darrel	Well Number: Well No. 2 Depth: Restoration To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled Bucyrus Erie 22W cable-tool rig up	14:40	
				to well - set up		
				D/old bentonite outside PVC = 4' below land		
				D/B inside PVC =		
				D/W = 7.9' below land		
				Started pulling casing - old bentonite	15:00	
				dropping while pulling.		
				Mixed #8 Enviroplug bentonite w/ water		
				to form a thick slurry (oatmeal		
				consistency) lots of unhydrated pieces		
				left in slurry - Poured slurry in annulus		
				as 8" casing was pulled back. Pulled		
				remaining 8" casing out of hole.		
				D/slurry = ground surface.		
				Dug down 1' around casing for cement		
				seal. - set 6" protective casing		
				tore down rig, moved off hole.	1650	

REMARKS:

StP. A[illegible]
10/27/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water A 6000 021 (5-85)

WELL FORT LEWIS #3

WELL LOG

BY

Tacoma Pump and Drilling Co., Inc.

30316 MOUNTAIN HIGHWAY
GRAHAM, WASHINGTON 98338
PHONE 847 – 6087

DATE STARTED APRIL 30, 81

DATE COMPLETED APRIL 30, 81

Depth 60' Ground Level

Size of Casing 8"

RIG - CABLE ☐ ROTARY ☒

STATIC LEVEL 26' PUMPING LEVEL –

GPM 60+ DRAWDOWN

SCREEN 4" PERF. PVC.

PERFORATIONS

Drilled for FORT LEWIS # 3

Address

NE 1/4, SW 1/4, SEC 19, T19, R2E

MATERIALS PENETRATED	CASING USED	START	STOP
TOPSOIL		0	5
SAND, GRAVEL, (DRY)		5	15
HARDPAN		15	27
CLAY (BROWN)		27	36
CLAY (GREEN) WATER		36	40
CLAY, LAYERED WITH SAND		40	60

Other Information: 58' OF 4" PERF PVC INSTALLED: BOTTOM/16'
PULLED 8" CASING TO 30' G.L.
WATER COMING THROUGH SAND LENSES IN THE CLAY

DRILLER [signature] 0193

DAILY CONTRACT INSPECTION REPORT

NOTE: Contractor fill in Blocks 1, 3, 4a, 5b, 7, 8, 9, and 10 daily or not less than once each week when no work is proceeding. Fill in 4b and 6d each Thursday and more often when appropriate. The Government will fill in the balance of the blanks.

1. Description of Work Being Done Including Location of Work.

INSTALLATION OF MONITORING WELL, SITE #3, FT. LEWIS - WELL DEPTH 58'.

Workmen on Job 2 Name of Contractor's Representative on Job TOM HANSEN GUS COOK

2. Government Representative's Instructions to Contractor:

38' HIT WATER, DRILLED TO 60', STATIC WATER LEVEL 26'.
PUT IN PVC TO 58', PULLED CASING TO 30', SEALED WITH BENTONITE.

3. Contractor's Remarks: Include difficulties encountered, delays, description of work not installed in accordance with contract requirements and corrective action being taken or planned and future coordination with using agency required.

4a. HOURS:	0800	1200	1500	4b. Percent Complete
Weather	CLOUDY, WARM, SUN		CLOUDY, RAIN, COOL	.75%
Temperature:				

5a. Inspector's Signature	5b. Signature of Contractor
[signature]	[signature]
Checked by Contract Administrator (Date)	Reviewed by Engineer (Initial) [initials] (Date) 1 May 81

6a. Date of Notice to Proceed	6b. Date Started	COMPLETION DATE 6c. ROR BY CONTRACTOR	6d. ESTIMATED
22 APRIL 1981	28 APRIL 1981		

7. Abbreviated Contract Name	8. Contractor
GROUNDWATER MONITORING WELL	TACOMA RIVER DRILLING

9. Contract No.	Reference No. (if applicable)	Specification No.
DACW-67-81-D-0083		3744

10. Above report is for DATE:	Report Serial No.
30 APRIL 1981	3

HFL FORM 1235-FEE
1 Dec 74

DRILL LOG	By: AIRHART	Rig: Bucyrus Erie 22W	Well Number: FORT LEWIS WELL #3	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-13-88	ONWEGO	Depth: ABANDONMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Measurements taken w/ steel tape # L30001		
				1. top of PVC 21'1¼" + 2'2½" = 23' 3¾" below carbon steel casing		
				to/bottom outside PVC 26'2½" + 2'2½" = 28'5"	"	" "
				to bottom inside PVC = 39'10¾" + 2'2½" = 42'1¼"	"	" "
				Pulled Bucyrus Erie 22W rig up to well, set		
				up. (rig was steam cleaned prior		
				to this)		
				22" to notch in casing to 2x4 on ground		
				Started bailing inside PVC w/ 3' dia	1250	
				dual bailer		
				Water is gray color and very turbid - it		
				also smells very strong (sewer smell) -		
				pieces of wood, hair (mouse hair ?), and decomposed		
				tissue (?) is found floating in water. Also		
				bailed a 3' long stick out of PVC.		

REMARKS:

S.P. [signature] 10/13/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (6-85)

I.28

DRILL LOG	By: AIRHART Date: 10-13-88	Rig: Bucyrus Eric 22W	Well Number: FORT LEWIS WELL #3 Depth: ABANDONMENT TO	Computer Number: NA	Project or Work Order No.: 11332 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				checked inside well w/ HNU 10.2 & 11.7 eV		
				probes - @ first appeared to have response w/		NOTE: casing is
				11.7 probe - checked again - no apparent		2' above land
				response.		surface
				Made up fishing tool w/ 4" core barrel	15:05	
				to fish out PVC		
				Successfully Fished out all of the	15:40	
				PVC out of hole - there is a		
				greenish - slimy substance (probably		
				bentonite) on entire length of PVC.		
				33' b.l.s. D/8 ~ 35' From top of casing - hole caved in when PVC was pulled		
				Added 3 50 lb. bags of Enviroplug Med.		
				bentonite chunks to 24'8" below top of casing 22'8" b.l.s.		
				Welding puller-head on 8" casing	16:30	
				Pulled ~ 6" of 8" casing		
				Added 3 50 lb. bags Enviroplug Med. bent. to 18' b.l.s.	16:50	

REMARKS:

b.l.s. = below land surface

[illegible signature] 10/13/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A 6000 021 (5 85)

Pg [illegible] of 3

DRILL LOG	By: AIRHART	Rig: B.E. 22W ONWEGO	Well Number: FORT LEWIS WELL #3	Computer Number: NA	Project or Work Order No.: 11837
	Date: 10-13-88		Depth: ABANDONMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
					16:55	Resumed pulling
				Pulled casing to ~ 24' below land (based		
				on our estimate of pipe length @ 30')		
				D/bentonite = 20' below land		
				Added 4 50 lb. bags of Enviroplug Med. bentonite	17:23	
				to 18' below land		
				Pulled casing to 20.5' below land		
				D/bent = 15' below land	17:35	
				Pulled casing to 19' below land	17:50	
				D/bent = 17' below land	17:55	
					19:00	Shut Down

REMARKS:

St D [illegible]
10/13/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-85)

I.29

page 1 of 2

DRILL LOG	By: AIRHART	Rig: Bucyrus Erie 22W	Well Number: FORT LEWIS WELL # 3	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-14-88	OWNED NO	Depth: ABANDONMENT TO		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 3 50 lb. bags of Enviroplug Med	07:30	
				bentonite to 11'		
				Pulled 8" casing to ~13' below land	0750	NOTE: Measured
				D/bent. = 13' below land (no cave)	0752	1st section of
						8" casing pulled
				Added 4 50 lb bags of Enviroplug Med. bent.	0755	out @ 12'3".
				to 6' below land		
				Pulled 8' casing to 9½' below land	0812	
				D/bent = 6½' below land	0815	
				Added 1 50 lb bag of Enviroplug Med bent.	0818	
				to 4½' below land		
				Adding 2' on to original estimate of		
				casing length (∴ 32' total length) Have		
				pulled 8" casing to 8½' below land		
				D/bent = 5½' below land	0836	
				Pulled 8" casing to 6'1" below land		
				D/bent = 6'2" below land	0850	

REMARKS:

StP. [signature] 10/14/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000 021 (6-85)

page 2 of 2

DRILL LOG	By: AIRHART	Rig: B.E.-22W ONWEGO	Well Number: FORT LEWIS - WELL #3	Computer Number: NA	Project or Work Order No.: [illegible]
	Date: 10-14-88		Depth: ABANDONMENT To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
8				Mixed 300 lbs Tilbury Type IP Portland-	15:30	
				Pozzolan cement and ~ 15 lbs -40 + 100		
				mesh BigHorn bentonite w/ ~ 30 gallons clean		
				water to make neat cement slurry.		
				Poured slurry to + 3' above land inside		
				8" casing		
				Pulled remaining 8" casing out of hole	15:50	
				(10' 4" section) w/ drive shoe		
1				Slurry settled out @ ground surface	16:05	
				Set 6' section of 6" dia carbon steel		
				casing (w/ 3' of stickup) inside slurry		

REMARKS:

[signature]
10/14/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A 6000 021 (5-85)

WELL FORT LEWIS #4

WELL LOG

BY

Tacoma Pump and Drilling Co., Inc.

30316 MOUNTAIN HIGHWAY
GRAHAM, WASHINGTON 98338
PHONE 847 - 6087

DATE STARTED APRIL 30, 81

DATE COMPLETED MAY 1, 81

Depth 98' Ground Level

Size of Casing 8"

RIG - CABLE ☐ ROTARY ☒

Drilled for FORT LEWIS # 4

STATIC LEVEL 22' PUMPING LEVEL —

Address

GPM 10+ DRAWDOWN —

SW 1/4, NE 1/4, SEC 19, T19, R2E

SCREEN 4" PERF PVC

PERFORATIONS

MATERIALS PENETRATED	CASING USED	START	STOP
TOPSOIL	0	0	4
GRAVEL, ROCK		4	12
SAND GRAVEL (DRY)		12	22
HARDPAN	—	22	31
SAND GRAVEL (WATER)		31	52
CLAY (DRY)		52	78
CLAY, SAND, (WET)		78	98

Other information: 55' OF 4" PVC INSTALLED BOTTOM/16'
PULLED 8" CASING TO 18' G.L.
WATER FLOW 32 - 38' SEEPAGE
38 - 52' 10-30 GPM

DRILLER [signature] 093

DAILY CONTRACT INSPECTION REPORT

NOTE: Contractor fill in Blocks 1, 3, 4a, 5b, 7, 8, 9, and 10 daily or not less than once each week when no work is proceeding. Fill in 4b and 6d each Thursday and more often when appropriate. The Government will fill in the balance of the blanks.

1. Description of Work Being Done Including Location of Work.

INSTALLATION OF MONITORING WELL, SITE #4, FT. LEWIS

Workmen on Job 2. Name of Contractor's Representative on Job JON HANSEN / GUS LEWIS

2. Government Representative's Instructions to Contractor:

31' HIT WATER, NOT GOOD FLOW TO ± 50'. 52'-77' NO WATER (BLUE-GREY CLAY)
78'-98' WATER BUT NOT SUITABLE. DECIDED TO PULL BACK TO ± 50' WHERE THERE WAS SOME GOOD WATER (ON TOP OF CLAY) BUT NO GREAT FLOW.

3. Contractor's Remarks: Include difficulties encountered, delays, description of work not installed in accordance with contract requirements and corrective action being taken or planned and future coordination with using agency required.

4a. HOURS:	0800	1200	1500	4b. Percent Complete
Weather	CLOUDY, COOL, CHILLY, DRIZZLE	→	CLOUDY, COOL, DRIZZLE, SUN	
Temperature:				

5a. Inspector's Signature	5b. Signature of Contractor
[signature]	[signature]
Checked by Contract Administrator (Date)	Reviewed by Engineer (Initial) [initials] (Date) [date]

6a. Date of Notice to Proceed	6b. Date Started	COMPLETION DATE 6c. ROR BY CONTRACTOR	6d. ESTIMATED
22 APRIL 1981	28 APRIL 1981		

7. Abbreviated Contract Name	8. Contractor
GROUNDWATER MONITORING WELLS	TACOMA PIPE & DRILLING

9. Contract No.	Reference No. (if applicable)	Specification No.
DAKF-57-81-D-0088		5144

10. Above report is for DATE:	Report Serial No.
1 MAY 1981	4

HFL FORM 1235-FEE
1 Dec 74

Well Ft. Lewis #4 Drilled Depth ______ Interval Logged 2.8' - 44.6'

Log Type NAT. GAMMA Date 10-25-88 16:50 Casing Size 8" CARBON STEEL

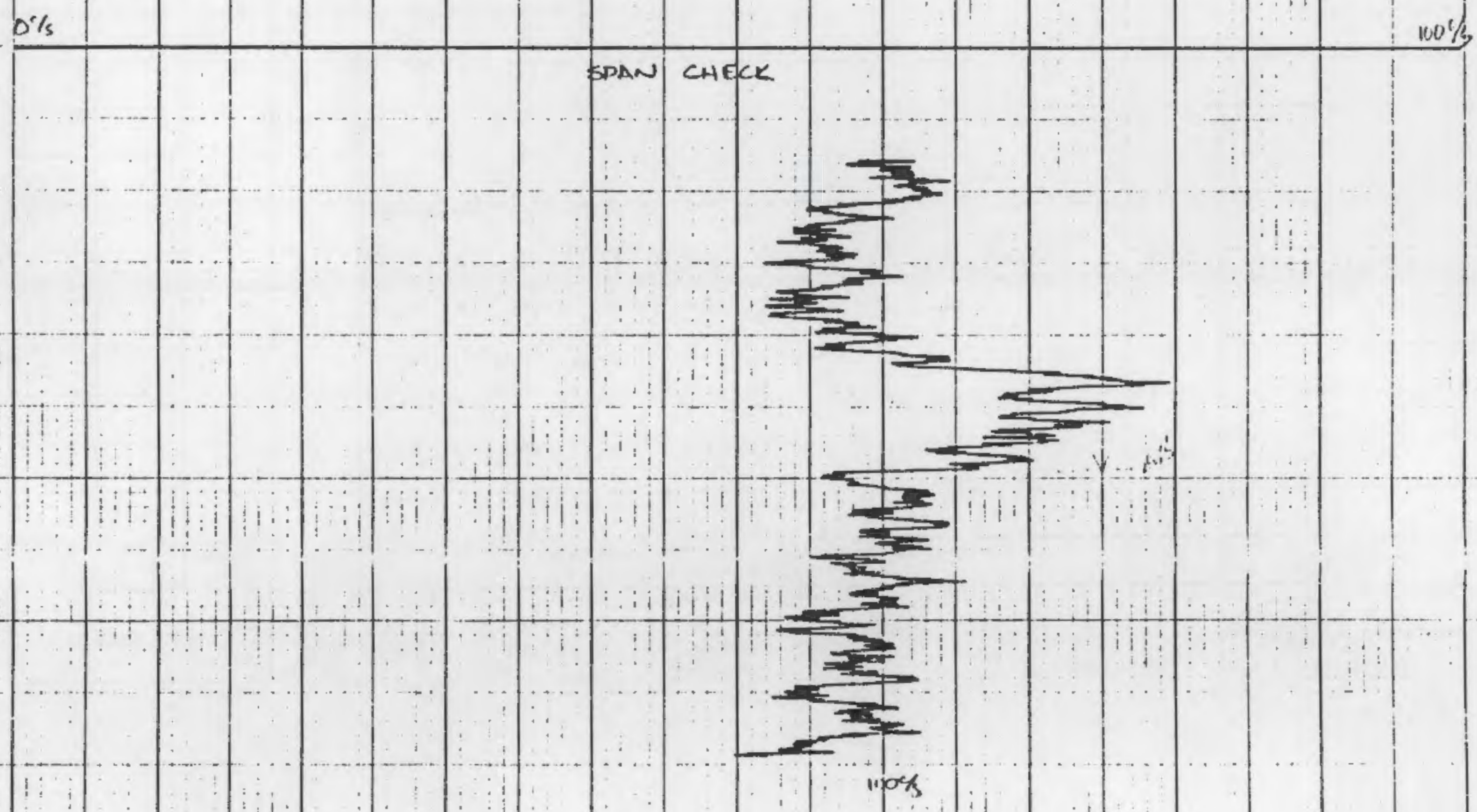
Logged By S.P. AIRHART Water Level Depth 24.3'

Logging Scales: Sensitivity 100c/s Time Constant 3

Vertical Scale 10'/in Logging Speed 5'/min.

Source Strength NA Spacer Length NA

Remarks: REF. PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



I.35

DRILL LOG	By: AIRHART Date: 10-27-88	Rig: BE 22W Darrel	Well Number: Well No. 4 Depth: RESTORATION To	Computer Number: NA	Project or Work Order No.: 11832 Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Took 2 photos of well	1745	
				D/B outside PVC casing (dry - very little	1750	
				bentonite seal) = 16.8' below land surface		
				D/B inside PVC = 46' below land surface		
				D/W = 24.6' below land surface		
				Pulled Bucyrus Erie 22W rig to hole -	1800	
				setting up.		

REMARKS:

StP. [illegible]
10/27/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000 021 (5-85)

I.36

DRILL LOG	By: AIRHART	Rig: BE 22W Darrel	Well Number: Well No. 4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-29-89		Depth: RESTURATION TO		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Welded on puller-head	0730	
				Started pulling 8" casing. Pulled	0800	
				casing up ~ 1'. D/B = 19' below land		
				Added 1/4 50 lb. bag of Enviroplug	0820	
				med bentonite to 17.5' below land		
				Added 15 50 lb. bags of Enviroplug Med.		
				bentonite & 4 50 lb. bags of Enviroplug		
				No. 8 bentonite. Gained only 1' - large		
				Void (18' below land)		
				Added 5 50 lb. bags of Baroid		
				coarse bentonite hole plug to 11' below		
				land.		
				Pulled 8" casing to 12'6" below land -	1500	
				D/bent. = 13' below land		
				Added 1 50 lb. bag hole plug to 10'	1530	
				below land - pipe pulling hard.		
				Added 4 more bags hole plug to	1630	
				ground surface while pulling		

REMARKS:

StP. A[illegible]
10/29/89

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

1.37

DRILL LOG	By: AIRHART	Rig: BE 22W	Well Number: Well No. 4	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-29-88	Darrel	Depth: RESTORATION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Added 1.5 more bags hole plug - pulled	1700	
				remaining 8" casing out of hole.		
				D/bent. = land surface		
				Set 6" protective casing around PVL -	1720	
				dug down 6" around protective		
				casing for concrete.		

REMARKS:

StPA [signature]
10/29/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

A-6000-021 (5-85)

WELL FORT LEWIS #11

WELL LOG
BY
Tacoma Pump and Drilling Co., Inc.

30316 MOUNTAIN HIGHWAY
GRAHAM, WASHINGTON 98338
PHONE 847 – 6087

DATE STARTED MAY 12, 81
DATE COMPLETED MAY 12, 81
Depth 44' Ground Level
Size of Casing 8"
RIG - CABLE ☐ ROTARY ☒
STATIC LEVEL 19' PUMPING LEVEL —
GPM 100+ DRAWDOWN —
SCREEN 4" PERF PVC
PERFORATIONS

Drilled for FORT LEWIS # 11

Address

MATERIALS PENETRATED	CASING USED	START	STOP
TOPSOIL		0	5
GRAVEL, CLAY		5	12
HARDPAN		12	25
HARDPAN (SEEPAGE)		25	30
SAND GRAVEL WATER		30	44

Other Information: 46' OF 4" PVC INSTALLED BOTTOM/16' PERF
PULLED 8" CASING TO 17' G.L.

DRILLER [illegible] 0193

DAILY CONTRACT INSPECTION REPORT

NOTE: Contractor fill in Blocks 1, 3, 4a, 5b, 7, 8, 9, and 10 daily or not less than once each week when no work is proceeding. Fill in 4b and 6d each Thursday and more often when appropriate. The Government will fill in the balance of the blanks.

1. Description of Work Being Done Including Location of Work.

INSTALLATION OF MONITORING WELL, SITE # 11, FT. LEWIS - WELL DEPTH 44'

INSTALLATION (COMPLETION) OF MONITORING WELL, SITE # 4, FT. LEWIS - WELL DEPTH ~~48'~~ 53'

Workmen on Job 2   Name of Contractor's Representative on Job JON HANSEN / GUS COSTS

2. Government Representative's Instructions to Contractor:

#11 +25' HIT WATER, DRILLED TO 44', STATIC WATER LEVEL 19'.
PUT IN PVC TO 44', PULLED CASING TO 17', SEALED WITH BENTONITE.

#4 31' HIT WATER, DRILLED TO 98', PULLED EVERYTHING BACK TO 48', STATIC WATER LEVEL 22'.
PUT IN PVC TO ~~48'~~ 53', PULLED CASING TO 18', SEALED WITH BENTONITE

3. Contractor's Remarks: Include difficulties encountered, delays, description of work not installed in accordance with contract requirements and corrective action being taken or planned and future coordination with using agency required.

4a. HOURS:	0800	1200	1500	4b. Percent Complete
Weather				100 %
Temperature:				

5a. Inspector's Signature	5b. Signature of Contractor
Sharon E. Klinter	[signature]
Checked by Contract Administrator (Date)	Reviewed by Engineer (Initial) [initials] (Date) 13 May 81

6a. Date of Notice to Proceed	6b. Date Started	COMPLETION DATE 6c. ROR BY CONTRACTOR	6d. ESTIMATED
22 APRIL 1981	28 APRIL 1981		

7. Abbreviated Contract Name	8. Contractor
GROUNDWATER MONITORING WELLS	TACOMA PIPE & DRILLING

9. Contract No.	Reference No. (if applicable)	Specification No.
DAKF-57-81-C-0088		3744

10. Above report is for DATE:	Report Serial No.
12 MAY 1981	10

HFL FORM 1235-FEE
1 Dec 74

Well FT. LEWIS #11 Drilled Depth ______ Interval Logged 1.4'-41.6'

Log Type NAT. GAMMA Date 10-25-88 14:15 Casing Size 8" carbon steel

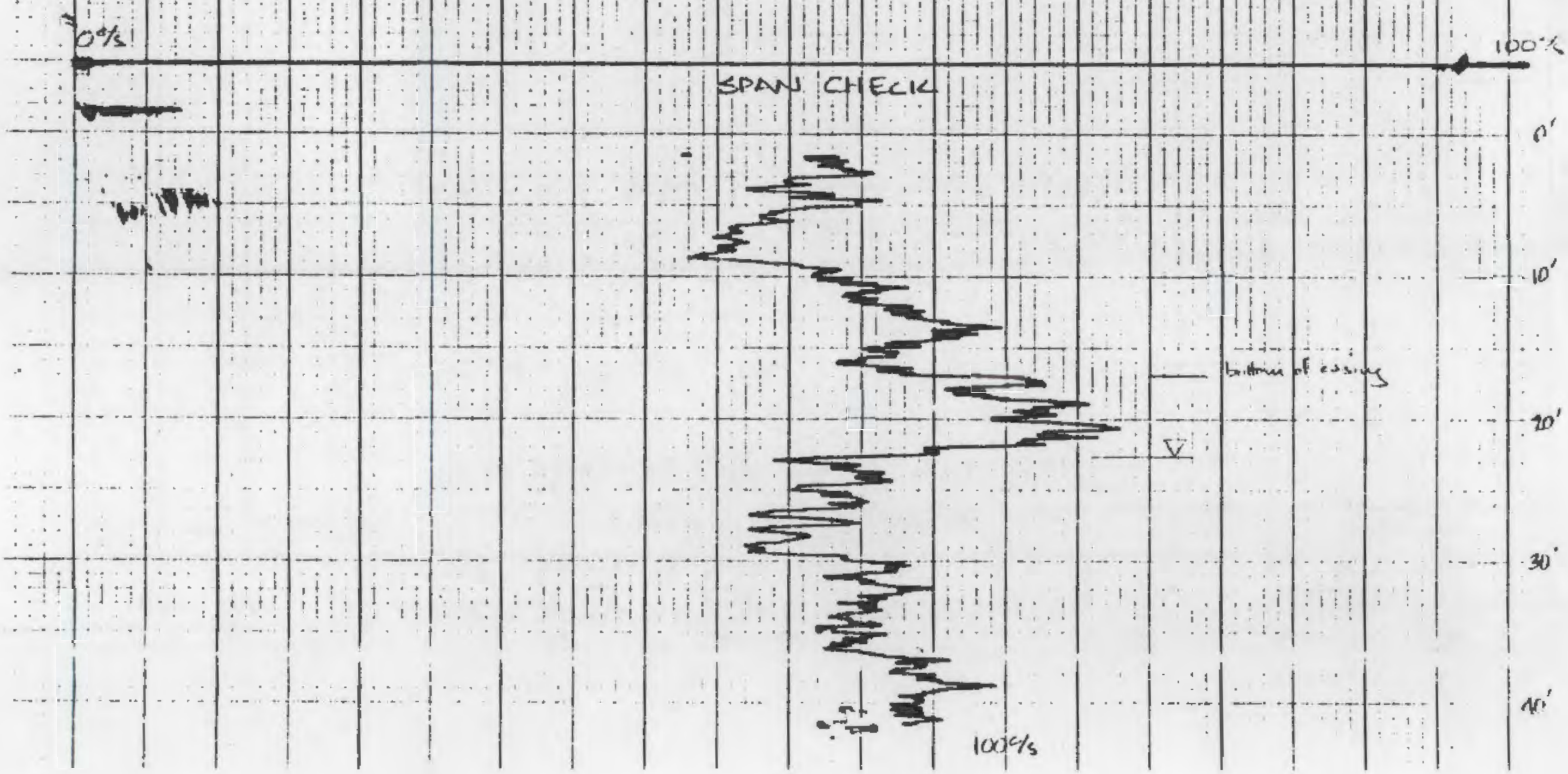
Logged By S.P. AIRHART Water Level Depth 23'

Logging Scales: Sensitivity 100c/s Time Constant 3

Vertical Scale 10'/in Logging Speed 15'/min

Source Strength NA Spacer Length NA

Remarks: REF. PROCEDURE GW-6 REV. 2
PROBE SERIAL # NG-001



I.41

DRILL LOG	By: S.P. AIRHART	Rig: Bucyrus Erie 22W	Well Number: Well NO. 11	Computer Number: NA	Project or Work Order No.: 11832
	Date: 10-25-88	Darrel Luelthe	Depth: Restoration To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Pulled steam-cleaned rig to well + set up		
				Logged hole w/ Nat. γ probe (1.4'-41.6')		
				D/B inside PVC = 41.7' below land		
				D/B outside PVC = 8.5' (bentonite on steel weight)		
				D/W = 22.5' below land (E-tape # 12175)		

REMARKS:

StPAirhart
10-25-88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water

DRILL LOG	By AIRHART Date 10-26-88	Rig B.E. 22W Darrel	Well Number Well No. 11 Depth Restoration To	Computer Number NA	Project or Work Order No. 11832 Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Took photos of well	0740	
				Welding on puller-head	0830-0840	
				Began pulling 8" casing - straight-lining.	0900	
				Pulled 7' - Noticed that a plug is coming		
				up w/ casing - Poked plug w/ rod -		
				Found bentonite slurry & gravel on end		
				of rod - vibrating casing to loosen plug -		
				Plug is dropping slowly.		
				Pulled 8" casing to 8' below land	1025	
				D/old bentonite = 9' below land		
				Added 2½ 50 lb bags of Med. Enviroplug	1030	
				bentonite chunks to +1.5' above land.		
				Added 2 50 lb bags around outside of 8"		
				casing to surface.		
				Pulled remaining 8" casing out of hole.		
				Noticed protective cap was off PVC. Checked		
				D/B inside PVC. D/B = 12' ∴ we know		
				bentonite spilled inside PVC.		

REMARKS:

St P. A[illegible]
10/26/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ____ Standing Water A-6000-021 (5-85)

DRILL LOG	By: AIRHART	Rig: B.E. 22W	Well Number: Well No. 11	Computer Number: N/A	Project or Work Order No.: 11832
	Date: 10-26-88	Darrel	Depth: RESTORATION To		Subcontract No.: NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Tried poking through bentonite plug w/	1230	
				heavy bar - unsuccessful.		
				Drillers rented a "contractor pump"		
				(centrifigal pump) w/ 200 gallon tank.		
				All equipment was steam cleaned		
				Washed out bentonite plug by jetting.		
				Drillers noted ~ 2' of plug washed out of		
				hole. Therefore most of bentonite		
				chunks fell in annulus and not in PVC.		
				NOTE: 4" PVC was lifted up ~ 8'		
				before bentonite was washed out.		
				Initially we were going to remove PVC and		
				abandon hole however it was decided		
				to rent pump - blow out bentonite - and		
				salvage hole.		
				checked D/B @ 31' below land. Bailed well	1545-1645	
				w/ 2" dia. dart bailer for ~ 1 hr. Noted small		
				amount of bentonite on end of bailer. Also		

REMARKS: noted milky color to water. Will set 1/3 h.p. pump for further clean-up.

SEP. [signature]
10/26/88

D - Drive Barrel H - Hard Tool L - Large M - Medium S - Small VC - Very Coarse C - Coarse F - Fine VF - Very Fine ___ Standing Water

A-6000.021 (5-85)

DRILL LOG	By AIRHART	Rig BEZZW	Well Number Well No. 11	Computer Number NA	Project or Work Order No. 11832
	Date 10-26-88	Darrel	Depth Restoration To		Subcontract No. NA

Total Casing	Depth	Drill Method	Wet/Dry Sample	LITHOLOGIC DESCRIPTION % Each Grain Size, Color, Roundness, Caliche, Etc.	Time	Drilling Comments
				Set 6" protective casing. Added 3 more	1700	
				50 lb. bags of Med. bentonite chunks		
				for remaining surface seal.		

REMARKS:

StP. Airhart
10/26/88

D - Drive Barrel   H - Hard Tool   L - Large   M - Medium   S - Small   VC - Very Coarse   C - Coarse   F - Fine   VF - Very Fine   ____ Standing Water

A 6000 021 (5 85)

APPENDIX J

<u>GROUND-WATER SAMPLE ANALYSES PROCEDURES</u>

APPENDIX J

GROUND-WATER SAMPLE ANALYSES PROCEDURES

This appendix lists procedures used to analyze ground-water samples from landfill wells for various constituents and the procedure used in obtaining ground-water samples from wells near Landfills 1 and 4. The notation PNL-580 in the procedure refers to Environmental Monitoring Procedures (PNL 1990).

am test inc.
14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle DATE REPORTED: 11/4/88

REPORT TO: Paul Eddy
P.O. Box 999
Richland, WA 99352

PARAMETER	EPA/STANDARD METHODS
pH	EPA 150.1
Pesticides + Herbicides & PCB's	EPA 608
Conductivity	EPA 120.1
Coliform	Standard Method 909
Oil & Grease	EPA 413.2
Total Organic Halides	EPA 450.1
Volatile Organic Aromatics	EPA 601
Total Dissolved Solids	EPA 160.1
Total Organic Carbon	EPA 415.2
Metals	EPA 200.7
Cyanide	EPA 335.3
Chloride, Fluoride, Nitrate, Sulfate	EPA 300.1
Phenol	EPA 420.1

REPORTED BY John T. Dailey
John T. Dailey

JTD/pb

Sample Collection Using the Hydrostar Pump

Upon arrival at the well head, immediately determine depth-to-water using the appropriate tapes, and record the determined values on the field record form.

Wear gloves when taking samples and when handling containers, especially those with added preservative.

Attaching the Pneumatic Cylinder Assembly

1. Insert the support for the pneumatic cylinder into the column support on the well head assembly* (Figure 1).
2. Pull the cylinder rod down until it is fully extended and has stopped.
3. Align the eyelet on the top portion of the turnbolt with the clevis pin hole on the lower portion of the cylinder rod.
4. Align the hole on the cylinder support with the column support on the well head so that the turnbolt eyelet and clevis pin hole on the cylinder rod are aligned when the piston is fully extended.
5. Insert the clevis pin through one of the intersecting pairs of holes on the column support and clip a hitch pin into the holes in the small end of the clevis pin.
6. Check the alignment on the turnbolt eyelet with the hole on the cylinder rod. The alignment must be nearly perfect, neither too high nor too low.
7. Adjust by rotating the turnbolt clockwise or counterclockwise.

* When inserting the cylinder support into the column support on the pump assembly, at least two holes on the cylinder support must overlap with two holes on the column support. If less than two holes overlap use the extension supplied with the Hydrostar pneumatic cylinder. Align the pumping system in the same manner as described above.

Operating the Pneumatic Cylinder

1. Attach either the purging hose (large diameter) or the teflon sampling hose to the outlet on the discharge tee of the sampling pump.

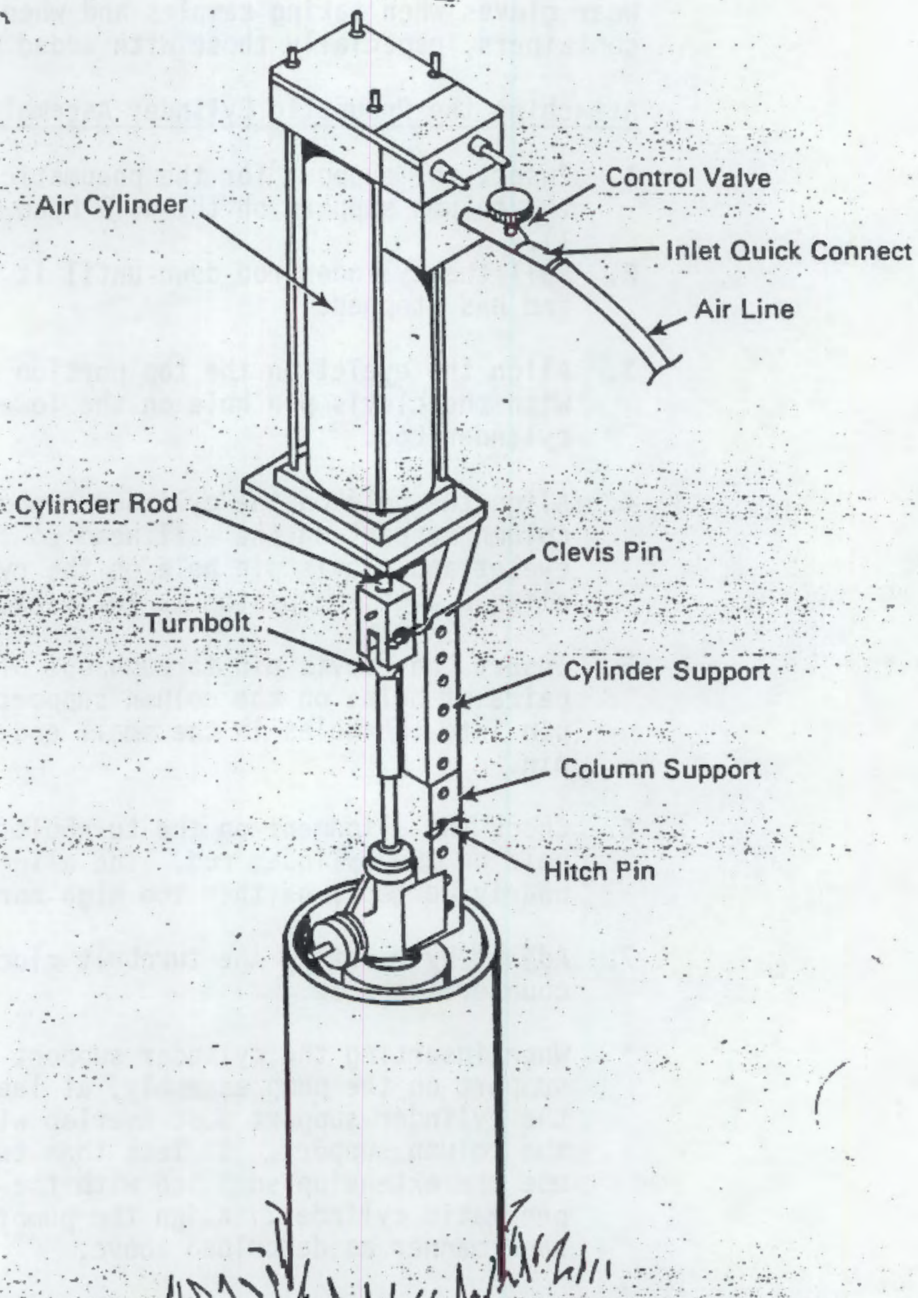

Control Valve
Air Cylinder
Inlet Quick Connect
Air Line
Cylinder Rod
Clevis Pin
Turnbolt
Cylinder Support
Column Support
Hitch Pin

FIGURE 1.

2. Attach the quick-connect on the supply hose to the unattached end of the control valve on the pneumatic cylinder. The input air pressure should not exceed 120 psi.

3. Turn air supply on to the control valve.

4. Turn on the control valve on the pneumatic cylinder. The piston will begin to operate.

5. Adjust stroke rate to no more than 60 per minute*. The stroke speed of the pneumatic cylinder can be adjusted with the control valve located on the top of the pneumatic cylinder. A stroke is defined as one downward and one upward extension.

* If the pneumatic cylinder assembly is not operating correctly, and the problems are not due to the well or the pump in the well, the well may be hand pumped as described in "Manual Operation."

<u>Sampling With Pneumatic Piston Assembly</u>

1. Slow down the pumping rate until the piston operates smoothly. This rate will be less than 10 strokes a minute.

2. Attach the Teflon sampling hose and purge at this rate for a minimum of two minutes.

3. Proceed with sampling all unfiltered samples according to PNL-580.

4. Attach the filter assembly and purge the filter according to directions listed in PNL-580. If too much pressure is exerted across the filter the membrane will rupture, usually resulting in a popping noise. If this happens, replace the filter and restart the filtering procedure.

5. Dismantle the pneumatic pumping assembly as described below.

<u>Removing the Pneumatic Pumping Assembly</u>

1. Disconnect the air supply at the pneumatic cylinder.

2. Disassemble pneumatic cylinder in reverse order of steps 1 through 7 in the section "Attaching Pneumatic Cylinder Assembly."

3. Replace well cap over top of well head.

Manual Operations

1. Insert the handle support into the column support on the pump head assembly so that at least two holes on the handle support overlap with two holes on the column support (Figure 2).

2. Slide the clevis pin through one of the intersecting pairs of holes on the column support.

3. Clip the hitch pin into the hole in the small end of the clevis pin.

4. Remove the turnbolt on the top of the rod at the well head.

5. Attach the turnbolt on the end of the wire rope attached to the handle assembly onto the threaded rod at the top of the well head.

6. Lift the handle so that the flat edge of the cam nearest the shackle is approximately parallel with the ground.

7. Pull all the slack out of the wire rope.

8. Using either an adjustable or 9/16" open end wrench, tighten both nuts on the shackle until the sheath on the wire rope is compressed. Remembering to keep all the slack out of the wire rope.

Manual Well Sampling

1. Attach either the purging hose (large diameter) or the Teflon sampling hose (small diameter) to the outlet on the discharge tee of the sampling pump.

2. Begin pumping the operating handle with smooth, even strokes. For best performance, use 20 to 45 strokes per minute for purging the well. Use less than 10 strokes per minute during sampling. When the filter assembly is attached, special attention is required to prevent rapid build up of pressure across the filter. If too much pressure is exerted across the filter the membrane will rupture, usually resulting in a popping noise. If this happens, replace the filter and begin sampling for the filtered sample according to the written procedure.

3. When sampling is completed follow the direction below to disassemble the handle assembly from the well head.

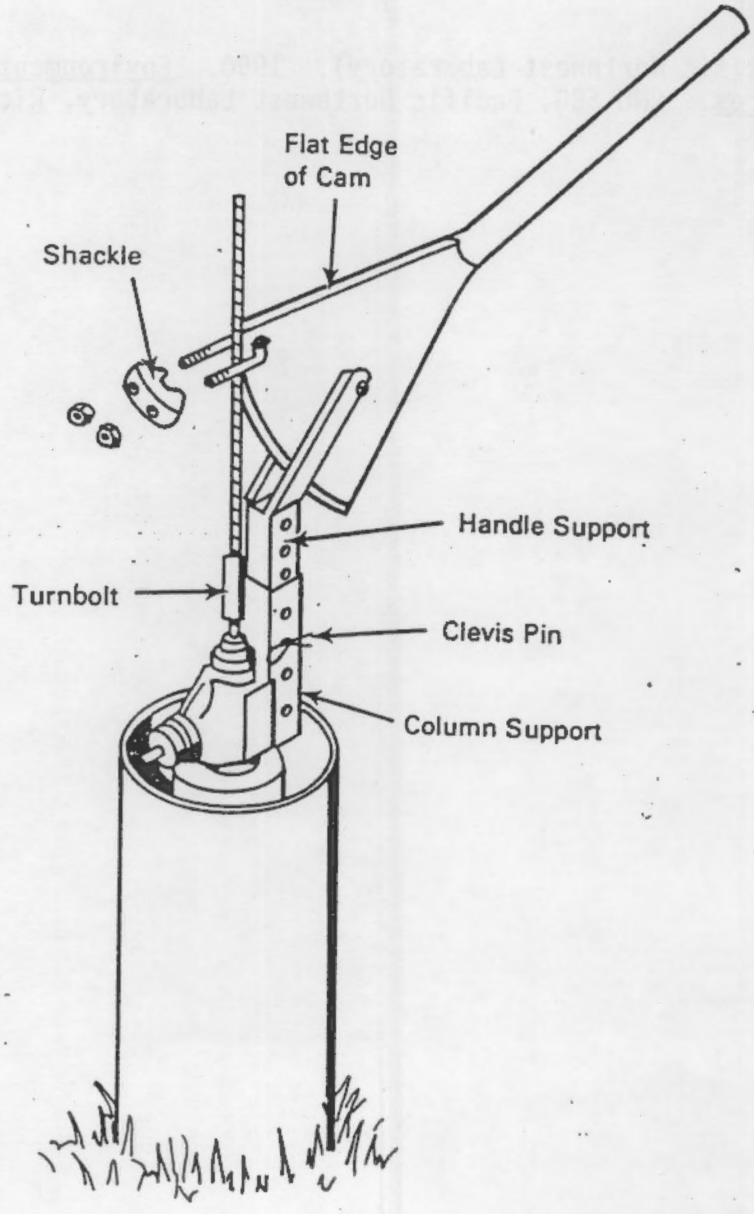

Flat Edge
of Cam
Shackle
Handle Support
Turnbolt
Clevis Pin
Column Support

Figure 2

Removing the Handle Assembly

Disassemble the handle assembly in reverse order of steps 1 through 8 in the section "Manual Operation."

REFERENCE

PNL (Pacific Northwest Laboratory). 1990. Environmental Monitoring Procedures. PNL-580, Pacific Northwest Laboratory, Richland, Washington.

APPENDIX K

GROUND-WATER SAMPLE ANALYSES RESULTS

APPENDIX K

GROUND-WATER SAMPLE ANALYSES RESULTS

This appendix contains the results of ground-water sample analyses for wells at Landfills 1 and 4.

Fort Lewis Quality Control Samples Identifiers

Late August Sampling Event

LFA-PNLA-----------------------------------Duplicate of LF1-PNL1
LFA-PNLB-----------------------------------Blank Sample
LFA-PNLC-----------------------------------USGS T103 Trace Element Std

Early September Sampling Event

LF1-PNL4-----------------------------------Duplicate Sample Taken

Early October Sampling Event

No QC Samples Taken

Late October Sampling Event

LF4-PNL4-----------------------------------Duplicate Sample Taken

Middle December Sampling

LF1-PNL5-----------------------------------Duplicate of LF1-PNL1
LF1-PNL6-----------------------------------Blank Sample
LF4-PNL7-----------------------------------USGS M1D0 Std

am test inc.
14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle

DATE REPORTED: 11/4/88

REPORT TO: Paul Eddy
P.O. Box 999
Richland, WA 99352

PARAMETER	EPA/STANDARD METHODS
pH	EPA 150.1
Pesticides + Herbicides & PCB's	EPA 608
Conductivity	EPA 120.1
Coliform	Standard Method 909
Oil & Grease	EPA 413.2
Total Organic Halides	EPA 450.1
Volatile Organic Aromatics	EPA 601
Total Dissolved Solids	EPA 160.1
Total Organic Carbon	EPA 415.2
Metals	EPA 200.7
Cyanide	EPA 335.3
Chloride, Fluoride, Nitrate, Sulfate	EPA 300.1
Phenol	EPA 420.1

REPORTED BY J. T. Dailey
John T. Dailey

JTD/pb

AM Test Analytical Results From Late
August, 1988 Sampling Event

am test inc.

14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy
P.O. Box 999
Richland, WA 99352

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	816809	816810	816811
Client Identification	LF1-PNL1	LF4-PNL1	LF4-PNL3
pH	6.35	6.25	6.20
Specific Conductance (umhos/cm @ 25°C)	310.	390.	138.
Total Coliform (MPN/100 ml)	220.	1,600.	17.
Oil & Grease (mg/l)	<1.4	<1.3	8.4
Total Organic Halides (ug/l as Cl⁻)	<10.	18.0	44.0
Gross Beta (pCI/L)	<2.	<2.	<2.
Radium (pCI/L)	<1.	<1.	<1.
Gross Alpha (pCI/l)	<1.	<1.	<1.
Total Dissolved Solids (mg/l)	418.	295.	524.
Total Organic Carbon (mg/l)	3.33	3.27 2.75]	1.14
Chloride (mg/l)	4.89	15.6	4.20 3.99]
Phenol (mg/l)	<0.008	<0.008	<0.16
Nitrate - Nitrogen (mg/l)	2.62	<0.01	0.771 0.751]
Fluoride (mg/l)	<0.10	<0.10	<0.10 <0.10]

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	816809	816810	816811
Client Identification	LF1-PNL1	LF4-PNL1	LF4-PNL3
Sulfate (mg/l)	61.6	11.2	11.4 10.4
Cyanide (mg/l)	<0.006	<0.006 <0.006	<0.006

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	816812	816813
Client Identification	LFA PNLA	LFA PNLB
pH	6.64	6.61
Specific Conductance (umhos/cm @ 25°C)	310.	81.0
Total Coliform (MPN/100 ml)	140.	<1.8
Oil & Grease (mg/l)	<2.9	<2.8
Total Organic Halides (ug/l as Cl^-)	<10.	<10. <10.
Gross Beta (pCI/L)	<2.	<2.
Radium (pCI/L)	<1.	<1.
Gross Alpha (pCI/l)	<1.	<1.
Total Dissolved Solids (mg/l)	298.	52.
Total Organic Carbon (mg/l)	3.45	1.43
Chloride (mg/l)	4.95	1.70
Phenol (mg/l)	<0.016	<0.016
Nitrate - Nitrogen (mg/l)	2.84	0.343
Fluoride (mg/l)	<0.10	<0.10
Sulfate (mg/l)	27.2	10.3
Cyanide (mg/l)	<0.006	<0.006

*Results to follow.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

SPIKE RECOVERIES

Parameter	Sample Number	Spike Conc. (mg/l)	Recovery (%)
Total Organic Carbon	816810	8.0	98.0
Chloride	816811	1.0	77.0
Nitrate - Nitrogen	816811	1.0	100.
Fluoride	816811	0.5	107.
Sulfate	816811	1.0	109.
Cyanide	816810	0.025	101.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	816808	816809	816810
Client Identification	LFA-PNLC	LF1-PNL1	LF4-PNL1
Iron	<0.01	600.	16.
Barium	0.044	4.0	0.13
Selenium	<0.002	<0.002	<0.002
Cadmium	<0.002	0.004	<0.002
Manganese	0.009	20.	3.6
Calcium	55.	210.	41.
Silver	<0.01	0.029	<0.01
Sodium	110.	24.	11.
Chromium	0.022	0.68	0.026
Lead	<0.02	<0.02	<0.02
Arsenic	<0.002	<0.002	<0.002
Mercury	<0.0002	0.0027 0.0030	<0.0002

All values are reported in mg/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	816811	816812	816813
Client Identification	LF4-PNL3	LFA-PNLA	LFA-PNLB
Iron	29.	460. 500.]	0.17
Barium	0.36	2.2 2.3]	<0.003
Selenium	<0.002	<0.002 <0.002]	<0.002
Cadmium	<0.002	0.006 0.004]	<0.002
Manganese	1.29	12.6 13.0]	0.005
Calcium	16.	118. 110.]	0.23
Silver	<0.01	0.018 0.030]	<0.01
Sodium	6.4	17. 16.]	2.7
Chromium	0.037	0.53 0.49]	<0.006
Lead	<0.02	<0.02 <0.02]	<0.02
Arsenic	<0.002	<0.002 <0.002]	<0.002
Mercury	<0.0002	0.0031	<0.0002

All values are reported in mg/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

SPIKE RECOVERIES

Element	Sample Number	Spike Concentration (mg/l)	Recovery (%)
Iron	816813	1.0	97.0
Barium	816813	1.0	97.0
Selenium	816813	0.5	86.0
Cadmium	816813	0.5	94.0
Manganese	816813	1.0	95.5
Calcium	816813	5.0	93.4
Silver	816813	0.050	88.0
Sodium	816813	2.5	112.
Chromium	816813	1.0	98.0
Lead	816813	1.0	93.0
Arsenic	816813	0.5	96.0

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	816809	816810	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL1	LF4-PNL1	
Chloromethane	ND	ND	2.
Vinyl Chloride	ND	ND	2.
Bromomethane	ND	ND	2.
Chloroethane	ND	ND	2.
Dichlorodifluoromethane	ND	ND	2.
Trichlorofluoromethane	ND	ND	2.
1,1-Dichloroethylene	ND	ND	2.
Methylene Chloride	ND	ND	10.
Trans-1,2-Dichlorothylene	ND	0.9	0.6
1,1-Dichloroethane	ND	ND	0.6
Chloroform	1.4	ND	0.6
1,1,1-Trichloroethane	ND	ND	0.6
Carbon Tetrachloride	ND	ND	0.6
1,2-Dichloroethane	ND	ND	0.6
Trichloroethylene	ND	13.9	0.6
1,2-Dichloropropane	ND	ND	0.6
Dichlorobromomethane	ND	ND	0.6
Trans-1,3-Dichloropropene	ND	ND	0.6
Cis-1,3-Dichloropropene	ND	ND	0.6
1,1,2-Trichloroethane	ND	ND	0.6
Tetrachloroethylene	ND	ND	0.6
Dibromochloromethane	ND	ND	0.6
Bromoform	ND	ND	0.6
1,1,2,2-Tetrachloroethane	ND	ND	0.6

ND = Not Detected.
All results reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs
DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
REPORT TO: Paul Eddy
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	816811	816812	DETECTION LIMIT (ug/l)
Client Identification	LF4-PNL3	LFA-PNLA	
Chloromethane	ND	ND	2.
Vinyl Chloride	ND	ND	2.
Bromomethane	ND	ND	2.
Chloroethane	ND	ND	2.
Dichlorodifluoromethane	ND	ND	2.
Trichlorofluoromethane	ND	2.5	2.
1,1-Dichloroethylene	ND	ND	2.
Methylene Chloride	ND	ND	10.
Trans-1,2-Dichlorothylene	ND	ND	0.6
1,1-Dichloroethane	ND	ND	0.6
Chloroform	0.6	1.4	0.6
1,1,1-Trichloroethane	ND	ND	0.6
Carbon Tetrachloride	ND	ND	0.6
1,2-Dichloroethane	ND	ND	0.6
Trichloroethylene	13.	ND	0.6
1,2-Dichloropropane	ND	ND	0.6
Dichlorobromomethane	ND	ND	0.6
Trans-1,3-Dichloropropene	ND	ND	0.6
Cis-1,3-Dichloropropene	ND	ND	0.6
1,1,2-Trichloroethane	ND	ND	0.6
Tetrachloroethylene	ND	ND	0.6
Dibromochloromethane	ND	ND	0.6
Bromoform	ND	ND	0.6
1,1,2,2-Tetrachloroethane	ND	ND	0.6

ND = Not Detected.
All results reported in ug/l.

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos. / Client Identification	816813 / LFA-PNLB	816813 DUPLICATE / LFA-PNLB	DETECTION LIMIT (ug/l)
Chloromethane	ND	ND	2.
Vinyl Chloride	ND	ND	2.
Bromomethane	ND	ND	2.
Chloroethane	ND	ND	2.
Dichlorodifluoromethane	ND	ND	2.
Trichlorofluoromethane	ND	ND	2.
1,1-Dichloroethylene	ND	ND	2.
Methylene Chloride	ND	ND	10.
Trans-1,2-Dichlorothylene	ND	ND	0.6
1,1-Dichloroethane	ND	ND	0.6
Chloroform	0.8	0.9	0.6
1,1,1-Trichloroethane	ND	ND	0.6
Carbon Tetrachloride	ND	ND	0.6
1,2-Dichloroethane	ND	ND	0.6
Trichloroethylene	ND	ND	0.6
1,2-Dichloropropane	ND	ND	0.6
Dichlorobromomethane	ND	ND	0.6
Trans-1,3-Dichloropropene	ND	ND	0.6
Cis-1,3-Dichloropropene	ND	ND	0.6
1,1,2-Trichloroethane	ND	ND	0.6
Tetrachloroethylene	ND	ND	0.6
Dibromochloromethane	ND	ND	0.6
Bromoform	ND	ND	0.6
1,1,2,2-Tetrachloroethane	ND	ND	0.6

ND = Not Detected.
All results reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

HERBICIDES IN WATER BY EPA METHOD 8150

Laboratory Sample Nos.	Client Identification	2,4-D	Silvex	2,4,5-T
816809	LF1-PNL1	ND	ND	ND
816810	LF4-PNL1	ND	ND	ND
816811	LF4-PNL3	ND	ND	ND
816812	LFA-PNLA	ND	ND	ND
816813	LFA-PNLB	ND	ND	ND
DETECTION LIMIT		1.0	0.1	0.1

ND = Not Detected

All values are reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WAATER BY EPA METHOD 608

Laboratory Sample Nos.	816809	816810	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL1	LF4-PNL1	
PESTICIDES			
Aldrin	ND	ND	0.04
Dieldrin	ND	ND	0.02
p,p'-DDT	ND	ND	0.12
p,p'-DDE	ND	ND	0.04
p,p'-DDD	ND	ND	0.11
Endosulfan I	ND	ND	0.14
Endosulfan II	ND	ND	0.04
Endosulfan Sulfate	ND	ND	0.66
Endrin	ND	ND	0.06
Endrin Aldehyde	ND	ND	0.23
Heptachlor	ND	ND	0.03
Heptachlor Epoxide	ND	ND	0.83
a-BHC	ND	ND	0.03
b-BHC	ND	ND	0.06
g-BHC	ND	ND	0.04
d-BHC	ND	ND	0.09
Toxaphene	ND	ND	2.4
Chlordane	ND	ND	0.14
Methoxychlor	ND	ND	1.76
PCB'S			
A-1016	ND	ND	1.0
A-1221	ND	ND	1.0
A-1232	ND	ND	1.0
A-1242	ND	ND	1.0
A-1248	ND	ND	1.0
A-1254	ND	ND	1.0
A-1260	ND	ND	1.0

ND = Not Detected
All values are reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs
DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
REPORT TO: Paul Eddy
P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WAATER BY EPA METHOD 608

Laboratory Sample Nos.	816811	816812	DETECTION LIMIT (ug/l)
Client Identification	LF4-PNL3	LFA-PNLA	
PESTICIDES			
Aldrin	ND	ND	0.04
Dieldrin	ND	ND	0.02
p,p'-DDT	ND	ND	0.12
p,p'-DDE	ND	ND	0.04
p,p'-DDD	ND	ND	0.11
Endosulfan I	ND	ND	0.14
Endosulfan II	ND	ND	0.04
Endosulfan Sulfate	ND	ND	0.66
Endrin	ND	ND	0.06
Endrin Aldehyde	ND	ND	0.23
Heptachlor	ND	ND	0.03
Heptachlor Epoxide	ND	ND	0.83
a-BHC	ND	ND	0.03
b-BHC	ND	ND	0.06
g-BHC	ND	ND	0.04
d-BHC	ND	ND	0.09
Toxaphene	ND	ND	2.4
Chlordane	ND	ND	0.14
Methoxychlor	ND	ND	1.76
PCB'S			
A-1016	ND	ND	1.0
A-1221	ND	ND	1.0
A-1232	ND	ND	1.0
A-1242	ND	ND	1.0
A-1248	ND	ND	1.0
A-1254	ND	ND	1.0
A-1260	ND	ND	1.0

ND = Not Detected
All values are reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88

REPORT TO: Paul Eddy

P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WAATER BY EPA METHOD 608

Laboratory Sample Nos.	816813	DETECTION LIMIT (ug/l)
Client Identification	LFA-PNLB	
PESTICIDES		
Aldrin	ND	0.04
Dieldrin	ND	0.02
p,p'-DDT	ND	0.12
p,p'-DDE	ND	0.04
p,p'-DDD	ND	0.11
Endosulfan I	ND	0.14
Endosulfan II	ND	0.04
Endosulfan Sulfate	ND	0.66
Endrin	ND	0.06
Endrin Aldehyde	ND	0.23
Heptachlor	ND	0.03
Heptachlor Epoxide	ND	0.83
a-BHC	ND	0.03
b-BHC	ND	0.06
g-BHC	ND	0.04
d-BHC	ND	0.09
Toxaphene	ND	2.4
Chlordane	ND	0.14
Methoxychlor	ND	1.76
PCB'S		
A-1016	ND	1.0
A-1221	ND	1.0
A-1232	ND	1.0
A-1242	ND	1.0
A-1248	ND	1.0
A-1254	ND	1.0
A-1260	ND	1.0

ND = Not Detected
All values are reported in ug/l.

REPORTED BY John T. Dailey

JTD/pb

Am Test Analytical Results From Early
September, 1988 Sampling Event

am test inc.
14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle - Pacific Northwest Labs

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy
P.O. Box 999
Richland, WA 99352

Laboratory Sample Nos.	817883	817884	817885
Client Identification	LF1-PNL2	LF1-PNL3	LF1-PNL4
pH	7.17	7.26	6.39 6.34
Specific Conductance (umhos/cm @ 25°C)	245.	120.	270. 265.
Total Coliform (MPN/100 ml)	<2.5	20.	<2.5
Oil & Grease (mg/l)	<1.2	<1.1	<1.2
Total Organic Halides (ug/l as Cl^-)	<10.	<10.	<10.
Gross Beta (pCI/L)	<2.	<2.	<2.
Radium (pCI/L)	<1.	1.3	<1.
Gross Alpha (pCI/l)	<1.	<1.	<1.
Total Dissolved Solids (mg/l)	151.	124.	177.
Total Organic Carbon (mg/l)	0.757	0.677 0.790	2.12
Chloride (mg/l)	2.74	4.60	3.65
Phenol (mg/l)	<0.008	<0.008	<0.008
Nitrate - Nitrogen (mg/l)	0.23	<0.01	1.83
Fluoride (mg/l)	0.72	<0.01	<0.01
Sulfate (mg/l)	3.51	12.5	23.6
Cyanide (mg/l)	<0.006	<0.006 <0.006	<0.006

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	817886	817887
Client Identification	LF4-PNL2	DUP. LF1-PNL4
pH	6.58	6.32
Specific Conductance (umhos/cm @ 25^{o}C)	440.	270.
Total Coliform (MPN/100 ml)	<2.5	<2.5
Oil & Grease (mg/l)	<1.2	<1.2
Total Organic Halides (ug/l as Cl^{-})	<10.	<10.
Gross Beta (pCI/L)	<1.	<1.
Radium (pCI/L)	<1.	<1.
Gross Alpha (pCI/l)	<1.	<1.
Total Dissolved Solids (mg/l)	293. 303.]	183.
Total Organic Carbon (mg/l)	2.28	2.52
Chloride (mg/l)	4.14	3.30 3.40]
Phenol (mg/l)	<0.008	<0.008
Nitrate - Nitrogen (mg/l)	<0.01	1.96 1.92]
Fluoride (mg/l)	<0.01	<0.01 <0.01]
Sulfate (mg/l)	26.4	23.7 24.0]
Cyanide (mg/l)	<0.006	<0.006

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

SPIKE RECOVERIES

Parameter	Sample Number	Spike Conc. (mg/l)	Recovery (%)
Total Organic Halides	817883	250.	93.1
Total Organic Carbon	817884	8.0	107.2
Chloride	817887	1.0	90.2
Nitrate - Nitrogen	817887	1.0	96.2
Fluoride	817887	0.5	86.4
Sulfate	817887	1.0	100.
Cyanide	817884	0.025	95.0

*Reported in ug/l as Cl^-.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	817883	817884	817885
Client Identification	LF1-PNL2	LF1-PNL3	LF1-PNL4
Iron	1.5	11.	2.7
Barium	0.012	0.078	0.026
Selenium	<0.002	<0.002	<0.002
Cadmium	<0.002	<0.002	<0.002
Manganese	0.080	0.368	1.07
Calcium	23.	13.	30.
Silver	<0.010	<0.010	<0.010
Sodium	5.3	3.3	5.3
Chromium	0.073	0.10	0.11
Lead	<0.02	<0.02	<0.02
Arsenic	<0.002	0.004	<0.002 <0.002[1]
Mercury	<0.0002	<0.0002	<0.0002

All values are reported in mg/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	817886	817887 DUP.
Client Identification	LF4-PNL2	LF1-PNL4
Iron	15.	3.4
Barium	0.106	0.033
Selenium	<0.002	<0.002
Cadmium	<0.002	<0.002
Manganese	4.3	1.0
Calcium	54.	29.
Silver	<0.010	<0.010
Sodium	10.4	4.6
Chromium	0.20	0.10
Lead	<0.02	<0.02
Arsenic	0.003 0.009]	<0.002
Mercury	<0.0002	<0.0002

All values are reported in mg/l.

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	817883	817884	DETECTION LIMIT
Client Identification	LF1-PNL2	LF1-PNL3	(ug/l)
Chloromethane	ND	ND	3.
Vinyl Chloride	ND	ND	3.
Bromomethane	ND	ND	3.
Chloroethane	ND	ND	3.
Dichlorodifluoromethane	ND	ND	3.
Trichlorofluoromethane	ND	ND	3.
1,1-Dichloroethylene	ND	ND	3.
Methylene Chloride	ND	ND	15.
Trans-1,2-Dichlorothylene	ND	ND	2.
1,1-Dichloroethane	ND	ND	2.
Chloroform	ND	ND	2.
1,1,1-Trichloroethane	ND	ND	2.
Carbon Tetrachloride	ND	ND	2.
1,2-Dichloroethane	ND	ND	2.
Trichloroethylene	ND	ND	2.
1,2-Dichloropropane	ND	ND	2.
Dichlorobromomethane	ND	ND	2.
Trans-1,3-Dichloropropene	ND	ND	2.
Cis-1,3-Dichloropropene	ND	ND	2.
1,1,2-Trichloroethane	ND	ND	2.
Tetrachloroethylene	ND	ND	2.
Dibromochloromethane	ND	ND	2.
Bromoform	ND	ND	2.
1,1,2,2-Tetrachloroethane	ND	ND	2.

ND = Not Detected.
All results reported in ug/l.

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	817885	817886	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL4	LF4-PNL2	
Chloromethane	ND	ND	3.
Vinyl Chloride	ND	ND	3.
Bromomethane	ND	ND	3.
Chloroethane	ND	ND	3.
Dichlorodifluoromethane	ND	ND	3.
Trichlorofluoromethane	ND	ND	3.
1,1-Dichloroethylene	ND	ND	3.
Methylene Chloride	ND	ND	15.
Trans-1,2-Dichlorothylene	ND	ND	2.
1,1-Dichloroethane	ND	ND	2.
Chloroform	ND	ND	2.
1,1,1-Trichloroethane	ND	ND	2.
Carbon Tetrachloride	ND	ND	2.
1,2-Dichloroethane	ND	ND	2.
Trichloroethylene	ND	5.7	2.
1,2-Dichloropropane	ND	ND	2.
Dichlorobromomethane	ND	ND	2.
Trans-1,3-Dichloropropene	ND	ND	2.
Cis-1,3-Dichloropropene	ND	ND	2.
1,1,2-Trichloroethane	ND	ND	2.
Tetrachloroethylene	ND	ND	2.
Dibromochloromethane	ND	ND	2.
Bromoform	ND	ND	2.
1,1,2,2-Tetrachloroethane	ND	ND	2.

ND = Not Detected.
All results reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs
REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos. / Client Identification	817887 DUP. LF1-PNL4 (ug/l)	817887 SPIKE RECOVERY (%)	DETECTION LIMIT (ug/l)
Chloromethane	ND	-	3.
Vinyl Chloride	ND	-	3.
Bromomethane	ND	-	3.
Chloroethane	ND	-	3.
Dichlorodifluoromethane	ND	-	3.
Trichlorofluoromethane	ND	-	3.
1,1-Dichloroethylene	ND	-	3.
Methylene Chloride	ND	-	15.
Trans-1,2-Dichlorothylene	ND	93.	2.
1,1-Dichloroethane	ND	82.	2.
Chloroform	ND	80.	2.
1,1,1-Trichloroethane	ND	105.	2.
Carbon Tetrachloride	ND	114.	2.
1,2-Dichloroethane	ND	75.	2.
Trichloroethylene	ND	66.	2.
1,2-Dichloropropane	ND	76.	2.
Dichlorobromomethane	ND	78.	2.
Trans-1,3-Dichloropropene	ND	115.	2.
Cis-1,3-Dichloropropene	ND	72.	2.
1,1,2-Trichloroethane	ND	63.	2.
Tetrachloroethylene	ND	81.	2.
Dibromochloromethane	ND	71.	2.
Bromoform	ND	-	2.
1,1,2,2-Tetrachloroethane	ND	-	2.

ND = Not Detected.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WATER BY EPA METHOD 608

Laboratory Sample Nos.	817883	817884	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL2	LF1-PNL3	
PESTICIDES			
Aldrin	ND	ND	0.04
Dieldrin	ND	ND	0.02
p,p'-DDT	ND	ND	0.12
p,p'-DDE	ND	ND	0.04
p,p'-DDD	ND	ND	0.11
Endosulfan I	ND	ND	0.14
Endosulfan II	ND	ND	0.04
Endosulfan Sulfate	ND	ND	0.66
Endrin	ND	ND	0.06
Endrin Aldehyde	ND	ND	0.23
Heptachlor	ND	ND	0.03
Heptachlor Epoxide	ND	ND	0.83
a-BHC	ND	ND	0.03
b-BHC	ND	ND	0.06
g-BHC	ND	ND	0.04
d-BHC	ND	ND	0.09
Toxaphene	ND	ND	2.4
Chlordane	ND	ND	0.14
Methoxychlor	ND	ND	1.76
PCB'S			
A-1016	ND	ND	1.0
A-1221	ND	ND	1.0
A-1232	ND	ND	1.0
A-1242	ND	ND	1.0
A-1248	ND	ND	1.0
A-1254	ND	ND	1.0
A-1260	ND	ND	1.0

ND = Not Detected
All values are reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WATER BY EPA METHOD 608

Laboratory Sample Nos.	817885	817886	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL4	LF4-PNL1	
PESTICIDES			
Aldrin	ND	ND	0.04
Dieldrin	ND	ND	0.02
p,p'-DDT	ND	ND	0.12
p,p'-DDE	ND	ND	0.04
p,p'-DDD	ND	ND	0.11
Endosulfan I	ND	ND	0.14
Endosulfan II	ND	ND	0.04
Endosulfan Sulfate	ND	ND	0.66
Endrin	ND	ND	0.06
Endrin Aldehyde	ND	ND	0.23
Heptachlor	ND	ND	0.03
Heptachlor Epoxide	ND	ND	0.83
a-BHC	ND	ND	0.03
b-BHC	ND	ND	0.06
g-BHC	ND	ND	0.04
d-BHC	ND	ND	0.09
Toxaphene	ND	ND	2.4
Chlordane	ND	ND	0.14
Methoxychlor	ND	ND	1.76
PCB'S			
A-1016	ND	ND	1.0
A-1221	ND	ND	1.0
A-1232	ND	ND	1.0
A-1242	ND	ND	1.0
A-1248	ND	ND	1.0
A-1254	ND	ND	1.0
A-1260	ND	ND	1.0

ND = Not Detected
All values are reported in ug/l.

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

PCB'S & PESTICIDES IN WATER BY EPA METHOD 608

Laboratory Sample Nos. / Client Identification	817887 DUP. LF1-PNL4	DETECTION LIMIT (ug/l)
PESTICIDES		
Aldrin	ND	0.04
Dieldrin	ND	0.02
p,p'-DDT	ND	0.12
p,p'-DDE	ND	0.04
p,p'-DDD	ND	0.11
Endosulfan I	ND	0.14
Endosulfan II	ND	0.04
Endosulfan Sulfate	ND	0.66
Endrin	ND	0.06
Endrin Aldehyde	ND	0.23
Heptachlor	ND	0.03
Heptachlor Epoxide	ND	0.83
a-BHC	ND	0.03
b-BHC	ND	0.06
g-BHC	ND	0.04
d-BHC	ND	0.09
Toxaphene	ND	2.4
Chlordane	ND	0.14
Methoxychlor	ND	1.76
PCB'S		
A-1016	ND	1.0
A-1221	ND	1.0
A-1232	ND	1.0
A-1242	ND	1.0
A-1248	ND	1.0
A-1254	ND	1.0
A-1260	ND	1.0

ND = Not Detected
All values are reported in ug/l.

-12-

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 9/26/88
DATE REVISED: 10/27/88
P.O. NO.: V5228 AD

HERBICIDES IN WATER BY EPA METHOD 8150

Laboratory Sample Nos.	Client Identification	2,4-D	Silvex	2,4,5-T
817883	LF1-PNL-2	ND	ND	ND
817884	LF1-PNL-3	ND	ND	ND
817885	LF1-PNL-4	ND	ND	ND
817886	LF4-PNL-2	ND	ND	ND
817887	LF1-PNL-4 Duplicate	ND	ND	ND
DETECTION LIMIT		1.0	0.1	0.1

ND = Not Detected

All values are reported in ug/l.

REPORTED BY J. T. Dailey
John T. Dailey

JTD/pb

Am Test Analytical Results From Late
October, 1988 Sampling Event

am test inc.

14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle - Pacific
Northwest Labs

Date Received: 10/31/88
DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy
P.O. Box 999
Richland, WA 99352

Laboratory Sample Nos.	822066	822067
Client Identification	LF4-PNL4	Duplicate LF4-PNL4
pH	6.29	6.35
Specific Conductance (umhos/cm @ 25^{o})	260.	270.
Total Coliform (CFU/100 ml)	<1.8	4.5
Oil & Grease (mg/l)	<1.	5.4
Total Organic Halide (ug/l as Cl^{-})	93.6	<10.
Gross Beta (pCI/L)	<2.0	<2.0
Radium (pCI/L)	<2.0	<2.0
Gross Alpha (pCI/L)	<1.0	<1.0
Total Dissolved Solids (mg/l)	239.	288.
Total Organic Carbon (mg/l)	1.23	1.26
Chloride (mg/l)	3.59	2.32

CLIENT: Battelle - Pacific
Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	822066	822067 Duplicate
Client Identification	LF4-PNL4	LF4-PNL4
Phenol (mg/l)	<0.008	<0.008
Nitrate - Nitrogen (mg/l)	1.34	1.38
Fluoride (mg/l)	<0.010	<0.010
Sulfate (mg/l)	20.5	20.9
Cyanide (mg/l)	<0.006	<0.006

CLIENT: Battelle - Pacific
Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	822068	822069
Client Identification	LF4-PNL5	LF4-PNL6A
pH	6.67	6.88
Specific Conductance (umhos/cm @ 25°)	92.	124.
Total Coliform (CFU/100 ml)	23.	49.
Oil & Grease (mg/l)	3.2	4.2
Total Organic Halide (ug/l as Cl^-)	102.	202.
Gross Beta (pCI/L)	<2.0	<2.0
Radium (pCI/L)	<2.0	<2.0
Gross Alpha (pCI/L)	<1.0	<1.0
Total Dissolved Solids (mg/l)	150.	275.
Total Organic Carbon (mg/l)	0.678 0.752	0.693
Chloride (mg/l)	1.41	2.94 2.90

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	822068	822069
Client Identification	LF4-PNL5	LF4-PNL6A
Phenol (mg/l)	<0.008	<0.008
Nitrate - Nitrogen (mg/l)	0.416	0.388 0.366]
Fluoride (mg/l)	<0.010	<0.010
Sulfate (mg/l)	7.20	6.97 6.72]
Cyanide (mg/l)	<0.006 <0.006]	<0.006

CLIENT: Battelle - Pacific
Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

SPIKE RECOVERIES

Parameter	Sample Number	Spike Conc. (mg/l)	Recovery (%)
Total Organic Carbon	822069	8.0	100.3
Phenol	822069	10.*	98.1
Nitrate - Nitrogen	822069	0.25	97.7
Fluoride	822069	0.25	109.7
Sulfate	822069	0.5	107.6
Cyanide	822069	0.025	93.5

*Reported in ug.

CLIENT: Battelle - Pacific
Northwest Labs

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy

Laboratory Sample Nos.	822066	822067 Duplicate
Client Identification	LF4-PNL4	LF4-PNL4
Iron (mg/l)	0.22	0.073
Barium (mg/l)	0.011	0.010
Selenium (mg/l)	<0.002	<0.002
Cadmium (mg/l)	<0.0005	<0.0005
Manganese (mg/l)	0.027	0.020
Calcium (mg/l)	32.	32.
Silver (mg/l)	0.0008	0.0016
Sodium (mg/l)	8.1	8.1
Chromium (mg/l)	0.013	0.012
Lead (mg/l)	<0.001	<0.001
Arsenic (mg/l)	<0.002	<0.002
Mercury (mg/l)	<0.0002 <0.0002]	<0.0002

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	822068	822069
Client Identification	LF4-PNL5	LF4-PNL6A
Iron (mg/l)	6.6 7.5]	0.17
Barium (mg/l)	0.092 0.104]	0.006
Selenium (mg/l)	<0.002 <0.002]	<0.002
Cadmium (mg/l)	<0.0005 0.0010]	<0.0005
Manganese (mg/l)	0.333	0.007
Calcium (mg/l)	10. 11.]	6.0
Silver (mg/l)	0.0018 0.0009]	0.0016
Sodium (mg/l)	3.4 4.4]	6.0
Chromium (mg/l)	0.012 0.011]	<0.006
Lead (mg/l)	0.004 0.004]	<0.001
Arsenic (mg/l)	0.005 0.006]	<0.002
Mercury (mg/l)	<0.0002	<0.0002

AT

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

SPIKE RECOVERIES

Parameter	Sample Number	Spike Conc. (mg/l)	Recovery (%)
Iron	822069	1.0	85.
Barium	822069	1.0	104.
Selenium	822069	0.25	106.
Cadmium	822069	0.5	96.
Manganese	822069	1.0	102.
Calcium	822069	10.	100.
Silver	822069	0.040	93.2
Sodium	822069	5.0	92.
Chromium	822069	1.0	100.
Lead	822069	1.0	93.
Arsenic	822069	0.5	96.
Mercury	822067	0.0050	100.

CLIENT: Battelle - Pacific
Northwest Labs

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	BLANK	DETECTION LIMIT
Client Identification	---	(ug/l)
Chloromethane	ND	2.0
Vinyl Chloride	ND	2.0
Bromomethane	ND	2.0
Chloroethane	ND	2.0
Dichlorodifluoromethane	ND	2.0
Trichlorofluoromethane	ND	2.0
1,1-Dichloroethylene	ND	2.0
Methylene Chloride	8.0	1.5
Trans-1,2-Dichloroethylene	ND	0.7
1,1-Dichloroethane	ND	0.7
Chloroform	1.0	0.7
1,1,1-Trichloroethane	ND	0.7
Carbon Tetrachloride	ND	0.7
1,2-Dichloroethane	ND	0.7
Trichloroethylene	ND	0.7
1,2-Dichloropropane	ND	0.7
Dichlorobromomethane	ND	0.7
Trans-1,3-Dichloropropene	ND	0.7
Cis-1,3-Dichloropropene	ND	0.7
1,1,2-Trichloroethane	ND	0.7
Tetrachloroethylene	ND	0.7
Dibromochloromethane	ND	0.7
Bromoform	ND	0.7
1,1,2,2-Tetrachloroethane	ND	0.7

All results are reported in ug/l.
ND = Not Detected.

AT

CLIENT: Battelle - Pacific Northwest Labs

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos. / Client Identification	822066 LF4-PNL4	822067 Duplicate LF4-PNL4	DETECTION LIMIT (ug/l)
Chloromethane	ND	ND	2.0
Vinyl Chloride	ND	ND	2.0
Bromomethane	ND	ND	2.0
Chloroethane	ND	ND	2.0
Dichlorodifluoromethane	ND	ND	2.0
Trichlorofluoromethane	ND	ND	2.0
1,1-Dichloroethylene	ND	ND	2.0
Methylene Chloride	26.	2.0	1.5
Trans-1,2-Dichloroethylene	0.8	0.8	0.7
1,1-Dichloroethane	ND	ND	0.7
Chloroform	ND	ND	0.7
1,1,1-Trichloroethane	ND	ND	0.7
Carbon Tetrachloride	ND	ND	0.7
1,2-Dichloroethane	ND	ND	0.7
Trichloroethylene	22.	19.	0.7
1,2-Dichloropropane	ND	ND	0.7
Dichlorobromomethane	ND	ND	0.7
Trans-1,3-Dichloropropene	ND	ND	0.7
Cis-1,3-Dichloropropene	ND	ND	0.7
1,1,2-Trichloroethane	ND	ND	0.7
Tetrachloroethylene	ND	ND	0.7
Dibromochloromethane	ND	ND	0.7
Bromoform	ND	ND	0.7
1,1,2,2-Tetrachloroethane	ND	ND	0.7

All results are reported in ug/l.
ND = Not Detected.

CLIENT: Battelle - Pacific
Northwest Labs

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

REPORT TO: Paul Eddy

GC ANALYSIS OF PURGEABLE HALOCARBONS BY EPA METHOD 601

Laboratory Sample Nos.	822068	822069	DETECTION LIMIT
Client Identification	LF4-PNL5	LF4-PNL6A	(ug/l)
Chloromethane	ND	ND	2.0
Vinyl Chloride	ND	ND	2.0
Bromomethane	ND	ND	2.0
Chloroethane	ND	ND	2.0
Dichlorodifluoromethane	ND	ND	2.0
Trichlorofluoromethane	ND	ND	2.0
1,1-Dichloroethylene	ND	ND	2.0
Methylene Chloride	1.5	2.5	1.5
Trans-1,2-Dichloroethylene	ND	ND	0.7
1,1-Dichloroethane	ND	ND	0.7
Chloroform	ND	0.7	0.7
1,1,1-Trichloroethane	ND	ND	0.7
Carbon Tetrachloride	ND	ND	0.7
1,2-Dichloroethane	ND	ND	0.7
Trichloroethylene	ND	ND	0.7
1,2-Dichloropropane	ND	ND	0.7
Dichlorobromomethane	ND	ND	0.7
Trans-1,3-Dichloropropene	ND	ND	0.7
Cis-1,3-Dichloropropene	ND	ND	0.7
1,1,2-Trichloroethane	ND	ND	0.7
Tetrachloroethylene	ND	ND	0.7
Dibromochloromethane	ND	ND	0.7
Bromoform	ND	ND	0.7
1,1,2,2-Tetrachloroethane	ND	ND	0.7

All results are reported in ug/l.
ND = Not Detected.

CLIENT: Battelle - Pacific
Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos. / Client Identification	822066 / LF4-PNL4	822067 Duplicate / LF4-PNL4	DETECTION LIMIT (ug/l)
PCB's*	ND	ND	0.5
Endrin	ND	ND	0.06
Lindane	ND	ND	0.04
Methoxychlor	ND	ND	0.5
Toxaphene	ND	ND	5.0

*PCB's analyzed for Arochlor 1016, 1221, 1232, 1242, 1248, 1254, 1260, & 1262.

ND = Not Detected.

All values are reported in ug/l.

CLIENT: Battelle - Pacific
Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

Laboratory Sample Nos.	822068	822069	DETECTION LIMIT
Client Identification	LF4-PNL5	LF4-PNL6A	(ug/l)
PCB's*	ND	ND	0.5
Endrin	ND	ND	0.06
Lindane	ND	ND	0.04
Methoxychlor	ND	ND	0.5
Toxaphene	ND	ND	5.0

*PCB's analyzed for Arochlor 1016, 1221, 1232, 1242, 1248, 1254, 1260, & 1262.

ND = Not Detected.

All values are reported in ug/l.

CLIENT: Battelle - Pacific Northwest Labs

REPORT TO: Paul Eddy

DATE REPORTED: 12/6/88
DATE REVISED: 1/4/88
P.O. NO.: V5228 AD

HERBICIDES IN WATER BY EPA METHOD 8150

Laboratory Sample Nos.	Client Identification	2,4-D (ug/l)	Silvex (ug/l)	2,4,5-T (ug/l)
822066	LF4-PNL4	ND	ND	ND
822067	LF4-PNL4 Duplicate	ND	ND	ND
822068	LF4-PNL5	ND	ND	ND
822069	LF4-PNL6A	ND	ND	ND
DETECTION LIMIT		1.0	0.1	0.1

ND = Not Detected.

REPORTED BY John T. Dailey

JTD/pb

Am Test Analytical Results From Middle
December, 1988 Sampling Event

am test inc.

14603 N.E. 87th St. • REDMOND, WASHINGTON 98052 • 206/885-1664

ANALYSIS REPORT

CLIENT: Battelle Northwest Laboratories

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

REPORT TO: George Last
P.O. Box 999
Richland, WA 99352

Laboratory Sample Nos.	Client Identification	Total Oil & Grease (mg/l)	Total Coliform (MPN)*
825627	LF1-PNL-1	7.7	<1.8
825628	LF1-PNL-5	11.8	<1.8
825629	Fort Lewis LF-4	8.5	<1.8
825630	LF1-PNL-6	8.3	<1.8
825631	Fort Lewis LF-2	9.4	<1.8
825632	Fort Lewis Well #2	21.6	13.
825633	LF4-PNL-3	8.6	<1.8
825634	Sequalitchew Lake	11.8	17.
825635	Fort Lewis LF-3	11.5	<1.8
825636	LF1-PNL-2	9.2	13.
825637	Fort Lewis LF-1	7.6	4.5
825638	LF1-PNL-3	8.2	21.
825639	LF1-PNL-4	8.2	22.

*NOTE: Samples received at Lab over 30 hours old - analyzed at Clients request.

MPN = Most probable number.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	BNA Method Blank 12/19/88	BNA Method Blank 12/21/88	825627 LF1-PNL 1	DETECTION LIMIT (ug/l)
Aniline	ND	ND	ND	1.0
2-Chlorophenol	ND	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	ND	1.0
Phenol	ND	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	ND	1.0
Benzyl Alcohol	ND	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	ND	1.0
2-Methylphenol	ND	ND	ND	1.0
Hexachloroethane	ND	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	ND	1.0
Nitrobenzene	ND	ND	ND	1.0
4-Methylphenol	ND	ND	ND	1.0
Isopherone	ND	ND	ND	1.0
2-Nitrophenol	ND	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	ND	1.0
Naphthalene	ND	ND	ND	1.0
Benzoic Acid	ND	ND	ND	5.0
4-Chloroaniline	ND	ND	ND	1.0
Hexachlorobutadiene	ND	ND	ND	1.0
2-Methylnaphthalene	ND	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.

AT

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	BNA Method Blank 12/19/88	BNA Method Blank 12/21/88	825627 LF1-PNL-1	DETECTION LIMIT (ug/l)
2-Chloronaphthalene	ND	ND	ND	1.0
2-Nitroaniline	ND	ND	ND	1.0
Acenaphthylene	ND	ND	ND	1.0
Dimethyl Phthalate	ND	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	ND	2.0
Acenaphthene	ND	ND	ND	1.0
3-Nitroaniline	ND	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	ND	5.0
Dibenzofuran	ND	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	ND	2.0
4-Nitrophenol	ND	ND	ND	4.0
Fluorene	ND	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	ND	1.0
Diethyl Phthalate	ND	ND	ND	1.0
4-Nitroaniline	ND	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	ND	1.0
Azobenzene	ND	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	ND	2.0
Hexachlorobenzene	ND	ND	ND	2.0
Pentachlorophenol	ND	ND	ND	5.0
Phenanthrene	ND	ND	ND	1.0
Anthracene	ND	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	ND	1.0
Fluoranthene	ND	ND	ND	1.0
Pyrene	ND	ND	ND	1.0
Benzidine	ND	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	BNA Method Blank 12/19/88	BNA Method Blank 12/21/88	825627 LF1-PNL-1	
Compounds	Concentration (ug/l)			DETECTION LIMIT (ug/l)
Chrysene	ND	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	ND	ND	ND	1.0
Di-N-Octyl Phthalate	ND	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	ND	1.0

Surrogate Compounds	Recovery (%)			AMOUNT SPIKED (ug/l)
2-Fluorophenol	37.	46.	42.	50.
D6-Phenol	26.	32.	26.	50.
D5-Nitrobenzene	48.	73.	72.	25.
2-Fluorobiphenyl	46.	74.	78.	25.
2,4,6-Tribromophenol	45.	82.	80.	50.
D24-Terphenyl	91.	100.	95.	25.

ND = Not Detected.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	825627 Dup. LF1-PNL-1	825628 LF1-PNL-5	825629 Ft. Lewis LF-4	DETECTION LIMIT (ug/l)
Aniline	ND	ND	ND	1.0
2-Chlorophenol	ND	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	ND	1.0
Phenol	ND	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	ND	1.0
Benzyl Alcohol	ND	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	ND	1.0
2-Methylphenol	ND	ND	ND	1.0
Hexachloroethane	ND	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	ND	1.0
Nitrobenzene	ND	ND	ND	1.0
4-Methylphenol	ND	ND	ND	1.0
Isopherone	ND	ND	ND	1.0
2-Nitrophenol	ND	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	ND	1.0
Naphthalene	ND	ND	ND	1.0
Benzoic Acid	ND	ND	ND	5.0
4-Chloroaniline	ND	ND	ND	1.0
Hexachlorobutadiene	ND	ND	ND	1.0
2-Methylnaphthalene	ND	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories
DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
REPORT TO: George Last
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	825627 Dup. LF1-PNL-1	825628 LF1-PNL-5	825629 Ft. Lewis LF-4	DETECTION LIMIT (ug/l)
2-Chloronaphthalene	ND	ND	ND	1.0
2-Nitroaniline	ND	ND	ND	1.0
Acenaphthylene	ND	ND	ND	1.0
Dimethyl Phthalate	ND	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	ND	2.0
Acenaphthene	ND	ND	ND	1.0
3-Nitroaniline	ND	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	ND	5.0
Dibenzofuran	ND	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	ND	2.0
4-Nitrophenol	ND	ND	ND	4.0
Fluorene	ND	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	ND	1.0
Diethyl Phthalate	ND	ND	ND	1.0
4-Nitroaniline	ND	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	ND	1.0
Azobenzene	ND	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	ND	2.0
Hexachlorobenzene	ND	ND	ND	2.0
Pentachlorophenol	ND	ND	ND	5.0
Phenanthrene	ND	ND	ND	1.0
Anthracene	ND	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	ND	1.0
Fluoranthene	ND	ND	ND	1.0
Pyrene	ND	ND	ND	1.0
Benzidine	ND	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories
REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825627 Dup.	825628	825629	
Client Identification	LF1-PNL-1	LF1-PNL-5	Ft. Lewis LF-4	
Compounds	**Concentration (ug/l)**			**DETECTION LIMIT (ug/l)**
Chrysene	ND	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	ND	ND	ND	1.0
Di-N-Octyl Phthalate	ND	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	ND	1.0

Surrogate Compounds	Recovery (%)			AMOUNT SPIKED (ug/l)
2-Fluorophenol	46.	45.	38.	50.
D6-Phenol	31.	30.	25.	50.
D5-Nitrobenzene	80.	76.	73.	25.
2-Fluorobiphenyl	77.	78.	80.	25.
2,4,6-Tribromophenol	84.	79.	88.	50.
D24-Terphenyl	92.	100.	95.	25.

ND = Not Detected.

CLIENT: Battelle Northwest Laboratories
DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
REPORT TO: George Last
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825630	825631	825632	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL-6	Ft. Lewis LF-2	Ft. Lewis Well #2	
Aniline	ND	ND	ND	1.0
2-Chlorophenol	ND	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	ND	1.0
Phenol	ND	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	ND	1.0
Benzyl Alcohol	ND	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	ND	1.0
2-Methylphenol	ND	ND	ND	1.0
Hexachloroethane	ND	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	ND	1.0
Nitrobenzene	ND	ND	ND	1.0
4-Methylphenol	ND	ND	ND	1.0
Isopherone	ND	ND	ND	1.0
2-Nitrophenol	ND	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	ND	1.0
Naphthalene	ND	ND	ND	1.0
Benzoic Acid	ND	ND	ND	5.0
4-Chloroaniline	ND	ND	ND	1.0
Hexachlorobutadiene	ND	ND	ND	1.0
2-Methylnaphthalene	ND	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825630	825631	825632	DETECTION LIMIT (ug/l)
Client Identification	LF1-PNL-6	Ft. Lewis LF-2	Ft. Lewis Well #2	
2-Chloronaphthalene	ND	ND	ND	1.0
2-Nitroaniline	ND	ND	ND	1.0
Acenaphthylene	ND	ND	ND	1.0
Dimethyl Phthalate	ND	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	ND	2.0
Acenaphthene	ND	ND	ND	1.0
3-Nitroaniline	ND	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	ND	5.0
Dibenzofuran	ND	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	ND	2.0
4-Nitrophenol	ND	ND	ND	4.0
Fluorene	ND	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	ND	1.0
Diethyl Phthalate	ND	ND	ND	1.0
4-Nitroaniline	ND	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	ND	1.0
Azobenzene	ND	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	ND	2.0
Hexachlorobenzene	ND	ND	ND	2.0
Pentachlorophenol	ND	ND	ND	5.0
Phenanthrene	ND	ND	ND	1.0
Anthracene	ND	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	ND	1.0
Fluoranthene	ND	ND	ND	1.0
Pyrene	ND	ND	ND	1.0
Benzidine	ND	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825630	825631	825632	
Client Identification	LF1-PNL-6	Ft. Lewis LF-2	Ft. Lewis Well #2	
Compounds	Concentration (ug/l)			DETECTION LIMIT (ug/l)
Chrysene	ND	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	ND	ND	ND	1.0
Di-N-Octyl Phthalate	ND	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	ND	1.0

Surrogate Compounds	Recovery (%)			AMOUNT SPIKED (ug/l)
2-Fluorophenol	45.	45.	34.	50.
D6-Phenol	33.	29.	22.	50.
D5-Nitrobenzene	80.	81.	76.	25.
2-Fluorobiphenyl	82.	83.	80.	25.
2,4,6-Tribromophenol	70.	84.	77.	50.
D24-Terphenyl	96.	100.	114.	25.

ND = Not Detected.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825633	825634	825635	DETECTION LIMIT (ug/l)
Client Identification	LF4-PNL-3	Seq.* Lake	Ft. Lewis LF-3	
Aniline	ND	ND	ND	1.0
2-Chlorophenol	ND	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	ND	1.0
Phenol	ND	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	ND	1.0
Benzyl Alcohol	ND	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	ND	1.0
2-Methylphenol	ND	ND	ND	1.0
Hexachloroethane	ND	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	ND	1.0
Nitrobenzene	ND	ND	ND	1.0
4-Methylphenol	ND	ND	ND	1.0
Isopherone	ND	ND	ND	1.0
2-Nitrophenol	ND	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	ND	1.0
Naphthalene	ND	ND	ND	1.0
Benzoic Acid	ND	ND	ND	5.0
4-Chloroaniline	ND	ND	ND	1.0
Hexachlorobutadiene	ND	ND	ND	1.0
2-Methylnaphthalene	ND	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.
*Seq. = Sequalitchew

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825633	825634	825635	DETECTION LIMIT
Client Identification	LF4-PNL-3	Seq.* Lake	Ft. Lewis LF-3	(ug/l)
2-Chloronaphthalene	ND	ND	ND	1.0
2-Nitroaniline	ND	ND	ND	1.0
Acenaphthylene	ND	ND	ND	1.0
Dimethyl Phthalate	ND	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	ND	2.0
Acenaphthene	ND	ND	ND	1.0
3-Nitroaniline	ND	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	ND	5.0
Dibenzofuran	ND	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	ND	2.0
4-Nitrophenol	ND	ND	ND	4.0
Fluorene	ND	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	ND	1.0
Diethyl Phthalate	ND	ND	ND	1.0
4-Nitroaniline	ND	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	ND	1.0
Azobenzene	ND	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	ND	2.0
Hexachlorobenzene	ND	ND	ND	2.0
Pentachlorophenol	ND	ND	ND	5.0
Phenanthrene	ND	ND	ND	1.0
Anthracene	ND	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	ND	1.0
Fluoranthene	ND	ND	ND	1.0
Pyrene	ND	ND	ND	1.0
Benzidine	ND	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.
*Seq. = Sequalitchew

AT

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825633	825634	825635	
Client Identification	LF4-PNL-3	Seq.* Lake	Ft. Lewis LF-3	
Compounds	Concentration (ug/l)			DETECTION LIMIT (ug/l)
Chrysene	ND	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	ND	ND	ND	1.0
Di-N-Octyl Phthalate	ND	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	ND	1.0

Surrogate Compounds	Recovery (%)			AMOUNT SPIKED (ug/l)
2-Fluorophenol	51.	42.	29.	50.
D6-Phenol	34.	30.	19.	50.
D5-Nitrobenzene	78.	79.	54.	25.
2-Fluorobiphenyl	79.	80.	59.	25.
2,4,6-Tribromophenol	90.	90.	60.	50.
D24-Terphenyl	115.	98.	83.	25.

*Seq. = Sequalitchew
ND = Not Detected.

CLIENT: Battelle Northwest Laboratories

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88

REPORT TO: George Last

PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	825636 LF1-PNL-2	825636 Dup. LF1-PNL-2	825637 Ft. Lewis LF-1	DETECTION LIMIT (ug/l)
Aniline	ND	ND	ND	1.0
2-Chlorophenol	ND	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	ND	1.0
Phenol	ND	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	ND	1.0
Benzyl Alcohol	ND	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	ND	1.0
2-Methylphenol	ND	ND	ND	1.0
Hexachloroethane	ND	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	ND	1.0
Nitrobenzene	ND	ND	ND	1.0
4-Methylphenol	ND	ND	ND	1.0
Isopherone	ND	ND	ND	1.0
2-Nitrophenol	ND	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	ND	1.0
Naphthalene	ND	ND	ND	1.0
Benzoic Acid	ND	ND	ND	5.0
4-Chloroaniline	ND	ND	ND	1.0
Hexachlorobutadiene	ND	ND	ND	1.0
2-Methylnaphthalene	ND	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. Client Identification	825636 LF1-PNL-2	825636 Dup. LF1-PNL-2	825637 Ft. Lewis LF-1	DETECTION LIMIT (ug/l)
2-Chloronaphthalene	ND	ND	ND	1.0
2-Nitroaniline	ND	ND	ND	1.0
Acenaphthylene	ND	ND	ND	1.0
Dimethyl Phthalate	ND	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	ND	2.0
Acenaphthene	ND	ND	ND	1.0
3-Nitroaniline	ND	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	ND	5.0
Dibenzofuran	ND	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	ND	2.0
4-Nitrophenol	ND	ND	ND	4.0
Fluorene	ND	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	ND	1.0
Diethyl Phthalate	ND	ND	ND	1.0
4-Nitroaniline	ND	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	ND	1.0
Azobenzene	ND	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	ND	2.0
Hexachlorobenzene	ND	ND	ND	2.0
Pentachlorophenol	ND	ND	ND	5.0
Phenanthrene	ND	ND	ND	1.0
Anthracene	ND	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	ND	1.0
Fluoranthene	ND	ND	ND	1.0
Pyrene	ND	ND	ND	1.0
Benzidine	ND	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825636	825636 Dup.	825637	
Client Identification	LF1-PNL-2	LF1-PNL-2	Ft. Lewis LF-1	
Compounds	**Concentration (ug/l)**			**DETECTION LIMIT (ug/l)**
Chrysene	ND	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	ND	ND	2.7	1.0
Di-N-Octyl Phthalate	ND	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	ND	1.0

Surrogate Compounds	Recovery (%)			AMOUNT SPIKED (ug/l)
2-Fluorophenol	51.	47.	40.	50.
D6-Phenol	35.	30.	27.	50.
D5-Nitrobenzene	77.	76.	66.	25.
2-Fluorobiphenyl	76.	78.	68.	25.
2,4,6-Tribromophenol	95.	89.	87.	50.
D24-Terphenyl	109.	102.	99.	25.

ND = Not Detected.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. / Client Identification	825638 LF1-PNL-3	825639 LF1-PNL-4	DETECTION LIMIT (ug/l)
Aniline	ND	ND	1.0
2-Chlorophenol	ND	ND	1.0
Bis (2-Chloroethyl) Ether	ND	ND	1.0
Phenol	ND	ND	1.0
1,3-Dichlorobenzene	ND	ND	1.0
1,4-Dichlorobenzene	ND	ND	1.0
1,2-Dichlorobenzene	ND	ND	1.0
Benzyl Alcohol	ND	ND	1.0
Bis (2-Chloroisopropyl) Ether	ND	ND	1.0
2-Methylphenol	ND	ND	1.0
Hexachloroethane	ND	ND	1.0
N-Nitrosodipropylamine	ND	ND	1.0
Nitrobenzene	ND	ND	1.0
4-Methylphenol	ND	ND	1.0
Isopherone	ND	ND	1.0
2-Nitrophenol	ND	ND	1.0
2,4-Dimethylphenol	ND	ND	1.0
Bis (2-chloroethoxy) Methane	ND	ND	1.0
2,4-Dichlorophenol	ND	ND	1.0
1,2,4-Trichlorobenzene	ND	ND	1.0
Naphthalene	ND	ND	1.0
Benzoic Acid	ND	ND	5.0
4-Chloroaniline	ND	ND	1.0
Hexachlorobutadiene	ND	ND	1.0
2-Methylnaphthalene	ND	ND	1.0
4-Chloro-3-Methylphenol	ND	ND	1.0
Hexachlorocyclopentadiene	ND	ND	2.0
2,4,6-Trichlorophenol	ND	ND	2.0
2,4,5-Trichlorophenol	ND	ND	2.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories
REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos.	825638	825639	DETECTION LIMIT
Client Identification	LF1-PNL-3	LF1-PNL-4	(ug/l)
2-Chloronaphthalene	ND	ND	1.0
2-Nitroaniline	ND	ND	1.0
Acenaphthylene	ND	ND	1.0
Dimethyl Phthalate	ND	ND	1.0
2,6-Dinitrotoluene	ND	ND	2.0
Acenaphthene	ND	ND	1.0
3-Nitroaniline	ND	ND	2.0
2,4-Dinitrophenol	ND	ND	5.0
Dibenzofuran	ND	ND	1.0
2,4-Dinitrotoluene	ND	ND	2.0
4-Nitrophenol	ND	ND	4.0
Fluorene	ND	ND	1.0
4-Chlorophenyl Phenyl Ether	ND	ND	1.0
Diethyl Phthalate	ND	ND	1.0
4-Nitroaniline	ND	ND	3.0
2-Methyl-4,6-Dinitrophenol	ND	ND	5.0
N-Nitrosodiphenylamine	ND	ND	1.0
Azobenzene	ND	ND	1.0
4-Bromophenyl Phenyl Ether	ND	ND	2.0
Hexachlorobenzene	ND	ND	2.0
Pentachlorophenol	ND	ND	5.0
Phenanthrene	ND	ND	1.0
Anthracene	ND	ND	1.0
Di-N-Butyl Phthalate	ND	ND	1.0
Fluoranthene	ND	ND	1.0
Pyrene	ND	ND	1.0
Benzidine	ND	ND	3.0
Benzy Butyl Phthalate	ND	ND	1.0
Benzo (a) Anthracene	ND	ND	1.0

ND = Not Detected.
All values are reported in ug/l.

CLIENT: Battelle Northwest Laboratories

REPORT TO: George Last

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88
PROJECT: Fort Lewis

GC/MS SEMIVOLATILES BY EPA METHOD 625

Laboratory Sample Nos. 825638 825639

Client Identification LF1-PNL-3 LF1-PNL-4

Compounds	Concentration (ug/l)		DETECTION LIMIT (ug/l)
Chrysene	ND	ND	1.0
3,3-Dichlorobenzidine	ND	ND	3.0
Bis (2-Ethylhexyl) Phthalate	2.3	ND	1.0
Di-N-Octyl Phthalate	ND	ND	1.0
Benzo (b) Fluoranthene	ND	ND	1.0
Benzo (k) Fluoranthene	ND	ND	1.0
Benzo (a) Pyrene	ND	ND	1.0
Indeno (1,2,3-cd) Pyrene	ND	ND	1.0
Dibenzo (a,h) Anthracene	ND	ND	1.0
Benzo (g,h,i) Perylene	ND	ND	1.0

Surrogate Compounds	Recovery (%)		AMOUNT SPIKED (ug/l)
2-Fluorophenol	47.	37.	50.
D6-Phenol	33.	25.	50.
D5-Nitrobenzene	70.	60.	25.
2-Fluorobiphenyl	73.	61.	25.
2,4,6-Tribromophenol	85.	75.	50.
D24-Terphenyl	96.	87.	25.

ND = Not Detected.

-20-

CLIENT: Battelle Northwest Laboratories

DATE RECEIVED: 12/16/88
DATE REPORTED: 12/31/88

REPORT TO: George Last

PROJECT: Fort Lewis

SPIKE DATA

Laboratory Sample No. 825635 Matrix Spike

Client Identification Ft. Lewis LF-3

Matrix Spike Compounds	Recovery (%)	Amount Residue (ug/l)	Amount Expected (ug/l)
2-Chlorophenol	54.	27.2	50.
Phenol	24.	11.9	50.
1,4-Dichlorobenzene	45.	11.2	25.
N-Nitrosodipropylamine	61.	15.3	25.
1,2,4-Trichlorobenzene	46.	11.5	25.
4-Chloro-3-Methylphenol	57.	28.5	50.
Acenaphthene	66.	16.6	25.
2,4-Dinitrotoluene	47.	11.8	25.
4-Nitrophenol	25.	12.4	50.
Pentachlorophenol	64.	32.2	50.
Di-N-Butylphthalate	57.	14.3	25.
Pyrene	76.	18.9	25.

Surrogate Compounds	Recovery (%)	Amount Spiked (ug/l)	Amount Found (ug/l)
2-Fluorophenol	35.	50.	17.3
D6-Phenol	25.	50.	12.3
D5-Nitrobenzene	62.	25.	15.5
2-Fluorobiphenyl	62.	25.	15.6
2,4,6-Tribromophenol	71.	50.	35.4
D14-Terphenyl	75.	25.	18.8

ND = Not Detected.

REPORTED BY ______________________
John A. Hicks

JAH/pb

DISTRIBUTIDN

No. of
Copies

OFFSITE

12 DOE/Office of Scientific and
Technical Information

13 K. Durbin
HQ, I Corps and Ft. Lewis
Attn: AFZH-DEQ
Fort Lewis, WA 98433-5000

ONSITE

DOE Richland Operations Office

J. J. Sutey

No. of
Copies

18 Pacific Northwest Laboratory

S. P. Airhart
P. G. Doctor
J. T. Falco
J. M. Hales
P. C. Hays
G. V. Last (2)
K. B. Olsen
W. T. Pennell
J. R. Raymond
L. E. Rogers
R. L. Skaggs
Publishing Coordination
Technical Report Files (5)