FINAL

FIELD INVESTIGATION REPORT
PHASE II REMEDIAL INVESTIGATION

EAST GATE DISPOSAL YARD
Fort Lewis, Washington
DSERTS NO. FTLE-67

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EXECUTIVE SUMMARY

The U.S. Army Corps of Engineers, Seattle District, on behalf of Fort Lewis Public Works, conducted a Phase II remedial investigation (RI) at the East Gate Disposal Yard (EGDY), located within the Logistics Center at Fort Lewis, Pierce County, Washington. The EGDY was previously identified as the primary source of trichloroethene (TCE) contamination in groundwater beneath the Logistics Center. This Phase II RI was conducted as a focused follow-up to an expanded site investigation (ESI) conducted in 1998–1999. The primary goals of the Phase II RI were to (1) obtain data required for the design of a thermal remedial action for the EGDY nonaqueous-phase liquid (NAPL) source area treatment and (2) further assess the greater EGDY dissolved-phase TCE plume through groundwater sampling and water level elevation measurement and mapping. The field investigation was conducted between June 2001 and April 2002 and consisted of a direct-push program, geophysical investigation, rotosonic drilling and monitoring well installation program, and an investigation of other potential source areas to the southwest of the EGDY (the “greater EGDY area”).

A total of 30 borings were advanced at the EGDY using a direct-push Geoprobe® drill rig. A membrane interface probe was utilized in conjunction with the Geoprobe rig to analyze for volatile organic compounds (VOCs) in the subsurface. A Site Characterization and Analysis Penetrometer System (SCAPS) direct-push rig with laser-induced fluorescence probe was to be used at the site instead of the Geoprobe rig; however, the gravelly and cobbly nature of subsurface soils prevented use of the SCAPS application at the site.

A test geophysical investigation was conducted by URS Corporation at the EGDY for the intended purpose of improving the three-dimensional understanding of subsurface stratigraphy at the site. Geophysical methods included electrical resistivity imaging, induced polarization, and ground-penetrating radar. Induced polarization results did not correlate well with the intrusive site data. Electrical resistivity and ground-penetrating radar results were of better apparent quality than induced polarization; however, the effective penetration depth of these methods was severely limited due to the signals being highly reflective off the rounded, coarse-grained subsurface materials. Therefore, the full geophysical characterization planned was not conducted. Because the SCAPS rig and geophysical methods were attempted and only marginally successful, other investigation tools were relied upon to successfully reach the project goals.

Seventy-six soil borings were drilled at the EGDY using a rotosonic drill rig to characterize the nature and extent of NAPL and subsurface stratigraphy. Continuous soil cores were obtained from each boring and logged. Select samples were submitted for chemical analysis and physical properties testing. Due to the aforementioned limitations with the direct-push program and the geophysical investigation, the rotosonic drilling program ended up being the primary means of

source area characterization. Twelve multi-port monitoring wells and one conventional well were installed within select sonic borings and screened within the Vashon aquifer. These wells were sampled to determine vertical profiles of TCE concentrations in groundwater throughout the EGDY.

Based on an analysis of aerial photographs and the results of a subsequent site reconnaissance, six areas outside the EGDY were physically explored to determine whether historical disposal occurred that might have contributed to the Logistics Center dissolved-phase TCE plume. In each of these areas, a backhoe was used to dig a series of trenches that intersected the area of concern. Although minor amounts of scrap metal and construction debris were encountered at one location, there was no evidence of historical contaminant disposal that could have contributed to the Logistics Center plume based on visual inspection of the backhoed trenches.

NAPL was encountered at 35 of the 76 rotosonic borings drilled, at depths ranging from ground surface to 46 feet below ground surface (bgs). The groundwater depth at the EGDY during the investigation averaged approximately 10 feet bgs; therefore, NAPL was encountered both in the vadose and saturated zones. NAPL presence was determined based on a combination of direct visual evidence, laboratory analytical and physical testing results, photoionization detector measurements, ultraviolet (UV) fluorescence, and Sudan IV dye testing.

NAPL was determined to be limited primarily to three main areas within the EGDY: an area adjacent to the East Gate infiltration galleries and recharge wells (NAPL Area 1), an area approximately 300 feet west-northwest of NAPL Area 1 (NAPL Area 2), and an area between East Lincoln Drive and the East Gate groundwater treatment plant (NAPL Area 3). These findings generally confirmed the ESI (URS 1999) results.

The main contaminants within the NAPL at the site were TCE, cis-1,2-dichloroethene (cis-1,2-DCE), and other hydrocarbons, including those comprising stoddard solvent, mineral spirits, light-end fuels (e.g., JP-7), motor oil, automatic transmission fluid, transformer oil, and hydraulic oil. In all three NAPL areas, NAPL was detected primarily in the Vashon recessional outwash deposits above the uppermost Vashon till unit (intermediate aquitard). NAPL was observed within this till unit at four locations and had penetrated up to 3 feet within the till. No NAPL was observed below the intermediate aquitard.

Limited NAPL was observed in four borings outside the three main NAPL areas at the EGDY, suggesting additional smaller source areas exist that were not fully characterized. Based on the relatively low level (i.e., less than 10,000 μg/L) of dissolved-phase TCE contamination in these areas and/or the lack of NAPL observed in nearby sonic borings, these NAPL sources are interpreted to be small in extent and volume (i.e., less than 2,500 square feet or 1,700 cubic yards).

NAPL Area 1 is approximately 25,400 square feet (0.6 acre) in size and up to 33 feet in depth, for a total volume of approximately 30,900 cubic yards. Chlorinated solvents and oils were the primary contaminants found within NAPL Area 1. NAPL Area 2 is approximately 51,100 square feet (1.2 acres) in size and up to 47 feet in depth, averaging approximately 28 feet in depth. The total volume of NAPL Area 2 is approximately 52,200 cubic yards. A component of NAPL Area 2 has migrated with groundwater flow toward the southwest; hence, the downgradient NAPL is generally shallower than the NAPL beneath the disposal trenches associated with NAPL Area 2. The primary contaminants found within NAPL Area 2 were those in a complex petroleum hydrocarbon mixture. The compound cis-1,2-DCE and, to a lesser extent, TCE were also contaminants of concern in NAPL Area 2. NAPL Area 3 is approximately 18,200 square feet (0.4 acre) in size and up to 30 feet in depth, for a total volume of approximately 20,100 cubic yards. Chlorinated solvents (primarily TCE) were the predominant contaminants found within NAPL Area 3. NAPL associated with NAPL Area 3 is present in lower percent NAPL saturated conditions than at NAPL Areas 1 and 2 and is more interspersed throughout the soil matrix in globules or ganglia than in the other two areas. The total remaining mass of source area NAPL is estimated at 800,000 lb, assuming an average porosity of 30 percent and a 5 percent average NAPL saturation (i.e., 5 percent of the void space filled with NAPL). Specifically, at NAPL Area 1, an estimated 210,000 lb of NAPL remain in the subsurface; at NAPL Area 2, an estimated 400,000 lb; and at NAPL Area 3, an estimated 140,000 lb. However, due to the relatively low level of NAPL saturation present within the soil matrix, no measurable dense or light NAPL (DNAPL or LNAPL) has been observed in the monitoring wells installed to date.

VOC analytical results and groundwater elevation data obtained during this investigation in the greater EGDY area suggest a component of groundwater flow and TCE plume transport is to the southwest from the upgradient portions of the EGDY corresponding to NAPL Areas 1 and 2. Groundwater flow and contaminant transport direction changes from southwesterly to the regional northwesterly direction as the Vashon TCE plume intersects Murray Creek, a surface expression of shallow groundwater.

The site-wide conceptual site model (CSM), including the EGDY and Logistics Center areas of concern, has been updated and included in Section 5 of this report. The CSM has been revised based on Phase II RI findings at the EGDY and from Sea Level aquifer borings completed near Interstate 5.

The Phase II RI was successfully implemented, and the subsurface NAPL characterization and stratigraphy data collected will be used as the basis for an in situ thermal remediation design for the EGDY. Additionally, the supplemental greater EGDY data was used to further characterize the local deviation in groundwater flow and contaminant transport behavior from the regional patterns and can be used in future groundwater treatment system optimization.

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ABBREVIATIONS AND ACRONYMS

API	American Petroleum Institute
ASTM	American Society for Testing and Materials
BFB	bromofluorobenzene
bgs	below ground surface
CCAL	continuing calibration
CCV	continuing calibration verification
CEC	cation exchange capacity
CERCLA	Comprehensive Environmental Response, Liability, and Compensation Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFC	chlorofluorocarbon
CI	chemical ionization
cis-1,2-DCE	cis-1,2-dichloroethene
CLP	Contract Laboratory Program
CMT	continuous, multi-channel, extruded polyethylene tubing
COC	contaminant of concern
CPT	cone penetrometer test
CSM	conceptual site model
DCE	total dichloroethene
DF	dilution factor
DNAPL	dense nonaqueous-phase liquid
DO	dissolved oxygen
DQO	data quality objectives
DRMO	Defense Reutilization Marketing Office
DSITMS	direct sampling ion trap mass spectrometer
EC	electrical conductivity
Ecology	Washington State Department of Ecology
EGDY	East Gate Disposal Yard
EE/CA	engineering evaluation/cost analysis
Eh	oxidation-reduction potential
EI	electron impact
EM	electromagnetic
EPA	U.S. Environmental Protection Agency
ER	electronic resistivity (imaging)
ERA	Environmental Resource Associates
ESD	Explanation of Significant Difference
ESI	expanded site investigation

ABBREVIATIONS AND ACRONYMS (Continued)

FS	feasibility study
FSP	field sampling plan
GCMS	gas chromatograph mass spectrometer
GPR	ground-penetrating radar
GPS	global positioning system
HCl	hydrochloric acid
HVAC	heating, ventilation, and cooling
I-5	Interstate 5
ICAL	initial calibration
ID	identification
IDW	investigation-derived waste
IP	induced polarization
IRP	Installation Restoration Program
IS	internal standard
ISRM	in situ redox manipulation
ITMS	Ion Trap Mass Spectrometer
K	hydraulic conductivity
LCS	laboratory control sample
LCSD	laboratory control sample duplicate
LIF	laser-induced fluorescence
LNAPL	light nonaqueous-phase liquid
MAMC	Madigan Army Medical Center
MDL	method detection limit
MIP	membrane interface probe
MRL	method reporting limits
MROD	Mount Rainier Ordnance Depot
MS/MSD	matrix spike/matrix spike duplicates
msl	mean sea level
NAD27	North American Datum of 1927
NAPL	nonaqueous-phase liquid
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
NGVD 29	National Geodetic Vertical Datum of 1929
NPL	National Priorities List
NTS	not to scale
NWTPH-Dx	Northwest total petroleum hydrocarbons—diesel range (extended)
ORP	oxidation-reduction potential
PAH	polycyclic aromatic hydrocarbon

ABBREVIATIONS AND ACRONYMS (Continued)

PARCCS	precision, accuracy, representativeness, comparability, completeness, and sensitivity
%D	percent difference
PCE	tetrachloroethene
PE	performance evaluation
PID	photoionization detector
PNNL	Pacific Northwest National Laboratory
POL	petroleum, oils, and lubricants
PQL	practical quantitation limits
PTS Lab	PTS GeoLabs, Incorporated
Pv	pore volume
PVC	polyvinyl chloride
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RABITT	reductive anaerobic biological in situ treatment technology
RAM	Remedial Action Monitoring
RCRA	Resource Conservation and Recovery Act
redox	oxidation reduction
RI	remedial investigation
ROD	Record of Decision
RPD	relative percent difference
RRF	relative response factor
RSD	relative standard deviation
SAP	sampling and analysis plan
SARA	Superfund Amendment and Reauthorization Act
SCAPS	Site Characterization and Analysis Penetrometer System
SDG	sample delivery group
SOP	standard operating procedure
STL	Severn Trent Laboratories
TCA	trichloroethane
TCE	trichloroethene
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TPH-D	total petroleum hydrocarbons—diesel
TPH-Dx	total petroleum hydrocarbons—diesel range (extended)
TPH-O	total petroleum hydrocarbons—oil
trans-1,2-DCE	trans-1,2-dichloroethene

ABBREVIATIONS AND ACRONYMS (Continued)

U	non-detect
UJ	estimated
URS	URS Corporation
USACE	U.S. Army Corps of Engineers
USCS	Unified Soil Classification System
USGS	U.S. Geological Survey
UV	ultraviolet
VC	vinyl chloride
VOA	volatile organic analysis
VOC	volatile organic compound
WAC	Washington Administrative Code

UNITS OF MEASURE

°C	degree Celsius
°F	degree Fahrenheit
cm	centimeter
cm/s	centimeter per second
eV	electronvolt
ft	foot
ft/day	foot per day
ft/ft	foot per foot
ft^3	cubic foot
g	gram
g/cc	gram per cubic centimeter
gpm	gallon per minute
kg	kilogram
L	liter
lb	pound
µg/L	microgram per liter
µg/kg	microgram per kilogram
µg/mL	microgram per milliliter
µm	micrometer
µS/cm	microSiemen per centimeter
µS/m	microSiemen per meter
meq/kg	milliequivalent per gram
mg/kg	milligram per kilogram
mg/L	milligram per liter
mL	milliliter
mm	millimeter
mS/m	milliSiemen per meter
mL/min	milliliter per minute
mV	millivolt
NTU	nephelometric turbidity unit
ppb	part per billion
ppm	part per million
yd^3	cubic yard

1.0 INTRODUCTION

The U.S. Army Corps of Engineers (USACE), Seattle District, on behalf of Fort Lewis Public Works, conducted a Phase II remedial investigation (RI) at the East Gate Disposal Yard (EGDY), also formerly known as Landfill 2, located in the Logistics Center at Fort Lewis, Pierce County, Washington. The field program of the Phase II RI consisted primarily of direct-push membrane interface probe (MIP) and piezometer installation followed by rotosonic boring and monitoring well installation. Soil, groundwater, and surface water samples were collected and analyzed during the approximate 8-month field investigation from June 2001 to April 2002. The field investigation was discontinuous because of work stoppages for alternate drill rig mobilizations in July and October 2001.

The investigation was conducted in accordance with guidelines and specifications set forth in the *Final Management Plan, Phase II Remedial Investigation, East Gate Disposal Yard and Logistics Center, Fort Lewis, Washington* (final management plan) (URS 2001b). This investigation report primarily addresses the nature and extent of the subsurface nonaqueous phase liquid (NAPL) contamination at the EGDY that was not included in the original RI and was not fully delineated in the expanded site investigation (ESI). The report then presents technical conclusions based on those results. The report also includes updated information on a site-wide conceptual site model (CSM) including dissolved-phase contamination downgradient of the EGDY source area and EGDY geohydrologic interpretation based on newly acquired data.

A dynamic investigation approach was developed and used for this project in order to continually focus the investigation on only those areas requiring further characterization. Because of the dynamic approach, multiple tools were used in the field investigation. Specific tasks conducted and the associated tools used during the Phase II RI field investigation are as follows:

- Exploratory trenching in potential source areas other than the EGDY was conducted using a track-mounted backhoe.
- In situ laser-induced fluorescence (LIF) data collection was attempted at the EGDY using a Site Characterization and Analysis Penetrometer System (SCAPS) drill rig.
- In situ MIP data were collected at the EGDY using a Geoprobe direct-push rig.
- Groundwater sampling for volatile organic compounds (VOCs) at the EGDY and southwest of the EGDY was conducted using a Geoprobe rig (at piezometer locations).

- Temporary piezometers were installed at the EGDY and southwest of the EGDY using a Geoprobe rig.
- Surface water sampling was conducted along the upper reaches of Murray Creek.
- A geophysical investigation was conducted on the northernmost portion of the EGDY using electrical resistivity (ER) imaging, induced polarization (IP), and ground-penetrating radar (GPR).
- Shallow (less than 110 feet below ground surface [bgs]) soil borings were drilled at the EGDY using a rotosonic drill rig.
- Shallow (less than 110 feet bgs) multi-port monitoring wells and one conventional single-screen well (to 30 feet bgs) were installed at the EGDY using a rotosonic drill rig.
- Conventional and multi-port well development, purging, and sampling were conducted for all newly installed groundwater monitoring wells.
- Offsite chemical and physical testing of soil and offsite chemical analysis of groundwater and surface water were conducted.
- Field monitoring of air (for health and safety purposes) and measurement of groundwater quality parameters were performed.
- Real-time surveying using global positioning system (GPS) and subsequent traditional surveying were conducted for all sample point locations and newly installed wells and piezometers.
- A topographic survey was completed at the EGDY using traditional survey techniques.

Detailed descriptions of the above items are in Section 2.

1.1 SITE DESCRIPTION AND HISTORY

This section describes the site location, topography, and layout as well as the general history and regulatory history of the site. The primary sources of information for this section are the RI report (Envirosphere 1988), the site history and CSM (Woodward-Clyde 1997), the ESI report (URS 1999), and the engineering evaluation/cost analysis (EE/CA) report (URS 2001a). The information below has been substantively captured from the final management plan (URS 2001b).

1.1.1 Site Location, Topography, and Layout

The Logistics Center is located in Pierce County, Washington, approximately 11 miles south of Tacoma and 17 miles northeast of Olympia (Figure 1-1, Inset A). The Logistics Center occupies about 650 acres of the Fort Lewis Military Reservation, located at Township 19 North, Range 2 East, Sections 21, 22, 26, and 27. It is bounded on the northwest by Interstate 5 (I-5) and beyond by the town of Tillicum, on the north by the American Lake Gardens Tract, on the west by the Madigan Army Medical Center (MAMC), and on the southwest by the Madigan Family Housing Area.

The EGDY is located southeast of the Logistics Center in an otherwise undeveloped portion of Fort Lewis (Figure 1-1, Inset B). The EGDY is now loosely defined as the area southeast of the intersection of Rainier Avenue and East Lincoln Drive in which landfill trenching and disposal activities historically took place. The EGDY site consists of a previously fenced area of approximately 13.5 acres. Waste disposal, however, occurred both inside as well as outside the fenced area. Therefore, the study area for the ESI (URS 1999) included not only the previously fenced area but also the property outside the fence, for a total area of 35 acres (Figure 1-2). A chain-link fence was installed along the shoulder of East Lincoln Drive in 2001, demarcating the new, northernmost perimeter of the EGDY.

The Logistics Center and EGDY are situated on an extensive upland glacial drift plain that occupies much of central Pierce County. The elevation of the area ranges from approximately 235 feet above mean sea level (msl) at American Lake to 290 feet above msl at the EGDY. Overall, the Logistics Center and most portions of the EGDY are relatively flat. The southwesternmost portion of the EGDY is slightly higher in elevation than the rest of the EGDY (by approximately 5 to 10 feet). Some slightly higher hills exist adjacent to the border of the Logistics Center, mainly to the west and south. The drift plain is crossed by the Puyallup River to the north and east and by the Nisqually River to the south, which are major drainages for the region. Natural surficial drainage systems have not developed in the area due to the high infiltration capacity of the soils and the level topography. Murray Creek, a small stream that originates from wetlands to the south of the EGDY and flows into American Lake, is the only perennial stream draining from the site vicinity (Envirosphere 1988).

The greater EGDY area is vegetated primarily with Douglas fir, black cottonwood, red alder, and wild cherry trees; Scotch-broom and other hardwood shrubs; and grasses. However, all trees and shrubs have been cleared from the former disposal trench locations. A few tree stumps remain that overlie small portions of subsurface NAPL and the dissolved-phase trichloroethene (TCE) contaminant plume.

1.1.2 General Site History

Initial development of the Logistics Center site began with construction of the Quartermaster Motor Base in 1941 (Envirosphere 1988). This facility was activated in April 1942. The facility was transferred to ordnance jurisdiction in August 1942 and renamed the Mount Rainier Ordnance Depot (MROD). It operated as the MROD until 1963, furnishing ordnance supplies, maintenance, and rebuilding services for Fort Lewis. In 1963, the facility was turned over to the Logistics Center to serve as the primary non aircraft maintenance facility for the post.

TCE was used as a degreasing agent at this facility until the mid-1970s, when its use was replaced with 1,1,1-trichloroethane (TCA). Waste TCE was disposed of with waste oils at several locations. The EGDY was used between 1946 and 1960 as a disposal site for waste generated at the MROD (Shannon & Wilson 1986). Trenches were excavated in the yard and reportedly received TCE and petroleum, oils, and lubricants (POL) from cleaning and degreasing operations. This material was transported to the EGDY in barrels and vats from the various use areas. About six to eight barrels of waste TCE and POL may have been disposed of per month (Shannon & Wilson 1986). At times this material was used to assist in burning other waste products. Table 1-1 summarizes waste types and chemicals known or suspected to have been disposed of in the EGDY. These trenches were subsequently covered and are no longer visible. The locations of these trenches are shown on Plate 1.

Subsequent to the ESI, the USACE analyzed aerial photographs to aid in locating potential additional historical source areas distant from the EGDY (USACE 2001a). A collection of aerial photographs from 1951, 1955, 1960, 1964, 1965, 1971, 1978, and 1981 was reviewed. Additional potential source areas identified from the aerial photograph analysis are discussed in Section 2.1.1 of this report.

1.1.3 Regulatory History

The Fort Lewis Logistics Center was assigned a Comprehensive Environmental Response, Compensation, and Liability Information System (CERCLIS) number WA72100900670 and was placed on the National Priorities List (NPL) in December 1989 under the Comprehensive Environmental Response, Liability, and Compensation Act (CERCLA) of 1980, as amended by the Superfund Amendment and Reauthorization Act (SARA) of 1986. The lead agency for the Logistics Center investigations and cleanup is the U.S. Army. An installation-wide Federal Facilities Interagency Agreement between the U.S. Army, U.S. Environmental Protection Agency (EPA), and Washington State Department of Ecology (Ecology) became effective on January 29, 1990. This RI is being conducted by Fort Lewis under the Installation Restoration Program (IRP). The following paragraphs provide an overview of the investigations and actions taken at the site.

In 1983, the EPA and Tacoma-Pierce County Health Department initiated studies to investigate potential contamination in the American Lake Gardens Tract area to the north of the Logistics Center. This study confirmed the presence of TCE and cis-1,2-dichloroethene (cis-1,2-DCE) in several domestic water supply wells in the American Lake Gardens Tract area, possibly originating from McChord Air Force Base. Contamination beneath the Logistics Center was also discovered and considered a potential source of contamination to the American Lake Gardens Tract area. This prompted an investigation in 1984 into the extent of groundwater contamination beneath the Logistics Center, where groundwater with a plume of TCE (and lesser concentrations of cis-1,2-DCE) was shown to be moving along the centerline of the Logistics Center. A groundwater study of the Tillicum area was prompted by the EPA in 1985 to investigate the potential impact to public water supply wells. This study indicated widespread, low-level TCE contamination in the upper, unconfined aquifer beneath Tillicum, originating from the Logistics Center. Contamination was also detected in the lower aquifer. A subsequent groundwater study was initiated in 1985 to identify the extent of groundwater contamination beneath the Logistics Center and potential sources of contamination. At that time, the upper aquifer groundwater plume was found to be at least 10,000 feet long, 2,500 feet wide, and 80 feet below the water table, primarily originating from the EGDY at the southeast end of the Logistics Center. More recent investigation of the upper aquifer plume has revised its dimensions to approximately 13,000 feet in length and approximately 4,000 feet in width.

A remedial investigation/feasibility study (RI/FS) under CERCLA was initiated in 1986 and completed in 1990. A Record of Decision (ROD) signed on September 25, 1990, prescribed two long-term groundwater pump-and-treat systems for the upper, unconfined aquifer (U.S. Army, EPA, and Ecology 1990). In addition, the ROD required further investigation of the lower aquifer and potential sources of soil contamination. The ROD specified that if the lower aquifer was found to be contaminated, the contaminated groundwater from the lower aquifer would be pumped and treated in the onsite treatment facilities. Operation of the groundwater pump-and-treat systems—one near the EGDY (the source area) and one near I-5 (the leading edge of the plume)—started in 1995. The systems consist of groundwater extraction wells, air-stripping towers for treatment of volatile organic contaminants (primarily TCE), and recharge wells or infiltration trenches for groundwater discharge. These systems operate primarily to maintain hydraulic control of the groundwater contaminant plume for protection of downgradient drinking water sources beyond the Fort Lewis boundary.

Further investigation of the lower aquifer conducted from 1991 through 1994 found that the hydrogeology beneath the Logistics Center is complex and may allow contamination from the upper aquifer to migrate through permeable soil to the lower aquifer. The Explanation of Significant Difference (ESD) from the ROD was prepared in part based on the findings of this lower aquifer study. The study concluded that not enough was known about the lower aquifer permeable window to design a remedial strategy for the lower aquifer. The ESD was signed in 1998 (U.S. Army, EPA, and Ecology 1998). The differences are described below.

The 1998 ESD specified:

> …using innovative technologies to accelerate treatment and/or control of the source area and the contaminant plume in the unconfined aquifer in addition to utilizing groundwater extraction and treatment in onsite treatment facilities. The extraction and treatment systems may be shut down at some time in the future if no longer required.

wherein the 1990 ROD had specified:

> …using groundwater extraction and treatment in onsite treatment facilities.

The 1998 ESD specified:

> …accelerating the cleanup of the unconfined aquifer through source control at the EGDY and the use of innovative technologies in the unconfined aquifer, and conduct[ing] additional studies on the transport of contaminants to and through the lower aquifer.

wherein the 1990 ROD had specified:

> …extending the groundwater extraction and treatment in onsite treatment facilities to the lower aquifer at this time.

A working group for the Fort Lewis IRP, made up of Fort Lewis Public Works, EPA, Ecology, Pacific Northwest National Laboratory (PNNL), and the U.S. Geological Survey (USGS), was established in November 1997. The USACE was included in the group in 2000. This group meets periodically to discuss future progress and future directions of the cleanup effort at Fort Lewis. As a result of the USACE's recommendation, and in concurrence with the regulators, drum removal at the EGDY was initiated in December 2000 under an Emergency Response Time-Critical Removal Action dated July 24, 2000, and was completed by July 2001 (GSA 2001). The group's focus on the remediation then shifted toward its present emphasis on source removal. These enhancements are being implemented in the overall strategy for remediating the site and have become part of the Administrative Record pursuant to Section 300.825(a)(2) of the National Oil and Hazardous Substances Pollution Contingency Plan (NCP).

1.2 PURPOSE OF REMEDIAL INVESTIGATION

The EGDY is the source area for widespread TCE contamination at the Fort Lewis Logistics Center. Soil and groundwater at the EGDY site are contaminated primarily with chlorinated and nonchlorinated hydrocarbons, including TCE. This contamination results from the past disposal of waste streams that likely consisted of spent degreasing solvents, lubricating oils, and fuel oils.

TCE contamination exists in the subsurface as free-phase product, dissolved in groundwater, and adsorbed onto solids. The final EE/CA for the EGDY and the Logistics Center at Fort Lewis (URS 2001a) recommends in situ thermal technologies to remediate the free-phase product and optimization of the existing groundwater pump-and-treat system to remove remaining dissolved-phase contamination. This Phase II RI characterization was undertaken because the ESD specifies the use of innovative technologies (such as thermal treatment, as recommended in the EE/CA) to accelerate source area cleanup since pump and treat alone (as specified in the ROD) will not fully clean up the site. For thermal treatment to proceed, the NAPL must be characterized.

The primary objective of this RI was to collect data required for design of in situ thermal treatment remedies and evaluation of the options for optimization of the existing groundwater pump-and-treat system. To support this objective, results of this RI were used to better define the type as well as horizontal and vertical extent of NAPL contamination and subsurface geologic constraints. Site-specific factors that might impact the effectiveness/deployment of in situ thermal technologies include vertical and horizontal distribution of NAPL with varying compositions; physical and chemical characteristics of the NAPL; depth of NAPL penetration; type, thickness, and heterogeneity of subsurface geologic material; and the presence of manmade subsurface structures/materials. These factors are addressed in Section 5. In situ thermal treatment methods under consideration include steam injection/stripping and electrical heating.

Secondary objectives of this project were (1) to investigate small, isolated potential source areas other than the EGDY that may be contributing to the overall Logistics Center dissolved-phase TCE plume and (2) to determine shallow hydrogeologic and dissolved-phase contaminant characteristics of the area southwest of the EGDY, including the Murray Creek-Vashon aquifer interconnection.

1.3 DATA QUALITY OBJECTIVES

Data quality objectives (DQOs) are quantitative and qualitative statements specified to ensure that data of appropriate quality are collected during field activities. The DQO process ensures that sufficient data are collected to make required decisions with a reasonable certainty and that only necessary data are collected. It was not practical to attempt to predetermine the specific amount of data sufficient to characterize the extent and composition of NAPL in the subsurface owing to the complexities of heterogeneity, variable flow paths, and diverse modes of occurrence. Instead, the number of sampling locations and depth of investigation were chosen in real time during the field investigation based on professional judgment of the project team using existing data and the up-to-date CSM. The dynamic nature of the investigation resulted in a continual refinement and improvement of investigative locations and depths based on the results of the previous locations and depths to help guide the TCE and NAPL characterization.

This investigation focused on collecting data used to aid the design of an in situ thermal treatment system that will enhance removal of contaminants from the subsurface. These data included the following:

- Chemical composition of contaminated soil and water phases
- Physical characteristics of the contaminated soil
- Geologic/hydrogeologic properties of the subsurface
- Distribution of NAPL in the subsurface

Physical composition of NAPLs within the EGDY was to be analyzed; however, no separate-phase liquids could be collected from the site during this investigation. Alternatively, four NAPL samples collected from intact drums removed during the drum removal project were submitted for physical testing in accordance with the requirements in the field sampling plan (FSP) of the final management plan (URS 2001b).

The overall project DQOs are as follows:

- DQO 1—Obtain data required for design of a thermal remedial action for NAPL source area treatment.

- DQO 2—Obtain data required to complete an evaluation of options for optimization of the existing pump-and-treat system.

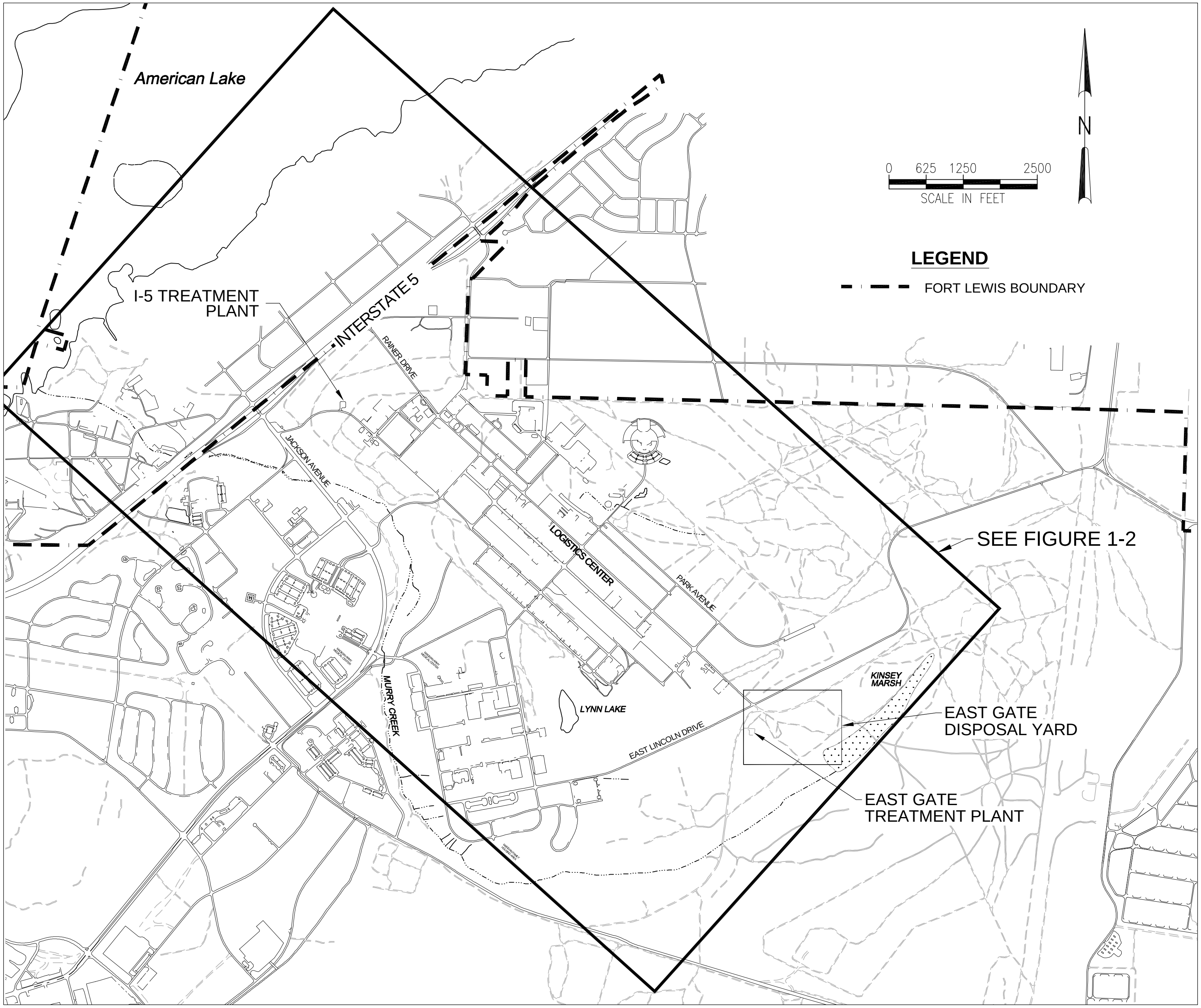
- DQO 3—Obtain data required to complete an evaluation of reactive barrier wall placement options.

- DQO 4—Provide analytical results that can be used to segregate and classify investigation-derived waste (IDW) as solid, hazardous, or dangerous waste according to the Resource Conservation and Recovery Act (RCRA) and Washington State Dangerous Waste Regulations.

- DQO 5—Ensure that the turnaround time for the field-generated data supports the real-time decision-making needs of the dynamic work plan.

1.4 REPORT CONTENTS AND ORGANIZATION

The purpose of this report is to present the EGDY and Logistics Center Phase II RI activities and results. The results are presented in a format that will benefit the anticipated thermal treatment remedial action for the EGDY site. The report addresses each of the topics listed in the project sampling and analysis plan (SAP) of the final management plan (URS 2001b). This section of the report provides introductory and background information. Section 2 lists and discusses activities performed during the Phase II RI, a data summary is provided in Section 3, data quality assurance is summarized in Section 4, data interpretation and an update to the combined EGDY/Logistics Center CSM are discussed in Section 5, data gaps and uncertainties are discussed in Section 6, conclusions are provided in Section 7, and references are listed in Section 8. Ancillary supporting documentation, including chemical data summaries, daily contractor quality control reports, data quality summary reports, boring logs and well completion records, pneumatic slug test summary, a geophysical investigation summary report, and sonic boring core photographs, are included in Appendices A through G, respectively.



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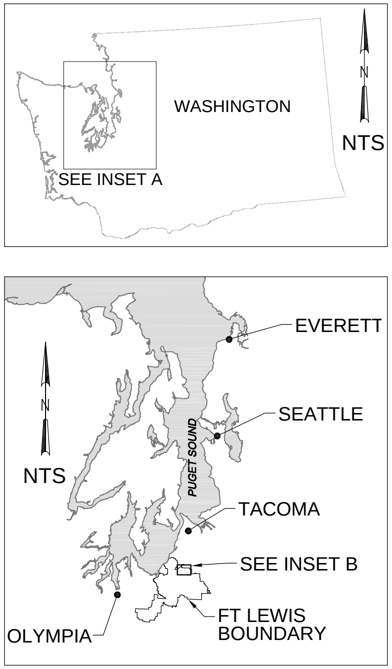

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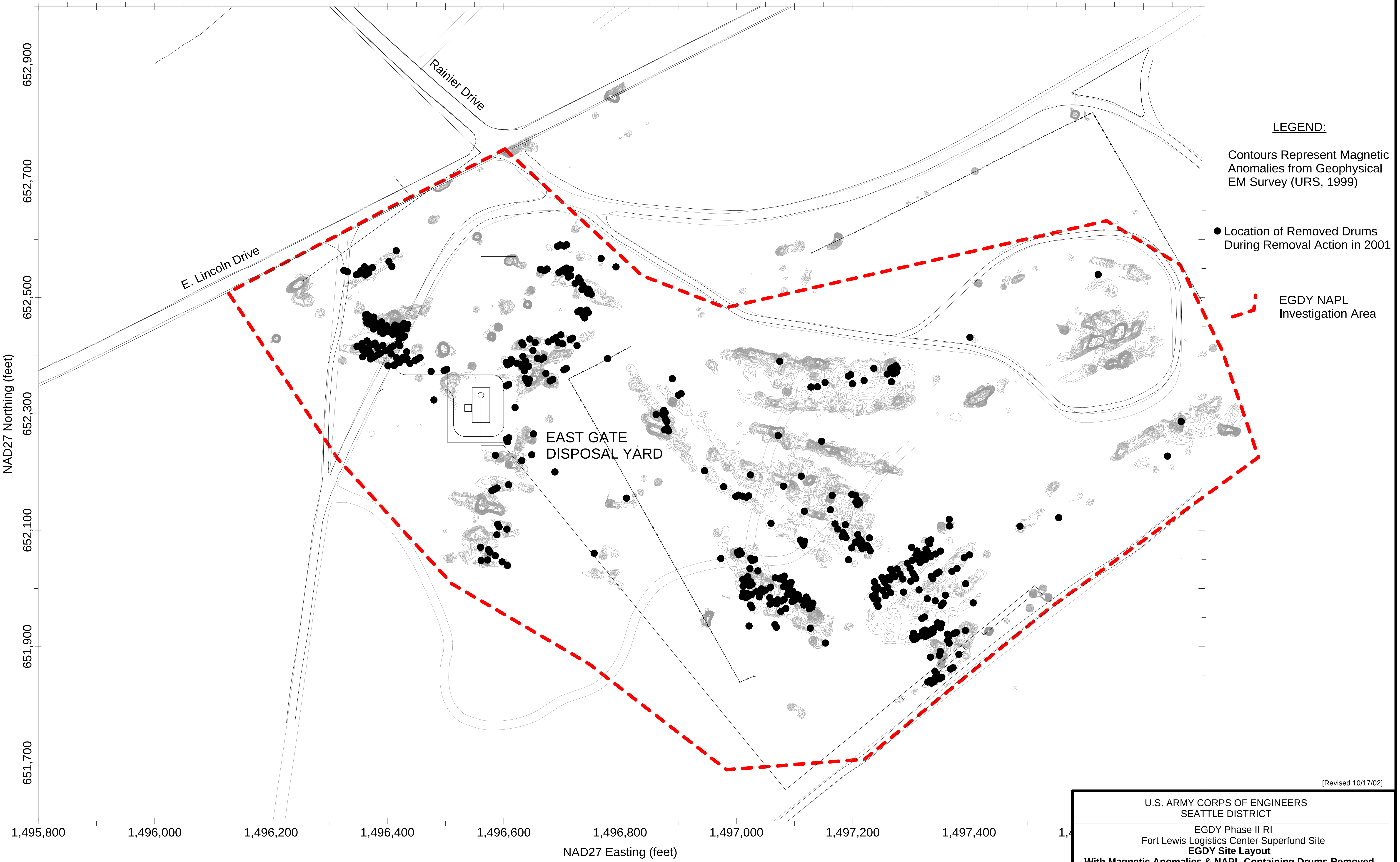
U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT

EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Site Location

Fort Lewis	**Figure 1-1**	Washington



[Revised 10/17/02]

U.S. ARMY CORPS OF ENGINEERS
SEATTLE DISTRICT

EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
EGDY Site Layout
With Magnetic Anomalies & NAPL-Containing Drums Removed

Fort Lewis	**Figure 1-2**	Washington

Table 1-1
SUMMARY OF WASTE/CHEMICAL TYPES AT THE EGDY

Waste Type	Potential Contaminants
Waste degreasing agent	TCE, cis-1,2-DCE, 1,1,1-trichloroethane, PCE
Waste oil	Total petroleum hydrocarbons, PCBs
Waste burning trenches	Dioxins/furans
Miscellaneous solid waste	Unknown
Sandblasting waste	Arsenic, chromium, cadmium, lead, copper, antimony
Compressed gas cylinders	Methyl bromide, acetylene

Notes:
cis-1,2-DCE = cis-1,2-dichloroethene
PCBs = polychlorinated biphenyls
PCE = tetrachloroethene
TCE = trichloroethene

2.0 INVESTIGATION ACTIVITIES SUMMARY

2.1 OVERVIEW OF THE PHASE II REMEDIAL INVESTIGATION

The final management plan for the EGDY/Logistics Center Phase II RI was issued in July 2001 and approved by Fort Lewis Department of Public Works and the EPA. Investigation of potential TCE contaminant source areas outside the EGDY took place in June 2001. This work occurred before the final management plan was issued because the contractor and equipment were already in place on site since the source area drum removal finished earlier than anticipated. Work methods and requirements associated with this phase of the investigation, however, did not change between draft and final versions of the final management plan. Field work at the EGDY, beginning with the SCAPS direct-push investigation, began on July 16, 2001. The Geoprobe direct-push investigation began on August 15, 2001, and was completed by September 26, 2001. The sonic drilling program at the EGDY began on October 31, 2001, and was completed by April 4, 2002. All required digging permits and utility location/avoidance procedures were followed prior to subsurface investigation for each phase of work.

It should be emphasized that because TCE, the primary contaminant of concern, was known to have been mixed with POL, TCE was found not only in dense NAPL (DNAPL) at the site, but in light NAPL (LNAPL) as well. This fact had important implications for TCE/NAPL characterization and sample collection depths during the Geoprobe MIP and sonic boring investigations, as discussed later in this section.

2.1.1 Investigation of Other Potential Source Areas

The presence of dissolved-phase TCE southwest of the EGDY counter to the regional groundwater gradient led to the investigation of potential TCE source areas outside the EGDY. A total of 12 areas were identified as being of interest based on an aerial photograph analysis performed by the USACE (2001a). An area of interest was defined as one of the following: a manmade depression (pit, ditch, or trench) or mound, an area cleared of vegetative cover, an area containing disturbed ground, or a suspected solid waste pile. These areas were evaluated to determine which of these features matched potential former TCE disposal practices. Based on the results of a site reconnaissance conducted by the USACE, only those areas with a reasonable probability of being TCE source areas were investigated further under this RI. Six areas were retained for subsequent physical exploration: Trenches 12, 13, and 14; Disturbed Area 1; and Cleared Areas 1 and 2. The areas investigated were much smaller than the EGDY, ranging in area from approximately 0.25 to 0.75 acre. The six areas were cleared of large vegetative matter and then excavated using a track-mounted backhoe. At each potential source area, a series of trenches up to 5 feet deep were dug to search for evidence of hydrocarbon contamination and/or manmade debris. This work, by Garry Struthers Associates (GSA 2001), was performed after completion of the trenching and drum removal at the EGDY using the same heavy equipment and operators.

2.1.2 Direct-Push Investigation (SCAPS/Geoprobe)

The final management plan called for the use of several tools utilizing the direct-push investigative method, including laser-induced fluorescence (LIF), cone penetrometer test (CPT), membrane interface probes (MIPs), GeoVis, and FLUTe ribbon NAPL samplers. Originally, these tools were to be used in conjunction with a SCAPS drill rig. SCAPS, or "Site Characterization and Analysis Penetrometer System," incorporates special penetrometers with sensors for contaminant detection and subsurface sampling equipment to map soil characteristics and contaminant distribution. A series of "dummy pushes" was performed using the SCAPS rig to test how deep the direct-push technique could effectively reach. A dummy push was a direct-push attempt without an instrumented probe attached to the end of the push rods. Due to the abundance of shallow coarse gravels and cobbles at the EGDY, push depth using the static force of the SCAPS rig was severely hindered, averaging only 10 feet in depth. The maximum depth penetrated by a dummy push was 19 feet. The project team concluded that SCAPS was not able to achieve the depth required for adequate site characterization, and hence a decision was made early on to terminate the SCAPS investigation and to perform in situ NAPL characterization using an MIP pushed by a Geoprobe drill rig. The USACE Tulsa District operated the SCAPS rig, Geoprobe rig, and the onsite laboratory and direct sampling ion trap mass spectrometer (DSITMS).

A Geoprobe Systems Model 6610DT direct-push rig was used to complete the direct-push investigation. Whereas the SCAPS rig used only a static force associated with the weight of the rig, the Geoprobe rig used a hydraulically powered hammer percussion technique to advance rods and probes into the subsurface. This technique was more successful because the hammering action helped redirect and/or pulverize gravel and cobbles during probe advancement. MIPs are compatible with Geoprobe rigs; however, all other direct-push tools with the exception of FLUTe could no longer be included in the investigation toolbox. Since it became evident that the sonic drilling program would be heavily relied upon for NAPL extent confirmation, the usefulness of FLUTe ribbon samplers was minimized and hence this tool was not utilized. MIPs, coupled with a DSITMS for onsite analysis, were the primary tools used with the Geoprobe direct-push investigation. A SCAPS/Geoprobe investigation report was published that describes this work in support of the Phase II RI (USACE 2002).

2.1.3 Sonic Drilling Investigation

A total of 76 soil borings were drilled within the EGDY in support of the Phase II RI using the rotosonic drilling method. This method, also known as vibratory drilling or sonic drilling, uses an eccentrically oscillating drill head to produce high-frequency vibratory energy that is then transmitted down a drill string to a core barrel to quickly advance through the subsurface. Other than the soil that is retrieved from inside the core barrel as a sample, drill cuttings are limited and are forced into the walls of the borehole. A drilling fluid such as water or air is usually not required with this drilling method, and no drilling fluid was used at the EGDY. Continuous soil cores were retrieved, logged, and evaluated for the presence of NAPL and sampled at each boring location. Twelve borings were converted into upper aquifer (Vashon aquifer) multi-port monitoring wells. One boring was converted into a shallow, Vashon aquifer DNAPL collection well. The remaining 63 sonic borings were abandoned and backfilled in accordance with Washington Administrative Code (WAC) requirements. The primary purpose of the sonic drilling investigation was to determine horizontal and vertical extents of NAPL. Secondary goals of the sonic drilling were to confirm the results of the Geoprobe MIP investigation and to install monitoring wells at the EGDY for NAPL and dissolved-phase contaminant monitoring. Boart Longyear, under contract with Cascade Drilling of Woodinville, Washington, performed the sonic drilling services using a Rotosonic 150 drill rig.

2.2 SUMMARY OF FIELD INVESTIGATION METHODS

2.2.1 Survey of Exploration and New Well Locations

Initial subsurface investigation locations were staked in the field based on positions relative to the existing electromagnetic survey grid developed during the ESI and maintained on site. SCAPS and Geoprobe direct-push exploration locations were surveyed while field activities were in progress using a portable Trimble GPS unit.

At the conclusion of the field investigation, a licensed surveyor, Thornton Land Surveying, Inc., of Gig Harbor, Washington, surveyed the horizontal and vertical positions of the Geoprobe push locations and Geoprobe-installed piezometers, sonic soil boring locations, and new groundwater monitoring wells. Ground surface elevations adjacent to monitoring wells and piezometers as well as inner casing and outer protective casing elevations were measured and recorded.

2.2.2 SCAPS LIF and CPT

The primary objective of the SCAPS LIF/CPT investigation was to determine the nature and extent of NAPL contamination beneath the ground surface at the EGDY. The protocol for LIF use was stated in Appendix A (Standard Operating Procedures) of the project SAP (URS 2001b). The primary objective was not achieved through SCAPS LIF/CPT because the SCAPS rig was unable to push the LIF/CPT probe, or dummy push rods, to a sufficient depth without excessive probe damage due to the gravelly and cobbly nature of the shallow subsurface soils at the EGDY. The limitations associated with the LIF/CPT, particularly the difficulty in employing it in coarse gravels and cobbles and its inability to penetrate to the maximum depth of investigation, were recognized as inherent risks, but the potential benefits warranted that the SCAPS rig be brought to the site.

SCAPS pushes using the LIF probe were denoted "SL" (for SCAPS LIF) and a sequential number (e.g., SL001). Three short-duration LIF/CPT pushes were attempted at the EGDY. These pushes were designated SL001, SL002, and SL003 and were 18.9 feet, 17.4 feet, and 17.8 feet deep, respectively. The SCAPS LIF method provides data on the in situ distribution of petroleum hydrocarbons based on the fluorescence response induced in the polycyclic aromatic hydrocarbon (PAH) compounds that are components of petroleum hydrocarbons. Additionally, one temporary microwell was installed at location SL001. The push was terminated at 13.0 feet bgs. One groundwater sample was collected from 10.5 to 12.8 feet bgs from this location and characterized on site using the DSITMS in the field laboratory prior to microwell abandonment and grouting of the boring.

The CPT data were recorded simultaneously alongside the LIF data during the use of the LIF probe. CPT and standard penetrometer testing have been widely used in the geotechnical industry for determining soil strength and soil type from measurements of tip resistance and sleeve friction on an instrumented probe. In this case, the CPT and LIF instrumentation were housed inside the same probe. Push locations SL001, SL002, and SL003 were prepushed with a dummy push rod; therefore, CPT data are not considered representative of the natural formation materials.

2.2.3 Geoprobe MIP

2.2.3.1 Geoprobe MIP/EC Probe

A Geoprobe drill rig was used to advance the MIP with electrical conductivity (EC) sensor to provide continuous, real-time chemical speciation of volatile organic compounds (VOCs). This was achieved by connecting the MIP to a mass spectrometer (DSITMS) housed in an onsite mobile laboratory via carrier gas flowing through a thin-diameter flexible tube. Continuous sample collection and analysis were performed by operating the MIP and DSITMS continuously, rather than at specific in situ depths. The advantage of operating the MIP in a continuous mode is that pockets or layers of separate-phase VOCs, even if in thin pockets or layers, may be discovered. The limitation of using continuous sample collection is a loss in accuracy in determining VOC concentration and sample collection depth.

A standard, commercially available Geoprobe Systems MIP was used to collect VOC samples and measure electrical conductivity. The standard MIP consists of 1/16-inch-diameter Teflon carrier gas lines, a removable membrane mounted within a 300-watt heater block, and a two-pole EC sensor. The temperature of the heater block, carrier gas flow rate, and EC sensor were controlled using a Geoprobe Systems Model 2500 MIP controller. Helium of 99.999 percent purity was used as the carrier gas, and the flow rate was set to 50 mL/min as indicated by a J&W Scientific ADM2000 Intelligent Flowmeter. The clean carrier gas flowed to the MIP's membrane interface window, where VOCs from the subsurface diffused across the membrane and into the carrier gas. The VOC-laden helium carrier gas returned from the MIP was analyzed by a Varian Saturn III Ion Trap Mass Spectrometer (ITMS) modified by Oak Ridge National Laboratories, Analytical Services Division, to allow direct sample injection and continuous sample analysis. The ITMS was fitted with a 20-cm-long, 100-µm-internal-diameter capillary (J&W part #160-2635), and a restrictor heated interface (Scientific Information Service, Inc. part #912000) operated at 105°C. The capillary interface limits flow into the ITMS to 1 percent of the incoming gas flow rate, which is compatible with both electron impact (EI) and chemical ionization (CI) sources. All analyses were performed using EI sources.

The EC sensor incorporated into the MIP measures the conductance to an electrical current applied between two poles, one on each side of the probe. Electrical conductance, reported as milliSiemens per meter (mS/m), provides a rough measure of soil water content. Since fine-grained soils have greater specific water retention, they tend to be associated with relatively large measured soil conductivity values. Unfortunately, however, most EC readings were not representative because the MIP/EC probe was advanced through a prepushed hole using a dummy probe, and hence soil that contacted the EC poles was not firmly or naturally seated against the probe. Prepushing was necessary to prevent excessive damage to the MIP/EC probe. A total of 30 locations were "dummy pushed" and characterized with the MIP/EC probe.

A total of 30 MIP push locations were drilled. MIP borings were denoted with "SM" followed by a sequential number (e.g., SM0003). The Geoprobe MIP push locations were designated SM0003, SM0005 through SM0012, and SM0029 through SM0049. There were no borings designated SM0001, SM0002, or SM0004 because direct-push borings were numbered consecutively, regardless of which tool/probe was used at each location. SCAPS LIF was used at borings 001, 002, and 003 (SL001, SL002, and SL003). The first MIP boring was to be SM0004; however, it was misidentified as SM0003 in the field. It was decided not to change the boring designation to avoid unnecessary confusion. Although direct-push borings numbered 0013 through 0028 were drilled and completed as piezometer locations, the MIP was not used at these locations. The Geoprobe rig averaged a dummy push depth of 33.1 feet bgs across the EGDY site. An average MIP push depth of 34.0 feet bgs was achieved.

2.2.3.2 MIP Quality Assurance

Change in MIP/DSITMS response due to membrane wear was determined before and after each in situ measurement event and was used to normalize measurements to allow comparisons between results. The MIP/DSITMS response to a check standard was determined before and after each push using one of two methods. Method 1 consisted of analyzing samples collected by the MIP from a sand and water mixture containing a known amount of check standard (as described in Standard Operating Procedure [SOP] M-0005-SWT-01 [URS 2001b]). Method 2 involved analyzing the return carrier gas stream after placing approximately 5 µL of 10 µg/mL check standard directly onto the MIP membrane heated to an operating temperature of 120°C. These quality assurance (QA) measurements were also used to determine a response factor to estimate in situ VOC concentrations.

The Method 1 QA check of the MIP/DSITMS was accomplished by preparing an aqueous solution containing a known concentration of the VOCs of interest. The aqueous solution and sand were simultaneously poured into a 2-L jig that surrounded the MIP membrane. The MIP heater was initiated and the DSITMS analyzed the returning carrier gas stream for a period of 4 minutes. This procedure is supposed to be repeated for three different concentrations in duplicate covering the desired concentration range according to SOP M-0005-SWT-01 to yield a calibration curve. Approximately 4 hours are required to complete the full calibration procedure for a range of three concentrations. Since each MIP had a lifetime of only about 1 day, and since the MIP was being operated in continuous mode, a decision was made to forego the full calibration procedure. Instead, a response factor was determined for a single aqueous concentration of a 1 mg/L mixture of TCE, dichloroethene (cis-1,2-DCE), and vinyl chloride (VC). The response factor was defined as the aqueous concentration (1 mg/L) divided by the maximum DSITMS signal (in counts) measured during the 4-minute sample analysis period.

The Method 2 QA check involved heating the MIP to operating temperature (120°C) and then dropping approximately 5 µL of 10 mg/mL (or 10 µg/L) check standard directly onto the MIP membrane. The 4-minute DSITMS analysis of the carrier gas stream began the moment the 5-mL drop was applied to the membrane. A response factor was determined for the single aqueous concentration of 10 mg/L for a mixture of TCE, cis-1,2-DCE, and VC. The response factor was defined as the aqueous concentration (10 mg/L) divided by the maximum DSITMS signal (in counts) measured during the 4-minute sample analysis period. The time required for the MIP-collected sample to travel through the 100 feet of 1/16-inch-diameter Teflon line was determined to be 100 seconds.

2.2.3.3 Depth Determination of DSITMS Data

The procedure to convert the DSITMS analysis results from time basis to a depth bgs involved several steps. The conversion is made possible because the DSITMS scan number and corresponding depth interval were recorded during each push.

Step 1 of the DSITMS time to sample depth conversion process involved manually entering the depth corresponding to the DSITMS scan for the full DSITMS analysis record of each push. Step 2 involved assigning a depth for each DSITMS analysis result, one for every second, by assuming a constant push rate between the known starting and ending depths of each drill rod advanced. A constant depth was entered between each stop and start when the probe was not in motion. Step 3 involved plotting MIP depth versus ITMS analysis result noting that the DSITMS results were offset by 100 seconds from the corresponding start depth (because it takes 100 seconds for carrier gas to travel from the probe membrane to the analyzer in the ITMS).

The depth of the MIP membrane is determined by tracking the depth of the probe beneath the ground surface. Once a VOC enters the MIP, it then has to travel a distance of 100 feet through the 1/16-inch-diameter transfer tubing to the surface for analysis by the DSITMS. The delay in time between sample collection and analysis was determined to be approximately 100 seconds using the Method 2 calibration procedure. The DSITMS performs an analysis of the return carrier gas stream every second; each analysis is called a scan. Hence the scan rate was one scan per second.

2.2.3.4 DSITMS Calibration and Performance

Instrument operating parameters were examined daily and adjusted when necessary. The mass axis of the mass spectrometer was calibrated daily and the direct sparging device was cleaned when found to be contaminated. A five-point calibration curve was established for TCE, DCE, TCA, vinyl chloride (VC), and tetrachloroethene (PCE). Calibration curves were prepared by analyzing a series of standards with concentrations ranging from 1.25 to 1,000 ppb according to SOP M-0005-SWT-01. A linear regression of the DSITMS response versus standard concentration data was used to construct the calibration curve, and the correlation coefficient (r-squared value) was used to check the linearity of the DSITMS response. R-squared values of 0.99 were routinely achieved for each of the analytes, thereby demonstrating the good degree of linearity of each resulting calibration curve.

For quality control purposes, instrument blanks and laboratory control samples (LCSs) were routinely analyzed. Duplicate or replicate samples were analyzed when sufficient sample was available and as required by SOP M-0005-SWT-01. Additionally, blank water samples were analyzed between contaminated sample runs to check for carry-over contamination.

LCSs were routinely analyzed to determine whether the response of the DSITMS instrument had changed significantly over a period of time. No corrective action was necessary when the integrated response for an analyte fell within ±50 percent of the established daily response for that analyte.

A single performance evaluation (PE) sample was provided to the field laboratory to verify the performance of the DSITMS method prior to the investigation. An evaluation of the results indicated that TCE was adequately characterized in the sample. However, results for DCE, TCA, VC, and PCE were reported at concentrations that fell outside the acceptance limits established. A review of the results indicated that the PE sample was composed of additional chlorinated hydrocarbon compounds and related isomers, which cannot be distinguished by the DSITMS (as discussed in SOP M-0005-SWT-01).

Additionally, 26 groundwater samples were collected in duplicate between August 25 and September 7, 2001, to monitor the general performance of the DSITMS within the EGDY and greater EGDY areas. The duplicate samples were collected and analyzed by Severn Trent Laboratories (STL) of Tacoma, Washington (formerly Sound Analytical Services, Inc.) using EPA Method SW-846 8260. The STL results for groundwater are reported in Appendix A (Table A-2). This technique uses a gas chromatograph mass spectrometer (GCMS) to identify and quantitate VOCs.

A linear regression was used to examine the correlation between the DSITMS and GCMS results. A relatively high r-squared value for TCE was reported (r2=0.99), demonstrating the good correlation between the DSITMS and GCMS for this analyte at relatively high (greater than 1 mg/L) and low (less than 1 mg/L) concentrations. However, r-squared values reported for DCE, TCA, and VC were much lower. These low r-squared values are believed to be attributed to one or more limitations of the DSITMS method. First, TCE breaks down during the mass spectrometer ionization process, yielding ion fragments corresponding to DCE and VC. When TCE is found in large concentrations (e.g., SG0009-16-19), ion fragments from TCE will cause false positive results for DCE and VC ions. Second, major differences in the purge profiles of the calibration standard and the sample for any given analyte may indicate an unexpected matrix effect. Upon closer examination of the purge profile for sample SG0003-16-19, it was noted that the standard 3-minute purge profile captured only a fraction of the DCE ion response for the sample, thereby resulting in the underestimation of DCE in the sample. This is evident when the DSITMS results are compared with the GCMS results of sample SG0003-16-19.

An examination of the groundwater data indicated that three samples (SG0003-16-19, SG0009-16-19, and SG0010-22-25) reported relatively high concentrations (greater than 1 mg/L) of chlorinated hydrocarbon contaminants compared to the results observed in the piezometers (less than 1 mg/L). Hence, a revised linear regression was calculated for only the piezometer results to compare the DSITMS and GCMS data collected from the greater EGDY locations and at concentrations near and below 1 mg/L. Data relating to the three high-concentration groundwater samples were not included in the regression. The new data reported relatively high r-squared values for both TCE and DCE, r2=0.99 and 0.98, respectively. The data relating to these two analytes suggests a good degree of linearity between the DSITMS and GCMS results. Both DSITMS results for TCE and VC showed greater linearity; however, each analyte continued to demonstrate a large number of false positive readings when compared with the GCMS data. An examination of the revised DSITMS PCE results was inconclusive.

A review of the field quality control data and the independent GCMS results indicates that the DSITMS method was an effective qualitative tool for monitoring groundwater samples for the presence or absence of volatile organic chlorinated hydrocarbons. The method was effective for quantifying these same groundwater samples for TCE when TCE was the suspected primary contaminant of concern. The ability of the method to adequately quantify other contaminants such as DCE, TCA, VC, and PCE was limited when the groundwater samples were composed of multi-component mixtures of chlorinated hydrocarbon compounds (as observed with the PE sample analysis) and when the samples were composed of relatively high concentrations (greater than 1 mg/L) of compounds that interfered with the analyst's ability to distinguish individual compounds from one another (as observed with sample SG0010-22-25).

2.2.4 Geoprobe Soil Sampling

Geoprobe soil sampling was attempted to collect soil samples for physical and chemical testing to correlate MIP results with fixed-laboratory results. Geoprobe soil sampling was largely unsuccessful after several sample attempts. On August 28, 2001, soil sampling using the Geoprobe rig was attempted at two locations: S0010 and S0009. A dummy tip was used to prepush each borehole to a selected depth just above the soil sample interval. Direct-push soil samples were denoted "SS" followed by a boring number, then the starting depth and the ending depth (e.g., SS0010-15-17).

The initial effort to collect a soil sample at S0010 was made with a Vertek soil sampler. A Vertek sampler was designed for use with a static force push rig like the SCAPS rig; however, sampling was attempted with the Geoprobe rig that was operating at the site at that time. The first sample attempt resulted in a loss of the sample. The dynamic percussion caused by the Geoprobe hammer tripped the tip release mechanism during soil sampler advancement, allowing soil to enter the sample chamber during sampler advancement instead of at the desired sample depth. The sample collected was thus nondiscrete and unusable. The difficulty in retracing the push rods and opening the sampler was also noted.

A second soil sampling effort was attempted at location S0010, this time with a Macro Core soil sampler, designed to operate with the Geoprobe drill rig. The rig was offset from the original boring location by approximately 1 foot, and dummy rods were again advanced to just above the desired sample depth (15 feet bgs). The Macro Core sampler was used to successfully collect soil samples over three push intervals (15 to 19, 19 to 22, and 22 to 25 feet bgs). Advancement and retraction of the rods and sampler were normal; however, extracting the sampling sleeve after each push became increasingly more difficult. A final effort was made to collect a soil sample from 25 to 28 feet bgs but was unsuccessful because the sampling tip jammed in the push rod and would no longer disengage when tripped for soil sampling.

A last Geoprobe soil sample was attempted at location S0009. The location was prepushed with the dummy tip to a depth of 14 feet bgs. The sampler tip again would not release when tripped, and the push rods had to be removed. It was observed that the Macro Core sampler had become severely damaged beyond repair due to its use in the gravelly and cobbly formation. No replacement part was available on site, and a decision was made to terminate Geoprobe soil sampling activities.

2.2.5 Geoprobe Piezometer Installation

The FSP of the final management plan (URS 2001b) identified 18 proposed locations for dissolved-phase VOC analysis and groundwater elevation characterization. These locations were either immediately adjacent to the EGDY or to the southwest of the EGDY between East Lincoln Drive and Transmission Line Road. Fifteen piezometers were installed by the SCAPS/Geoprobe drill team in the area southwest of the EGDY. Piezometers installed as part of the Phase II RI were designated LC-169 through LC-183. The piezometers were installed in direct-push borings 0013 through 0021, 0023 through 0026, 0033, and one unnumbered boring. The boring numbers correspond to the groundwater grab sample numbers discussed in Section 2.2.8. One boring did not receive a boring number because no groundwater grab sample was collected from that location, although piezometer LC-183 eventually was installed at that location. The objective of the piezometer installation was to characterize groundwater elevation and flow regime near the EGDY.

All piezometers were installed using the Geoprobe rig. The work plan originally called for the piezometer installation via the SCAPS drill rig; however, the SCAPS push penetration depths experienced at the EGDY prevented the use of the SCAPS rig for the piezometer installations.

Each piezometer, from bottom to top, consisted of a drive point, prepacked screen, polyurethane foam seal, bentonite sleeve, piezometer casing, and a protective casing. Piezometers were installed using 2.125-inch-diameter push rods. A 2.25-inch-diameter steel drive point was attached to a 5-foot length of GeoInsight PrePak well screen filled with 20/40 silica sand. The diameter of the 0.010-inch slotted polyvinyl chloride (PVC) screen was 0.81 inch, whereas the diameter of the 65 mesh stainless steel screen wrap was 1.4 inch. Each screen was attached to a 0.5-foot-long polyurethane foam seal and then to a GeoInsight bentonite sleeve. The sleeve consisted of unhydrated granular bentonite wrapped in a degradable paper sleeve. The bentonite sleeve length was 1.8 feet, and the diameter of the seal, after hydration, was up to 2.5 inches (the diameter of the probe hole). A 3/4-inch-diameter PVC casing was then attached to the well screen above the bentonite sleeve and was completed with a stick-up of approximately 2.5 feet above ground surface. The annular space between the PVC casing and the boring sidewall above the bentonite seal was filled with a high solids silica cement grout in the ratio of 60:40 Portland cement to silica flour. A 2.5-inch-diameter steel protective casing with locking aluminum cap was installed over the PVC casing to complete each piezometer. See Appendix D for piezometer as-built records.

2.2.6 Rotosonic Drilling, Soil Sampling, and Monitoring Well Installation

A sonic drilling program was implemented between October 31, 2001, and April 4, 2002, at the EGDY as part of the Phase II RI. Sonic drilling included the following:

- Collection of continuous soil core samples from each of 76 borings, which ranged in depth from 37 to 118 feet bgs
- Evaluation for the presence or absence of NAPL
- Collection of soil samples from select locations and depths for chemical analysis and physical property testing
- Installation of 13 monitoring wells in the upper aquifer for dissolved-phase VOC analysis

Sonic borings were denoted with “RS” (for rotosonic) followed by a sequential number (e.g., RS0001).

The sonic drilling program aimed to meet the following objectives:

- Determination of horizontal and vertical extents of NAPL through soil sample collection and analysis and visual observation
- Retrieval of samples of aquitard material for visual identification and physical property testing for characterization of thickness and continuity of the intermediate aquitard, where and if present
- Retrieval of soil samples to determine the presence and nature of the Second Non-Glacial confining unit below the EGDY
- Collection of groundwater samples to determine the nature of the upper aquifer below the intermediate aquitard (where and if present)
- Control for MIP direct-push locations and geophysics
- Assessment and collection of LNAPL and DNAPL for chemical and physical property testing

All but the last objective were met. A shallow, conventional monitoring well was installed at one location heavily laden with NAPL; however, NAPL did not flow or collect inside the well over the duration of the field investigation, and hence a sample could not be collected for testing. Alternatively, four NAPL samples collected from intact drums removed during the drum removal action were submitted for physical testing.

2.2.6.1 Rotosonic Drilling and Soil Sampling Methodology

The placement of initial sonic borings was based on a combination of Geoprobe MIP push results and the existing conceptual site model of the EGDY developed from previous investigations. The first boring (RS0001) was intentionally placed in an area thought to be free of NAPL contamination as stated in a technical memorandum dated August 3, 2001 (USACE 2001b). This was done to demonstrate that a borehole seal could effectively be placed at the intermediate aquitard (Vashon till), below any highly contaminated zone, prior to boring advancement to the base of the upper aquifer. The next three borings (RS0002 through RS0004) were intentionally placed within the three suspected NAPL areas, down to the base of the upper aquifer, for NAPL and stratigraphic characterization. Subsequent borings were then located based on information gained at previous borings in an attempt to characterize NAPL horizontal and vertical extent and stratigraphy. As such, the dynamic field investigation approach described in the project management plan was effectively used.

Drilling locations were marked in the field by driving 12-inch wooden stakes into the ground and writing the boring number on the stake in indelible ink. Sonic boring numbers were sequential, beginning with RS0001 and ending with RS0076. Once a location was chosen, the drill team placed black visqueen sheeting on the ground surface around the stake in the direction of the rig. The visqueen provided ground surface protection in case hydraulic fluid, diesel fuel, or oil were to leak from the rig. The Rotosonic 150 drill rig was then driven in place so that the drill rig mast was situated over the staked location. The supply truck, containing drill rods, core barrels, and other essential drill tools, was then backed up so that its back end and the back of the drill rig were joined together to make a work platform for the drill team. The drill team usually consisted of a rig operator and two helpers.

Actual drilling began by vibrating into the ground an 8-inch-nominal-diameter by 10-foot-long soil core barrel that was attached to the sonic head of the drill rig. The cutting shoe of the core barrel was studded with carbide buttons, and the shoe and core barrel were slowly rotated to cut through the subsurface and advance the barrel. After core barrel advancement, the rig operator would pull the full or partially full barrel up out of the borehole to working level on the rig platform. A tubular plastic sleeve with a knot tied at the bottom was placed over the bottom of the barrel and the barrel vibrated, causing the soil sample to be extruded from the barrel into the plastic sleeve. The bottom of the sample interval was marked with indelible ink on the plastic sleeve containing the sample. Each plastic sleeve was filled with no more than 2.5 feet of soil core. The empty core barrel was then placed down the borehole annulus and the drilling process was then resumed. Drill rods were attached to the drill string between the sonic head of the rig and the core barrel so that the core barrel was continually in contact with soil at the bottom of the boring.

Temporary steel casing was used in the drilling process to prevent borehole collapse and to isolate contaminated zones. As soon as the borehole annulus began caving, usually at about 10 to 15 feet in depth, a nominal 8-inch-inner-diameter casing was placed in the borehole to keep the hole open. A cleanout run was performed after each casing advancement in order to dispose of disturbed soil that had sloughed inside the casing. If the boring was to be advanced greater than 40 to 45 feet bgs, a casing reduction took place. This involved termination of the 8-inch-inner-diameter casing and 8-inch core barrel usage and placement of a 3- to 5-foot-thick bentonite seal inside the casing. Borehole advancement was continued below the bottom of the 8-inch-inner-diameter casing and seal using a nominal 6-inch-inner-diameter casing and core barrel. If significant contamination was encountered at a particular boring location, the water inside the 8-inch-inner-diameter casing was bailed after seal placement to minimize the downward spread of contaminants.

A ground rule was established in the technical memorandum (USACE 2001b), which was written after completion of the final management plan, to terminate any sonic boring that encountered pooled DNAPL (specifically called “pooled NAPL” in the memorandum but referring to DNAPL) at the base of the upper portion of the upper aquifer (NAPL pooled above a lower permeability unit consisting of till and/or glaciolacustrine silt). Pooled DNAPL was defined as free-flowing pure phase product that would drain from a soil core before or after splitting. If a boring was terminated due to pooled DNAPL, a conventional DNAPL collection monitoring well was to be constructed that would not penetrate the lower permeability unit. No pooled DNAPL was observed at the EGDY in any of the sonic borings, and hence none of the borings had to be terminated due to the pooled DNAPL ground rule. Although significant NAPL was encountered within the soil matrix at boring RS0003 and a DNAPL collection well was installed (LC-186), the NAPL did not meet the criteria for pooled DNAPL.

As each boring was being drilled and sampled, the continuous soil samples contained in the plastic sleeves were set out on the ground and logged. The bags were cut open lengthwise to expose the soil cores, and the soil column was then logged by an experienced field geologist to identify and record formation stratigraphy and any NAPL present. Recorded stratigraphic information included depth, color, soil type, estimated density based on drill penetration rate and qualitative thumb penetration test, and qualitative moisture content. Original field logs were recorded on a 1-inch equals 1-foot scale. Soil type was classified in accordance with American Society for Testing and Materials (ASTM) D2488-90, Standard Practice for Description and Identification of Soils (Visual-Manual Procedure). Attempts to identify established stratigraphic units were made by the field geologist, and approximate percentages of the fine-grained materials, sands, and gravels were also noted when possible.

In addition to stratigraphy, any contaminant-related features such as odor, staining, unusual solid constituents such as manmade debris, or the visible presence of NAPL was noted on the logs. The following NAPL descriptions were documented on the boring logs for each sonic soil boring:

- No Visible Evidence—No visible evidence of oil on soil sample.
- Sheen—Any visible sheen present in the water on soil particles as described by the sheen testing method presented later in this section.
- Staining—Visible brown or black staining on soil. Can be visible as mottling or in bands. Typically associated with fine-grained soils.
- Coating—Visible brown or black oil coating soil particles. Typically associated with coarse-grained soils such as coarse sand, gravels, and cobbles.
- Oil Wetted—Visible brown or black oil wetting the soil sample. Oil appears as a liquid and is not held by soil grains. Soils oozing petroleum typically contain approximately 2 to 3 percent petroleum.

Field screening methods were used in addition to visual observations to help evaluate the presence of TCE and other potential contaminants in the soil. Field screening methods included the use of a photoionization detector (PID) for detection of VOCs; use of an ultraviolet (UV) lamp for detection of PAHs in soil; sheen testing; and dye testing with Sudan IV hydrophobic dye for the presence of solvents and/or hydrocarbons.

A Photovac 2020 PID was used to detect VOCs in air emanating off the sample by placing the inlet tip of the unit within 1 inch of a freshly exposed surface of the soil core. PID readings were displayed on the digital readout of the instrument and recorded on the field logs in parts per million (ppm), with the instrument calibrated daily to a 100-ppm isobutylene standard. A 10.4-eV bulb was used in the PID. The PID data was used as a semiquantitative measure of VOC soil contamination, and a qualitative indicator of the potential for TCE, which is a VOC. PID data were also used to ensure compliance with the project site safety and health plan (URS 2001b).

A Raytector 5-2 UV lamp equipped with a 6-watt, long-wave bulb was used to detect PAH contamination in the continuous sonic soil cores. The UV lamp was shined over the soil cores in a darkened environment to observe any soil fluorescence intervals related to relatively high concentrations of PAHs in the soil. The fluorescence is mostly caused by the unique molecular structure of PAHs, a class of organic compounds found in crude oils, petroleum products, and coal tar distillates. Pure TCE will not fluoresce; however, if the assumption holds that TCE is commingled with PAH compounds on site, TCE presence, although not necessarily NAPL presence, can be detected with the UV lamp. A simple positive or negative fluorescence was noted for the continuous core sample. The core was placed in a metal shed that was moved from boring to boring in order to have a dark environment compatible with the fluorescence technique. This UV fluorescence technique has proved useful for field screening of petroleum-contaminated soil on projects by others (Colligan and LaManna 1993).

A qualitative sheen test was conducted periodically on the soil cores to determine petroleum-product presence or absence. Generally, soil subsamples were collected and sheen tested every 2 to 5 feet along the entire length of the core. Sheen screening is a sensitive method that can be effective in detecting petroleum-based products in concentrations lower than regulatory cleanup guidelines. Water sheen testing involved placing soil in a small plastic bag of distilled water and observing the water surface for signs of sheen. Sheens were classified as follows:

- No Sheen (NS)—No visible sheen on water surface
- Slight Sheen (SS)—Light colorless film; spotty to globular; spread is irregular, not rapid; areas of no sheen on water surface remain; film dissipates rapidly
- Moderate Sheen (MS)—Light to heavy film; may have some color or iridescence; globular to stringy; spread is irregular to flowing; few remaining areas of no sheen on water surface
- Heavy Sheen (HS)—Heavy colorful film with iridescence; stringy in appearance; spread is rapid; sheen flows off the sample; most of water surface may be covered with sheen

Sudan IV dye was used as an additional indicator for the potential presence of solvents and/or hydrocarbons, and indirectly as an indicator of NAPL presence or absence. Sudan IV is a solid hydrophobic dye that remains in powder form while in pure water but readily dissolves in the presence of solvent and/or petroleum hydrocarbons. Water and dye mixtures were prepared by placing a small amount of dye in 15 mL of distilled water inside a 50-mL vial. An approximate 5-mL soil aliquot was then placed in the prepared water/dye mixture, and the vial was shaken vigorously for 20 seconds. A positive or negative reading was recorded based on whether the dye appeared to dissolve and stick to the sidewall of the vial. Heavily dissolved dye on the vial sidewall often coincided with visible NAPL globules within the soil sample matrix, and hence a qualitative correlation was developed. Sometimes the dye appeared to dissolve a small amount, making it difficult to determine a definitive positive or negative result. In these cases, a question mark was placed on the boring log for that particular test, indicating an "indeterminate" response.

After visual observation and PID measurements of the soil, selected intervals were chosen for soil chemical analysis. Soil sample depths for chemical analysis were generally selected when one of the following was encountered: the water table, visible or UV evidence of NAPL, or a less permeable stratigraphic unit. The sampling technician or geologist donned clean nitrile gloves before collecting the sample. Soil grab samples were collected for VOC and total petroleum hydrocarbon (TPH) analysis by placing soil into precleaned, laboratory-provided sample containers. VOC samples were collected first to minimize volatilization during chemical sample collection and handling, followed by TPH collection. VOC sampling methodology followed EPA SW-846 Method 5035. For VOC collection, a 4-ounce wide-mouth glass jar was filled with approximately 25 grams of soil sample using a decontaminated stainless steel spoon, taking care to minimize the amount of coarse-grained particles included in the sample. A premeasured volume of methanol preservative was then poured into the 4-ounce sample container so that the soil was completely immersed in methanol. Grab samples for TPH were collected by filling an 8-ounce wide-mouth glass jar with a homogenized section of soil from the same interval as that of the VOC sample. Headspace was minimized by completely filling the sample jars with soil. Again, care was taken to avoid larger-sized soil particles. TPH samples were analyzed for diesel-range organics using method NWTPH-Dx (Northwest total petroleum hydrocarbons—diesel range [extended]). The sample jars were labeled and stored below 25°C during collection and were stored below 4°C thereafter until hand-carried to STL. Samples were generally delivered to STL the day of sample collection or the day following, except on weekends when the laboratory was closed. Samples kept on site overnight were stored in either a locked refrigerator or in an ice chest inside the locked field trailer. A quick turnaround time of 48 hours was requested for all analytical samples sent to STL.

Field screening and laboratory results were combined to determine actual NAPL extent within each boring. Usually, NAPL intervals interpreted from different techniques were similar; however, a conservative approach was used when results differed. NAPL intervals with combined lines of evidence generally corresponded with any zone interpreted to contain NAPL based on any method (including visual, PID, UV, sheen test, dye test, and analytical laboratory results).

Physical parameter samples were then collected for laboratory analysis after chemical sample collection and after all visual and field screening methods were performed. PTS GeoLabs Incorporated (PTS Lab) of Santa Fe Springs, California, performed the physical testing. Physical samples were generally collected when soil type changed significantly and when a significant NAPL-containing zone was encountered. There were two classes of physical soil samples: disturbed and undisturbed. Disturbed samples were collected in 16-ounce, wide-mouth plastic jars from the same borings from which continuous core and chemical samples were collected.

Undisturbed samples were collected from unique borings collocated adjacent to original borings and targeted specific depths based on materials encountered in the original borings. A total of seven collocated borings were completed, from which 21 undisturbed samples were obtained. Undisturbed samples were collected either in 3.5-inch-diameter Lexan sleeves, 2-inch-diameter brass sleeves, or 6-inch-diameter steel sleeves precut in 6-inch lengths. Undisturbed samples were then tested in a vertical orientation. The collocated borings contained the letter “a” after the original boring designation (i.e., boring RS0006a collocated adjacent to RS0006). Physical parameter testing included grain size, bulk density, effective porosity, cation exchange capacity (CEC), total organic carbon (TOC), hydraulic conductivity, and NAPL saturation. Samples collected for TOC analysis were stored and shipped at 4°C as required in the FSP.

In conjunction with the sonic drilling and sampling program at the EGDY, a slug testing program was also performed to evaluate the in situ permeability contrast between various hydrogeologic units beneath the site. PNNL performed the slug testing while physical sampling took place at borings RS0002a, RS0012a, RS0019a, RS0024a, and RS0048a. Pneumatic slug tests were conducted within the temporary drill casing and a temporary screen using compressed nitrogen gas as the displacing (slug) volume. The water column within the drill casing was depressed by increasing the air pressure in the casing above the water column. When the water level was depressed to a predetermined level and the gas pressure stabilized within the test interval, the air pressure within the drill casing was rapidly released. The instantaneous release of gas from the temporary drill casing initiated a pneumatic slug withdrawal test. All tests and analyses were conducted in accordance with the procedures outlined in the PNNL letter report, *Fort Lewis East Gate Disposal Yard Slug Test Characterization Results* (Battelle 2002), presented in Appendix E.

2.2.6.2 Monitoring Well Installation Methodology

A total of 12 multi-port monitoring wells and one conventional, single-screened well were installed at the EGDY during the Phase II RI field program. All monitoring wells were installed in existing rotosonic soil borings using either the sonic rig or a crane truck. Well designations were sequential, beginning with LC-184 and ending with LC-196 in accordance with the existing monitoring well numbering system in place for the Logistics Center. The individual ports within multi-port wells were designated in sequential order by a dash followed by the port number placed after the well number (e.g., Port 1 in well LC-184 was denoted as LC-184-1). All well installation activities were supervised or monitored by a qualified geologist knowledgeable in the site geology and well installation requirements set forth in the Ecology minimum standards for construction and maintenance of wells (WAC 173-160) and in EM 1110-1-4000, *Monitor Well Design, Installation, and Documentation at Hazardous and/or Toxic Waste Sites* (USACE 1998a). The prime drilling contractor was responsible for obtaining and submitting all well drilling permits and logs, as required by the State of Washington.

The 12 multi-port monitoring wells constructed were designated LC-184, LC-185, and LC-187 through LC-196. These wells corresponded to sonic borings designated RS0001, RS0002, RS0004, RS0005, RS0008, and RS0070 through RS0076 in respective sequential order. Each multi-port well installed at the EGDY was made of continuous, multi-channel, extruded polyethylene tubing called CMT tubing manufactured by Solinst Canada Ltd. CMT well tubing has a 1.7 inch outer diameter and is customized with up to seven individually screened intervals, called ports, from which groundwater samples are collected. The six outside chambers of a CMT well are 7/16 inch in diameter, whereas the inside chamber is 3/8 inch in diameter. LC-184, LC-185, and LC-187 through LC-189 were constructed with four ports each, whereas LC-190 through LC-193, LC-195, and LC-196 contained six ports each. LC-194 was constructed with five ports. Each port is connected to the top of the CMT well head through its own individual chamber. Ports are constructed above ground prior to CMT well installation. A port is constructed by drilling four 5/16-inch-diameter holes 1 inch apart into the specified CMT chamber and clamping a stainless steel, fine wire mesh screen around the openings. One vent hole is drilled 3 inches below the bottom of the screened port, and hot-melt polyethylene glue is placed between the vent hole and the screen. The vent hole allows the well to be inserted into a borehole without capturing air in the unused portion of the chamber below the port, allowing for easier installation.

Once constructed above ground, the CMT well was installed in the borehole. The CMT tubing was placed down the cased borehole off a reel, and a rigid, 2-inch-diameter insertion pipe was placed over the CMT tubing to straighten it and prevent bentonite from adhering to the port screens. The ports were constructed to correspond to the depths of the most permeable zones within the borehole. Alternating zones of 10/20 silica sand filter pack and 3/8-inch-diameter bentonite chips were placed down the annular space between drill casing and insertion tubing. Filter pack zones centered on the ports were generally 6 feet long, with 3 feet below and 3 feet above the port. Bentonite zone lengths varied, depending on how far apart the ports were constructed. The depth was measured frequently with a sounding tape, and the casing and insertion tubing were incrementally raised as the level of sand or bentonite was raised, making sure to keep 2 to 3 feet of well materials inside the casing at all times. Once the uppermost port received its filter pack, a 3-foot bentonite seal was placed, followed by a 2-foot fine 20/40 sand layer. The remainder of the annulus was grouted with a cement-silica mixture in the ratio of 60 percent Portland cement to 40 percent Halliburton Class G silica flour and no more than 7 gallons of water per cubic foot of mix. The grout was mechanically mixed and placed from the bottom of the grout interval up to near ground surface with a tremie tube, allowing room to cement-in a protective cover. The well was finished with an approximate 2.5-foot stick-up above ground surface and with an 8-inch-diameter locking steel protective cover. This well also received a concrete pad and four protective bollards placed at the edges of the pad. See Appendix D for well diagrams of all CMT multi-port wells installed at the EGDY.

The one conventional, single-screened monitoring well was installed as a DNAPL collection well in boring RS0003 and designated LC-186. This well was constructed with 2-inch-diameter PVC screen and casing. The screen was 0.020 inch slotted, 10 feet in length, and fitted with a flush-threaded end cap at the bottom. The casing was schedule 40 PVC and was flush-jointed to the well screen. The well was installed through a temporary 8-inch-diameter casing that was pulled up incrementally as the well materials were being added down the annular space of the borehole between the drill casing and well casing. The filter pack, consisting of 10/20 silica sand, was placed from the bottom of the screen to 3 feet above the top of the screen. The top of the filter pack was often sounded during retraction of the drill casing by the drill team to ensure that the filter pack remained within the casing during removal. A 4-foot-thick bentonite seal, consisting of 3/8-inch-diameter sodium-montmorillonite chips, was placed above the sand pack, followed by a 1-foot layer of fine-grained (20/40) silica sand. The remainder of the annular space above the fine sand was backfilled with cement-silica grout in the ratio of 60 percent Portland cement to 40 percent Halliburton Class G silica flour and no more than 7 gallons of water per cubic foot of mix. The grout was mechanically mixed and placed from the bottom of the grout interval up to near ground surface with a tremie tube, allowing room to cement-in a protective cover. The well was finished with an approximate 2.5-foot stick-up above ground surface and with an 8-inch-diameter locking steel protective cover. This well also received a concrete pad and four protective bollards placed at the edges of the pad. See Appendix D for a well diagram of LC-186.

2.2.7 Surface Water Sampling

On July 20 and 21, 2001, 12 surface water samples were collected along Murray Creek southwest of the EGDY for VOC analysis using the DSITMS in the onsite laboratory operated by the USACE Tulsa District. These sampling locations were approximately evenly spaced at 300- to 400-foot intervals beginning near the headwaters of Murray Creek and the existing sampling location SW-MC-1. New sampling locations were designated in sequential order beginning with SW-MC-0005 and ending with SW-MC-0016. The “SW” in the sample location stands for Surface Water, and the “MC” stands for Murray Creek. Locations were temporarily denoted by wooden stakes with sampling station designations written in indelible ink. GPS coordinates were obtained for all surface water sample collection locations. At each sampling location, a grab sample was collected 2 to 3 feet from the southern creek bank using a disposable Teflon bailer. The bailer was tipped and the sample emptied into four hydrochloric acid (HCl)-preserved 40-mL glass sample vials. The vials were brought back to the onsite laboratory and stored in the refrigerator until they were analyzed for VOCs by the DSITMS.

2.2.8 Groundwater Sampling

2.2.8.1 Piezometer Location Sampling

Twenty-eight groundwater grab samples were collected at the 15 Geoprobe-installed piezometer locations. Groundwater samples at these locations were collected by lowering and raising a disposable Teflon bailer inside the cavity of the Geoprobe push rods. No purging of the water inside the rods was conducted prior to sample collection. Whenever possible, sample collection was attempted at two discrete depths, shallow and deep, at each piezometer location. At some locations, Geoprobe push rod refusal prevented the collection of a deeper groundwater grab sample. Samples were collected by directly filling six 40-mL volatile organic analysis (VOA) vials preserved with HCl from the bailer. The sample jars were labeled and stored below 25°C during collection and were stored below 4°C thereafter. Direct-push groundwater grab samples were denoted by "SG" (for SCAPS-Team-acquired groundwater), followed by the boring number, followed by the top and bottom depths from which the grab sample was collected. For example, SG0013-14-19 designates a groundwater grab sample from direct-push boring 0013, collected from 14 to 19 feet bgs. See Table 2-1 for a list of groundwater grab sample and corresponding piezometer IDs. Groundwater samples were collected in duplicate and analyzed for VOCs in both the onsite laboratory and fixed laboratory (STL). STL used methodology SW-846 8260B to analyze these samples. A quick turnaround time of 48 hours was requested for all analytical samples sent to STL.

The onsite laboratory operated by the USACE Tulsa District performed VOC analyses using a DSITMS following SOP M-0005-SWT-01 of the SAP (URS 2001b). Water samples were prepared for analysis on site by pouring off enough water from the 40-mL sample vial to create a 1/4-inch headspace at the top of the vial. The vial was then attached to the direct sparging device and sparged by allowing 99.999 percent pure helium to flow through the vial. VOCs were purged directly from the liquid samples, and conveyed directly into the spectrometer ion source by means of the helium stream, where the compounds were ionized by electron impact. Full-scan mass spectra were acquired continuously and were used to identify the VOCs. Characteristic ions unique to the target analytes were monitored for a selected period of time to establish an accumulated (integrated or averaged) response, and the response was compared to that from a comparably generated calibration factor for quantitation.

2.2.8.2 Monitoring Well Sampling

The CMT multi-port monitoring wells installed during the Phase II RI were developed generally between 2 and 7 days after well completion. The well development process removed fines from the well chambers and ports that had accumulated during installation. Well development was performed by inserting 1/4-inch-outer-diameter polyethylene tubing down the CMT chamber to be developed until it stopped at the port's bottom plug. Because water levels in the chambers of all EGDY multi-port wells were generally shallow (10 to 15 feet bgs), a peristaltic pump was used to pump groundwater from the well chambers. The peristaltic pump was attached to the 1/4-inch tubing, and sample chambers were developed by low-volume pumping of groundwater until water quality parameters of pH, temperature, specific conductance, oxidation-reduction potential (ORP), dissolved oxygen (DO), and turbidity stabilized and the development water was clear in appearance to the unaided eye. Generally, parameter stabilization involved three successive readings where each of the following criteria were met: ±0.1 for pH; ±3 percent for conductance; ±10 percent for temperature, turbidity, and DO; and ±10 mV for ORP. Turbidity readings of 10 nepholometric turbidity units (NTUs) or less were desired but not always achieved.

CMT multi-port monitoring wells were purged and sampled following well development. The wells were allowed to equilibrate at least 1 week after development before purging and sampling occurred. The USACE Seattle District SOP for low-flow purging and sampling, as provided in the project FSP, was followed. The low-flow sampling technique provides data that are more reproducible and representative than data from a higher flow method and also generates less investigation-derived waste than the higher flow method. An exception to the SOP was that the groundwater level in the purged CMT chamber could not be monitored at the same time that purging took place. This is because the water level meter probe will not fit down the CMT chamber with a 1/4-inch-outer-diameter sample tubing already inserted into the chamber. As with well development, water quality parameters were measured and recorded until they stabilized, and then the port was sampled. The process was repeated for all chambers/ports at a particular multi-port well. A total of four 40-mL HCl-preserved vials were filled from each port and constituted a single groundwater sample. The sample jars were labeled and stored below 25°C during collection and were stored below 4°C thereafter. Sample IDs for groundwater grab samples from multi-port wells were denoted by the well number, followed by the port number, followed by the date the sample was collected. For example, LC0184-01-112901 designates a groundwater grab sample from Port 1 of well LC-184 on November 29, 2001 (11/29/01). The sonic boring ID was different than the monitoring well ID. See Table 2-2 for a list of monitoring well IDs and corresponding boring IDs. Samples were analyzed for VOCs by STL using Method SW-846 8260B. A quick turnaround time of 48 hours was requested for all analytical samples sent to STL.

The conventional, single-screened monitoring well (LC-186) installed during the Phase II RI was purged and sampled on December 3, 2001, 4 weeks after well completion. Because a sheen of LNAPL was detected floating on the water table, this well was not developed as specified in the final management plan (URS 2001b). The well was purged using a peristaltic pump and 1/4-inch-outer-diameter disposable polyethylene tubing. The same water quality parameters as for the multi-port wells were monitored until stable. Samples were then collected into two 1-L amber glass jars for TPH-Dx analysis by Method NWTPH-Dx and into four 40-mL glass vials for VOC analysis using SW-846 8260B methodology. The sample jars were labeled and stored below 25°C during collection and were stored below 4°C thereafter until hand-carried to STL for analysis. The groundwater sample collected from this well was designated LC0186-120301.

2.2.9 Geophysical Investigation

URS Corporation (URS) was contracted to perform a geophysical survey of a 5-acre parcel of the EGDY located between the existing groundwater treatment plant and East Lincoln Drive (the area later referred to as NAPL Area 3). The objective of the geophysical investigation was to characterize the nature, depth, and extent of the subsurface stratigraphy beneath the 5-acre parcel in order to better understand potential NAPL behavior in relation to the stratigraphy. Of particular interest was the suspected lower permeability unit at approximately 35 to 40 feet in depth consisting of glacial till and/or glaciolacustrine silt. This unit was of interest because it was originally hypothesized that this unit controlled the migration of DNAPL on site. Also of interest was the Second Non-Glacial unit located approximately 100 to 110 feet bgs. Three types of geophysical investigation techniques—ER, IP, and GPR—were selected to accomplish the survey objective. See Appendix F for a detailed explanation of each of the geophysical techniques implemented.

2.3 DEVIATIONS FROM THE FINAL MANAGEMENT PLAN

After a 5-day trial period from July 16 through 20, 2001, an evaluation of the SCAPS fieldwork by the project team concluded that the SCAPS rig was not able to achieve the required push depths at the site to meet the project objectives. SCAPS push rods using a dummy tip and at times an MIP/CPT probe continually refused on shallow gravel and cobbles less than 20 feet deep. Only three LIF pushes could be recorded, none of which were to a depth sufficient to characterize the bottom of detected contamination. A decision was made to terminate the SCAPS investigation and to instead rely on a Geoprobe direct-push rig to obtain direct-push subsurface data. The MIP was used in conjunction with the Geoprobe rig; however, LIF, CPT, and GeoVis tools, being compatible only with SCAPS, dropped out from the investigation toolbox and thus limited the usefulness of this phase of the investigation.

Use of the Geoprobe rig to obtain MIP data presented a dilemma in MIP data interpretation. The SOP (M-0005-SWT-01) in the project FSP (URS 2001) pertaining to the MIP and ion trap mass spectrometer applied only when these instruments were operated by, and in conjunction with, the SCAPS push rig. No SOP was specified for use of the MIP with the Geoprobe rig. Because detailed characterization of the potentially small NAPL layers or zones depends on very closely spaced vertical contaminant measurements, it was decided to run the MIP via the Geoprobe rig in a continuous mode. Time limitations would have prevented the use of the MIP with the Geoprobe rig at closely spaced discrete sample intervals, as could have been done much more quickly with the SCAPS/MIP setup. Section 2.2.3 discusses the operating procedures and calibration methods associated with the use of the MIP in conjunction with the Geoprobe rig.

Because LIF data could not be collected on site, and because the results of the Geoprobe/MIP investigation were able to be compared with analytical results from just three soil samples from one boring using direct-push sampling, many more sonic borings were drilled than originally anticipated. Although the FSP called for 19 soil borings to be drilled using the sonic rig, a total of 76 were eventually drilled at the EGDY. The additional number of sonic borings, in effect, replaced the LIF as the primary means of NAPL nature and extent characterization and MIP data verification. This deviation from the final management plan caused the EGDY field investigation to be longer than anticipated by approximately 2 to 3 months.

The FSP called for the dimensions of the larger-sized sonic borehole annulus to be 10 inches in diameter and the smaller-sized borehole to be 6 inches in diameter. The sonic drilling subcontractor had available only 8-inch- and 6-inch-nominal-diameter drill casings; therefore, the larger-sized borehole ended up being less than 10 inches. Because of the vibratory, side-to-side action of the casing during advancement, the borehole annulus using 8-inch-diameter casing is slightly larger than 8 inches, although smaller than 10 inches. This deviation from the final management plan is not of critical importance. What is important is that the difference between well diameter (1.7 inches for CMT wells) and the ID of the smaller-diameter casing (6 inches) be greater than 4 inches in accordance with Ecology and USACE guidance. This requirement was met.

Two field-screening tools were used to aid in the qualitative description of soil cores that were not addressed in the FSP. NAPL presence or absence in the sonic-drilled soil cores is of vital interest for successful NAPL characterization. Therefore, a UV lamp commercially available for use in PAH organic compound detection was added to the soil logging tools of the site geologist. Also, a dye test procedure using Sudan IV, a hydrophobic dye that dissolves in the presence of solvents and/or hydrocarbons, was developed and used by the site geologist to aid in contaminant and NAPL characterization of the soil cores. This deviation from the final management plan was beneficial to the data interpretation process.

The in situ pneumatic slug testing was not included in the FSP and was added based on discussions and recommendations made by PNNL during one of the working group project update meetings. This deviation from the final management plan was beneficial to data interpretation and comparison.

There was a minor discrepancy in the number of multi-port monitoring wells installed at the EGDY compared to the number in the FSP. The FSP called for up to 11 CMT multi-port monitoring wells to be installed at the EGDY as part of the Phase II RI sonic drilling program. Instead, 12 CMT wells were installed at the EGDY, one more than anticipated. Also, only one of four potential DNAPL collection wells was installed, and none of the four potential water table wells were installed on site. The discrepancy in well numbers is due to the difficulty in anticipating field conditions prior to the investigation. For example, the planned installation of four DNAPL collection wells assumed that four locations with pooled DNAPL could be found; however, no pooled DNAPL was encountered.

The FSP called for the placement of centralizers every 40 feet along the outside of each CMT well stem to ensure that the well is installed plumb and that the filter pack is adequately placed around the port screens. The drilling company and drill operator raised concerns that bentonite was likely to become lodged on top of the centralizers, which would cause bridging of well materials, thus preventing continuous filter packs from being placed within the screened zones and compromising well integrity. An alternate solution to keep the well plumb was devised by placing a rigid insertion pipe over the outside of the CMT well, which was incrementally raised as filter sand and bentonite were added to the bottom of the well. This deviation from the original plan did not adversely affect well integrity or use.

The FSP called for the use of 0.020-inch slotted well screen prepacked with #20 filter sand for the conventional 2-inch PVC DNAPL collection wells. A non-prepacked well screen was used because a prepacked screen was not available on site at the time RS0003 was drilled and subsequently converted into DNAPL collection well LC-186. A field decision was made to use a non-prepacked well screen and to manually install a 10/20 silica sand pack around the screen to expedite well completion in a highly contaminated area. This deviation from the management plan is believed to have had no effect on the well's ability to collect NAPL.

Two soil physical parameter test methods used differed from the ones stated in the FSP. For bulk density, Method API RP40 was used in place of ASTM D2937. For TOC measurement, the Walkley-Black Method was used in place of SW-846 9060. Also, percent NAPL saturation was measured using Method SW-846 9081. This parameter was inadvertently left off the list of physical properties parameters in the final management plan. Because it is not expected that the TOC and bulk density results would differ significantly from either of their corresponding methods, these deviations from the FSP do not appear to have affected the data.

DNAPL samples were to be collected in DNAPL collection wells installed during the Phase II RI; however, no DNAPL entered the lone DNAPL collection well installed during the investigation. Instead, NAPL physical properties testing results were used from the samples collected during the source area drum removal conducted by Garry Struthers Associates (GSA 2001).

The FSP called for water level measurements in new piezometers, monitoring wells, and existing monitoring wells in the greater EGDY area to be measured at least once during the Phase II RI field investigation. Because the field investigation lasted longer than anticipated, four rounds of water levels were measured and recorded between September 2001 and March 2002.

2.4 DISPOSITION OF INVESTIGATION-DERIVED WASTE

Investigation-derived waste (IDW) is defined as any solid or liquid material used or generated during the field investigation program. Solid IDW generated during the Phase II RI includes soil, onsite laboratory waste, and trash. Liquid IDW generated during the field program includes well development/purge water and water bailed from sonic boreholes, onsite laboratory waste, and decontamination water. IDW management was in accordance with the project FSP.

Soil cuttings generated during the sonic drilling investigation, including excess soil sample material, were collected and stockpiled at a preapproved location adjacent to NAPL Area 2 at the EGDY. The final stockpile dimensions were approximately 25 feet long, 20 feet wide, and 8 feet high. The stockpile was covered with plastic-coated tarps, and the tarps were secured in place by wooden pallets placed over them. The stockpile is to be buried in a shallow pit in NAPL Area 2, an area slated for follow-on thermal treatment. No soil cuttings were generated with the SCAPS or Geoprobe rigs.

One calibration technique of the MIP during SCAPS and Geoprobe work required that store-bought sand be mixed with a water-calibration standard mixture. The MIP sand was separately contained in a 40-gallon lab pack drum and disposed of off site at a RCRA-approved facility by the USACE Tulsa District under contract with Safety-Kleen on January 8, 2002. Approximately 4 cubic feet of MIP sand IDW was generated.

Nonhazardous trash such as empty cement and bentonite bags, plastics, paper, and scrap well materials was disposed of off site by the drilling contractor.

Water generated on site during drilling, well development, and sampling was collected and temporarily containerized in two 600-gallon Baker tanks located near the front gate of the EGDY. A waste stream protocol was developed by Fort Lewis Department of Public Works through an initial analytical evaluation of the first full tank of water. The Defense Reutilization Marketing Office (DRMO) wastewater hauler under contract with Fort Lewis emptied the tanks. A total of approximately 4,200 gallons of wastewater was generated during the Phase II RI and disposed of off site.

The MIP calibration technique that produced solid IDW also generated liquid IDW. The calibration liquid was separated from the solids into a 40-gallon lab pack drum and subsequently disposed of at an off-site RCRA-approved facility by the USACE Tulsa District under contract with Safety-Kleen on January 8, 2002. Approximately 20 gallons of MIP calibration liquid waste was generated.

Decontamination wash water was allowed to drain onto the ground surface in accordance with the FSP. Generally, most decontamination associated with sonic drilling occurred in a centralized location located approximately 250 feet northeast of the covered soil stockpile at the EGDY.

Table 2-1
PIEZOMETER/SAMPLE IDENTIFIER

Piezometer ID	Groundwater Sample ID
LC-169	SG0013
LC-170	SG0014
LC-171	SG0015
LC-172	SG0016
LC-173	SG0017
LC-174	SG0018
LC-175	SG0019
LC-176	SG0020
LC-177	SG0021
LC-178	SG0033
LC-179	SG0023
LC-180	SG0024
LC-181	SG0025
LC-182	SG0026
LC-183	NA

Note:
No groundwater grab sample was collected from LC-183.

Table 2-2
MONITORING WELL/SONIC BORING IDENTIFIER

Well ID	Boring ID
LC-184	RS0001
LC-185	RS0002
LC-186	RS0003
LC-187	RS0004
LC-188	RS0005
LC-189	RS0008
LC-190	RS0070
LC-191	RS0071
LC-192	RS0072
LC-193	RS0073
LC-194	RS0074
LC-195	RS0075
LC-196	RS0076

Note:
That is, well LC-184 was installed in sonic boring RS0001.

3.0 DATA SUMMARY

3.1 OTHER POTENTIAL SOURCE AREAS

Six potential source areas other than the EGDY were investigated by excavation with a backhoe. These areas were named Trench 12, 13, and 14, Disturbed Area 1, and Cleared Area 1 and 2 and are shown on Figure 3-1. Other features shown on the figure were ruled out as likely source areas based on walk-throughs of each site. The site features and exploratory trenches dug in search of past disposal activities associated with each area are summarized in Table 3-1. The areas investigated were much smaller than the EGDY, ranging from approximately 0.25 to 0.75 acre. A total of 42 exploratory trenches were dug at the six sites investigated and were labeled T001 through T042. The trenches were approximately 3 feet wide by 3 to 5 feet deep. No evidence of past petroleum-waste disposal activities was observed in any of the trenches.

3.2 EXPLORATION LOCATION SURVEY

Traditional survey techniques were employed by Thornton Land Surveying, Inc. to measure horizontal and vertical positions of the 76 sonic borings, 30 Geoprobe/MIP borings, 13 monitoring wells, and 15 piezometers. Other EGDY features not associated with Phase II RI field work were surveyed to finalize thermal treatment plans and specifications and to verify agreement between new and old survey data, but are not reported in this document. A topographic survey was conducted and the resultant contours are shown on Plate 1. Horizontal coordinates were reported in NAD27 (North American Datum of 1927); vertical coordinates were reported in NGVD 29 (National Geodetic Vertical Datum of 1929). For all wells and piezometers, the elevation of the top of the PVC or polyethylene inner riser and the top of the steel protective casing were reported, in addition to ground surface elevation. In accordance with the FSP, all survey measurements were made to the nearest 0.05 foot or less. Table 3-2 summarizes survey data for all new borings, piezometers, and wells installed during the EGDY Phase II RI.

3.3 SCAPS LIF DATA

Three short-duration LIF pushes were attempted at the EGDY. These pushes were designated SL001, SL002, and SL003 and were 18.9 feet, 17.4 feet, and 17.8 feet deep, respectively. Although minor PAH detection occurred at these locations, these data have not been included in this report because the borings were considered test borings to determine the push capability of the SCAPS rig with the LIF probe attached. Also, the depth of all three borings was insufficient to characterize contamination depth.

3.4 GEOPROBE MIP DATA

A total of 30 direct-push borings were drilled using a Geoprobe-driven MIP with VOC speciation analyzed by the onsite DSITMS (Figure 3-2). Five pushes were completed in NAPL Area 1 located directly north of the existing treatment system infiltration galleries and infiltration wells. These borings were designated SM0037, SM0042, SM0043, SM0048, and SM0049. Five pushes were also completed in NAPL Area 2 located approximately 300 feet west-northwest of NAPL Area 1. These borings were designated SM0035, SM0036, SM0044, SM0046, and SM0047. A total of six pushes were completed in the area spanning NAPL Areas 2 and 3. These locations were designated SM0005, SM0030, and SM0038 through SM0041. A total of 14 MIP pushes were completed in NAPL Area 3 located between East Lincoln Drive and the existing EGDY groundwater treatment plant. Because almost three times as many MIP pushes were conducted in NAPL Area 3 than in the other areas, NAPL Area 3 was characterized more completely using MIP than any other area. MIP pushes in NAPL Area 3 included SM0003, SM0006 through SM0012, SM0029, SM0031 through SM0034, and SM0045.

Chlorinated solvents were the primary contaminants found within NAPL Area 1 and were associated with pushes SM0042, SM0048, and SM0049. At SM0042, DCE was the major contaminant of concern (COC) at a depth of 7 to 10 feet bgs and at an estimated peak concentration of 100 mg/L based on the interpreted MIP results. TCE was the primary COC at locations SM0048 and SM0049. At SM0048, estimated peak TCE concentration was 300 mg/L at 22 to 24 feet bgs. Since refusal at this location occurred at approximately 24 feet, the bottom of the TCE zone was not determined. At SM0049, TCE was encountered at 23 to 32 feet bgs at an estimated peak concentration of 150 mg/L. TCE concentration dropped off considerably below 32 feet at SM0049. The estimated peak concentrations of DCE and TCE from MIP data analyses were sufficiently high, at approximately 1/6 and 1/4 of their respective solubility limits, to represent likely NAPL presence at these three push locations.

A complex petroleum hydrocarbon mixture was the primary contaminant found by the MIP/DSITMS within NAPL Area 2. Pushes SM0035, SM0036, SM0044, and SM0046 all contained the complex hydrocarbon mixtures, while SM0047, the push located farthest to the southwest and downgradient of the center of the NAPL area, contained primarily DCE but also other minor chlorinated solvents and aromatic hydrocarbons. The DCE at SM0047 was in fairly low concentrations, with the highest being estimated at 20 mg/L at 18 to 25 feet bgs. The hydrocarbon mixtures encountered in NAPL Area 2 were too complex to obtain individual estimated concentrations for all specific VOCs due to a lack of identified standard in the hydrocarbon mixture; however, based on the total ion counts recorded on the DSITMS, it was determined that NAPL was likely present at locations SM0036 (11 to 27 feet bgs), SM0044 (11 to 27 feet bgs), and SM0046 (17 to 27 feet bgs). LNAPL was observed in a bailed sample from a temporary microwell placed inside boring SM0035 from about 10 feet bgs. This observation agreed with high total ion counts recorded at boring SM0035 beginning at approximately 10 feet bgs. At locations SM0036 and SM0046, the push terminated below the contamination; however, at SM0044 the push refused at the estimated contaminant mixture maximum, and so NAPL is believed to be present deeper than 27 feet bgs at SM0044.

Nearly half of all MIP/DSITMS pushes completed at the EGDY (14 of 30) were in NAPL Area 3. Chlorinated solvents, specifically TCE, were the predominant contaminant found within this NAPL area. The largest concentrations of TCE were found in SM0008, SM0009, SM0010, and SM0045. All four of these locations are located within the estimated 1,000 mg/L dissolved-phase TCE contour at NAPL Area 3. DCE was the principal solvent detected at SM0008, at a peak concentration of 140 mg/L from 3 to 11 feet bgs. At SM0009, TCE was the principal solvent found, at a peak concentration of 125 mg/L from 11 to 14 feet bgs. At these locations and depths, it was determined that NAPL was possibly present. TCE was the main contaminant detected at SM0033, at a peak concentration of 600 mg/L from 2 to 18 feet bgs. Immediately adjacent to SM0033 is SM0010. The estimated peak concentration of TCE found at SM0010 (20,000 mg/L) indicates that a NAPL globule contacted the MIP membrane at approximately 16 feet bgs. There was also a large reduction in EC (approximately 30 mS/m) measured at 16 feet bgs, indicating the likely presence of a nonelectrically conducting fluid. Chlorinated solvents such as TCE are not electrically conductive. It was determined that NAPL is likely present at locations SM0010 and SM0033.

Because SM0033 was completed within 2 feet horizontally from SM0010, the results from these two MIP borings were compared. From the MIP/DSITMS data plots (Appendix B of the SCAPS investigation report [USACE 2002]), agreement can be seen in magnitude and distribution of TCE in the unsaturated zone (0 to 13 feet bgs). The greatest difference in results occurs between the depths of 15 and 20 feet bgs. The large TCE concentration found in SM0010 is in contrast to the relatively low TCE concentration in SM0033 at these depths. Although the concentration of TCE found in SM0033 at 16 feet bgs (350 mg/L) was substantially less than that found at the same depth in SM0010 (20,000 mg/L), the SM0033 concentration is believed to be indicative of the presence of NAPL nearby. Comparison of results from SM0010 and SM0033 suggests that NAPL is present within NAPL Area 3, but it is located within the soil matrix in discrete pockets, ganglia, or globules, without extensive lateral distribution.

The hypothesis that contaminants in NAPL Area 3 exist in isolated pockets, ganglia, or globules without significant lateral distribution is further supported by the results from two other collocated pushes, SM0009 and SM0034. TCE found in SM0009 was at a peak concentration of approximately 120 mg/L at a depth of 12 feet bgs, close to the capillary fringe. The results from SM0034, located just 1 foot horizontally to the east of SM0009, showed a lack of significant TCE concentration until approximately 27 feet bgs. Although mass spectra from both pushes contain TCE, there are subtle differences suggesting a different source composition.

The pushes completed in a broad area between NAPL Areas 2 and 3 were SM0005, SM0030, and SM0038 through SM0041. No significant contaminants were found in five of the six MIP borings located between NAPL Areas 2 and 3. TCE was detected at SM0030, located within the EGDY treatment plant fence line, at an estimated peak concentration of 240 mg/L at 7 to 18 feet bgs. NAPL is considered possible at SM0030 based on these results, but this likely represents an isolated area of contamination separate from the three main NAPL areas.

Section 4 of the SCAPS investigation report (USACE 2002) contains a more complete discussion and conclusions regarding the Geoprobe MIP data. Appendix B in the SCAPS investigation report contains plots depicting MIP/DSITMS-related analytical data, including estimated TCE concentrations, for each of the 30 MIP push locations.

3.5 GEOPROBE SOIL SAMPLING DATA

Direct-push soil sampling data are limited because only three soil samples were collected during the direct-push program using a Geoprobe rig. Soil samples acquired using the Geoprobe rig were all from boring SM0010, located near the center of NAPL Area 3. Soil sample intervals at SM0010 were 15 to 19 feet, 19 to 22 feet, and 22 to 25 feet bgs. The soil from these intervals was poorly sorted, silty, sandy gravel, with rounded gravel up to 3/4 inch in diameter. Aliquots from the first and third sample intervals were sent to the analytical laboratory for VOC and TPH-Dx analysis. The sample ID numbers were SS0010-15-17 (15 to 17 feet bgs) and SS0010-23-24 (23 to 24 feet bgs) (see Table A-1 in Appendix A). TCE was detected in the first sample at a concentration of 7,500 µg/kg and in the second at 6,800 µg/kg. Little knowledge can be gained from these two results; however, in comparison with the MIP results plot in Appendix B of the SCAPS investigation report (USACE 2002) for SM0010, it can be seen that TCE contamination begins at approximately 16 feet bgs and is in its highest concentration from about 16 to 18 feet bgs. The MIP plot shows TCE still present to a depth of approximately 29 feet, but below 22.5 feet the concentration drops significantly.

3.6 ROTOSONIC BORINGS—SOIL SAMPLING DATA

A total of 76 sonic borings were drilled at the EGDY. The sonic boring locations are shown in Figure 3-3, and the boring logs are provided in Appendix D.

3.6.1 Analytical Sampling Results

A total of 228 soil samples (not including quality assurance/quality control [QA/QC] samples) collected from the sonic drilling program were analyzed by STL, the contracted fixed laboratory. Sonic-related soil sampling occurred between October 31, 2001, and March 6, 2002. Between two and nine samples were collected at varying depths at each of 69 borings to characterize extent and nature of contamination at the EGDY. (A total of 76 borings were drilled; of these, 7 had no samples collected.) Samples were tested for VOCs by EPA SW-846 Method 5035/8260 and for TPH diesel-range organics using Method NWTPH-Dx. Table 3-3 is a summary of all sonic borings from which analytical and physical samples were collected. This table shows the number of samples collected at each boring and corresponding depths; it also lists the borings at which NAPL was visually observed along with corresponding TPH, TCE, and cis-1,2-DCE concentrations. NAPL depths, along with analytical results corresponding to the NAPL intervals, are shaded in the table to illustrate how high concentrations of TCE, cis-1,2-DCE, and TPH are associated with the NAPL areas.

3.6.1.1 VOC Data

Complete soil VOC results are presented in Table A-1 in Appendix A. The predominantly detected VOCs were cis-1,2-DCE and TCE. Of the two, TCE was the most commonly detected compound, with concentrations ranging from non-detect up to an estimated concentration (based on a dilution, or D-flagged) of 12,100,000 µg/kg (1.2 percent) in sample RS0024-41. Other samples with TCE concentrations in excess of 1,000,000 µg/kg were RS0002-6-6.5 (boring RS0002 at 6- to 6.5-foot depth) at 2,990,000 µg/kg, RS0005-12-13 at 1,860,000 µg/kg, RS0012-14-15 at 1,100,000 µg/kg, and RS0060-6-7 at 2,460,000 µg/kg.

TCE and cis-1,2-DCE concentrations were generally lower in NAPL Area 2 than in NAPL Areas 1 and 3. In areas of visible NAPL contamination, the TCE values of corresponding analytical samples ranged from non-detect to 12,100,000 µg/kg. The arithmetic mean (mean) TCE value for samples collected within NAPL zones based on visual observation was 328,000 µg/kg. Cis-1,2-DCE values from visually observed NAPL zones ranged from non-detect to 82,000 µg/kg, with a mean value of 6,700 µg/kg. In contrast, the mean values for TCE and cis-1,2-DCE from samples that were collected in zones of no visible NAPL were 620 µg/kg and 115 µg/kg, respectively. Hence, the difference in mean TCE and cis-1,2-DCE concentrations between NAPL-containing zones and non-NAPL-containing zones is between two to three orders of magnitude. A value equal to one-half the detection limit was substituted for non-detect results when calculating the abovementioned means. The marked difference in analytical results between NAPL-contaminated soil and non-NAPL-contaminated soil further supports the visual classification of NAPL presence as shown in Table 3-3. Further interpretation of the soil VOC data is discussed in Section 5.

3.6.1.2 TPH Data

A summary of soil TPH results is presented in Table A-1 in Appendix A. TPH results are reported in the first two data rows of the table and are presented for #2 diesel oil (TPH, #2 Diesel) and motor oil (TPH, Motor Oil). Values for #2 diesel ranged from non-detect up to 8,850 mg/kg, while values for motor oil ranged from non-detect up to 15,300 mg/kg.

Of the three main NAPL areas, TPH concentrations were lowest in NAPL Area 3. TPH as #2 diesel values from visually observed NAPL zones ranged from non-detect to 8,850 mg/kg, with a mean of 1,200 mg/kg, while TPH as motor oil values within the same NAPL zones ranged from non-detect to 13,500 mg/kg, with a mean of 2,100 mg/kg. In contrast, the mean values for TPH as #2 diesel and TPH as motor oil from samples that were not collected in zones of visible NAPL were 8 mg/kg and 20 mg/kg, respectively. This represents a difference in TPH concentrations greater than two orders of magnitude between NAPL-containing zones and non-NAPL-containing zones. A value equal to one-half the detection limit was substituted for non-detect results when calculating the abovementioned means. The difference in TPH results between NAPL-contaminated soil and non-NAPL-contaminated soil, along with the VOC differences, further supports the visual classification of NAPL presence as shown in Table 3-3. These data are discussed further in Section 5.

3.6.2 Physical Sampling Results

A total of 36 soil samples from 15 different sonic borings were subjected to physical property testing. Physical property samples from borings RS0002, RS0002a, RS0003, RS0004, RS0006a, RS0007a, RS0008, RS0009, RS0012a, RS0019a, RS0024a, RS0048a, RS0065, RS0066, and RS0068 were selected for analysis by the contracted physical testing laboratory, PTS. Not every physical sample was analyzed for all physical parameters. The following number of physical parameter analyses were run: 30 grain size distribution tests, 30 bulk density tests, 26 effective porosity tests, 30 CEC tests, 33 TOC tests, 18 tests on percent NAPL saturation, and 21 permeability tests (from which hydraulic conductivity, or K, values were calculated). Of the 36 samples, 21 were undisturbed samples collected directly into Lexan, brass, or steel sleeves. The remaining 15 were disturbed samples, collected into loose, plastic sample sleeves and then replaced into 16-ounce sample jars. See Table 3-4 for a complete summary of soil physical properties data.

3.6.2.1 Grain Size

Soil particle grain size testing was conducted following the methodology described in ASTM D422, Standard Test Method for Particle-Size Analysis of Soils. In summary, the distribution of particle sizes larger than 75 µm (retained on the No. 200 sieve) is determined by sieving, whereas the distribution of particle sizes smaller than 75 mm is determined by a sedimentation process, using a hydrometer to secure the necessary finer-grained data. Of the 30 samples submitted, test results indicated 17 of 30 were classified as gravels, 6 as coarse sand, 3 as medium sand, 1 as fine sand, and 3 as silt. The goal for grain size distribution sample collection was to collect a representative number of samples from each soil type encountered. Twenty-one grain size samples were submitted to the laboratory as undisturbed samples; nine were submitted as disturbed samples. A much higher percentage of the undisturbed samples were classified as gravels compared to the disturbed samples (76 percent of undisturbed compared with 11 percent of disturbed samples). The three samples classified as silts were RS0004-36, RS0004-102-107, and RS0002-107-108. Sample RS0004-36 was from the Vashon unit (lower permeability glaciolacustrine silt) at the EGDY; RS0004-102-107 and RS0002-107-108 were from the Second Non-Glacial unit. Based on the geologist's classification, 16 of the soil samples submitted for grain size analysis were Vashon recessional outwash deposits (Qvr), 11 were Vashon till (Qvt), 2 were Second Non-Glacial Deposits (Qpon), and 1 was Vashon glaciolacustrine silt (Qvl). The specific geologic units are discussed in detail in Section 5. The field geologist's visual classification, as depicted on the sonic boring logs in Appendix D, was in general agreement with the laboratory grain size results.

3.6.2.2 Bulk Density

Bulk density testing was conducted using the American Petroleum Institute Recommended Practice 40 (API RP40). This method is an equivalent method to ASTM D2937 for bulk density determination (Young 2002), which was specified in the final management plan. Bulk density is the weight per unit volume of a soil mass that has been oven-dried to a constant weight. Of the 30 bulk density measurements, the values ranged from a low of 1.27 g/cc (sample RS0009-13-14) to a high of 2.17 g/cc (RS0002-18-19 and RS0007a-10-11). For all tested samples classified as Qvr, the mean bulk density was 1.91 g/cc, while the bulk density for only undisturbed Qvr samples was 1.95 g/cc. For all tested samples classified as Qvt, the mean bulk density was 1.95 g/cc, while the bulk density for only undisturbed Qvt samples was 1.96 g/cc. The mean bulk density for the two Qpon samples (both disturbed) was 1.52 g/cc. The mean bulk density for the single, disturbed Qvl sample was 1.53 g/cc.

3.6.2.3 Effective Porosity

Method API RP40 was also used in determining effective porosity. Effective porosity is defined as the volume of void spaces through which water or other fluids can travel in the soil sample divided by the total volume occupied by the soil sample. Effective porosity is a value less than total porosity since total porosity includes the volume of all void spaces, including nonconnected, or "dead," pores. Of the 26 effective porosity measurements, the values ranged from a low of 18.0 percent (RS0003-35-37) to a high of 44.3 percent (RS0004-102-107). It should be noted that the lowest effective porosity value corresponded with a till-like material described as silty gravel to silty sand (termed GM-SM in the Unified Soil Classification System [USCS]) from 35 to 37 feet bgs at location RS0003. Also, the three effective porosity values greater than 40 percent were all from fine-grained silt, silty sand, or sandy silt (ML or SM-ML in the USCS) corresponding with non-glacial units. Because porosity is considered more representative from undisturbed samples, means were computed for undisturbed samples from the different geologic units. Mean effective porosities for undisturbed Qvr and Qvt samples were identical, at 28.7 percent. Mean values for Qpon and Qvl effective porosities (both from disturbed samples only) were 42.6 percent and 43.9 percent, respectively.

3.6.2.4 Cation Exchange Capacity

Cation exchange capacity testing was conducted using Method SW-846 9081. CEC is a measure of the ability of a soil sample to absorb cations. A total of 30 soil samples were tested for CEC. The values ranged from a low of 20 milliequivalents per kilogram (meq/kg) (RS0002-18-19) to a high of 250 meq/kg (RS0004-102-107). For Qvr materials the mean CEC value was 60.8 meq/kg, while for Qvt materials the mean was 63.6 meq/kg. The mean CEC values for Qpon and Qvl materials were 180 meq/kg and 160 meq/kg, respectively.

3.6.2.5 Total Organic Carbon

Total organic carbon testing was performed using the Walkley-Black Method. The final management plan called for the use of Method SW-846 9060 to determine TOC. Good correlation has been established between Walkley-Black and SW-846 9060 methods when carbonaceous marine sediment or high iron content environments are not present (Young 2002). Organic matter content in soil is typically measured as TOC and is determined by subtracting inorganic carbon from total carbon. The laboratory performed a total of 33 TOC tests. TOC values are artificially raised from natural conditions when organic contaminants are present in soil or even groundwater. To compensate for this, an extraction of non-native organic carbon was performed using toluene to strip out petroleum hydrocarbons during laboratory testing; therefore, only native TOC values have been reported, and values should be consistent between samples from NAPL-contaminated borings and zones and clean borings and zones. TOC values ranged from a low of less than 100 mg/kg (non-detected at RS0008-31) to a high of 17,400 mg/kg (RS0066-10-11). The 17,400 mg/kg value was more than twice as great as the next highest TOC value (7,200 mg/kg at RS0004-102-107).

TOC results were separated by material type. The mean TOC value for Qvr sample materials was 1,360 mg/kg (excluding the 17,400 mg/kg outlier), and the mean TOC for Qvt materials was 1,090 mg/kg. For Qpon the mean TOC value was 6,600 mg/kg, and for Qvl the mean value was 3,400 mg/kg.

3.6.2.6 Percent NAPL Saturation

Percent NAPL saturation testing was conducted using Method API RP40. This testing was planned but was mistakenly left out of the final management plan. This parameter is a measure of the percentage of total soil pore volume occupied by NAPL. Eighteen samples were selected for percent NAPL saturation testing. Ten of 18 samples tested were non-detect at the limit of NAPL saturation quantitation (less than 0.1 percent pore volume [Pv] for 6 samples, less than 0.01 percent Pv for 4 samples). Six of the 10 samples that were non-detect were in zones that were visibly contaminated with NAPL based on the original sonic boring located immediately adjacent to the physical sample boring, suggesting that NAPL may be present at one location but absent at the same depth only a few feet away. One soil sample (RS0019a-25-25.5) had a reported value of 68.6 percent Pv. This result is questionable because, based on the boring logs of RS0019a and RS0019, no NAPL was observed over this sample interval (25 to 25.5 feet bgs). The laboratory was contacted, and there were no obvious errors detected regarding the reporting of this sample (Young 2002). The second highest reported value was 11.6 percent Pv at RS0006a-9-10. Boring log RS0006 indicated obvious, visible NAPL at the sample depth of 9 to 10 feet bgs; therefore, this value is believed to be valid. The mean percent NAPL saturation value for samples where NAPL was detected, excluding the apparent outlier (the 68.6 percent Pv value), was 3.7 percent Pv and was based on averaging seven values. The mean percent NAPL saturation value, including all non-detected samples (at one-half their detection limit) but excluding the 68.6 percent outlier value, was 1.6 percent Pv. The mean value for all samples from intervals of observed NAPL based on visual identification from original sonic borings was 2.3 percent Pv. The mean value for all samples tested for NAPL saturation (including non-detects at one-half their detection limit and the 68.6 percent outlier) was 5.3 percent Pv.

3.6.2.7 Hydraulic Conductivity

Hydraulic conductivity (K) from physical soil samples was determined using the methodology described in ASTM D5084, Standard Test Method for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter. Hydraulic conductivity is a coefficient of proportionality describing the rate at which water can move through a permeable material such as soil. A total of 21 K values were obtained from the samples sent to the laboratory for testing. All samples from which K was measured were undisturbed. The first 3 samples (RS0006a-6.5-7.5, RS0006a-9-10, and RS0006a-24.3-25.3) were tested in a horizontal orientation, and the remaining 18 samples were tested in a vertical orientation. Testing using vertical orientation means that the principal flow through the sample is vertical. It is recognized that horizontal flow is the principal flow direction in the natural environment at the EGDY; however, the drilling process allows collection of undisturbed samples only in the vertical direction. To test these coarse-grained, vertically collected samples in the horizontal direction, the sample was frozen using liquid nitrogen and then a subsample was cored in the horizontal direction (Young 2002).

Hydraulic conductivity values ranged from a low of 0.0044 ft/day (1.56E-6 cm/s) from sample RS0012a-35-35.5 to a high of 27.2 ft/day (9.59E-3 cm/s) from sample RS0024a-22.5-23. Mean K values were determined for two groupings of samples, the first group corresponding to glacial outwash gravels and sands (GW to GW-SW USCS classifications) and the second group corresponding to glacial till or till-like material (gravels and medium to coarse sands within a matrix of finer grained silts and clays, GM to GM-SM). The arithmetic mean value of the 13 glacial outwash samples was 2.7 ft/day (1.0E-3 cm/s); the arithmetic mean value of the 8 glacial till and till-like samples was 0.003 ft/day (1.0E-4 cm/s). The geometric mean value for the outwash samples was 0.5 ft/day (1.7E-4 cm/s) and the geometric mean value for till and till-like samples was 0.1 ft/day (4.1E-5 cm/s).

3.7 ROTOSONIC BORINGS—IN SITU SLUG TEST DATA

In conjunction with physical soil sample collection using the sonic drill rig, a pneumatic slug testing program was performed by PNNL to evaluate the in situ permeability contrast between various hydrogeologic units beneath the EGDY. A letter report on slug test results, issued March 28, 2002, was prepared by PNNL (Battelle 2002) and is included in this report as Appendix E. Some slug tests were not evaluated because of apparent silt liquefaction due to sonic drilling that altered the in situ results. Also, a few slug tests were aborted because of time limitations. The borings and respective intervals from which successful slug test data were evaluated and reported were as follows:

- RS0012a, 17 to 20 feet bgs (Steilacoom gravel, above Vashon recessional outwash)
- RS0012a, 27 to 30 feet bgs (till and till-like material within Vashon recessional outwash)
- RS0019a, 30 to 33 feet bgs (till and till-like material)
- RS0024a, 21 to 24 feet bgs (Steilacoom gravel)
- RS0024a, 41 to 44 feet bgs (till and till-like material, Vashon till)

Tests at the above locations and depths helped the slug testing program meet its primary objective of quantifying the field-scale permeability contrast between the various hydrogeologic units, indicating that the relative K values for the various units varied by at least two orders of magnitude (i.e., from approximately 1.9 ft/day [7.0E-4 cm/s] in the till and till-like units to greater than 200 ft/day [greater than 7.1E-2 cm/s] in the outwash gravels). See Table 3-5 for a summary of in situ pneumatic slug test results (Battelle 2002). Pneumatic slug test results indicate hydraulic conductivity values greater than those measured using laboratory methods. The values are in general agreement considering the laboratory primarily measured vertical K values, which are generally one to two orders of magnitude less than horizontal K values at the Logistics Center site, as reported in the groundwater modeling performed during the remedial design and discussed in Section 5.

3.8 GROUNDWATER AND SURFACE WATER SAMPLING DATA

A total of 96 water samples (not including QA/QC samples) were collected during the EGDY Phase II RI. This total includes 84 groundwater samples and 12 surface water samples. Of the 84 groundwater samples, 56 were collected from the monitoring wells installed during the Phase II RI, while 28 were collected as discrete grab samples using a Geoprobe rig. Surface water sampling of Murray Creek took place on July 20 and 21, 2001. Sample collection from Geoprobe locations occurred from August 20 to September 11, 2001, while sampling of groundwater monitoring wells took place from November 29, 2001, to May 1, 2002. STL analyzed all received groundwater samples for VOCs by Method SW-846 8260B. The groundwater sample collected from the DNAPL collection well LC-186 was also analyzed for TPH-Dx using Method NWTPH-Dx. VOC analyses were performed on surface water samples using the SCAPS onsite mobile laboratory and the DSITMS (Method SW-846 8265). See Appendix A (Table A-2) for a summary of groundwater VOC results.

3.8.1 Groundwater Results at Geoprobe Locations

Three of the 28 groundwater samples collected using a Geoprobe rig were from MIP borings within the EGDY, while the other 25 were from eventual piezometer locations in the greater EGDY area. The three samples collected at the EGDY were all from MIP borings near the center of NAPL Area 3 (SM0003, SM0009, and SM0010). TCE and cis-1,2-DCE were the only COCs detected at significantly elevated concentrations at these locations. TCE results ranged from 17,000 to 61,000 µg/L (D-flagged), while cis-1,2-DCE results ranged from 920 to 13,000 µg/L (D-flagged).

The 25 groundwater samples collected using the Geoprobe rig from the greater EGDY area were taken from the eventual location of 15 piezometers, the locations of which are shown in Figure 3-4. At one piezometer location (LC-169), three groundwater grab samples were collected; at eight piezometer locations (LC-170, LC-172 through LC-177, and LC-180 [see Table 2-1 for corresponding sample IDs]), two groundwater grab samples were collected; at five locations (LC-171, LC-178, LC-179, LC-181, and LC-182 [see Table 2-1 for corresponding sample IDs]), one groundwater grab sample was collected; and at one location (LC-183 [see Table 2-1 for corresponding sample IDs]), no groundwater sample was collected due to insufficient water in the direct-push boring at the time of piezometer installation. TCE and cis-1,2-DCE were the only COCs detected at significantly elevated concentrations at these locations. TCE values ranged from non-detect (less than 0.4 µg/L) to 930 µg/L (D-flagged), and cis-1,2-DCE values ranged from non-detect (less than 0.4 µg/L) to 1,200 µg/L (D-flagged). Interpretation of the groundwater VOC data is discussed in Section 5.

3.8.2 Groundwater Results at New Monitoring Wells

Twelve new multi-port monitoring wells were installed at the EGDY and were designated LC-184, LC-185, and LC-187 through LC-196. Wells LC-184, LC-185, and LC-187 through LC-189 were constructed with four sampling ports each, LC-194 with five ports, and LC-190 through LC-193, LC-195, and LC-196 with six ports each. The port number was placed after the well number in the sample designation. For example, Port 1 at well LC-184 was designated LC-184-1 (and was the shallowest of the four ports). All multi-port well ports were sampled for VOCs. VOCs of interest included TCE, with values from non-detect (less than 1 µg/L) to 11,000 µg/L (J-flagged) (at LC-195-3), and cis-1,2-DCE, with values from non-detect (less than 1 µg/L) to 5,730 µg/L (at LC-195-2). No other COCs were detected; however, detection levels were elevated due to the necessary dilutions to obtain quantitative TCE and cis-1,2-DCE results. Generally, the shallower ports had higher levels of contamination present. New monitoring well locations are shown in Figure 3-3.

One conventional, single-screened groundwater monitoring well was installed within NAPL Area 1 at the EGDY for the purpose of NAPL collection. This well was designated LC-186. LC-186 did not collect a measurable amount of NAPL over the course of the field investigation; however, it was sampled for dissolved-phase constituents including VOCs and TPH. TCE was detected at 11,200 µg/L (D-flagged), and cis-1,2-DCE was detected at 1,180 µg/L. Other VOCs of interest were TCA at 0.111 µg/L (J-flagged), PCE at 11.7 µg/L, and VC at 0.539 µg/L. TPH was detected at 0.243 mg/L (J-flagged) for #2 diesel and was non-detect (less than 0.474 mg/L) for motor oil.

3.8.3 Surface Water Results

A total of 12 surface water samples were collected along Murray Creek southwest of the EGDY during the Phase II RI. The surface water samples were analyzed for VOCs using the DSITMS in the onsite laboratory operated by the USACE Tulsa District. See Figure 3-5 for locations of surface water samples SW-MC-0005 through SW-MC-0016. TCE was the only detected VOC in surface water samples. TCE concentrations ranged from non-detect (less than 1 µg/L) to 2.33 µg/L. See Table 3-6 for a summary of surface water sampling results using the onsite DSITMS.

3.9 GROUNDWATER ELEVATION DATA

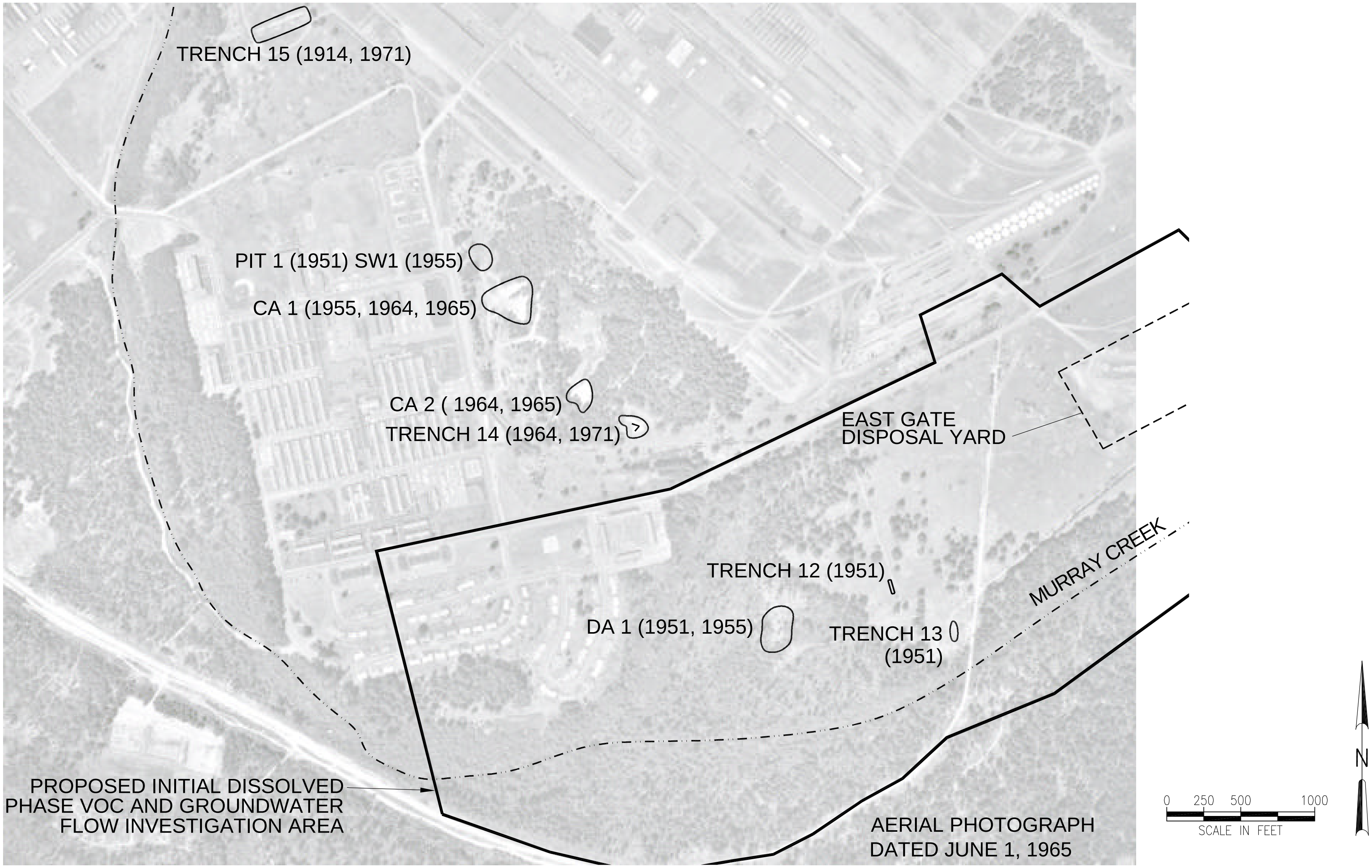
Groundwater level data was recorded in 61 groundwater monitoring wells and piezometers throughout the EGDY and greater EGDY area during the Phase II field investigation. Four rounds of water level data were collected during the following periods: September 19, 2001 (Round 1); November 29-30, 2001 (Round 2); January 17-18, 2002 (Round 3); and March 2-4, 2002 (Round 4). Round 1 water level measurement included only the newly installed piezometers LC-169 through LC-181 and LC-183. Water levels from multi-port wells LC-190 through LC-196 were collected in early April 2002; however, this was not considered a formal "round" of water level monitoring. The groundwater levels were converted to elevations using existing and newly acquired survey data. See Table 3-7 for a listing of wells and piezometers monitored and the groundwater elevation data from all four rounds of water level collection. Since nearly all water levels measured were from upper aquifer wells in the greater EGDY area, only upper aquifer potentiometric surface maps were generated from the collected data. Groundwater elevation data and potentiometric surface maps generated from these data are interpreted in Section 5.

3.10 GEOPHYSICAL RESULTS

The geophysical investigation was conducted on an approximately 5-acre parcel centered on NAPL Area 3 at the EGDY. The investigation location, along with results of this investigation that used ER, IP, and GPR techniques, are reported and discussed in Appendix F. Generally, the geophysical results were inconclusive with regard to stratigraphic characterization. In particular, the IP results did not correlate well with nearby sonic boring stratigraphic data. The groundwater table was apparently a strong GPR reflector, preventing useful GPR interpretation below 8 to 15 feet bgs. ER results loosely correlate with sonic boring logs in NAPL Area 3 in that no definitive, continuous aquitard material exists in this portion of the EGDY. All three geophysical techniques were unsuccessful in attaining depths deep enough to evaluate the Second Non-Glacial unit present across the EGDY at approximately 110 feet bgs. Because the soil data acquired from sonic cores was visually verifiable and of high quality (as opposed to interpreted data from geophysical methods), the data obtained and interpretations made from sonic drilling supersede any interpretation made from the geophysical data regarding stratigraphic characterization.

3.11 NAPL PHYSICAL RESULTS

No samples of NAPL for physical property tests were collected from soil or groundwater during the Phase II RI because of the insufficient volume of NAPL in soil and the absence of NAPL in monitoring wells. Alternatively, three NAPL samples of a composite from several intact drums removed during the drum removal action were submitted for physical testing. Results are presented in Tables 3-8a, b, c, and d and are discussed further in Section 5.



LEGEND

○ PROPOSED SOURCE AREAS TO INVESTIGATE OUTSIDE OF EASTGATE DISPOSAL YARD
CA - CLEARED AREA
DA - DISTURBED AREA
SW - SOLID WASTE AREA

SOURCE: USACE 2001

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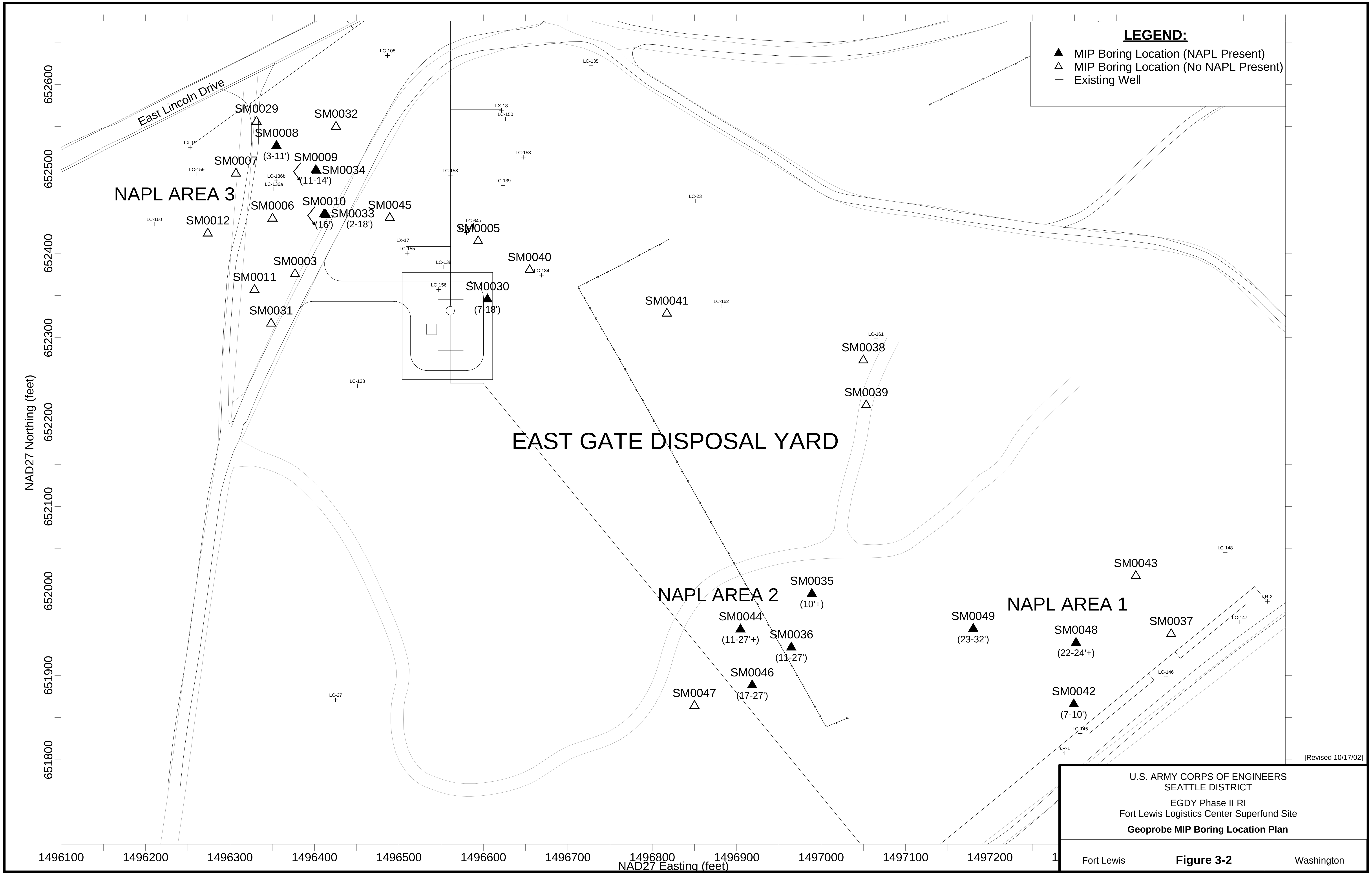
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Additional Potential Source Areas
Identified from Aerial Photographs

Fort Lewis	**Figure 3-1**	Washington

FILENAME: T:\COE\egate\Sub-Tasks\PHASEII-RI\CFig 3-1.dwg
EDIT DATE: 10/25/02 AT: 15:07



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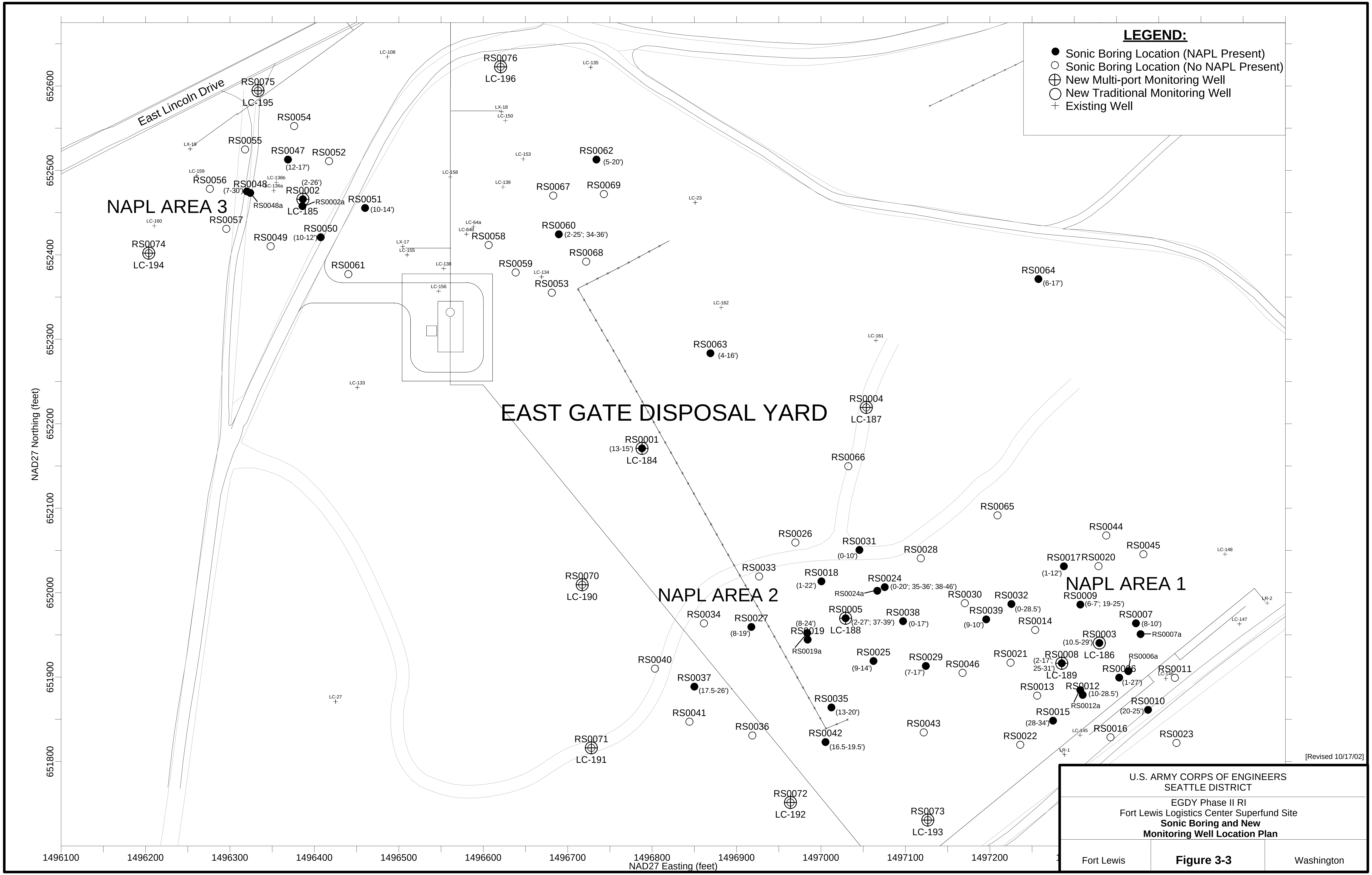
SEATTLE DISTRICT

EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Geoprobe MIP Boring Location Plan

Fort Lewis	**Figure 3-2**	Washington



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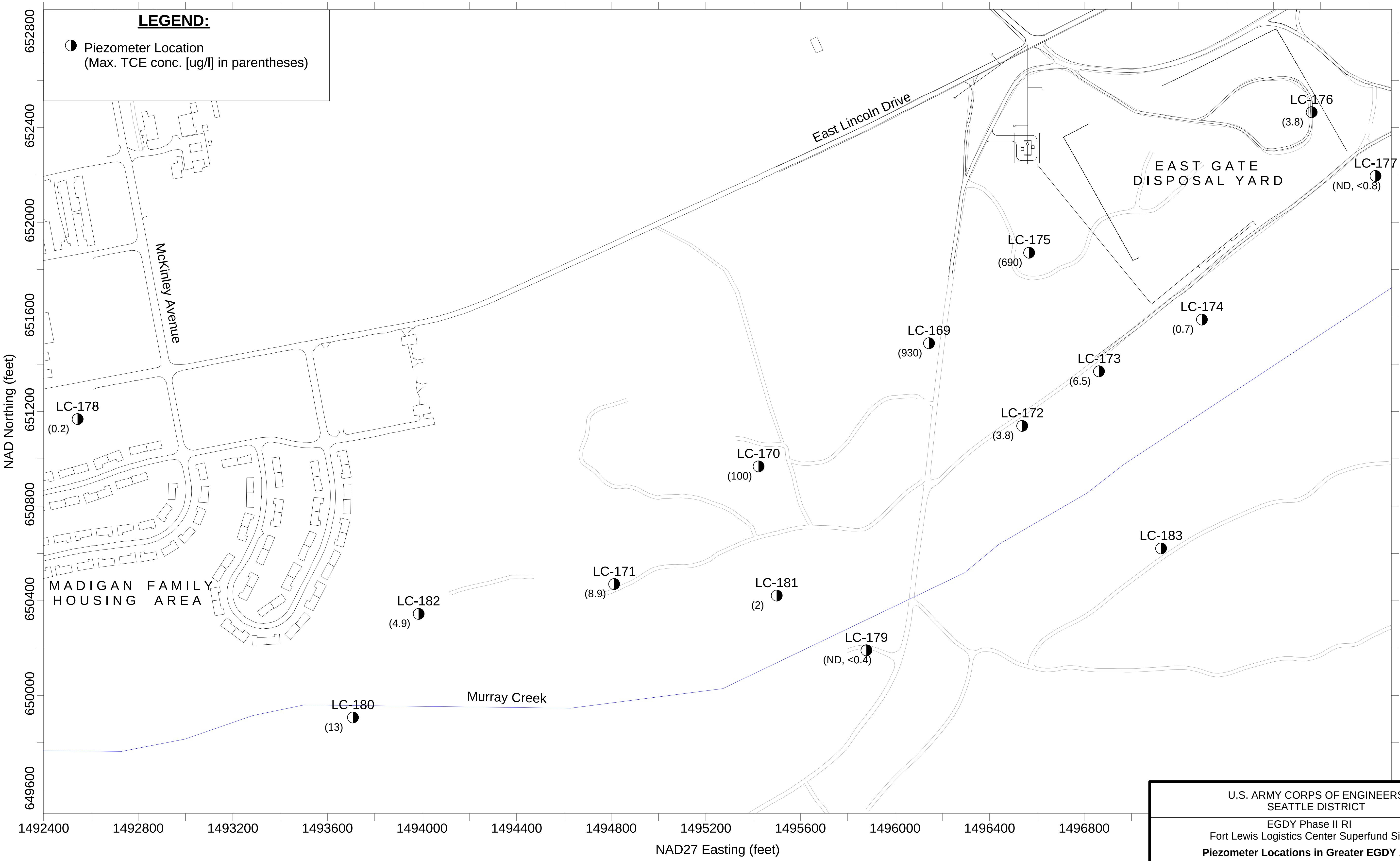
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Sonic Boring and New
Monitoring Well Location Plan

Fort Lewis	**Figure 3-3**	Washington



[Revised 10/17/02]

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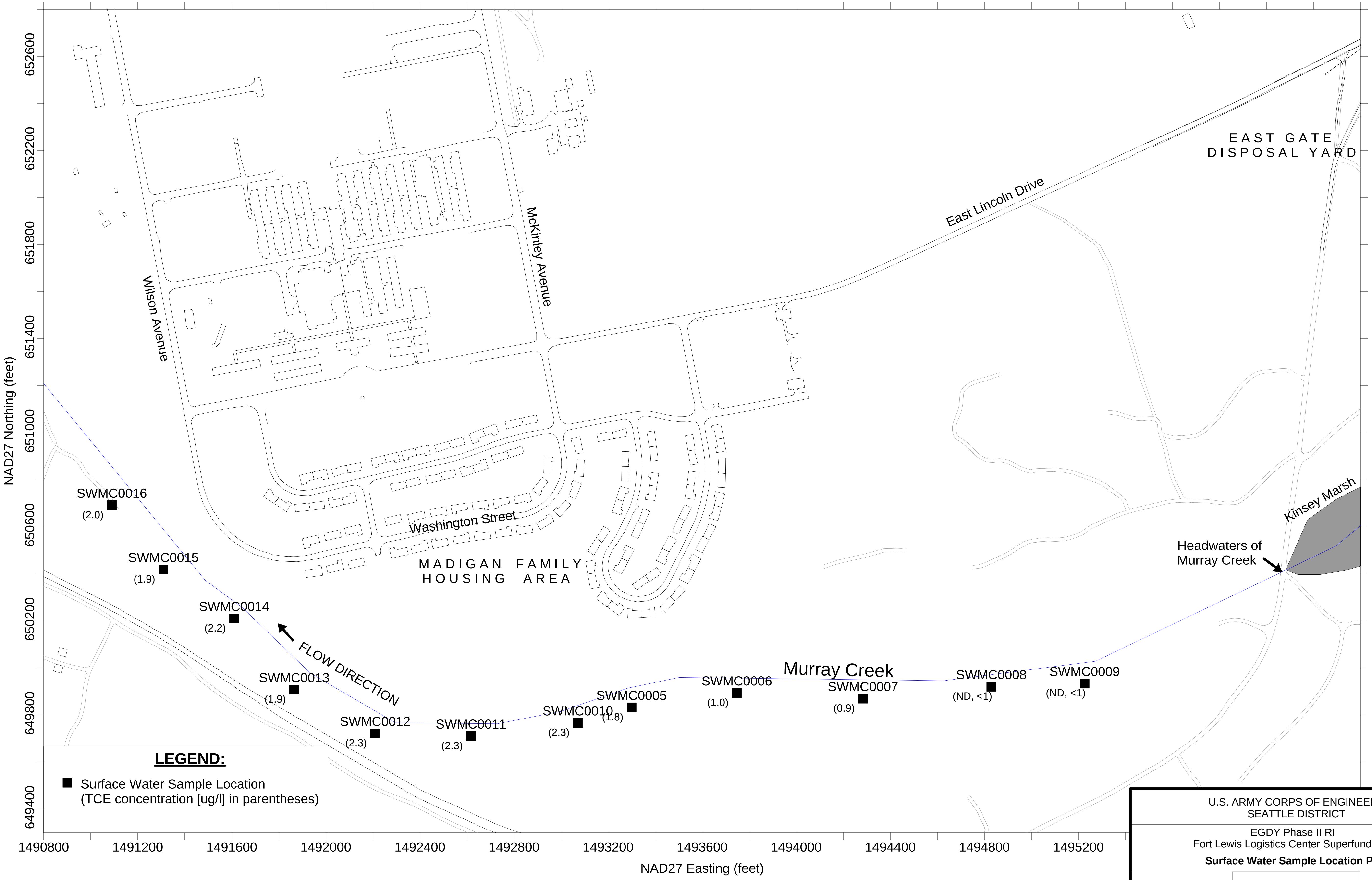
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Piezometer Locations in Greater EGDY Area

Fort Lewis | **Figure 3-4** | Washington



[Revised 10/17/02]

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EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Water Sample Location Plan

Fort Lewis	**Figure 3-5**	Washington

Table 3-1
SITE FEATURES OF OTHER POTENTIAL SOURCE AREAS

Feature	Aerial Photo Dates	Location	Dimensions and Bearing	Excavation Results
Trench 12	1951	Approx. 1,300 ft. SSE of the S corner of the DRMO Yard fence and 1,700 ft. SW of the SW corner of the EGDY fence in an undeveloped area off of a trail system	Approx. 100 ft in length bearing N to S	7 trenches dug (T012-T018); no evidence of disposal
Trench 13	1951	Approx. 1,300 ft SSE of the S corner of the DRMO Yard fence and 1,500 ft SW of the SW corner of the EGDY fence in an undeveloped area off of a trail system	Approx. 5,700 sf, bearing N to S	6 trenches dug (T001-T006); no evidence of disposal
Trench 14	1964, 1971	Approx. 1,000 ft W of the S corner of the DRMO Yard fence and 3,200 ft W of the SW corner of the EGDY fence in an undeveloped area	L-shaped trench: 50 ft NW to SE leg and 45 ft SW to NE leg	7 trenches dug (T019-T025); scrap metal & construction debris uncovered; no evidence of chemical disposal
DA 1	1951, 1955	Approx. 1,000 ft E of Coolidge Ave. (Madigan Family Housing Area) and 1,200 ft due S of the S corner of the DRMO Yard fence	General polygon, approx. 55,800 sf	5 trenches dug (T007-T011); no evidence of disposal
CA 1	1955, 1964, 1965	Approx. 300 ft SE of the intersection of McKinley Ave. and Garfield St., E of railroad, W of N end of Lynn Lake	General polygon, approx. 77,200 sf	7 trenches dug (T030-T036); potential abandoned outfall discovered; no evidence of chemical disposal
CA 2	1964, 1965	Just S of the S end of Lynn Lake	General polygon, approx. 25,700 sf	4 trenches dug (T026-T029); no evidence of disposal

Notes:
Directions: N = North; S = South; E = East; W = West; SW = Southwest;
SE = Southeast; SSE = South-southeast
Units: ft = feet; sf = square feet
CA = cleared area
DA = disturbed area
DRMO = Defense Reutilization Marketing Office
EGDY = East Gate Disposal Yard

Table 3-2
SURVEY DATA

Location ID	Northing	Easting	GS Elevation (ft msl)
SONIC BORINGS			
RS0001	652219.3	1497053.7	277.93
RS0002	651969.7	1497029.2	276.90
RS0003	651916.3	1497285.1	277.52
RS0004	652009.4	1496717.1	279.03
RS0005	651816.1	1496728.1	277.70
RS0006	651899.3	1497353.2	276.85
RS0007	651963.7	1497373.0	276.78
RS0008	651751.5	1496963.9	278.14
RS0009	651985.8	1497307.2	277.95
RS0010	651861.1	1497387.3	278.52
RS0011	651899.2	1497419.2	277.12
RS0012	651878.8	1497310.0	277.65
RS0013	651878.1	1497256.1	279.67
RS0014	651955.9	1497253.7	278.11
RS0015	651848.3	1497274.8	279.31
RS0016	651828.6	1497342.9	279.69
RS0017	652031.2	1497287.6	277.79
RS0018	652013.3	1497000.6	277.33
RS0019	651944.4	1496984.1	277.77
RS0020	652031.4	1497328.6	278.71
RS0021	651917.0	1497224.6	278.71
RS0022	651819.8	1497236.0	282.20
RS0023	651821.9	1497421.0	278.06
RS0024	652006.5	1497075.6	276.72
RS0025	651918.9	1497062.2	278.46
RS0026	652059.3	1496969.6	276.89
RS0027	651959.4	1496917.5	278.07
RS0028	652040.6	1497118.2	277.54
RS0029	651913.1	1497124.2	276.56
RS0030	651987.4	1497170.4	277.33
RS0031	652050.5	1497045.4	276.67
RS0032	651986.5	1497225.5	277.38
RS0033	652019.1	1496926.6	277.25
RS0034	651963.7	1496861.3	278.36
RS0035	651864.0	1497012.3	282.80
RS0036	651830.8	1496918.7	283.61
RS0037	651888.6	1496849.9	283.54
RS0038	651966.2	1497097.1	276.76
RS0039	651968.3	1497195.7	277.37
RS0040	651909.9	1496803.3	283.68
RS0041	651847.2	1496844.1	283.30
RS0042	651823.1	1497005.3	283.70
RS0043	651834.5	1497121.6	281.83
RS0044	652067.6	1497337.8	278.28

Table 3-2 (Continued)
SURVEY DATA

Location ID	Northing	Easting	GS Elevation (ft msl)
SONIC BORINGS (Continued)			
RS0045	652045.5	1497381.8	279.04
RS0046	651905.0	1497167.7	278.22
RS0047	652512.8	1496368.7	276.91
RS0048	652473.3	1496324.1	277.49
RS0049	652410.1	1496348.2	277.34
RS0050	652420.8	1496407.4	276.91
RS0051	652455.5	1496460.0	277.28
RS0052	652511.0	1496417.3	276.06
RS0053	652355.2	1496681.1	276.09
RS0054	652552.6	1496376.1	276.39
RS0055	652524.9	1496317.9	277.69
RS0056	652478.1	1496276.2	277.46
RS0057	652430.9	1496295.7	278.31
RS0058	652411.7	1496606.3	275.55
RS0059	652379.2	1496638.4	274.94
RS0060	652424.4	1496689.5	275.61
RS0061	652377.2	1496440.1	275.74
RS0062	652512.8	1496734.1	280.25
RS0063	652283.5	1496869.0	276.68
RS0064	652371.4	1497257.6	282.01
RS0065	652091.6	1497208.9	277.44
RS0066	652149.7	1497032.3	278.01
RS0067	652470.1	1496682.9	276.71
RS0068	652392.1	1496721.9	276.70
RS0069	652472.0	1496742.8	280.32
RS0070	651730.7	1497126.5	279.42
RS0071	652402.1	1496203.8	282.62
RS0072	652594.5	1496333.2	283.13
RS0073	652622.7	1496620.5	283.79
RS0074	652402.1	1496203.8	276.73
RS0075	652594.5	1496333.2	278.23
RS0076	652622.7	1496620.5	279.25
RS0002a	652457.7	1496385.8	277.30
RS0006a	651907.1	1497364.0	277.05
RS0007a	651950.8	1497378.6	277.14
RS0012a	651884.5	1497307.1	277.90
RS0019a	651952.2	1496983.7	277.31
RS0024a	652002.2	1497066.6	276.70
RS0048a	652475.1	1496320.1	277.81

Table 3-2 (Continued)
SURVEY DATA

Location ID	Northing	Easting	GS Elevation (ft msl)
GEOPROBE MIP BORINGS			
SM0003	652377.1	1496377.0	276.49
SM0005	652416.1	1496593.9	275.89
SM0006	652442.9	1496350.3	277.53
SM0007	652496.2	1496307.1	277.82
SM0008	652529.1	1496355.0	276.73
SM0009	652500.3	1496401.5	276.17
SM0010	652447.9	1496411.4	276.74
SM0011	652358.4	1496329.1	276.24
SM0012	652425.2	1496273.6	277.19
SM0029	652557.7	1496331.4	277.24
SM0030	652347.3	1496604.9	277.20
SM0031	652318.6	1496348.7	276.48
SM0032	652551.7	1496425.5	277.22
SM0033	652447.4	1496413.3	276.73
SM0034	652498.9	1496402.7	276.15
SM0035	651998.4	1496989.0	277.68
SM0036	651934.9	1496964.7	278.55
SM0037	651950.7	1497414.5	277.56
SM0038	652274.9	1497050.1	279.38
SM0039	652221.7	1497053.3	279.15
SM0040	652381.9	1496654.8	275.54
SM0041	652330.3	1496817.3	276.61
SM0042	651867.5	1497299.2	277.84
SM0043	652019.5	1497372.6	279.18
SM0044	651956.2	1496904.5	278.06
SM0045	652443.7	1496489.1	277.24
SM0046	651890.0	1496918.4	283.73
SM0047	651865.6	1496849.9	283.74
SM0048	651940.4	1497301.9	277.69
SM0049	651956.8	1497180.1	277.32

Table 3-2 (Continued)
SURVEY DATA

			Elevation (ft msl)		
Location ID	**Northing**	**Easting**	**GS**	**PVC**	**RIM**
PIEZOMETERS					
LC-169	651488.7	1496143.8	280.90	284.16	284.18
LC-170	650968.0	1495423.3	281.14	284.12	284.16
LC-171	650470.5	1494813.0	277.01	280.00	280.02
LC-172	651139.2	1496537.9	284.19	287.17	287.19
LC-173	651369.7	1496862.9	280.78	283.83	283.85
LC-174	651588.7	1497298.0	280.73	283.52	283.54
LC-175	651871.5	1496567.3	281.19	284.18	284.20
LC-176	652465.1	1497761.8	282.10	285.05	285.07
LC-177	652195.7	1498032.3	281.56	284.53	284.55
LC-178	651167.8	1492543.7	278.65	278.52	278.65
LC-179	650190.9	1495879.2	273.67	276.66	276.66
LC-180	649906.4	1493707.8	270.36	273.24	273.25
LC-181	650421.7	1495499.8	278.11	281.27	281.30
LC-182	650344.9	1493986.0	269.47	272.44	272.46
LC-183	650621.2	1497125.4	303.67	306.63	306.64
MONITORING WELLS					
LC-184	652170.8	1496788.0	277.93	280.82	281.12
LC-185	652465.8	1496386.3	276.90	279.57	279.74
LC-186	651940.3	1497329.7	277.52	280.22	280.53
LC-187	652219.3	1497053.7	279.03	281.42	282.08
LC-188	651969.7	1497029.2	277.70	280.49	280.77
LC-189	651916.3	1497285.1	278.14	280.81	281.13
LC-190	652009.4	1496717.1	279.42	281.92	282.28
LC-191	651816.1	1496728.1	282.62	285.19	285.61
LC-192	651751.5	1496963.9	283.13	285.66	285.90
LC-193	651730.7	1497126.5	283.79	286.77	287.21
LC-194	652402.1	1496203.8	276.73	279.23	279.83
LC-195	652594.5	1496333.2	278.23	280.89	281.35
LC-196	652622.7	1496620.5	279.25	281.77	282.56

Notes:
Survey conducted by Thornton Land Surveying of Gig Harbor, WA
Horizontal coordinates measured in WA State Plane -
South in U.S. survey feet
Horizontal datum is North American Datum of 1927 (NAD27)
Vertical datum is National Geodetic Vertical Datum of 1929 (NGVD 29)
ft msl = feet mean sea level
GS = ground surface
MIP = membrane interface probe
PVC Elevation = top of polyvinyl chloride (PVC) inner casing
RIM Elevation = top of outer, steel casing rim

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0001	10/31/01	11/5/01	110	Near NA #2	13.0-15.0	LNAPL	sandy GRAVEL with some fines	same				
RS0001-12-12.5									ND	ND	53	265
RS0001-28.5-29									1,050	ND	ND	ND
RS0002	11/2/01	11/4/01	110	NA #3	2.0-26.0	L/DNAPL	sandy GRAVEL	increasing fine sand				
RS0002-6-6.5									2,990,000	25,400	4,350	13,500
RS0002-15-16									7,070	399	47	148
RS0002-54-55									ND	ND	ND	ND
RS0002-18-19									PHYSICAL SAMPLE			
RS0002-107-108									PHYSICAL SAMPLE			
RS0002a	2/20/02	2/20/02	46	NA #3	Yes							
RS0002a-20.5-21									PHYSICAL SAMPLE			
RS0002a-24.5-25									PHYSICAL SAMPLE			
RS0002a-45-45.5									PHYSICAL SAMPLE			
RS0003	11/6/01	11/6/01	37	NA #1	10.5-29.0	L/DNAPL	sandy GRAVEL/ GRAVEL	medium SAND with gravel (SP)				
RS0003-10.5-11									2,510	4,450	1,400	2,890
RS0003-22-23									187,000	318	178	309
RS3003-22-23									136,000	219	195	391
RS0003-28-29									12,400	ND	162	425
RS0003-35-37									PHYSICAL SAMPLE			

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	**Date Started**	**Date Completed**	**Total Depth (feet)**	**EGDY Location**	**NAPL Depth (feet)**	**LNAPL/ DNAPL**	**NAPL Geologic Unit**	**Geologic Unit Below NAPL**	**TCE (µg/kg)**	**cis-1,2-DCE (µg/kg)**	**TPH-Dx (mg/kg)**	**TPH-O (mg/kg)**
RS0004	11/7/01	11/13/01	110	NA #2	None							
RS0004-11-12									ND	ND	ND	ND
RS0004-30-31									244	ND	ND	ND
RS0004-36									PHYSICAL SAMPLE			
RS0004-102-107									PHYSICAL SAMPLE			
RS0005	11/14/01	11/17/01	109	NA #2	2.0-27.0	L/DNAPL	sandy GRAVEL/ SAND	fine SAND (GM)				
					37.0-39.0	DNAPL	silty sandy GRAVEL with cobbles	same				
RS0005-12-13									1,860,000	40,700	8,190	15,300
RS0005-38-39									210	ND	1,340	2,200
RS0005-55-56									3,680	ND	46	87
RS0006	11/17/01	11/18/01	110	NA #1	1.0-27.0	L/DNAPL	silty sandy GRAVEL	well sorted SAND, occasional gravel				
RS0006-5-6									192,000	82,800	673	1,760
RS0006-8-9									52,000	10,900	6,200	10,900
RS3006-8-9									75,000	13,400	4,280	7,870
RS0006-26-27									491	ND	123	314
RS0006-28-29									240	ND	ND	ND
RS3006-28-29									230	ND	ND	ND
RS0006-51-52									ND	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0006a	1/3/02	1/3/02	29	NA #3	3.0-13.0+	L/DNAPL?	See RS0006 for detailed geologic description					
RS0006a-6.5-7.5									PHYSICAL SAMPLE			
RS0006a-6.5-7.5									40,800	29,300	5,350	9,600
RS0006a-9-10									PHYSICAL SAMPLE			
RS0006a-9-10									229	274	115	253
RS0006a-24.3-25.3									PHYSICAL SAMPLE			
RS0006a-24.3-25.3									1,410	85	ND	41.6 (J)
RS0007	11/19/01	11/19/01	57	NA #1	8.0-10.0	LNAPL	sandy GRAVEL with cobbles	slight increase in fines				
RS0007-8-9									158	ND	1,120	4,130
RS0007-18-19									149	ND	ND	ND
RS0007-28-29									ND	ND	ND	ND
RS0007-47-48									ND	ND	ND	ND
RS0007a	12/17/01	12/17/01	34	NA #3	7.0-12.0	LNAPL	See RS0007 for detailed geologic description					
RS0007a-10-11									PHYSICAL SAMPLE			
RS0007a-9-9.5									ND	ND	682	2,500
RS3007a-9-9.5									ND	ND	833	2,840
RS0007a-24-25									PHYSICAL SAMPLE			
RS0007a-29.5-30.5									PHYSICAL SAMPLE			

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	**Date Started**	**Date Completed**	**Total Depth (feet)**	**EGDY Location**	**NAPL Depth (feet)**	**LNAPL/ DNAPL**	**NAPL Geologic Unit**	**Geologic Unit Below NAPL**	**TCE (µg/kg)**	**cis-1,2-DCE (µg/kg)**	**TPH-Dx (mg/kg)**	**TPH-O (mg/kg)**
RS0008	11/27/01	11/30/01	107	NA #1	2.0-17.0	LNAPL	sandy GRAVEL	same, with increasing fines				
					25.0-31.0	DNAPL	silty sandy GRAVEL	medium SAND with occasional gravel				
RS0008-6.5-7.5									203	4,370	ND	ND
RS0008-29-30									10,300	ND	ND	ND
RS0008-31									PHYSICAL SAMPLE			
RS0008-42-43									ND	ND	ND	ND
RS0009	12/1/01	12/1/01	45	NA #1	6.0-7.0	DNAPL	silty GRAVEL	silty sandy GRAVEL (GP)				
					19.0-25.0							
RS0009-6-7									187,000	22,200	1,580	2,060
RS0009-8-9									562	154	ND	ND
RS0009-13-14									PHYSICAL SAMPLE			
RS0009-22.5-23.5									17,000	961	388	673
RS0009-27-27.5									PHYSICAL SAMPLE			
RS0009-38-39									1,840	ND	14	34
RS0009-41-42									PHYSICAL SAMPLE			
RS0009-42-43									ND	ND	ND	ND
RS0010	12/2/01	12/2/01	41	NA #1	20.0-25.0	DNAPL	silty sandy GRAVEL	same				
RS0010-20-21									ND	ND	ND	ND
RS0010-31-32									ND	ND	ND	ND
RS3010-31-32									ND	ND	ND	ND
RS0011	12/2/01	12/2/01	41	NA #1	None							
RS011-11-12									ND	ND	ND	ND
RS0011-23-23.5									ND	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0012	12/3/01	12/3/01	51	NA #1	10.0-28.5	L/DNAPL	silty sandy GRAVEL	silty sandy GRAVEL with trace clay				
RS0012-6-7									488	674	67	214
RS0012-14-15									1,100,000	ND	753	1,250
RS0012-38-39									ND	ND	ND	ND
RS0012a	2/27/02	2/27/02	42	NA #1	Yes							
RS0012a-27-27.5									PHYSICAL SAMPLE			
RS0012a-30-30.5									PHYSICAL SAMPLE			
RS0012a-35-35.5									PHYSICAL SAMPLE			
RS0012a-40-40.5									PHYSICAL SAMPLE			
RS0013	12/4/01	12/4/01	42	NA #1	None							
RS0013-13-14									ND	ND	ND	ND
RS0013-30.5-31.5									763	ND	ND	ND
RS0014	12/4/01	12/4/01	42	NA #1	None							
RS0014-10-11									597	668	ND	ND
RS0014-26-27									3,750	ND	ND	ND
RS0015	12/5/01	12/5/01	52	NA #1	28.0-34.0	DNAPL	silty sandy GRAVEL	silty GRAVEL with trace clay				
RS0015-7-8									ND	ND	20	ND
RS0015-33-34									7,900	ND	182	348
RS0015-36-37									ND	ND	ND	ND
RS0016	12/10/01	12/10/01	41	NA #1	None							
RS0016-8-9									223 (J)	ND	ND	ND
RS0016-30-31									147 (J)	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	**Date Started**	**Date Completed**	**Total Depth (feet)**	**EGDY Location**	**NAPL Depth (feet)**	**LNAPL/ DNAPL**	**NAPL Geologic Unit**	**Geologic Unit Below NAPL**	**TCE (µg/kg)**	**cis-1,2-DCE (µg/kg)**	**TPH-Dx (mg/kg)**	**TPH-O (mg/kg)**
RS0017	12/10/01	12/11/01	41	NA #1	1.0-12.0	LNAPL	silty sandy GRAVEL	same				
RS0017-7-8									ND	2,260	1,580	1,740
RS3017-7-8									ND	3,360	1,200	1,400
RS0017-13-14									ND	ND	ND	ND
RS0018	12/11/01	12/11/01	64	NA #2	1.0-22.0	L/DNAPL	gravel (3/4" diameter)	compact gravelly SILT (till-like)				
RS0018-7-7.5									11,000 (D10)	13,700 (D10)	2,750	4,920
RS0018-18									457	187	42	88
RS0019	12/12/01	12/13/01	117	NA #2	8.0-24.0	L/DNAPL	silty sandy GRAVEL	same				
RS0019-8.5-9									264	1,260	3,520	8,730
RS3019-8.5-9									227	1,100	3,560	8,700
RS0019-14-14.5									ND	268	684	1,430
RS0019-17.5-18									ND	468	600	898
RS0019-21.5-22									ND	281	70	114
RS0019-26.5-27									2,230	ND	ND	ND
RS0019-40.5-41									140 (J)	ND	ND	ND
RS0019-50-51									102 (J)	ND	ND	ND
RS0019-55-56									ND	ND	ND	ND
RS0019-88-89									ND	ND	ND	ND
RS0019a	2/18/02	2/18/02	33	NA #2	Yes							
RS0019a-13-14									PHYSICAL SAMPLE			
RS0019a-25-25.5									PHYSICAL SAMPLE			
RS0019a-29.5-30									PHYSICAL SAMPLE			
RS0020	12/14/01	12/15/01	46	NA #1	None							
RS0020-7-7.5									ND	ND	17	81
RS0020-12-13									ND	ND	ND	30
RS3020-12-13									ND	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0021	12/16/01	12/16/01	40	NA #1	None							
RS0021-8-9									ND	ND	ND	ND
RS0021-18.5-19.5									1,290	726	ND	ND
RS0021-26-27									142	ND	ND	ND
RS0021-33-34									2,130	ND	ND	ND
RS0022	12/16/01	12/16/01	46	NA #1	None							
RS0022-14-15									96.7 (J)	ND	ND	ND
RS0022-35.5-36.5									325	ND	ND	ND
RS0023	12/16/01	12/17/01	40	NA #1	None							
RS0023-5-6				NA #1					ND	ND	ND	ND
RS0023-24.5-25									ND	ND	ND	ND
RS0024	1/4/02	1/4/02	107	NA #2	0.0-20.0	L/DNAPL	silty sandy GRAVEL	same, slightly finer grained				
					35.0-36.0	DNAPL	SAND	silty sandy GRAVEL (GW)				
					38.0-46.0	DNAPL	silty sandy GRAVEL	silty gravelly SAND				
RS0024-7-7.5									21,800	31,100	810	1,000
RS0024-19.5-20									3,300	4,740	79	129
RS0024-35-36									30,100	807	69	117
RS0024-41									12,100,000	ND	1,490	1,790
RS0024-50-50.5									ND	ND	ND	ND
RS0024a	2/21/02	2/26/02	42	NA #2	Yes							
RS0024a-22.5-23									PHYSICAL SAMPLE			
RS0024a-33.5-34									PHYSICAL SAMPLE			
RS0024a-42.5-43									PHYSICAL SAMPLE			
RS0025	1/5/02	1/5/02	59	NA #2	9.0-14.0	LNAPL	gravelly SAND	sandy GRAVEL				
RS0025-12-13									128 (J)	ND	363	602
RS0025-20-21									390	ND	19.1 (J)	52.1 (J)
RS3025-20-21									500	ND	17.6 (J)	43.9 (J)
RS0025-41-42									107	ND	ND	ND
RS0025-50-50.5									270	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0026	1/6/02	1/6/02	57	NA #2	None							
RS0026-13-14									213	ND	ND	ND
RS0026-26-27									249	ND	ND	ND
RS0026-29-30									199 (J)	ND	ND	ND
RS0026-44-44.5									548	ND	ND	ND
RS0027	1/7/02	1/7/02	60	NA #2	8.0-19.0	L/DNAPL	sandy GRAVEL	same				
RS0027-9-10									ND	401	225	385
RS0027-18-19									ND	ND	47	91
RS0027-26-27									87.1 (J)	ND	ND	ND
RS0027-35-36									ND	ND	ND	ND
RS0027-59-60									ND	ND	ND	ND
RS0028	1/8/02	1/16/02	60	NA #2	None							
RS0028-12-13									ND	ND	ND	ND
RS0028-26-27									ND	ND	ND	ND
RS0028-38.5-39.5									ND	ND	ND	ND
RS3028-38.5-39.5									ND	ND	ND	ND
RS0028-59-60									ND	ND	ND	ND
RS0029	1/16/02	1/17/02	60	NA #2	7.0-17.0	L/DNAPL	gravelly medium SAND	gravelly coarse SAND				
RS0029-8-8.5									313	160 (J)	490	1,060
RS0029-16-17									131 (J)	ND	15.6 (J)	38.4 (J)
RS0029-25-26									276	ND	ND	ND
RS0029-44.5-45.5									114 (J)	ND	ND	ND
RS0029-59-59.5									ND	ND	ND	ND
RS3029-59-59.5									ND	ND	ND	ND
RS0030	1/17/02	1/17/02	60	NA #2	None							
RS0030-9-10									ND	ND	ND	ND
RS0030-20-21									ND	ND	ND	ND
RS0030-28-29									ND	713	ND	ND
RS0030-46-47									ND	ND	ND	ND
RS0031	1/18/02	1/18/02	57	NA #2	0.0-10.0	LNAPL	sandy GRAVEL	silty sandy GRAVEL				
RS0031-5.5-6.5									3,230	939	286	522
RS0031-17-18									274	103 (J)	21.5 (J)	44.6(J)
RS0031-27-28									129 (J)	ND	ND	ND
RS0031-43-44									107 (J)	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0032	1/19/02	1/19/02	60	NA #2 / NA #1	0.0-28.5	L/DNAPL	silty sandy GRAVEL	medium SAND				
RS0032-7-8									262 (D10)	2,680	922	2,150
RS0032-22-23									26,100 (D10)	286	212	478
RS0032-27-28									141,000 (D50)	71.4 (J)	36	84
RS0032-29-30									ND	ND	ND	ND
RS3032-29-30									ND	ND	ND	ND
RS0032-51-52									ND	ND	ND	ND
RS0033	1/19/02	1/20/02	57	NA #2	None							
RS0033-13.5-14.5									ND	ND	ND	ND
RS0033-21-22									294	ND	ND	ND
RS0033-30-31									456	ND	ND	ND
RS0033-48-49									198	ND	ND	ND
RS0034	1/20/02	1/20/02	60	NA #2	None							
RS0034-7-8									ND	ND	ND	ND
RS0034-20-21									ND	ND	ND	ND
RS0034-31-32									ND	ND	ND	ND
RS0035	1/21/02	1/21/02	60	NA #2	13.0-20.0	LNAPL	medium SAND	same				
RS0035-13-14									1,900	523	764	1,080
RS0035-18-19									139 (J)	521	198	272
RS0035-21-22									97.3 (J)	387	ND	ND
RS0035-35-36									220	ND	ND	ND
RS0036	1/22/02	1/22/02	60	NA #2	None							
RS0036-19.5-20.5									ND	66.4 (J)	ND	ND
RS0036-28-29									ND	101 (J)	ND	ND
RS0036-33-34									112 (J)	69.6 (J)	ND	ND
RS0036-43-44									ND	ND	ND	ND
RS3036-43-44									ND	ND	ND	ND
RS0037	1/22/02	1/22/02	60	NA #2	17.5-26.0	L/DNAPL	silty GRAVEL with cobbles	silty sandy GRAVEL				
RS0037-17-18									657	918	803	1,140
RS0037-25-26									ND	343	88	167
RS0037-31-32									ND	207	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION								
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0038	1/23/02	1/23/02	60	NA #2	0.0-17.0	L/DNAPL	gravelly SAND	GRAVEL & COBBLES				
RS0038-7-8									ND	29,300	8,850	8,130
RS0038-10-11									ND	702	90	101
RS0038-20-21									ND	ND	ND	ND
RS0038-30-31									641	ND	ND	ND
RS0038-46-47									158	ND	ND	ND
RS0039	1/29/02	1/29/02	60	NA #2 / NA #1	9.0-10.0	LNAPL	silty GRAVEL	same				
RS0039-10.5-11.5									ND	ND	ND	ND
RS3039-10.5-11.5									ND	ND	ND	ND
RS0039-28-29									546	ND	ND	ND
RS0040	1/29/02	1/29/02	60	NA #2	None							
RS0040-15-16									ND	ND	ND	ND
RS0040-24-25									106 (J)	ND	ND	ND
RS0040-35-36									174	ND	ND	ND
RS0041	1/30/02	1/30/02	60	NA #2	None							
RS0041-18-19									ND	113 (J)	ND	ND
RS0041-28-29									187	ND	ND	ND
RS0042	1/30/02	1/30/02	60	NA #2	16.5-19.5	LNAPL	sandy GRAVEL	medium SAND				
RS0042-16-17									ND	ND	ND	ND
RS0042-21-22									189	ND	ND	ND
RS0043	1/31/02	1/31/02	60	NA #2	None							
RS0043-16-17									260	340	ND	ND
RS0043-28-29									247	ND	ND	ND
RS0043-50-51									153 (J)	ND	ND	ND
RS0044	1/31/02	1/31/02	60	NA #1	None							
RS0044-4.5-5.5									1,190	911	15.1 (J)	107
RS0044-25-26									ND	ND	ND	ND
RS0045	2/1/02	2/1/02	60	NA #1	None							
RS0045-8-9									512	ND	ND	ND
RS0045-36-37									ND	ND	ND	ND
RS3045-36-37									ND	ND	ND	ND
RS0046	2/1/02	2/2/02	60	NA #2	None							
RS0046-8-9									ND	ND	ND	ND
RS0046-36-37									775	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0047	2/2/02			NA #3	12.0-17.0	L/DNAPL						
RS0047-9-10									619	ND	ND	ND
RS0047-11-12									1,870	1,130	ND	ND
RS0047-16-17									4,580	306	ND	ND
RS3047-16-17									4,860	286	ND	ND
RS0047-33-34									1,090	93.5 (J)	ND	ND
RS0048	2/3/02	2/3/02	57	NA #3	7.0-30.0	L/DNAPL	silty GRAVEL	same				
RS0048-8.5-9.5									2,480	101 (J)	ND	ND
RS0048-16-17									7,630 (D10)	1,170	ND	ND
RS0048-24-25									36,700 (D20)	610	ND	45.2 (J)
RS0048-30-31									1,630	ND	ND	ND
RS0048a	2/19/02	2/19/02	44	NA #3	Yes							
RS0048a-15.5-16									PHYSICAL SAMPLE			
RS0048a-27.5-28									PHYSICAL SAMPLE			
RS0049	2/4/02	2/4/02	60	NA #3	None							
RS0049-9-10									1,840	126 (J)	ND	ND
RS0049-15-16									2,100	262	ND	ND
RS0049-23-24									1,480	ND	ND	ND
RS0049-33-34									698	ND	ND	ND
RS0050	2/4/02	2/5/02	107	NA #3	10.0-12.0	LNAPL						
RS0050-10-11									6,200	708	ND	ND
RS0050-25-26									2,670	ND	ND	ND
RS0050-33-34									1,040	ND	ND	ND
RS0050-50-51									ND	ND	ND	ND
RS3050-50-51									ND	ND	ND	ND
RS0051	2/5/02	2/5/02	60	NA #3	10.0-14.0	LNAPL	loose sandy GRAVEL, trace silt	same				
RS0051-10-11									5,380	115	ND	ND
RS0051-13.5-14.5									2,150	ND	ND	ND
RS0051-42-44									ND	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	**Date Started**	**Date Completed**	**Total Depth (feet)**	**EGDY Location**	**NAPL Depth (feet)**	**LNAPL/ DNAPL**	**NAPL Geologic Unit**	**Geologic Unit Below NAPL**	**TCE (µg/kg)**	**cis-1,2-DCE (µg/kg)**	**TPH-Dx (mg/kg)**	**TPH-O (mg/kg)**
RS0052	2/6/02	2/6/02	60	NA #3	None							
RS0052-7-8									1,320	ND	ND	ND
RS0052-26-27									398	ND	ND	ND
RS0052-34-35									1,820	ND	ND	ND
RS0052-54-55									295	ND	ND	ND
RS3052-54-55									199	ND	ND	ND
RS0053	2/6/02	2/6/02	57	Between NA #2 and NA #3	None							
RS0053-8-9									ND	105	ND	ND
RS0053-19-20									195	ND	ND	ND
RS0053-30.5-31									2,010	226	ND	ND
RS0053-53-54									ND	ND	ND	ND
RS0054	2/12/02	2/14/02	60	NA #3	None							
RS0054-8-9									1,880	2,600	ND	ND
RS0054-17-18									1,270	194	ND	ND
RS0054-28-29									173	ND	ND	ND
RS0054-41-42									454	ND	ND	ND
RS3054-41-42									438	ND	ND	ND
RS0055	2/13/02	2/14/03	60	NA #3	None							
RS0055-12-13									231	202	ND	ND
RS0055-14-15									1,150	624	ND	ND
RS0055-30-31									ND	ND	ND	ND
RS0056	2/14/02	2/15/02	60	NA #3	None							
RS0056-12-13									937	ND	ND	ND
RS0056-31-32									ND	ND	ND	ND
RS0057	2/14/02	2/15/02	60	NA #3	None							
RS0057-11-12									5,200	ND	ND	ND
RS0057-25-26									5,590	ND	ND	ND
RS0058	2/15/02	2/16/02	60	Between NA #2 and NA #3	None							
RS0058-7-8									2,610	590	ND	ND
RS0058-25-26									2,310	ND	ND	ND
RS0058-35-36									504	ND	ND	ND
RS0058-36-37									682	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0059	2/15/02	2/16/02	111	Between NA #2 and NA #3	None							
RS0059-10-11									3,620	267	ND	ND
RS3059-10-11									4,600	401	ND	ND
RS0059-30-31									532	ND	ND	ND
RS0060	2/16/02	2/19/02	66	Between NA #2 and NA #3	2.0-25.0	L/DNAPL	sandy GRAVEL with cobbles	sandy GRAVEL				
					34.0-36.0	DNAPL	sandy GRAVEL	same				
RS0060-6-7									2,460,000	ND	149	310
RS0060-17-18									206,000	ND	ND	ND
RS0060-26-27									2,790	ND	ND	ND
RS0060-40-41									ND	ND	ND	ND
RS0060-47-48									ND	ND	ND	ND
RS0060-57-58									ND	ND	ND	ND
RS0061	3/1/02	3/1/02	37	NA #3	None							
RS0061-9-9.5									1,190	ND	ND	ND
RS0061-13-14									3,990	280 (J)	ND	ND
RS0061-16-17									786	ND	ND	ND
RS0061-24-24.5									1,400	ND	ND	ND
RS0062	3/1/02	3/2/02	77	Between NA #2 and NA #3	5.0-20.0	L/DNAPL	sandy GRAVEL, loose	same				
RS0062-7-7.5									25,000 (D10)	2,380	197	731
RS0062-13-14									10,600	16,400 (D10)	3,600	3,260
RS0062-23.5-24									2,030	ND	ND	ND
RS0062-36-37									327(J)	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0063	3/2/02	3/2/02	75	Between NA #2 and NA #3	4.0-16.0	L/DNAPL	sandy GRAVEL, loose	silty GRAVEL, loose				
RS0063-4-5									ND	101,000	5,900	9,840
RS0063-9-10									ND	ND	28	56
RS0063-19-19.5									1,990	259 (J)	ND	ND
RS0064	3/3/02	3/4/02	105	400' North of NA #1	6.0-17.0	LNAPL	sandy GRAVEL, loose	same				
RS0064-10-11									369	ND	362	1,330
RS0064-16-17									547	ND	815	2,350
RS0064-21-22									ND	ND	ND	ND
RS0065	3/4/02	3/4/02	54	North of NA #1	None							
RS0065-12.5-13									ND	ND	ND	ND
RS0065-14-15									PHYSICAL SAMPLE			
RS0065-23-24									PHYSICAL SAMPLE			
RS0065-24-24.5									ND	ND	ND	ND
RS0065-33-34									PHYSICAL SAMPLE			
RS0066	3/5/02	3/5/02	57	NE of NA #2	None							
RS0066-10-11									1,280	1,770	15	136
RS0066-10-11									PHYSICAL SAMPLE			
RS0066-32-33									592	ND	ND	ND
RS0067	3/5/02	3/5/02	57	Between NA #2 and NA #3	None							
RS0067-9-9.5									2,100	ND	ND	ND
RS0067-26-27									546	ND	ND	ND

Table 3-3
NAPL OBSERVATIONS AT SONIC BORINGS

BORING INFORMATION					CONTAMINANT INFORMATION							
Sonic Boring/ Sample ID	Date Started	Date Completed	Total Depth (feet)	EGDY Location	NAPL Depth (feet)	LNAPL/ DNAPL	NAPL Geologic Unit	Geologic Unit Below NAPL	TCE (µg/kg)	cis-1,2-DCE (µg/kg)	TPH-Dx (mg/kg)	TPH-O (mg/kg)
RS0068	3/6/02	3/6/02	58	Between NA #2 and NA #3	None							
RS0068-6-7									ND	ND	ND	ND
RS0068-12-13									PHYSICAL SAMPLE			
RS0068-23-24									PHYSICAL SAMPLE			
RS0068-25-26									ND	ND	ND	ND
RS0069	3/6/02	3/6/02	57	Between NA #2 and NA #3	None							
RS0069-16-17									ND	ND	ND	ND
RS0069-30-31									3,100	ND	ND	ND

Notes:
Yes under "NAPL Depth" column indicates NAPL observed but depths not characterized due to lack of continuous sampling
Boring IDs ending in "a" were co-located and generally within 10 feet of parent borings
Shaded cells indicate NAPL depths and corresponding analytical sample results within NAPL zones
cis-1,2-DCE = cis-1,2-dichloroethene
(D##) = value based on a dilution of original sample
GM, GP, GW, SP = United Soil Classification System
(J) = estimated value
µg/kg = microgram per kilogram
mg/kg = milligram per kilogram
NA #1 = NAPL Area 1
NA #2 = NAPL Area 2
NA #3 = NAPL Area 3
NAPL = nonaqueous-phase liquid (L = light, D = dense)
ND = non-detect
TCE = trichloroethene
TPH-Dx = total petroleum hydrocarbons - diesel
TPH-O = total petroleum hydrocarbons - oil

Table 3-4
SUMMARY OF EGDY SOIL PHYSICAL PROPERTIES DATA

Boring/ Sample ID	Depth (feet bgs)	Interpreted Geologic Unit [1]	Sample Orientation [2]	Disturbed or Undisturbed Sample [3]	Bulk Density (g/cc)	Effective Porosity (% Vb)	NAPL Saturation (% Pv)	Total Organic Carbon [4] (mg/kg)	Cation Exchange Capacity (meq/kg)	Effective Permeability to Water (millidarcy)	Effective Hydraulic Conductivity (cm/s)	Effective Hydraulic Conductivity (feet/day)
RS0002a-20.5-21	20.5-21.0	Qvr	V	U	1.94	29.1	ND (<0.1)	**1850**	32	443	4.35E-04	1.2
RS0002a-24.5-25	24.5-25.0	Qvr	V	U	1.82	33.1	ND (<0.1)	**1700**	70	585	5.75E-04	1.6
RS0002a-45-45.5	45.0-45.5	Qvt	V	U	1.91	30.1	NA	1050	59	327	3.22E-04	0.9
RS0003-35-37	35.0-37.0	Qvt	V	D	2.16	18.0	NA	600	61	NA	NA	NA
RS0004-36	36.0	Qvl	V	D	1.53	43.9	NA	3400	160	NA	NA	NA
RS0004-102-107	102.0-107.0	Qpon	V	D	1.46	44.3	NA	7200	250	NA	NA	NA
RS0006a-6.5-7.5	6.5-7.5	Qvr	H	U	2.07	24.1	4.2	NA	70	260	2.49E-04	0.7
RS0006a-9-10	9.0-10.0	Qvr	H	U	2.06	25.1	11.6	NA	91	22.9	2.22E-05	0.1
RS0006a-24.3-25.3	24.3-25.3	Qvr	H	U	1.67	37.9	0.2	NA	73	414	3.99E-04	1.1
RS0007a-10-11	10.0-11.0	Qvr	V	U	2.17	19.8	5.7	**5900**	70	170	1.68E-04	0.5
RS0007a-24-25	24.0-25.0	Qvr	V	U	2.15	21.0	NA	330	69	138	1.37E-04	0.4
RS0007a-29.5-30.5	29.5-30.5	Qvt	V	U	2.16	21.0	NA	2800	52	18.4	1.82E-05	0.1
RS0008-31	31.0	Qvr	V	D	1.73	NA	NA	ND (<100)	89	NA	NA	NA
RS0009-13-14	13.0-14.0	Qvr	V	D	1.27	NA	NA	170	62	NA	NA	NA
RS0009-27-27.5	27.0-27.5	Qvt	V	D	1.77	NA	NA	270	66	NA	NA	NA
RS0009-41-42	41.0-42.0	Qvt	V	D	1.85	NA	NA	320	46	NA	NA	NA
RS0012a-27-27.5	27.0-27.5	Qvt	V	U	2.12	22.5	ND (<0.01)	**1100**	61	322	3.11E-04	0.9
RS0012a-30-30.5	30.0-30.5	Qvt	V	U	1.92	30.8	ND (<0.01)	930	80	76.6	7.40E-05	0.2
RS0012a-35-35.5	35.0-35.5	Qvr	V	U	1.94	29.1	ND (<0.01)	630	110	1.62	1.56E-06	0.004
RS0012a-40-40.5	40.0-40.5	Qvr	V	U	2.09	24.4	0.9	582	60	89.8	8.69E-05	0.2
RS0019a-13-14	13.0-14.0	Qvr	V	U	1.81	33.9	ND (<0.1)	**3750**	38	235	2.29E-04	0.6
RS0019a-25-25.5	25.0-25.5	Qvt	V	U	1.75	36.0	68.6	1950	100	6.49	6.38E-06	0.02
RS0019a-29.5-30	29.5-30.0	Qvt	V	U	1.89	30.7	ND (<0.1)	1600	43	39.1	3.83E-05	0.1
RS0024a-22.5-23	22.5-23.0	Qvr	V	U	1.67	39.2	ND (<0.1)	1550	34	9773	9.59E-03	27.2
RS0024a-33.5-34	33.5-34.0	Qvt	V	U	1.93	30.2	0.6	770	65	72.2	6.99E-05	0.2
RS0024a-42.5-43	42.5-43.0	Qvt	V	U	1.97	28.0	ND (<0.01)	**560**	67	3.54	3.43E-06	0.01
RS0048a-15.5-16	15.5-16.0	Qvr	V	U	1.97	28.1	ND (<0.1)	**2250**	42	186	1.83E-04	0.5
RS0048a-27.5-28	27.5-28.0	Qvr	V	U	1.96	27.7	2.9	**2100**	43	154	1.50E-04	0.4
RS0065-14-15	14.0-15.0	Qvr	NA	D	NA	NA	NA	760	NA	NA	NA	NA
RS0065-23-24	23.0-24.0	Qvr	NA	D	NA	NA	NA	340	NA	NA	NA	NA
RS0065-33-34	33.0-34.0	Qvr	NA	D	NA	NA	NA	800	NA	NA	NA	NA
RS0066-10-11	10.0-11.0	Qvr	NA	D	NA	NA	NA	17400	NA	NA	NA	NA
RS0068-12-13	12.0-13.0	Qvr	NA	D	NA	NA	NA	430	NA	NA	NA	NA
RS0068-23-24	23.0-24.0	Qvr	NA	D	NA	NA	NA	800	NA	NA	NA	NA

Table 3-4 (Continued)
SUMMARY OF EGDY SOIL PHYSICAL PROPERTIES DATA

					Particle Size Distribution (% by weight)					
Boring/ Sample ID	Depth (feet bgs)	Interpreted Geologic Unit	Description (USCS/ASTM)	Median Grain Size (mm)	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt & Clay Combined	Silt/Clay
RS0002-18-19	18.0-19.0	Qvr	Coarse sand	2.466	19.87	37.83	27.29	9.99	5.03	NA
RS0002-107-108	107.0-108.0	Qpon	Silt	0.023	0.00	0.00	0.00	15.11	84.89	70.35/14.54
RS0002a-20.5-21	20.5-21.0	Qvr	Gravel	3.578	44.52	18.94	23.13	9.30	4.10	NA
RS0002a-24.5-25	24.5-25.0	Qvr	Gravel	2.626	37.18	19.71	32.34	8.56	2.21	NA
RS0002a-45-45.5	45.0-45.5	Qvt	Gravel	4.014	48.73	11.03	23.39	12.16	4.69	NA
RS0003-35-37	35.0-37.0	Qvt	Coarse sand	1.979	26.83	23.00	21.30	22.42	6.45	NA
RS0004-36	36.0	Qvl	Silt	0.024	0.00	0.00	0.65	13.23	86.12	71.04/15.09
RS0004-102-107	102.0-107.0	Qpon	Silt	0.030	0.00	0.00	1.25	21.68	77.07	65.05/12.02
RS0006a-6.5-7.5	6.5-7.5	Qvr	Gravel	3.379	38.89	22.25	24.59	10.74	3.53	NA
RS0006a-9-10	9.0-10.0	Qvr	Gravel	2.917	41.51	13.76	23.51	14.11	7.11	NA
RS0006a-24.3-25.3	24.3-25.3	Qvr	Medium sand	1.737	7.09	33.06	51.58	5.17	3.10	NA
RS0007a-10-11	10.0-11.0	Qvr	Gravel	4.975	50.89	10.39	20.57	15.06	3.09	NA
RS0007a-24-25	24.0-25.0	Qvr	Gravel	3.700	43.01	18.23	23.56	10.53	4.67	NA
RS0007a-29.5-30.5	29.5-30.5	Qvt	Coarse sand	1.388	29.69	14.20	36.73	16.10	3.27	NA
RS0008-31	31.0	Qvr	Fine sand	0.196	0.00	0.00	18.68	47.25	34.08	26.45/7.63
RS0009-13-14	13.0-14.0	Qvr	Medium sand	0.592	0.00	1.99	80.90	16.49	0.61	NA
RS0009-27-27.5	27.0-27.5	Qvt	Gravel	2.960	40.90	15.92	29.71	10.32	3.15	NA
RS0009-41-42	41.0-42.0	Qvt	Medium sand	0.605	14.20	11.61	35.04	28.68	10.47	NA
RS0012a-27-27.5	27.0-27.5	Qvt	Gravel	3.378	39.51	22.85	24.42	8.43	4.79	NA
RS0012a-30-30.5	30.0-30.5	Qvt	Gravel	3.831	44.79	14.12	16.82	20.34	3.93	NA
RS0012a-35-35.5	35.0-35.5	Qvr	Gravel	4.253	47.33	17.53	24.95	7.20	3.00	NA
RS0012a-40-40.5	40.0-40.5	Qvr	Coarse sand	1.409	31.95	13.24	24.42	22.41	7.97	NA
RS0019a-13-14	13.0-14.0	Qvr	Gravel	5.308	53.64	29.17	18.90	6.19	1.10	NA
RS0019a-25-25.5	25.0-25.5	Qvt	Gravel	0.451	28.68	0.96	21.91	29.93	18.53	NA
RS0019a-29.5-30	29.5-30.0	Qvt	Gravel	3.079	41.93	13.80	23.16	13.57	7.54	NA
RS0024a-22.5-23	22.5-23.0	Qvr	Gravel	5.934	57.76	19.36	16.83	4.69	1.35	NA
RS0024a-33.5-34	33.5-34.0	Qvt	Coarse sand	2.590	33.29	21.84	25.49	12.36	7.02	NA
RS0024a-42.5-43	42.5-43.0	Qvt	Coarse sand	0.796	23.67	12.82	28.19	24.48	10.85	NA
RS0048a-15.5-16	15.5-16.0	Qvr	Gravel	1.729	33.64	14.09	26.54	17.01	8.72	NA
RS0048a-27.5-28	27.5-28.0	Qvr	Gravel	4.524	49.33	11.68	20.16	12.27	6.56	NA

Table 3-4 (Continued)
SUMMARY OF EGDY SOIL PHYSICAL PROPERTIES DATA

Notes:

[1] See Section 5 of this report for descriptions of these units

[2] V = vertical, H = horizontal

[3] D = disturbed, U = undisturbed

[4] Bold type in total organic carbon column indicates sample collected within a NAPL zone based on visual evidence

cm/s = centimeter per second
feet bgs = feet below ground surface
feet/day = feet per day
g/cc = grams per cubic centimeter
meq/kg = milliequivalents per kilogram
mg/kg = milligram per kilogram
mm = millimeter
NA = not applicable
ND = non-detect
% Pv = percent pore volume per cubic centimeter
% Vb = percent bulk volume per cubic centimeter

Table 3-5
PNEUMATIC IN SITU SLUG TEST RESULTS

Boring ID	Location at EGDY	Hydrogeologic Unit [1]	Test Interval (feet bgs)	Best Estimate Horizontal K (cm/sec)	Best Estimate Horizontal K (feet/day)
RS0012a	NAPL Area #1	Steilacoom Gravel (Qvr)	17-20	NA	NA
RS0012a	NAPL Area #1	Upper Till (Qvt)	27-30	4.70E-03	13
RS0019a	NAPL Area #2	Upper Till (Qvt)	30-33	7.00E-03	20
RS0024a	NAPL Area #3	Steilacoom Gravel (Qvr)	21-24	>7.1E-02	>200
RS0024a	NAPL Area #3	Intermediate Till (Qvt)	41-44	7.50E-04	2

Notes:

[1] See Section 5 of this report for descriptions of these units

Best estimate K represents the average value from Bouwer & Rice and type-curve analysis methods.

See *Fort Lewis EGDY Slug Test Characterization Results* (Battelle [PNNL] 2002) in Appendix E for additional details.

cm/sec = centimeter per second
EGDY = East Gate Disposal Yard
feet bgs = feet below ground surface
feet/day = feet per day
K = hydraulic conductivity
NA = not applicable; test responses severely impacted by well bore damage and positive skin effects.
NAPL = nonaqueous-phase liquid

Table 3-6
SUMMARY OF SURFACE WATER RESULTS

Location/ Sample ID	Date Collected	Units	Analyte				
			TCE	DCE	TCA	PCE	VC
SW-MC-0005	7/20/01	µg/L	1.81	<1	<1	<1	<1
SW-MC-0006	7/20/01	µg/L	1.04	<1	<1	<1	<1
SW-MC-0007	7/20/01	µg/L	0.94	<1	<1	<1	<1
SW-MC-0008	7/20/01	µg/L	<1	<1	<1	<1	<1
SW-MC-0009	7/20/01	µg/L	<1	<1	<1	<1	<1
SW-MC-0010	7/21/01	µg/L	2.28	<1	<1	<1	<1
SW-MC-0011	7/21/01	µg/L	2.3	<1	<1	<1	<1
SW-MC-0012	7/21/01	µg/L	2.33	<1	<1	<1	<1
SW-MC-0013	7/21/01	µg/L	1.87	<1	<1	<1	<1
SW-MC-0014	7/21/01	µg/L	2.15	<1	<1	<1	<1
SW-MC-0015	7/21/01	µg/L	1.89	<1	<1	<1	<1
SW-MC-0016	7/21/01	µg/L	2.01	<1	<1	<1	<1

Notes:
Compounds of concern analyzed using onsite DSITMS (direct sampling ion trap mass spectrometer)
DCE = cis-1,2 dichloroethene
µg/L = microgram per liter
TCA = 1,1,1-trichloroethane
TCE = trichloroethene
PCE = tetrachloroethene
VC = vinyl chloride

Table 3-7
GROUNDWATER ELEVATION DATA

	Groundwater Elevation (feet msl)				
Well ID	**Sep-01**	**Nov-01**	**Jan-02**	**Mar-02**	**Apr-02**
UPPER VASHON WELLS					
LC-24	--	--	269.99	270.59	--
LC-26	--	--	266.31	266.34	--
LC-50A	--	268.07	268.62	268.87	--
LC-51	--	268.07	268.62	271.79	--
LC-52	--	--	268.96	269.30	--
LC-56	--	--	--	270.56	--
LC-57	--	265.89	267.92	267.39	--
LC-64A	--	266.12	269.53	269.62	--
LC-108	--	268.98	270.73	271.25	--
LC-133	--	264.57	266.37	267.22	--
LC-135	--	264.60	267.20	266.10	--
LC-136A	--	266.88	267.98	268.80	--
LC-136B	--	268.83	270.24	270.77	--
LC-138	--	270.22	271.22	271.69	--
LC-139	--	270.99	271.94	272.53	--
LC-145	--	270.86	272.00	272.59	--
LC-147	--	270.99	271.94	272.53	--
LC-148	--	270.86	272.00	272.59	--
LC-149A	--	272.09	273.39	274.09	--
LC-149C	--	260.84	261.89	269.39	--
LC-149D	--	261.38	262.50	269.45	--
LC-150	--	264.38	265.89	267.23	--
LC-153	--	267.16	268.66	269.12	--
LC-155	--	268.72	270.07	270.50	--
LC-156	--	267.16	268.66	269.12	--
LC-158	--	268.72	270.07	270.50	--
LC-159	--	--	--	268.36	--
LC-160	--	--	--	268.26	--
9700-MW-1	--	--	267.98	268.33	--
9700-MW-2	--	--	269.11	269.46	--
9700-MW-3	--	--	268.67	268.98	--
LC-169	269.22	267.72	268.15	268.47	--
LC-170	269.57	268.37	268.92	269.32	--
LC-171	266.83	268.58	269.23	269.63	--
LC-172	271.42	270.02	270.59	271.01	--
LC-173	270.05	268.98	270.15	270.53	--
LC-174	270.70	269.55	271.64	272.28	--
LC-175	272.68	271.03	272.43	273.01	--
LC-176	270.70	269.55	271.64	272.28	--
LC-177	269.48	267.36	267.71	267.89	--
LC-178	268.80	--	266.49	266.67	--
LC-179	269.42	268.07	268.47	268.81	--
LC-180	268.80	267.24	267.64	267.93	--
LC-181	269.13	270.23	271.19	271.53	--
LC-182	--	268.22	269.32	269.52	--
LC-183	269.13	268.42	269.52	269.77	--

Table 3-7
GROUNDWATER ELEVATION DATA

	Groundwater Elevation (feet msl)					
Well ID	**Sep-01**	**Nov-01**	**Jan-02**	**Mar-02**	**Apr-02**	
LC-186	--	268.42	269.89	270.12	--	
PZ-02S	--	--	--	271.71	--	
PZ-02D	--	--	--	271.76	--	
PZ-04	--	--	--	272.03	--	
S-1	--	--	--	271.73	--	
ST-1	--	--	--	271.18	--	
ST-5	--	--	--	270.90	--	
ST-6	--	--	--	268.88	--	
ST-8	--	--	--	270.90	--	
ST-10	--	--	--	268.88	--	
LOWER VASHON WELLS [1]						
LC-64B	--	265.89	267.39	267.39	--	
LC-184-4	--	268.42	269.72	269.82	--	
LC-185-4	--	264.77	267.65	266.57	--	
LC-187-4	--	268.52	270.17	270.44	--	
LC-188-4	--	270.44	271.44	272.14	--	
LC-189-4	--	--	272.26	273.46	--	
COMBINED UPPER/LOWER VASHON MULTI-PORT WELLS [1]						**Vertical Gradient [2]**
LC-184-1	--	268.22	269.32	269.52	--	-0.30
LC-184-2	--	268.42	269.52	269.77	--	
LC-184-3	--	268.32	269.46	269.62	--	
LC-184-4	--	268.42	269.72	269.82	--	
LC-185-1	--	263.87	266.57	265.32	--	-1.25
LC-185-2	--	264.92	267.42	266.37	--	
LC-185-3	--	264.97	267.44	266.47	--	
LC-185-4	--	264.77	267.65	266.57	--	
LC-187-1	--	268.52	269.82	270.12	--	-0.32
LC-187-2	--	268.42	269.89	270.12	--	
LC-187-3	--	268.62	270.12	270.45	--	
LC-187-4	--	268.52	270.17	270.44	--	
LC-188-1	--	269.34	270.49	271.14	--	-1.00
LC-188-2	--	269.84	270.79	271.39	--	
LC-188-3	--	270.69	271.54	272.29	--	
LC-188-4	--	270.44	271.44	272.14	--	
LC-189-1	--	--	271.21	271.71	--	-1.75
LC-189-2	--	--	271.41	272.11	--	
LC-189-3	--	--	272.11	273.38	--	
LC-189-4	--	--	272.26	273.46	--	
LC-190-1	--	--	--	--	270.42	0.8
LC-190-2	--	--	--	--	270.42	
LC-190-3	--	--	--	--	270.02	
LC-190-4	--	--	--	--	269.92	
LC-190-5	--	--	--	--	269.92	
LC-190-6	--	--	--	--	269.62	

Table 3-7
GROUNDWATER ELEVATION DATA

	Groundwater Elevation (feet msl)					
Well ID	**Sep-01**	**Nov-01**	**Jan-02**	**Mar-02**	**Apr-02**	
LC-191-1	--	--	--	--	270.79	-0.17
LC-191-2	--	--	--	--	270.24	
LC-191-3	--	--	--	--	270.29	
LC-191-4	--	--	--	--	270.24	
LC-191-5	--	--	--	--	270.29	
LC-191-6	--	--	--	--	270.39	
LC-192-1	--	--	--	--	271.06	0.65
LC-192-2	--	--	--	--	270.96	
LC-192-3	--	--	--	--	270.46	
LC-192-4	--	--	--	--	270.31	
LC-192-5	--	--	--	--	271.86	
LC-192-6	--	--	--	--	270.41	
LC-193-1	--	--	--	--	271.07	-1.8
LC-193-2	--	--	--	--	270.92	
LC-193-3	--	--	--	--	270.52	
LC-193-4	--	--	--	--	270.62	
LC-193-5	--	--	--	--	272.07	
LC-193-6	--	--	--	--	272.87	
LC-194-1	--	--	--	--	268.03	2.75
LC-194-2	--	--	--	--	266.63	
LC-194-3	--	--	--	--	265.88	
LC-194-5	--	--	--	--	266.43	
LC-194-6	--	--	--	--	265.28	
LC-195-1	--	--	--	--	267.24	0.95
LC-195-2	--	--	--	--	267.24	
LC-195-3	--	--	--	--	265.09	
LC-195-4	--	--	--	--	265.44	
LC-195-5	--	--	--	--	266.09	
LC-195-6	--	--	--	--	266.29	
LC-196-1	--	--	--	--	271.01	4.47
LC-196-2	--	--	--	--	270.18	
LC-196-3	--	--	--	--	266.92	
LC-196-4	--	--	--	--	266.88	
LC-196-5	--	--	--	--	266.97	
LC-196-6	--	--	--	--	266.54	
SEA LEVEL AQUIFER WELLS						
LC-26D	--	267.89	269.99	270.59	--	
LC-50D	--	264.52	266.72	267.22	--	

Notes:
-- = Water level measurement not collected
[1] Last digit of well ID represents number of port
[2] Vertical hydraulic gradient (foot per foot) calculated for March or April measurements between upper and lower ports (negative number indicates upward gradient)
feet msl = feet mean sea level

Table 3-8a
NAPL PHYSICAL TEST RESULTS - SAMPLE DESCRIPTION

Sample ID	Description	NAPL Treatment Area
EDC032110161	non-halogenated oily liquid	1
EDC032110162	halogenated oily liquid	1, 3, and southeast of 3
EDC032110163	duplicate of EDC032110162	
EDC032110164	halogenated oily sludge	1 and 3

Notes:

For details of NAPL sample collection, see Garry Struthers Associates, Inc. (GSA). 2001:
Closure Report for Trenching/Drum Removal, East Gate Disposal Yard,
Fort Lewis, Washington.

NAPL = nonaqueous-phase liquid

Table 3-8b
NAPL PHYSICAL TEST RESULTS - INTERFACIAL TENSION

Phase Pair	Temperature (°F)	Interfacial Tension (dynes/cm)
EDC032110161/DI Water	74	13.51
EDC032110162/DI Water	74	2.97*
EDC032110163/DI Water	74	2.21*
EDC032110164/DI Water	Not Suitable for Testing - Oily Sludge	

Notes:

Method - DuNuoy Method (ASTM D971)

* ASTM D971 specifically states that in this instance the platinum ring must be *pushed* from the water phase to the DNAPL phase.

DI = deionized

dynes/cm = dynes per centimeter

°F = degrees Fahrenheit

NAPL = nonaqueous-phase liquid

Table 3-8c
NAPL PHYSICAL TEST RESULTS - SPECIFIC GRAVITY, DENSITY, AND VISCOSITY

Sample ID	Temperature (°F)	Gravity (API)	Specific Gravity	Density (g/cc)	Viscosity centistokes	Viscosity centipoise
					(g/cc)	
EDC032110161						
	60	38.6				
	72		0.8270	0.8251	3.72	3.07
	100		0.8186	0.8129	2.67	2.17
	130		0.8110	0.7997	2.09	1.67
EDC032110162						
	60	18.6				
	72		1.2615	1.2581	26.2	33.0
	100		1.2476	1.2390	2.91	3.61
	130		1.2346	1.2174	1.28	1.56
EDC032110163						
	60	18.1				
	72		1.2559	1.2531	7.97	9.99
	100		1.2500	1.2413	4.04	5.01
	130		1.2294	1.2122	1.07	1.30
EDC032110164						
	60	1.2				
	72		1.0901	1.0877	1012	1101
	100		1.0797	1.0722	158	169
	130		1.0694	1.0545	6.10	6.43

Notes:
Methods - ASTM D445, API RP40
API = American Petroleum Institute standard operating procedure
°F = degrees Fahrenheit
g/cc = grams per cubic centimeter
NAPL = nonaqueous-phase liquid

Table 3-8d
NAPL PHYSICAL TEST RESULTS - DISTILLATION

Sample ID:	EDC032110161	EDC032110162	EDC032110163	EDC032110164
Percent Sample Distilled Off	**Temperature (°F)**			
IBP	170	195	195	194
5	234	199	199	196
10	243	200	200	198
15	256	201	201	200
20	269	203	202	201
25	280	204	203	202
30	287	205	204	202
35	298	205	205	203
40	306	206	206	209
45	317	207	206	602
50	326	207	207	694
55	336	208	208	766
60	344	209	208	825
65	360	338	209	870
70	380	651	531	903
75	416	743	696	929
80	772	826	793	952
85	853	898	879	972
90	918	949	941	991
95	978	990	987	1009
FBP	1030	1027	1027	1030

Notes:
Method - ASTM D86
IBP = initial boiling point
FBP = final boiling point
°F = degrees Fahrenheit
NAPL = nonaqueous-phase liquid

4.0 DATA QUALITY ASSURANCE SUMMARY

After review of the laboratory data deliverables, an evaluation was performed to determine how well the analytical portion of the project was executed and to what extent the chemical data achieved the project-specific DQOs. Data quality and related data gaps in relation to conceptual site model development are discussed in Section 5. The precision, accuracy, representativeness, comparability, completeness, and sensitivity (PARCCS) were evaluated and are summarized in this section. Overall data quality was high, and the data are acceptable for all project-specific purposes. The onsite analyses were performed by the SCAPS Team (USACE Tulsa District); the offsite confirmatory sample analyses were performed by STL; and offsite geotechnical sample analyses were performed by PTS Lab. The onsite and offsite analyses were compliant with the project-approved SAP (URS 2001b), except for the items discussed in the following subsections.

4.1 DATA QUALITY REVIEW METHODS

Data were reviewed in accordance with the project-specific criteria established in the SAP for the PARCCS parameters. Data were validated following the intent of EPA Contract Laboratory Program (CLP) National Functional Guidelines for Organic Data Review (EPA-540/R-99/008, October 1999) and EPA Region 9 RCRA Corrective Action Program Data Review Guidance Manual (Assessed May 1999). Results for the following laboratory QC samples were reviewed:

- Field duplicates and matrix duplicates (TPH-Dx only)
- Matrix spike/matrix spike duplicates (MS/MSDs)
- Laboratory control sample/laboratory control sample duplicates (LCS/LCSDs)
- PE samples (VOC only)
- Equipment rinsate, trip, and method blanks
- Surrogates
- Instrument tuning standards (VOC only)
- Initial and continuing calibration standards

Additionally, chain-of-custody and cooler receipt forms were reviewed, as part of sample representativeness, to evaluate sample integrity during shipping and handling and to verify contractual and technical holding times. Laboratory practical quantitation limits (PQLs) were reviewed to determine if project-specific reporting limit requirements were met. Frequency of collection and analysis of field and laboratory QC samples were reviewed to evaluate completeness and adherence to the SAP.

The sample delivery groups (SDGs) that were reviewed are included in Appendix C. It should be noted that not all SDGs associated with this site investigation were subjected to the data review process. Review of data produced on site by the SCAPS Team is discussed in the final SCAPS EGDY investigation report (USACE 2002).

4.2 SUMMARY OF PRECISION, ACCURACY, REPRESENTATIVENESS, COMPARABILITY, COMPLETENESS, AND SENSITIVITY REVIEW FOR CHEMICAL ANALYSES

The data quality summary reports (Appendix C) were reviewed to identify trends in QC parameters that may impact overall data usability. Infrequent and random exceedances of QC limits are expected and do not necessarily limit data usability. General discussion of the QC exceedances and resulting data qualification are discussed in the following sections. The EGDY quality assurance project plan (QAPP), Appendices B and C, present the method references, laboratory reporting limits, and QC limits (URS 2001b).

4.2.1 Precision

Precision examines the distribution of the reported values around their mean. The distribution of reported values refers to how different the individual reported values are from the average reported value. Precision may be affected by the natural variation of the matrix or contamination within that matrix, as well as by errors made in the field and/or laboratory handling procedures. Precision is evaluated using analyses of primary and field duplicate samples or matrix duplicate (MD) samples, laboratory MS/MSDs, and duplicate LCSs, which not only exhibit sampling and analytical precision, but also indicate analytical precision through the reproducibility of the analytical results. Relative percent difference (RPD) is used to evaluate precision. RPD QC limits for primary and field duplicate evaluation are ≤ 30 percent RPD for aqueous samples and ≤ 50 percent RPD for subsurface soil and NAPL samples. The RPD QC limits for MS/MSDs, LCS/LCSDs, and MDs are those established by the laboratories and referenced in the EGDY QAPP, Appendices B and C (URS 2001b). The data quality indicator of precision was acceptable for this project.

The required frequency of field duplicate samples and laboratory MS/MSDs is 10 percent and 5 percent, respectively, and the required frequency of LCS/LCSDs and MDs is one per analytical batch. The required frequency was met.

RPDs were generally within project-specific QC limits. Specific exceedances are referenced in Appendix C. Exceedances were likely due to one or more of the following analytical variances:

- High levels of target analytes in samples, which require secondary dilutions to bring the concentrations within the linear range of calibration (e.g., VOCs in soil and groundwater). High dilution factors tend to cause RPD inaccuracies. Also, high levels of target analytes result in diluting out or masking the matrix spike analytes.

- Sample heterogeneity for subsurface soil samples.
- Primary and field duplicate results near or below the PQL, which tend to have RPDs outside QC limits.

The organic analytical results did not require qualification based upon RPD exceedances, according to EPA National Functional Guidelines for Data Review.

4.2.2 Accuracy

Accuracy measures the analytical bias in a measurement system. Sources of error can be the sampling process, field contamination, preservation, sample handling, sample matrix, sample preparation, and analytical techniques. Sampling and laboratory accuracy may also be assessed by evaluating the results from equipment rinsate blanks, trip blanks, and method blanks. The QC blank data helps to assess the potential contribution of contamination from various sources. The laboratory objective for accuracy is to equal or exceed the accuracy demonstrated for the applied analytical methods on samples of the same matrix. The percent recovery criterion is used to estimate accuracy based on recovery in MS/MSDs, LCS/LCSDs, PE samples, surrogates, internal standards, and calibration standards. The MS/MSDs, surrogates, and internal standards, which give an indication of matrix effects that may affect target analyte quantitation and identification, are also a good gauge of method efficiency. The data quality indicator of accuracy was acceptable for this project.

The required frequency for collection and/or analysis of QC samples was met for all parameters except for equipment rinsate blanks for subsurface soil (4.7 percent) and groundwater (2.2 percent), and field duplicates for subsurface soil (9.4 percent). The frequencies were slightly below the project-specific frequency of 5 percent for equipment rinsate blanks and 10 percent for field duplicates. No qualifiers were recommended based on this variance.

Several VOC target compounds were detected in the QC blanks. Sample results less than 10 times the associated QC blank concentration for common laboratory contaminants (e.g., methylene chloride) and 5 times for all other compounds were qualified as non-detect (U) at the appropriate quantitation limit, per EPA National Functional Guidelines for Organic Data Review. The affected samples are summarized in Table 4-1.

The VOC QC blanks presented in Table 4-2 exhibited contamination. However, the associated sample results did not require qualification, according to EPA National Functional Guidelines for Organic Data Review, because their values were either non-detect or were 10 times greater than the associated QC blank concentrations for common laboratory contaminants (e.g., methylene chloride) or 5 times for all other compounds.

MS/MSDs and LCS/LCSDs were generally within project-specific QC limits. The organic analytical results did not require further qualification based upon MS/MSD and LCS/LCSD exceedances, according to EPA National Functional Guidelines for Organic Data Review. Exceedances were likely due to one or more of the following analytical variances:

- Matrix spike analytes being diluted out or masked due to the presence of high levels of target analytes in samples
- Sample heterogeneity for soil samples
- Presence of matrix interference

It was determined during the data quality review that STL added VOC MS/MSD compounds (including surrogates) at the instrument level for soil samples preserved with methanol. This is contrary to Method SW-5035 criteria (i.e., add MS/MSD/surrogate compounds to the soil sample containers, then take an aliquot of the methanol and analyze). Consequently, the laboratory was unable to demonstrate extraction efficiency of the target compounds from the methanol, only purge efficiency of the instrumentation. The laboratory is currently in the process of revising their SOPs, and for the next phase of work the laboratory will add VOC MS/MSD compounds (including surrogates) to the methanol-preserved soil sample containers. Because the soil data are not being used for health-risk purposes but rather to qualitatively assess the extent of TCE and NAPL contamination in the soil, no qualifiers were recommended based on this variance.

Five blind soil PE samples (for VOCs only) provided by Environmental Resource Associates (ERA) were submitted to the STL for this site investigation. The results are summarized in Table 4-3. The PE results for cis-1,2-DCE, trans-1,2-DCE, PCE, TCE, and VC were within ERA QC limits, except for the following instances:

- PE sample LC9185-02-113001 (i.e., SDG No. 102531) exhibited a slightly elevated recovery of cis-1,2-DCE. The laboratory-reported result (103 µg/L) was determined from a secondary dilution analysis (dilution factor of 10 [DF10]). The undiluted result for cis-1,2-DCE (87.8 µg/L) was within ERA QC limits, but its concentration exceeded the laboratory's linear range of calibration. The PE exceedance may likely be due to sample dilution rather than a lack of instrument accuracy because the daily continuing calibration vertification (CCV) standard percent difference (%D) was within QC limits.

- PE sample SG9026-20-25 (SDG No. 100696) exhibited a slightly elevated recovery of cis-1,2-DCE. The laboratory-reported result (95 µg/L) was determined from a secondary dilution analysis (DF10), and the PE exceedance may likely have been due to sample dilution rather than a lack of instrument accuracy. It should also be noted that the initially reported trans-1,2-DCE result for PE sample SG9026-20-25 (130 µg/L) was outside ERA QC limits (67.7–126 µg/L), but when the appropriate number of significant figures is used, the revised trans-1,2-DCE result (i.e., 126 µg/L) is acceptable.

- PE sample SG9033-17-20 exhibited a slightly low recovery for tetrachloroethene. The laboratory result (3.17 µg/L) was reported from an undiluted analysis, but the secondary dilution result (3.70 µg/L) was within ERA QC limits. The daily CCV standard %Ds and LCSs were within QC limits.

Because these data are primarily being used to confirm the extent of TCE and NAPL contamination, no qualifiers were recommended based on these PE exceedances.

Surrogate recoveries were within method QC limits, except for the following instances:

- The VOC analysis of groundwater sample 1DW0001 (SDG No. 102493) and groundwater samples SG0003-16-19, SG0009-16-19, and SG3009-16-19 (SDG No. 100415) exhibited a slightly low or high recovery for toluene-d8. Since National Functional Guidelines for Organic Data Review requires only the surrogate bromofluorobenzene (BFB) to be monitored for low concentration water analyses, no qualifiers were recommended based on this variance.

- The VOC analysis of subsurface soil sample RS0011-23-23.5 (SDG No. 102529) exhibited a slightly low surrogate recovery for ethylbenzene-d10. The sample results were qualified as estimated (UJ), per National Functional Guidelines for Organic Data Review.

- The VOC analysis of subsurface soil samples RS00024-35-36 (SDG No. 103174), RS0025-12-13 (SDG No. 103204), RS0035-13-14 (SDG No. 103538), and RS0038-7-8 (SDG No. 103538) exhibited a slightly elevated surrogate recovery for ethylbenzene-d10. The detected sample results were qualified as estimated (J), per National Functional Guidelines for Organic Data Review. For sample RS00024-35-36, the TCE result was reported from a secondary dilution, which exhibited acceptable surrogate recoveries. Therefore, it did not require qualification.

- The VOC analysis of subsurface soil samples RS0006-8-9 and RS3006-8-9 (SDG No. 102306) exhibited a slightly elevated surrogate recovery for toluene-d8. The detected sample results from the undiluted analyses were qualified as estimated (J), per National Functional Guidelines for Organic Data Review. The TCE and 1,2,4-TCE results were reported from secondary dilutions, which exhibited acceptable surrogate recoveries. Therefore, these compounds did not require qualification.

- The VOC analysis of trip blanks RSTB013102 (SDG No. 103729) and RSTB020402 (SDG No. 103841) exhibited an extremely elevated surrogate recovery for BFB (339 percent and 360 percent, respectively) as a result of the laboratory inadvertently fortifying the trip blank vials with TPH-gasoline range surrogates (i.e., BFB and trifluorotoluene). The trip blanks were also fortified with VOC surrogates at the instrument level, which includes BFB. Because no target compounds were detected in the trip blanks, no qualifiers were recommended based on this variance, per National Functional Guidelines for Organic Data Review.

Internal standard (IS) recoveries (VOCs only) were not evaluated during the data summary review due to laboratory software limitations. The laboratory case narratives did not indicate any IS outliers. No qualifiers were recommended based on this reporting variance.

All initial calibrations (ICALs) were within QC limits (<30.0 percent relative standard deviation [RSD]), except for the following instances:

- The VOC ICAL associated with subsurface soil samples RS0003-22-23 and RS3003-22-23 (SDG No. 102032) exhibited an elevated percent RSD for TCE. The detected results were qualified as estimated (J), per National Functional Guidelines for Organic Data Review.

- The VOC ICAL associated with groundwater samples SG0013-27-30, SG0014-29-32, SG0016-30-33, SG0017-28-31, and trip blank TB927 (SDG No. 100347) exhibited an elevated percent RSD for chloromethane. The detected results were qualified as estimated (J), per National Functional Guidelines for Organic Data Review.

- The following groundwater and/or subsurface soil VOC target compounds were not reported by the laboratory due to poor linearity (>30.0 percent RSD) and/or relative response factor (RRF) (<0.05): 1,1,2-trichloro-1,2,2-trifluoroethane, 1,3,5-trichlorobenzene, 2-chloroethyl vinyl ether, 1,4-dioxane, 2-butanone, 2-hexanone, 4-methyl-2-pentanone, acetone, acrylonitrile, benzyl chloride, carbon

> disulfide, cis-1,4-dichloro-2-butene, ethyl acetate, ethyl ether, hexane, iodomethane, methyl-t-butyl ether, tetrahydrofuran, trans-1,4-dichloro-2-butene, and vinyl acetate. Because these target compounds were not expected to be present in the groundwater and subsurface soil samples, no qualifiers were recommended based on this variance.

It should be noted that subsurface soil VOC instrument calibration and sample analysis were performed on a GCMS equipped with an ion trap mass spectrometer detector and an on-column ICAL calibration range of 0.4 to 40 ppb. Instrument calibration and sample analysis should have been performed on a less sensitive instrument (e.g., with a quadrupole mass spectrometer detector) using higher levels of calibration standards, which is more appropriate for poorer responding compounds and medium-level analyses (i.e., soil samples preserved in methanol).

The VOC continuing calibrations (CCALs) exhibited elevated %Ds (>25.0%D [subsurface soil] and >30.0%D [groundwater]) for one or more of the following target compounds: bromomethane, bromochloromethane, bromoform, n-butylbenzene, sec-butylbenzene, t-butylbenzene, chloromethane, hexachlorobutadiene, 4-isopropyltoluene, 1,2,3-trichlorobenzene, 1,2,3-trichloropropane, and TCE. The affected VOC results (specifically referenced in Appendix C) were qualified as estimated (J or UJ), per National Functional Guidelines for Organic Data Review. Instrument calibrations for all other fractions were within QC limits.

4.2.3 Representativeness

Representativeness expresses the degree to which the sample data accurately and precisely represent the characteristics of a population of samples, parameter variations at a sampling point, or environmental conditions. Representativeness is a qualitative parameter, which is most concerned with the proper design of the sampling program or subsampling of a given sample. Objectives for representativeness are defined for sampling and analysis tasks and are a function of the project-specific DQOs. Field sampling procedures, as described in the SAP (URS 2001b), have been selected with the goal of obtaining representative samples for the media of concern.

Representativeness is evaluated by examining sample tracking information and chain-of-custody cooler receipt documentation. This evaluation verifies contractual and technical holding times and proper documentation to allow traceability of laboratory analytical results to specific field sample locations. Representativeness can also be assessed by the evaluation of field duplicate precision, as discussed in Section 4.2.1. The data quality indicator of representativeness was acceptable for this project.

Sample integrity was generally maintained in accordance with SAP procedures, except for variances specifically referenced in Appendix C. Exceptions include the following:

- Cooler temperatures outside the QC limits of 4°C ±2°C (SDG Nos. 103237, 103538, 104034, 104344, and 105613). It is not expected that the cooler temperature exceedances (range from –2.0°C to 9.7°C) would adversely affect the sample results because the VOC subsurface soil samples were field-preserved with methanol for medium-level analysis, and the chemical nature of TPH-Dx in soils. The cooler temperature associated with the groundwater samples in SDG No. 105613 was only slightly above 6°C. The elevated cooler temperatures are not expected to adversely affect the VOC results. The affected samples are presented in Table 4-4.

- Cooler temperatures not recorded (SDG Nos. 100524, 102064, 102493, 102430, 102587, 102588, 102628, 102759, 102855, and 102931). The affected samples were refrigerated on site immediately upon sample collection, then transported directly to the laboratory in iced coolers by URS field personnel. Therefore, the lack of temperature measurement upon receipt at the laboratory does not adversely affect the data. No qualifiers were recommended based on this variance.

- Incorrect analysis (semivolatiles) requested on the chain-of-custody form (SDG No. 101970).

- Sample not documented on the chain-of-custody form, but sample container received by the laboratory and appropriate analyses performed (SDG Nos. 102493 and 103764 for VOC).

- Recorded time discrepancy (SDG No. 104034). The time the cooler was relinquished by field personnel referenced on the chain-of-custody form was chronologically after the time of sample receipt at the laboratory.

- Headspace (i.e., air bubbles) present in aqueous VOA vials (SDG Nos. 100347, 104368, 105557, and 105680). The air bubbles present in the VOA vials were less than 5 mm in diameter and therefore are not considered a nonconformance per EPA Method SW-5030B (i.e., purge-and-trap procedure for aqueous samples). No qualifiers were recommended based on this variance.

- Groundwater samples for TPH-Dx analysis not preserved with HCl to a pH <2 (SDG No. 102588). The samples were extracted within 2 days of collection and analyzed 1 to 2 days thereafter. Therefore, no qualifiers were recommended based on this variance because TPH-Dx is not expected to significantly degrade within 2 days of sample collection.

- The use of increased soil sample size for VOC analysis (i.e., generally 1.5 to 4 times the required amount), which affects the extraction efficiency of target compounds from the methanol. Method SW-5035 requires a 1:1 ratio (i.e., volume-to-volume) of soil to methanol. In instances where high levels of target compounds (e.g., TCE) are present in the soil samples, the amount of methanol may not have been sufficient to extract all of the target compounds from the soil sample. This may have resulted in potentially biased low results.

Because the data are being used to qualitatively assess the extent of TCE and NAPL contamination in the subsurface soil and groundwater, these analytical and field-sampling nonconformances do not adversely affect the usability of the data. No qualifiers were recommended based on these variances.

The TPH-Dx diesel and/or motor oil results for several subsurface soil samples were qualified as estimated (J) (specifically referenced in Appendix C) because of the presence of coeluting matrix interference (e.g., jet fuel, mineral spirits, kerosene, fuel oil #6, heavy oil, and/or lube oil), which likely affected diesel and/or motor oil pattern recognition and quantitation.

The initial VOC analysis for groundwater sample 1DW0001 (SDG No. 102493) exhibited linear range exceedances for the following target compounds: cis-1,2-DCE, TCE, methylene chloride, chloroform, 1,1,1-trichloroethane, toluene, m+p-xylene, o-xylene, and 1,2,4-trimethylbenzene. The sample was reanalyzed, and methylene chloride, chloroform, 1,1,1-trichloroethane, toluene, m+p-xylene, o-xylene, and 1,2,4-trimethylbenzene were not detected in the subsequent secondary dilutions. Therefore, the initial analysis results were qualified as estimated (J), per National Functional Guidelines for Organic Data Review.

The TCE secondary dilution result for sample RS0005-12-13 (SDG No. 102243) exceeded the linear range of calibration and was qualified as estimated (J), per National Functional Guidelines for Organic Data Review.

The VOC results for several samples may be inaccurate due to instrument carryover from the analysis of high concentration samples. The laboratory did not analyze an instrument blank after the high concentration samples. The affected sample results were qualified as estimated (J) (specifically referenced in Appendix C), per National Functional Guidelines for Organic Data Review.

The sample dilution factors (DFs) referenced by the laboratory on the analytical summaries did not always reflect the actual level of analysis. The DFs were revised accordingly during the data review.

The secondary dilution analyses for several samples were performed with the DF too high. The resulting on-column concentrations were below the mid-level point of the ICAL curve (i.e., 20 mg/L) for the target compound with the highest concentration. No qualifiers were recommended based on this variance.

There were several instances where PQLs, method detection limits (MDLs), and method reporting limits (MRLs) were not adjusted to reflect the appropriate DFs. The affected PQLs, MDLs, and MRLs were revised accordingly during the data review.

For VOCs, the laboratory reported MRLs along with PQLs on the soil analytical summaries, while the laboratory reported MDLs along with PQLs on the groundwater summaries. The laboratory MRLs are equivalent to ½ the PQLs. No qualifiers were recommended based on this variance.

For all geotechnical analyses, the laboratory did not submit case narratives or raw data (except for particle size analyses). Therefore, the following QC parameters were not evaluated during the data review: holding times (for TOC and CEC only), instrument calibration, method blank contamination, MS/MSD precision and accuracy, LCS accuracy, matrix duplicate precision, and percent completeness.

4.2.4 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. This goal is achieved through using standard techniques to collect and analyze representative samples and reporting analytical results in appropriate units. Complete field documentation using standardized data collection forms supports the assessment of comparability. Comparability is limited by other PARCCS parameters because only when precision and accuracy are known can data set comparison be performed with confidence. For data sets to be comparable, it is imperative that the analytical methods and procedures be strictly followed.

Comparability is evaluated by examining the laboratory analytical data and comparing the reported results for compliance with the project-specific approved methods and SOPs. The data review determined that the analytical results are acceptable for use, despite minor deviations from the methods and SOPs. The data quality indicator of comparability was met by the laboratories.

Comparability is also evaluated by comparing interlaboratory split sample results. However, split samples were not a project-specific requirement.

4.2.5 Completeness

Completeness is defined as a measure of the amount of valid data (usable for project-specific purposes) obtainable from a measurement system compared to the total amount of measurements expected to be obtained under normal conditions. It is important that appropriate QA procedures be maintained to ensure that valid data are obtained and the desired level of completeness meets the project-specific DQOs. An overall project-specific goal of 98 percent was established for completeness (or usability) of the analytical data. The percent completeness for each sampling event is referenced in the data quality summary review reports (Appendix C). The overall completeness for this project was above 98 percent.

4.2.6 Sensitivity

The sensitivity (i.e., reporting limits) of the analytical methods is driven by the project-specific DQOs. All reporting limits met the project-specific requirements, except for the following minor variance:

- The laboratory aqueous PQL for bromomethane (0.8 mg/L) is not in accordance with the SAP requirement (0.4 mg/L). The laboratory MDLs range from 0.139 mg/L to 0.174 mg/L, depending upon the instrumentation. PQLs are typically 5 to 10 times greater than MDLs. It should be noted that the low points of the ICALs range from 0.2 to 0.4 mg/L for bromomethane. No qualifiers were recommended based on this variance.

It should be noted that several VOC subsurface soil and groundwater samples required secondary dilutions because of the high levels of target analytes, which resulted in elevated reporting limits for non-detect analytes.

4.3 OVERALL DATA USABILITY

After review of information contained in the laboratory data deliverables, an evaluation was performed to determine how well the analytical portion of the project was executed and to what extent the chemical data achieved the project-specific DQOs identified in the SAP.

The overall DQOs for this project were to generate data to support the following uses:

- Define the extent of TCE and NAPL contamination, which will be evaluated and integrated into the EGDY CSM.

- Obtain data required to design a thermal remedial action for NAPL source area treatment.
- Obtain data required to complete an evaluation of options for optimization of the existing pump-and-treat system.
- Obtain data required to complete an evaluation of reactive barrier wall replacement options.
- Provide analytical results that can be used to segregate and classify investigation-derived waste as solid, hazardous, or dangerous waste according to RCRA and Washington State Dangerous Waste Regulations.
- Characterize subsurface soil for geochemical and physical characteristics.

Despite the minor data QC issues identified above and in Appendix C, the analytical data reported for this project is usable for project purposes.

Table 4-1
SUMMARY OF QUALIFIED DATA FOR QC BLANK CONTAMINATION

Sample ID	Associated QC Blank	Affected Compounds
All samples from SDG No. 101970	TB110201	Bromomethane
LC0184-02-112901	LCTB112901	Chloroform
LC0184-01-112901		Toluene
RS0005-12-13	RS6012-14-15	Chloroform
RS0005-38-39, RS0009-8-9, RS0012-6-7, RS0013-13-14, RS0013-30.5-31.5, and RS0014-10-11		TCE
SG0013-27-30, SG0014-29-32, SG0017-28-31, SG003-16-19, SG3009-16-19, and SG0026-19-24	SG6026-19-24	Methylene Chloride
SG0015-18-23, SG0016-18-23, SG0018-30-33, SG0017-28-31, SG0017-19-24, SG0019-15-20, SG0019-29-32, SG0018-20-25, SG0009-16-19, SG3009-16-19, SG0023-18-23, SG3020-14-19, SG0020-14-19, SG0024-5-10, SG0024-19-22, SG3025-13-18, SG0025-13-18, SG0026-19-24, and SG0033-17-20		Naphthalene
RS0006A-9-10 and RS0006A-24.3-25.3	RS6024-7-7.5	cis-1,2-DCE
RS00024-7-7.5, RS00024-19-20, and RS00024-35-36		Toluene
LC0186-120301	LC6186-120301	Chloroform and Toluene
LC3186-120301		Toluene
LC9186-120301, LC0189-01-121101, LC0189-02-121101, LC0189-03-121101, and LC0189-04-121101	Method blank	Styrene
LC0189-03-121101	LC6186-120301	TCE
RS0006-28-29, RS3006-28-29, RS0007-8-9, RS0007-18-19	RS6006-28-29	TCE
RS0016-8-9, RS0016-30-31, RS0018-18, RS0019-8.5-9.0, RS3019-8.5-9.0, RS0019-40.5-41, RS0019-50-51, RS0021-26-27, RS0022-14-15, RS0022-35.5-36.5	RS6020-7.0-7.5	TCE
RS0018-7-7.5		Chloroform
RS0018-18, RS0019-8.5-9.0, RS0019-14-14.5, RS0019-17.5-18, RS3019-8.5-9.0, RS0019-21.5-22, RS0021-18.5-19.5		cis-1,2-DCE
RS0018-7-7.5, RS0019-17.5-18		Toluene
All samples associated with SDG No. 103977	Method blank and RSTB021202	Chloromethane
RS0061-16-17, RS3061-24-24.5, RS0062-36-37, RS0064-10-11, RS0064-16-17, RS0066-10-11, RS3066-10-11, RS0066-32-33, and RS0067-26-27	RS6062-36-37 and RSTBW030202	TCE

Notes:
SDG = sample delivery group; QC = quality control; TCE = trichloroethene; cis-1,2-DCE = cis-1,2-dichloroethene

Table 4-2
VOC QUALITY CONTROL BLANKS EXHIBITING CONTAMINATION

QC Blank	Contaminant
Method Blank (SDG No. 102493)	Methylene chloride
LCTB113001 (SDG No. 102531)	Methylene chloride
RS6012-14-15	Methylene chloride, Toluene, PCE, and 1,4-Dichlorobenzene
TB927 (SDG No. 100347) and Method Blank (SDG No. 103841)	Chloromethane
SG6024-7-7.5	Methylene chloride, Chloroform, Toluene, and 1,4-Dichlorobenzene
LC6186-120301 and LCTB120301 (SDG No. 102588)	Methylene chloride, Chloroform, TCE, Tetrachloroethene, and 1,4-Dichlorobenzene
LCTB121101 (SDG No. 102759)	Chloroform, Bromodichloromethane, Toluene, Dibromochloromethane, and 1,4-Dichlorobenzene
RS6006-28-29	Chloroform and Toluene
RS6020-7.0-7.5 and RS6TB121401	Methylene chloride, Toluene, Tetrachloroethene, and 1,4-Dichlorobenzene
RS6028-59-60, RS6040-24-25,	Chloroform and 1,4-Dichlorobenzene
RSTBW011602, RSTBW012902 RS6055-30-31 and RSTBW021302	1,4-Dichlorobenzene

Notes:
QC = quality control
SDG = sample delivery group
PCE = tetrachloroethene
TCE = trichloroethene

Table 4-3
PERFORMANCE EVALUATION SAMPLE RESULTS

PE Sample ID	Compound	Lab Results	ERA QC Limits
LC9184-01-112901	cis-1,2-DCE	92.4 μg/L	50.3 – 94.8 μg/L
	trans-1,2-DCE	147 μg/L	96.9 – 178 μg/L
	PCE	1.54 μg/L	1.29 – 2.39 μg/L
	TCE	4.1 μg/L	2.52 – 4.35 μg/L
	VC	2.09 μg/L	0.942 – 2.88 μg/L
LC9185-02-113001	cis-1,2-DCE	**103 μg/L**	50.3 – 94.8 μg/L
	trans-1,2-PCE	163 μg/L	96.9 – 178 μg/L
	PCE	1.37 μg/L	1.29 – 2.39 μg/L
	TCE	2.94 μg/L	2.52 – 4.35 μg/L
	VC	2.02 μg/L	0.942 – 2.88 μg/L
SG9026-20-25	cis-1,2-DCE	**95 μg/L**	44.4 – 83.6 μg/L
	trans-1,2-DCE	126 μg/L	67.7 – 126 μg/L
	PCE	4.9 μg/L	3.25 – 5.98 μg/L
	TCE	5.4 μg/L	3.49 – 5.99 μg/L
	VC	2.0 μg/L	1.20 – 2.80 μg/L
SG9033-17-20	cis-1,2-DCE	74 μg/L	44.4 – 83.6 μg/L
	trans-1,2-DCE	95 μg/L	67.7 – 126 μg/L
	PCE	3.17 μg/L	3.25 – 5.98 μg/L
	TCE	3.6 μg/L	3.49 – 5.99 μg/L
	VC	1.3 μg/L	1.20 – 2.80 μg/L
LC9186-120301	cis-1,2-DCE	84.9 μg/L	50.3 – 94.8 μg/L
	trans-1,2-DCE	137 μg/L	96.9 – 178 μg/L
	PCE	1.53 μg/L	1.29 – 2.39 μg/L
	TCE	3.79 μg/L	2.52 – 4.35 μg/L
	VC	2.21 μg/L	0.942 – 2.88 μg/L

Notes:
PE exceedances are indicated in bold.
PE = performance evaluation
ERA = Environmental Resource Associates
QC = quality control
cis-1,2-DCE = cis-1,2-dichloroethene
trans-1,2-DCE = trans-1,2-dichloroethene
PCE = tetrachloroethene
TCE = trichloroethene
VC = vinyl chloride

Table 4-4
COOLER TEMPERATURE EXCEEDANCES

SDG No.	Sample ID	Cooler Temperature (°C)
103237	All subsurface soil samples	9.7
103538	All subsurface soil samples	0.0
104034	All subsurface soil samples	-2.0
104344	All subsurface soil samples	0.1
105613	All groundwater samples	6.3

Note:
SDG = sample delivery group

5.0 DATA INTERPRETATION/CONCEPTUAL SITE MODEL

5.1 PHYSICAL SYSTEM

5.1.1 Geology

5.1.1.1 Regional Geology

The area affected by solvents contamination at the Fort Lewis Logistics Center (MAMC area, Logistics Center, and the city of Tillicum), hereafter referred to as the study area, is located within the southern Puget Sound Lowland (Figure 5-1). The Puget Sound Lowland is a north-south trending structural trough bounded on the east by the Cascade Mountains and on the west by the Olympic Mountains. The study area is located on an upland with low to moderate relief at elevations from 270 to 290 feet above msl. The study area upland is bounded to the north by the Puyallup River valley, to the south by the Nisqually River valley, to the east by the foothills of the Cascades, and to the west by Puget Sound. The study area is underlain by a complex sequence of glacial and non-glacial Quaternary sediments up to 2,000 feet thick. The Cordilleran ice sheet may have advanced into the Puget Sound region during the Pleistocene, with intervening periods of non-glacial deposition. Glacial sedimentary deposits in the Puget Sound region typically include glaciolacustrine, high-energy glaciofluvial, and ice-contact facies such as till. Lowland sedimentation during non-glacial periods is likely to have been dominated by relatively low-energy fluvial systems, mudflows/lahars, marine deposition toward the center of the lowland, and large upland areas where erosion or no deposition occurred.

5.1.1.2 Site Geology

Lithologic data are available for the study area from a large number of soil borings drilled for exploration purposes and from monitoring and water supply wells. The boring logs from investigations prior to the Phase II RI are not included with this report. However, Table 5-1 is a list of borings and interpreted geologic contacts used to develop the stratigraphy and hydrostratigraphy discussed in this section.

The following discussion of the study area geology is an adaptation of the stratigraphic interpretation set forth in Borden and Troost (2001), with interpretations also based on new data collected during the EGDY Phase II RI and from new lower aquifer wells that were unavailable to Borden and Troost. Cross-section A-A′ (Figures 5-2 through 5-4), which has one end in the source area (EGDY) and the other end past the downgradient edge of the contaminated groundwater, illustrates the major stratigraphic and hydrostratigraphic features of the study area. Figure 5-5 shows the seven cross-section locations (B-B′ through H-H′) in the source area where the density of stratigraphic data collected during the Phase II RI is high. Figures 5-6 through 5-12 (cross-sections B-B′ through H-H′) give the stratigraphic detail.

At least three glacial and three non-glacial units have been identified in the sediments that occur above sea level in the study area. These units (from youngest to oldest) are as follows:

- Vashon Drift (glacial), less than 15,000 years old
- Olympia Beds (non-glacial), approximately 15,000 to 60,000 years old
- Pre-Olympia Drift (glacial), approximately 60,000 to 80,000 years old
- Second Non-Glacial Deposits, approximately 100,000 years old
- Third Glacial Drift, approximately 100,000 to 1,100,000 years old
- Third Non-glacial Deposits, more than 1,000,000 years old

This sequence is not always present everywhere beneath the study area because deposition did not occur on upland areas during non-glacial periods and deep erosional troughs were excavated during interglacial and glacial periods.

The unit names provided below are from Borden and Troost (2001) and replace the previous stratigraphic nomenclature used for the study area in previous site-related documents. The names used previously are provided in parentheses in the following unit-specific descriptions to allow correlation with geologic and hydrogeologic discussions in previous reports.

Holocene—Anthropomorphic Deposits. The most recent materials emplaced in the study area consist of manmade fill (e.g., utility trenches, building and road subgrade, and waste). The most important Holocene deposits related to solvents contamination at the Logistics Center are in the numerous trenches located in the EGDY that were excavated and backfilled with hazardous waste, debris, and burned material. Trench deposits containing metallic debris (e.g., drums) were located where the geophysical anomalies are shown on Plate 1 and typically extend to less than 10 to 12 feet bgs (i.e., above the groundwater table). Trenches containing nonmetallic waste were identified by examining the available aerial photographs from 1940 to present. The locations of trenches identified from aerial photographs are included on Plate 1.

Vashon Drift Deposits *(Vashon Glacial Drift Deposits in previous reports)*—Qv. Vashon Drift deposits are the youngest nonanthropomorphic deposits in the study area and their deposition and erosional history are reflected in the topography. The surface topography of the study area is characterized by swales (produced by the intersection of past braided stream channels), kettles and ice contact depressions of irregular shape, and drumlinoid hills of remnant till deposits. Vashon Drift deposits, from youngest to oldest, consist of Vashon recessional outwash (including the Steilacoom gravel), Vashon till/ice contact deposits/glaciolacustrine silt, Vashon advance outwash, and glaciolacustrine silt/clay. Vashon Drift deposits typically extend from ground surface to approximate elevations of 210 to 185 feet (NGVD 29). In the region of a deep erosional trough (see discussion below), these deposits extend downward to elevation 50 feet.

Vashon Recessional Outwash (Vashon Recessional Outwash/Steilacoom Gravel in previous reports)—Qva. The Steilacoom gravel consists of sand and gravel deposited in braided channels formed by the rapid discharge of glacial Lake Puyallup at the end of the Vashon glacial period. Vashon recessional outwash was deposited in similar high-energy braided stream channels in front of the retreating ice sheet; thus, the Steilacoom gravel and recessional outwash are difficult to distinguish as separate units. For this CSM, the term recessional outwash is used to describe both the recessional outwash and the Steilacoom gravel. The recessional outwash may contain lenses of ice contact till deposited as portions of the retreating ice sheet left behind or rafted by outwash streams melted in the outwash plain. Ice contact till deposits consist of poorly sorted sand and gravel with silt and clay. Borden and Troost report the recessional outwash deposits as consisting of interbedded, brown to gray sandy gravel and sand with minor silt interbeds. Similar materials encountered in the study area generally consist of loose, well-graded, brown to gray sandy, cobbly gravel at or near ground surface to 5 to 50 feet (typically less than 30 feet) bgs. This unit is present at the surface throughout the study area.

Vashon Till and Ice Contact Deposits (Vashon Till in previous reports)—Qvt. Borden and Troost describe this unit as dense, gray, silty sandy gravel and gravelly sandy silt, generally matrix supported. Similar materials encountered in the study area consist of brown or gray, loose (ice contact) to dense (till), well-graded gravel in a matrix of sand, silt, and clay. This unit has been identified beneath much of the study area but has been confirmed to be absent at some locations—most notably immediately downgradient of NAPL Area 3 in the EGDY. Where present, this unit ranges in thickness from 4 to 35 feet and is typically found between elevations 220 and 270 feet (NGVD 29).

A second Vashon till deposit may be present with intervening outwash deposits below the till described above (Figure 5-4). This lower till is generally thinner and less laterally continuous than the upper till. The presence of two till units during the Vashon age may indicate a retreat and second advance of the ice sheet through this area. This is not unlikely considering the proximity of the study area to the terminus of the advancing ice sheet.

Figure 5-13 is a topographic contour map of the top of the uppermost Vashon till and glaciolacustrine silt unit (see discussion below) at the EGDY. These two units were combined because the till and the glaciolacustrine silt are present at roughly the same elevation. However, the two units may not abut each other directly and may be separated by more permeable materials. In six borings where till and lacustrine materials were encountered together, till and the lacustrine silt abutted each other in two borings (RS0066 and RS0076). In the other four borings (RS0026, RS0053, RS0058, RS0068), more permeable materials separated the materials. Also, till is present above the lacustrine silt in some borings and below the lacustrine silt in others. Therefore, the combined till and lacustrine unit may or may not be equivalent to a single low-permeability unit (see the hydrogeology discussion in Section 5.1.2). A relatively continuous, narrow, and long depression extends across this surface from the groundwater treatment infiltration area toward the center of the EGDY, which may then turn to the west. This depression may be the expression of an erosional channel. Figure 5-14 is an isopach map of the combined upper Vashon till and the glaciolacustrine silt. The erosional channel discussed above is coincident with a relatively thin portion of the till/lacustrine unit. It is possible that erosion may have cut through this unit in localized areas. At the northwestern edge of the EGDY, the till/lacustrine unit is completely absent, likely eroded by a recessional outwash/Steilacoom gravel channel.

Vashon Advance Outwash (Vashon Advance Outwash in previous reports)—Qva. Borden and Troost described this unit as interbedded, brown to gray sandy gravel and sand with minor silt interbeds. These materials are similar to the recessional outwash deposits and are difficult to separate from each other due to the potential presence of multiple till units deposited during the Vashon age and multiple advance and recessional deposits. Similar materials encountered in the study area consist of brown to gray, medium to coarse sandy gravel with cobbles, and fine to medium brown sand.

Glaciolacustrine Silt/Clay (Undifferentiated Till/Silt in previous reports)—Qvl. Borden and Troost described this unit as gray, laminated to massive silt and clayey silt with minor fine sand interbeds. Similar materials in the study area consist of very stiff to hard, dark gray clayey massive silt varying in thickness from 10 to 150 feet, typically between elevations of 50 and 200 feet (NGVD 29). This unit has been identified as lake fill sediments within a deep erosional trough running north-south across the middle of the Logistics Center.

Figure 5-15 is a topographic contour map of the base of the Vashon Drift deposits for the entire study area. The erosional trough is clearly visible as a depression trending north-south at the base of the Vashon Drift deposits. The contours represent the discontinuity between the Vashon glacial deposits and previous deposits of glacial and non-glacial origin. Much of the trough may be filled with lacustrine silts, but portions of the margins of the trough are filled with sand and gravel (Figure 5-4).

A second glaciolacustrine deposit was encountered beneath the center of the EGDY at a higher elevation than the deep erosional trough sediments discussed above, suggesting that the two deposits may have been deposited at different times during the Vashon age. The EGDY glaciolacustrine silt unit is present at approximately the same elevation as the upper Vashon till (215 to 250 feet NGVD 29). The relative timing of the deposition of this lacustrine silt and the uppermost Vashon till is uncertain due to the observed presence of till above and below the silt in different borings.

Olympia Beds *(Undifferentiated Non-Glacial[1] in previous reports)*—Qob. Borden and Troost described this unit as mottled, massive, organic-rich, clayey, sandy gravel (mudflows) or lavender silt, peat, sand and gravelly sand (fluvial overbank deposits). This unit may be present in some areas in the northern portion of the EGDY. Similar materials encountered in or near the EGDY consist of alluvial sand and gravel with silt, dense silty gravel, stiff silt, scattered wood, and peat. This unit may be up to 40 feet thick and located between elevations 180 and 250 feet (NGVD 29).

Pre-Olympia Drift *(Undifferentiated Till and Advance Vashon Outwash in previous reports)*—Qpog. This unit is not subdivided into an outwash and till sequence by Borden and Troost, who describe it as gray to brown, fine- to medium-grained sand with minor sandy gravel interbeds, oxidized at the top, common silt interbeds at the base, with discontinuous till. Previous stratigraphic interpretations may have misidentified this unit as undifferentiated till or Vashon advance outwash. Similar materials encountered in the study area consist of very fine to coarse sand with lenses of gravelly sand and sandy silt and brown to gray, medium to coarse sandy gravel with cobbles (fluvial) and dense, light brown to gray brown, silty gravel with sand and clay seams (till). Where present, this unit is typically 10 to 70 feet thick between elevations 110 and 190 feet (NGVD 29).

Second Non-Glacial Deposits *(Kitsap Non-Glacial Deposits in previous reports)*—Qpon. Borden and Troost described this unit as consisting of mottled, massive, organic rich, clayey, sandy gravel (mudflows) or lavender silt, peat, sand, and gravelly sand (fluvial overbank deposits). Similar materials encountered in the study area consist of peat, dark gray to black, lavender to pink clayey, often organic silt, silty sand, and sandy silt with occasional fine gravel. This unit may be continuous throughout the study area except for within a deep erosional trough (Figure 5-4) that runs roughly north-south through the middle of the Logistics Center. The upper portion of this unit consists of silt, the surface of which slopes west-northwest across the Logistics Center from approximately 170 to 110 feet elevation (NGVD 29). The thickness of the silt portion of this unit varies from a few feet to 25 feet. Hence, areas where the base of the Vashon Drift is present below an elevation of approximately 110 feet (NGVD 29) are areas where the silt portion of the Second Non-Glacial Deposits are absent.

Third Glacial Drift *(Salmon Springs Glacial Drift in previous reports)*—Qpog$_2$. Borden and Troost describe this unit as consisting of interbedded, orange to dark gray, sandy gravel and sand with minor silt interbeds, intensely iron-oxide-stained at top (recessional outwash); dense, gray, silty, sandy gravel and gravelly, sandy silt, generally matrix supported (till); and interbedded, gray to brown to dark gray sandy gravel and sand with minor silt interbeds (advance outwash).

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[1] Qv glaciolacustrine deposits may also have been combined with the undifferentiated non-glacial unit in previous reports.

Materials encountered in the study area match this description. This unit, or a portion of this unit, is continuous throughout the study area.

Third Non-Glacial Deposits *(Puyallup Non-Glacial Deposits in previous reports*)—Qpon$_2$. Borden and Troost describe this unit as consisting of lavender silt, peat, sand and gravelly sand (fluvial overbank deposits). This description is representative of materials observed within the study area. This unit has been observed only at a few locations due its depth. Its extent, character, and continuity are thus poorly understood.

5.1.1.3 Soil Geochemistry

Total organic carbon data for soils were collected as part of the EGDY Phase II RI. These data were from soil samples contaminated with NAPL and from soil samples collected in areas contaminated only with dissolved-phase contamination. Samples collected from NAPL-contaminated soils likely contained a large percentage of anthropomorphic organic carbon relative to native organic carbon. Even TOC samples from areas contaminated only with dissolved-phase organic compounds will show elevated TOC relative to the native organic carbon. An extraction of non-native organic carbon was performed using toluene to strip out petroleum hydrocarbons during laboratory testing; therefore, only native TOC values have been reported. TOC values for soils ranged from non-detect (less than 100 mg/kg) to 17,400 mg/kg. The 17,400 mg/kg value may be considered an outlier because it is more than twice as great as the next highest value of 7,200 mg/kg. It is possible, however unverified, that the laboratory extraction process to remove anthropogenic TOC was not performed on this sample.

The TOC present varied slightly by geologic material types sampled. The mean Vashon recessional outwash TOC value was 1,360 mg/kg, the mean Vashon till was 1,090 mg/kg, the Second Non-Glacial unit was 6,600 mg/kg, and the shallow glaciolacustrine silt was 3,400 mg/kg. Measured TOC is low because the glacial depositional environment responsible for the emplacement of the sampled site sediments is typically low in organic materials. Layers of peat and organic-rich deposits were encountered deep (approximately 100 to 110 feet bgs) beneath the EGDY within the Second Non-Glacial unit, accounting for the higher TOC values in this unit. A layer of peat was also encountered in one boring (RS0050) within the Vashon recessional outwash near NAPL Area 3. The peat materials at RS0050 were not encountered in any other nearby borings, indicating that the extent of this thin layer is limited to an area bound by the other borings. TOC data were not collected for the peat materials in boring RS0050.

5.1.2 Hydrogeology

In this CSM, the term aquifer is used to describe materials that are of relatively high permeability and yield economically significant quantities of water to wells or springs. Aquifer is the term used to describe a confining bed that retards but does not prevent the flow of water to an adjacent aquifer. The term aquitard should not be interpreted to mean that materials thus classified will stop the migration of NAPL. Although quantitative hydraulic conductivity data have been collected at selected locations throughout the study area, these measurements apply to a very small percentage of the total volume of subsurface materials. Also, hydraulic conductivity measurements have been biased toward materials assumed to have high permeability, because it is primarily through these units that dissolved-phase contamination is transported. Since hydraulic conductivity data are limited by the expense of collecting quality data, the qualitative terms aquifer and aquitard are assigned to units based upon their material descriptions (e.g., grain size, sorting, and compaction) when measured hydraulic conductivity data are not available.

5.1.2.1 Aquifers and Aquitards

The primary aquifers and aquitards that influence the flow of groundwater in the study area are discussed below. Alternate names used in previous reports and site documents are included in parentheses after the names that are now in common usage for these units in the region. Several names such as “Kitsap” and “Salmon Springs” are erroneous and misleading and will no longer be used to describe units in the study area.

Vashon Aquifer ***(Upper Aquifer in previous reports).*** The Vashon Drift, Olympia Beds, and Pre-Olympia Drift encompass the Vashon unconfined aquifer (Figure 5-4). The Vashon aquifer has been called the upper aquifer in many previous site investigation reports. Vashon till and ice contact deposits, glaciolacustrine silt/clay, and Olympia Beds may act locally as discontinuous aquitards within the Vashon aquifer. Vashon outwash deposits and the Pre-Olympia Drift deposits comprise the relatively high hydraulic conductivity materials within the Vashon aquifer. The Vashon aquifer varies in thickness from 100 to 130 feet (including discontinuous aquitard units) and is continuous throughout the study area.

Intermediate Aquitard. A somewhat laterally continuous upper till layer within the Vashon aquifer (Figure 5-4) may separate the Vashon aquifer locally into an upper and lower permeable unit separated by this relatively low-permeability till (also glaciolacustrine silt in the EGDY). The top of this till unit is typically below the water table but is present near or above the water table in the center of the Logistics Center and near the I-5 extraction well field. A second, lower till layer is present beneath much of the study area but is not as laterally continuous as the upper till.

Non-Glacial Aquitard ***(Kitsap Aquitard in previous reports).*** The Second Non-Glacial Deposits are a regional aquitard (referred to as the Kitsap aquitard in previous reports) separating the Vashon aquifer from the Sea Level aquifer (referred to as the lower aquifer or Salmon Springs aquifer in previous reports). This aquitard is locally dissected by Vashon Drift, most noticeably in the middle of the Logistics Center where Vashon-age deposits fill an erosional trough that cuts through this aquitard. Permeable Vashon-Drift-age materials may fill portions of the margins of this trough (Ebasco 1993), creating a continuous, relatively high permeable pathway between the Vashon aquifer and the Sea Level aquifer (Figure 5-4). The upper portion of the Second Non-Glacial unit is a silt unit with presumed aquitard properties. Sand and gravel deposits interpreted as deposited during this non-glacial period are presumed to be aquifer materials and are not part of the hydrostratigraphic unit designated as the Non-Glacial aquitard.

Sea Level Aquifer *(Salmon Springs Aquifer and/or Lower Aquifer in previous reports)*. The Third Glacial Drift deposits and permeable lower deposits of the Second Non-Glacial unit comprise the Sea Level aquifer (called the Salmon Springs aquifer or lower aquifer in previous reports). Till within the Third Glacial Drift acts as a discontinuous aquitard within the Sea Level aquifer.

Deeper Aquifer and Aquitard Units. The Third Non-Glacial Deposits presumably are an aquitard separating the Sea Level aquifer from lower aquifers. Groundwater contamination is not known to have penetrated to the elevation of this unit. Therefore, this aquitard and deeper units are not described as part of this CSM.

5.1.2.2 Hydraulic Conductivity

Hydraulic conductivity values have been generated from four sources: calculations from pumping tests performed on wells screened in the Vashon aquifer (USACE 1993), slug tests on Vashon outwash and till in the EGDY, tracer tests in the EGDY (USGS 1999), and laboratory permeability measurements of soil cores from the EGDY outwash and till materials. Each method measures hydraulic conductivity in a different manner and on a different scale. The differences affecting the interpretations of these results are discussed in the following subsections.

Pumping Tests. Pumping-test-derived hydraulic conductivity measurements typically provide a bulk hydraulic conductivity value for the materials across which the pumped well and nearby observation wells are screened. Therefore, the hydraulic conductivity properties of both high and low hydraulic conductivity materials within that screened interval are measured. Because extraction wells are typically not screened across very low-permeability materials, the hydraulic conductivity values measured from pumping tests likely include only thin, discontinuous lenses of low-permeability material. Pumping test results typically apply to a volume that extends tens to hundreds of feet from the pumped well. Pumping tests provide estimates of the bulk horizontal and vertical hydraulic conductivity. Vertical hydraulic conductivities derived from pumping test data in the study area are typically 100 times less than calculated horizontal hydraulic conductivities.

Slug Tests. Slug tests are performed on a very discrete vertical interval (a few feet in length) within a borehole and represent conditions within a few inches or feet of the borehole. Slug test results provide a bulk horizontal and vertical hydraulic conductivity for the small interval tested.

Laboratory Tests. Laboratory tests are performed on a small (less than 1 foot long) sample of cored material. Permeability samples collected using the rotosonic drill rig must be considered somewhat disturbed due to the vibrations produced by the drilling. However, samples were collected within brass, steel, or Lexan sleeves to minimize this disturbance. In all but three intervals, permeability tests were performed on vertically oriented samples. For horizontal sedimentary materials, vertical hydraulic conductivities are typically 10 to 100 times lower than horizontal hydraulic conductivities (see pumping test discussion above).

Tracer Tests. Tracer tests typically estimate the highest hydraulic conductivity pathways because the tracer material travels preferentially through these zones. Tracer tests measure the horizontal hydraulic conductivity over a scale of tens to hundreds of feet.

Laboratory test and slug test hydraulic conductivity data collected during the EGDY Phase II RI are included in Tables 3-4 and 3-5. Hydraulic conductivity data calculated from pumping tests during the extraction well installation and testing (USACE 1993) are summarized in Table 5-2. Hydraulic conductivity data from tracer tests (USGS 1999) are summarized in Table 5-3. Measured hydraulic conductivity data for the Non-Glacial aquitard and the Sea Level aquifer are not available. The locations of hydraulic conductivity measurements made in the vicinity of the EGDY are shown in Figure 5-16.

Calculated values of hydraulic conductivity within the Vashon aquifer materials range from 0.004 ft/day (laboratory permeability test) to 3,800 ft/day (tracer test). In the EGDY, values from pumping tests ranged from 16 to 114 ft/day. At the I-5 extraction well field of the Logistics Center, values from pumping tests for the Vashon aquifer materials ranged from 53 to 1,141 ft/day. Values from tracer tests performed near the infiltration galleries ranged from greater than 110 ft/day to 3,800 ft/day (USGS 1999). Only one slug test was performed within the permeable Vashon outwash materials in the EGDY, and this test yielded a value greater than 200 ft/day. Laboratory permeability tests yielded values for the Vashon aquifer materials ranging from 0.004 ft/day to 27.2 ft/day. These values are several orders of magnitude lower than those obtained by the other methods used, which is likely because vertical hydraulic conductivity was measured. The tracer test results were higher than the pumping test results, although a direct comparison is not possible because the two infiltration wells (LR-1 and LR-2) are screened in the lower Vashon aquifer beneath the Vashon till aquitard. The tracer tests were conducted in the upper Vashon aquifer above the Vashon till aquitard. Based on the above lines of evidence, the permeable Vashon aquifer deposits likely have horizontal hydraulic conductivity values that range from 10 to more than 1,000 ft/day and vertical hydraulic conductivity values that range from 0.004 to 30 ft/day.

Low-permeability ice contact and till deposits within the Vashon aquifer were also subjected to laboratory permeability measurements and pneumatic slug tests. The slug test results for these units ranged from approximately 2 to 20 ft/day. Laboratory permeability measurements for these units ranged from 0.0097 to 0.9 ft/day.

5.1.2.3 Groundwater Flow

Groundwater flow within the Vashon aquifer is regionally toward the northwest (Figure 5-17). Locally the flow direction can deviate from this regional gradient because of various factors. In the EGDY, flow is locally toward the west-southwest but may vary by season (Figures 5-18 and 5-19) for the upgradient half of the EGDY. A spring located southwest of the EGDY in a swale that intersects the water table is the origin of Murray Creek. This spring likely acts as a drain on the aquifer, locally diverting flow to the southwest. During testing of the in situ redox manipulation (ISRM) technology (Battelle 2000), local variations in groundwater flow direction were noted in the area near groundwater treatment extraction well RW-1. Near all extraction wells, the flow directions are generally toward the extraction wells a short distance upgradient of the extraction wells.

Although not enough piezometers are present around MAMC to accurately quantify the groundwater gradient, it is anticipated that Vashon aquifer pumping of cooling water for MAMC and the subsequent reinfiltration of cooling water to the Vashon aquifer via infiltration ponds locally disrupts the regional gradient in the vicinity of the hospital. Pumping rates for the heating, ventilation, and cooling (HVAC) system at the hospital vary from 900 to 4,500 gpm, depending on the season. Three HVAC extraction wells (MAMC-1, -6, and -7) are screened within the Vashon aquifer, and one extraction well (MAMC-3) is screened within the Sea Level aquifer (Figure 5-2). All four extraction wells are pumped continuously.

Calculated horizontal hydraulic gradients within the Vashon aquifer typically range from 0.001 to 0.004 ft/ft. Hydraulic gradients are much steeper in the vicinity of extraction wells. Using typical hydraulic conductivity values from pumping tests of 16 ft/day minimum and 1,100 ft/day maximum yields an estimated range of groundwater flow velocities of 0.05 to 15 ft/day within the Vashon aquifer. Vertical hydraulic gradients calculated within the Vashon aquifer from newly installed multi-port wells range from upward (0.033 ft/ft) in the vicinity of the EGDY infiltration galleries and recharge wells to downward (0.059 ft/ft) in the vicinity of NAPL Area 3, away from the lower Vashon aquifer recharge wells. Mean vertical gradients within the Vashon aquifer at the EGDY are upward at 0.019 ft/ft near NAPL Areas 1 and 2, downward at 0.011 ft/ft in the vicinity of NAPL Area 3.

The elevation of the water table surface within the Vashon aquifer varies seasonally by approximately 5 to 6 feet and as much as 15 feet over periods of several years. However, the regional flow direction remains relatively constant.

Calculated vertical gradients across the Non-Glacial aquitard are downward and range from 0.01 to 0.012 ft/ft upgradient of the permeable window in the aquitard to 0.33 to 0.57 ft/ft downgradient of the permeable window (URS 2001c).

Interpreted groundwater flow direction within the Sea Level aquifer is also generally toward the northwest upgradient of the permeable window within the Non-Glacial aquitard (Figure 5-20). Downgradient of this window, flow is toward the west-northwest. A more complete set of groundwater elevation data collected by the USGS as part of its continuing lower aquifer investigation indicates that recharge from American Lake to the Sea Level aquifer increases the aquifer water levels beneath the lake, which subsequently direct groundwater flow in a more westerly direction around the southern end of the lake. Water level measurements from a lower aquifer well located on Silcox Island in American Lake and from LC-166D indicate that groundwater pressures in the Sea Level aquifer beneath American Lake are higher than water pressures between MAMC and the lake.

The hydraulic gradient within the Sea Level aquifer is approximately 0.002 ft/ft upgradient of the permeable window and 0.01 to 0.025 ft/ft downgradient of the permeable window. It is unknown why the hydraulic gradient steepens abruptly at this window. One possible explanation is that the lower aquifer upgradient of the window may be separated from the aquifer downgradient of the window by a deep silt-filled channel (Figure 5-4). Production pumping from the Sea Level aquifer by Fort Lewis and local municipal users downgradient of this silt-filled trench may artificially lower the potentiometric surface, thus increasing recharge from the Vashon aquifer to the Sea Level aquifer through the permeable window.

The elevation of the potentiometric surface within the Sea Level aquifer varies seasonally by 5 to 10 feet in wells upgradient of the permeable window between the Vashon and Sea Level aquifers and approximately 7 to 20 feet in wells near and downgradient of the permeable window (with the exception of well LC-166D, which varies less than 10 feet seasonally). Despite the rather large changes in potentiometric surface elevation between upgradient and downgradient wells and within individual wells, the regional flow direction remains relatively constant.

5.1.2.4 Surface Water

Three surface water bodies are in the study area: Murray Creek, American Lake, and Lynn Lake.

Murray Creek. Murray Creek is a permanent stream with its headwaters located at a spring southwest of the EGDY. The location of this spring may move upstream or downstream with time, depending on the elevation of the water table surface. Kinsey Marsh, located at the upstream headwaters area, may periodically be flooded by rain events and/or high groundwater table elevations. For the purposes of this CSM, Kinsey Marsh is considered an ephemeral upstream extension of Murray Creek.

Murray Creek has been determined to be a gaining stream from the spring/Kinsey Marsh area to the area near MAMC, where it becomes a losing stream until it enters American Lake (Shapiro 1996). This conclusion is confirmed by continued groundwater elevation monitoring as part of the Logistics Center Remedial Action Monitoring (RAM) program. Measurements of groundwater elevations near Murray Creek have been consistently lower than the elevation of the creekbed near MAMC and higher than the creekbed elevation at Murray Creek's upstream origin.

American Lake. American Lake is a permanent lake located downgradient of the Logistics Center. The lake has a mean surface elevation of 232 feet above msl. Murray Creek is the main inlet of surface water into American Lake. The surface elevation of American Lake is controlled primarily by the level of groundwater within the adjacent Vashon aquifer. The maximum elevation of the lake, approximately 233 feet above msl, is controlled by a culvert installed in 1956 to connect American Lake to Sequalitchew Creek to prevent flooding.

Lynn Lake. Lynn Lake is a shallow, ephemeral lake that forms when the groundwater table rises above the ground surface in this small localized depression approximately 3,000 feet west of the EGDY.

5.1.2.5 Groundwater and Surface Water Geochemistry

The following geochemical parameters have been measured from wells screened within the Vashon aquifer and/or the Sea Level aquifer: dissolved oxygen, specific conductivity, iron, manganese, pH, oxidation-reduction potential (Eh), oxygen (^{18}O), hydrogen (^{2}H), carbon (^{13}C), tritium (^{3}H), chlorofluorocarbons (CFCs), and sulfur hexafluoride (SF_6). Dissolved oxygen, specific conductivity, pH, and Eh are measured routinely as part of the sampling protocol at wells sampled as part of the remedial action monitoring program (URS 2001c). These parameters were also measured during the EGDY Phase I ESI (URS 1999) during groundwater sample collection. Iron and manganese data were also collected during the EGDY Phase I ESI. The USGS has collected the following environmental tracers as part of a Sea Level aquifer study (USGS report in draft while investigation continues): the stable isotopes oxygen (^{18}O), hydrogen (^{2}H), carbon (^{13}C); the radioactive hydrogen isotope tritium (^{3}H); and the synthetic or rare compounds CFCs and sulfur hexafluoride (SF_6).

Dissolved Oxygen. Typically, dissolved oxygen varies between 4 and 9 mg/L in the Vashon aquifer (URS 2001c), with an average value of 6.5 mg/L. For the average groundwater temperature of 12°C, the solubility of oxygen in fresh water is approximately 11 mg/L. Dissolved oxygen typically varies between 1 and 7 mg/L in the Sea Level aquifer, with an average value of 4 mg/L. The Vashon aquifer is therefore generally higher in dissolved oxygen than the Sea Level aquifer. Dissolved oxygen is elevated within the Sea Level aquifer immediately downgradient of the permeable window within the Non-Glacial aquitard. Notable exceptions to these trends include low dissolved oxygen levels (less than 2 mg/L) in areas of the EGDY within and immediately downgradient of the NAPL source areas in the Vashon aquifer (Plate 1) and low dissolved oxygen levels at the bottom of American Lake (Dinicola 2002) and in well LC-166D, which is on the side of American Lake opposite from the Logistics Center.

pH. Measured pH values for the Vashon and Sea Level aquifers are generally neutral. Typical values range from 5.1 to 8.9, with a mean value of 6.5.

Specific Conductivity. Measured specific conductivity values for the Vashon and Sea Level aquifers are generally in the range of 82 to 180 µS/cm, with a mean value of 122 µS/cm. There does not appear to be any significant difference between specific conductance values of the two aquifers.

Eh. Measured oxidation-reduction potential values for the Vashon and Sea Level aquifers are generally in the range of –160 to +259 mV, with a mean of +137 mV. Values for Eh are generally lower in the Sea Level aquifer than in the Vashon aquifer.

Iron and Manganese. Measured dissolved iron values within the EGDY area Vashon aquifer groundwater ranged from non-detect (less than 0.05 mg/L) to 2.4 mg/L based on drive point sampling during the Phase I ESI (URS 1999). Dissolved manganese values ranged from non-detect (less than 0.01 mg/L) to 1.2 mg/L.

Environmental Tracers. Groundwater environmental tracer data were collected (Dinicola 2002) to help interpret the relationship between Vashon aquifer and Sea Level aquifer groundwater and groundwater migration pathways. The tracers included common ions and selected general groundwater chemistry analytes; stable isotopes of oxygen (^{18}O), hydrogen (^{2}H), and carbon (^{13}C); the radioactive hydrogen isotope tritium (^{3}H); and the synthetic or rare compounds CFCs and sulfur hexafluoride (SF_6). Tracer concentrations were determined for samples from 37 wells and from nearby American Lake during 1999 and 2000.

Groundwater in the Vashon and Sea Level aquifers upgradient of the EGDY as well as surface water in American Lake have different and identifiable environmental tracer signatures. Relative to Vashon aquifer groundwater, Sea Level aquifer groundwater is depleted in ^{18}O and ^{2}H; has very low concentrations of (^{3}H), CFCs, and SF_6; and is anaerobic. Relative to both groundwaters, American Lake water is substantially enriched in ^{18}O and ^{2}H and has relatively high concentrations of CFCs, and SF_6. Water immediately above the bottom of American Lake is also anaerobic.

An analysis of the environmental tracer data and dissolved oxygen data indicates that a relatively small amount of Vashon aquifer groundwater is reaching the Sea Level aquifer upgradient of the known window in the intervening confining bed. Evidence supporting this conclusion includes slightly increased concentrations of dissolved oxygen, ^{18}O, and ^{2}H in Sea Level aquifer groundwater immediately downgradient of the EGDY and detections of TCE in the Sea Level aquifer at very low levels (generally less than 10 µg/L) upgradient of the window. A substantial amount of Vashon aquifer groundwater may be reaching the Sea Level aquifer by flowing directly through the window in the intervening confining bed. Substantial increases in dissolved oxygen, ^{18}O, ^{2}H, and TCE concentrations in Sea Level aquifer groundwater immediately downgradient of the window suggest this possibility.

There may be a substantial amount of recharge from American Lake to both the Vashon and Sea Level aquifers. Anaerobic Sea Level aquifer groundwater beneath American Lake is substantially enriched in ^{18}O and ^{2}H.

5.1.3 Physical Properties of NAPL

NAPL materials removed during the trench excavation/drum removal program (GSA 2001) consisted primarily of oils and greases mixed with varying percentages of halogenated and nonhalogenated solvents. A small percentage of the total NAPL volume removed from buried drums consisted of nearly pure solvent (TCE). Because the wastes were primarily mixed oils and solvents in varying proportions, the physical properties of NAPLs likely vary over a large range across the site.

During the drum removal program, composite samples of NAPL from drums were tested for interfacial surface tension (water-oil), specific gravity, density, viscosity, and boiling point distillation. The three samples collected were taken from drums containing materials representative of the three major kinds of NAPL observed during the drum removal program (see Section 3.11 and Tables 3-8a, b, c, and d). No samples of NAPL for physical property tests were collected from the soil or groundwater because of insufficient NAPL volume in soil and absence of NAPL in monitoring wells. However, the density of NAPL relative to groundwater was based on the observed presence of NAPL above, at, or below the water table.

The measured density values for the NAPL samples at 72°F were 0.83, 1.3, and 1.1 g/cc for samples collected from drums near NAPL Area 1, NAPL Areas 1 and 3, and NAPL Areas 1 and 3, respectively. An increase in temperature from 72°F to 130°F resulted in a 3 percent decrease in density for each of the three samples. NAPL mixtures that are less dense and more dense than water are present on site. Presumably, NAPL mixtures with a higher percentage of chlorinated solvents will be more dense than mixtures that contain mostly oil and little of the dense chlorinated solvents. Pure TCE and cis-1,2-DCE, for example, have densities of 1.46 and 1.26

g/cc, respectively, whereas typical diesel and hydraulic mixtures have densities in the range of 0.8 to 0.9 g/cc.

The measured viscosity values for the NAPL samples at 72°F were 3.72, 8.0, and 1,012 centistokes for samples collected from drums near NAPL Area 1, NAPL Areas 1 and 3, and NAPL Areas 1 and 3, respectively. An increase in temperature from 72°F to 130°F resulted in a decrease in viscosity of 44, 98.7, and 99.4 percent for the three samples, respectively.

The measured interfacial tension values for the NAPL samples at 74°F were 13.5 dynes/cm (from drums near NAPL Area 1), and 2.97 dynes/cm (from drums near NAPL Areas 1 and 3). A second sample from NAPL Areas 1 and 3 was a thick, oily sludge that was not suitable for this test.

Measured distillation results for the three samples yielded an initial boiling point of 170°F, 194°F, and 195°F for the respective samples. Final boiling points when 100 percent of the sample was distilled occurred at 1,030°F, 1,027°F and 1,030°F for the three samples, respectively.

The physical properties of NAPL described above are from a small volume of material and are assumed to represent the general range of physical properties of NAPL at the site.

5.2 CONTAMINATION CHEMISTRY

5.2.1 NAPL Chemical Description

VOC results for all soil samples were reviewed to assess the possibility of patterns at different areas of the site. Table 5-4 is a summary of all rotosonic soil borings with detections of VOCs other than TCE or cis-1,2-DCE. Full analytical results for these samples are in Appendix A. It is important to note that reporting levels for many of the VOC analyses were significantly elevated due to the concentration of TCE in the samples, which could influence whether other VOCs were reported for any particular sample. NAPL Area 2 has the most complex mixture of VOCs and the highest concentration of VOCs other than TCE and cis-1,2-DCE. The VOC contaminant mixture found in RS0063, which was collected in an area outside of the defined treatment areas, appears to be very similar to the mixture found in NAPL Area 2.

Measurements of the weight percentages of the compounds TCE, cis-1,2-DCE, TPH as oil (TPH-O), and TPH as diesel (TPH-D) were calculated from the analytical results of soil samples collected from NAPL-contaminated soil. It was assumed that these four compounds made up the majority of the NAPL mass for each sample. The weight percentages were averaged for each NAPL treatment area to determine the proportions of the NAPL mixture for each area (Tables

5-5 through 5-7). Table 5-8 summarizes the estimated mass and composition of NAPL by treatment area. The most obvious conclusion that can be drawn from this analysis is that the percentage of TCE relative to other TPH compounds in NAPL Area 3 is significantly different than that of the other two treatment areas. This conclusion is also supported by visual observations of the cores in this area; the NAPL appeared to be colorless, which is different from the NAPL observed in other areas of the site.

5.2.2 Petroleum Hydrocarbon Product Type Identification and Location

To determine what different petroleum product types are present at the site, laboratory NWTPH-Dx analysis chromatograms were reviewed for 63 soil samples with detections of diesel-range petroleum products. Only 45 samples from 27 locations had chromatograms showing TPH concentrations high enough to be evaluated. The site was divided into four general areas for this evaluation: NAPL Areas 1, 2, and 3 and the area east and northeast of the groundwater treatment plant. Only one location from NAPL Area 3 had a reviewable chromatogram (RS0002); therefore, a more complete evaluation of the product types present in this area could not be performed.

The NWTPH-Dx method is applicable for the identification of semivolatile petroleum products by pattern matching (or “fingerprinting”) for nonhalogenated organic compounds from C12 to C32. Specific petroleum products (e.g., mineral spirits, diesel fuel, hydraulic oil, or lube oil) can be identified by comparing chromatograms from site samples to those of “pure” product standards. Often a laboratory will run a series of different “pure” products for this purpose. For this project, the laboratory analyzed two calibration standards with every sample analysis group:

- #2 diesel fuel
- Motor oil

Additionally, the laboratory provided a historical chromatogram library for 41 different petroleum products for use in product fingerprinting analysis. If specific product types cannot be identified from comparisons to available standard chromatograms, patterns may still be observed that represent other unidentified product types or even naturally occurring organic materials. Unidentified patterns can be compared to each other and grouped to help characterize the site.

Four product type patterns were observed (identified as A through D). Representative chromatograms are shown in Figure 5-21. Product types observed at each location with TPH detections and chromatograms available for review are listed in Table 5-9.

Product type A is characterized by a distinct pattern from approximately C6 (toluene) to C11. It was observed in samples collected from almost every location evaluated. The pattern is very similar to either stoddard solvent or mineral spirits.

Product type B is characterized by an indistinct pattern from approximately C10 to C16. It was observed only in samples collected from NAPL Area 2 and the area east and northeast of the groundwater treatment plant. The pattern did not match any chromatogram in the historical library provided by the laboratory; however, it is in the carbon range typical of light-end fuels (e.g., JP-7) and not as heavy as diesel fuel.

Product type C is characterized by an indistinct pattern from approximately C16 to C36. It was observed in samples collected from every location evaluated. Although the pattern did not match any chromatogram in the historical library provided by the laboratory, it looks like a mixture of several different types of oil—potentially motor oil, automatic transmission fluid, transformer oil, or hydraulic oil. The relative proportion of any of these product types shifts from sample to sample, and distinct products in any specific sample could not be identified.

Product type D is characterized by a distinct alkane pattern from approximately C22 to greater than C36. It was observed infrequently (in samples collected from 7 of the 27 locations with readable chromatograms) and only in samples collected from NAPL Area 1, NAPL Area 3, and the area east and northeast of the groundwater treatment plant. The pattern did not match any chromatogram in the historical library provided by the laboratory.

5.3 OCCURRENCE OF NAPL

The presence of NAPL in the study area is currently assumed to be limited to the EGDY. Other potential source areas were investigated and found to be free of NAPL contamination (see Section 3). The following lines of evidence were used to determine the distribution of NAPL in the source area: the location of NAPL-containing drums and observed NAPL-contaminated soils during the drum excavation/removal program (GSA 2001), groundwater TCE concentration distribution, MIP results (USACE 2002), and NAPL testing of sonic drill cores (Section 3). The results of these lines of evidence are presented on Plate 1. The logic for developing a threshold of 10,000 µg/L for TCE dissolved in groundwater as an indicator of nearby NAPL presence was presented in the Phase I technical memorandum (URS 1999). For this Phase II investigation, the threshold was lowered to 1,000 µg/L due to new understanding that most of the NAPL was mixed waste, resulting in a reduced effective solubility of TCE for the mixed NAPL. Because a uniform effective solubility of TCE cannot be determined for the diverse wastes present in the EGDY, the value of 1,000 µg/L was not used as an absolute threshold, but rather as a decision-making guide.

Three major NAPL source areas were identified within the general EGDY area. From upgradient to downgradient they are named NAPL Area 1, NAPL Area 2, and NAPL Area 3 (Plate 1). The boundaries of the NAPL areas were delineated based upon multiple lines of evidence presented above. These three NAPL areas are currently designated to be treated by thermal methods. NAPL was also observed at several locations outside the three main NAPL areas (at sonic borings RS0060, RS0062, RS0063, and RS0064 [Plate 1]). Based on the relatively low level (i.e., less than 10,000 µg/L) of dissolved-phase TCE contamination in these areas and/or the lack of NAPL observed in nearby sonic borings, these NAPL sources are interpreted to be small in extent and volume.

NAPL was detected primarily in the Vashon recessional outwash deposits above the uppermost Vashon till unit (intermediate aquitard). NAPL was observed within this till unit at four locations: RS0012 and RS0015 in NAPL Area 1 and RS0005 and RS0024 in NAPL Area 2. No NAPL was observed below the intermediate aquitard. Measurements of dissolved-phase TCE in groundwater immediately below the intermediate aquitard were typically less than 1,000 µg/L, thereby indicating that NAPL has not penetrated below this unit. Figure 5-5 shows the location of cross-sections through the EGDY, and Figures 5-6 through 5-11 are cross-sections through the three major NAPL areas that show the distribution of observed NAPL in relation to the known geologic units. Figure 5-12 is a cross-section that shows the relationship of each of the three NAPL areas to each other and the hydrogeology across the source area.

The elevations of the upper and lower interpreted extent of NAPL for each of the three major NAPL areas are shown in Figures 5-22 through 5-27. Figures 5-28 through 5-30 show the interpreted net NAPL thickness within each of the three major NAPL areas. The net NAPL thickness was computed by contouring the net thickness of measured NAPL-contaminated soil at each sonic location where NAPL-contaminated soil was observed (Table 3-3).

NAPL Area 1 is approximately 25,400 square feet. The deepest NAPL was detected at a depth of 34 feet (245 feet elevation) at sonic boring RS0015. NAPL was detected near the surface in the vicinity of the disposal trenches and dives downward toward the west in the general direction of groundwater flow.

NAPL Area 2 is approximately 51,100 square feet. The deepest NAPL was detected within the intermediate aquitard at a depth of 47 feet (230 feet elevation) at boring RS0024. The deepest NAPL is present below the disposal trenches. West of the disposal trenches, the NAPL thins and is present mainly within the smear zone of the high and low water table elevations. NAPL at the southern end of Area 2 was not encountered below an elevation of 259 feet. Therefore, NAPL Area 2 has been divided into three subareas to reflect the differing distribution of NAPL within this area.

NAPL Area 3 is approximately 18,200 square feet. The deepest NAPL was encountered at 30 feet bgs (247 feet elevation) in sonic boring RS0048. NAPL was encountered primarily in the northern portion of this area. The NAPL area was extended to the south to include all of the disposal trenches that had contained numerous NAPL-filled drums.

In addition to these three NAPL areas, LNAPL was detected in three exploratory trenches (Plate 1) during the EGDY Phase I ESI (URS 1999). The extent of this LNAPL is unknown but is likely limited to the EGDY. LNAPL was also encountered during the sonic drilling program at boring location RS0064 (Plate 1).

5.3.1 Vadose Zone

All NAPL not recovered during the drum excavation/disposal program at the EGDY is believed to have been poured directly into the disposal trenches or to have leaked from drums deposited within those trenches. All disposal trenches containing metallic waste and trenches known to have been used for liquid waste disposal were excavated during the drum removal remedial action. Native materials were encountered above the water table during this remedial action at all excavated trench locations. The fluctuating water table may have risen above the base of these trenches during high water table years. However, during disposal activities, the trenches would not likely have been excavated below the water table due to the loose and collapsible nature of the soil. Therefore, the vadose zone was likely contaminated directly at every location where NAPL first entered the system. NAPL-contaminated soil above the water table was encountered during the drum removal program and was generally left in place. Vadose zone contamination is limited to the soil below disposal trenches where NAPL was disposed. When sufficient to overcome capillary forces within the vadose zone, NAPL drained to the water table.

5.3.2 Water Table Smear Zone

NAPL that drained to the water table that was more dense than water continued to drain downward into the saturated zone. NAPL that was less dense than water accumulated at the water table and moved downgradient with groundwater as a separate phase on top of the water table. Dynamic cones of depression associated with the EGDY primary extraction wells, along with seasonal water table fluctuations, have caused LNAPL migrating with groundwater to move up and down through the soil with the water table, thus leaving a smear zone of NAPL at residual saturation between the high and low groundwater table elevations. The LNAPL encountered north of NAPL Area 2 in the EGDY Phase I RI may behave in this manner. LNAPL may coincide with DNAPL but they are indistinguishable from each other because the LNAPL continues to migrate with the DNAPL below the water table.

5.3.3 Saturated Zone

NAPL that is more dense than water (DNAPL) will migrate below the water table until it reaches its value of residual saturation. DNAPL was encountered in all three main NAPL areas and at sonic boring locations RS0060, RS0062, and RS0063 outside the main NAPL areas (Plate 1). DNAPL was observed to stop abruptly within assumed relatively permeable units, suggesting that either subtle changes in grain size distribution occurred to overcome the downward driving force of the DNAPL or the DNAPL simply reached its residual saturation level and stopped moving. At a few locations, the DNAPL was observed to have stopped at a low hydraulic conductivity material such as the intermediate aquitard (till). However, the NAPL was also observed within the intermediate aquitard, which means that this unit is not a complete barrier to downward NAPL migration. No NAPL was encountered below the intermediate aquitard.

It is not known whether DNAPL is still mobile beneath the EGDY. However, several lines of evidence suggest that DNAPL is immobile. The base of DNAPL was often observed to be within units interpreted to have high hydraulic conductivities rather than at the boundary of a level with low hydraulic conductivity. This suggests that DNAPL may be at residual saturation at these locations. Also, DNAPL does not appear to have penetrated more than 46 feet bgs despite 30 to 60 years of migration time. No NAPL entered DNAPL collection well LC-186 between the time of installation and the conclusion of the field program (an approximate 4-month period). Additionally, the generally low values of the NAPL saturation data suggest residual saturation has been attained.

5.3.4 NAPL Volume/Mass Estimates

NAPL occurrence data, compiled from visual observations of NAPL in rotosonic boring cores, were used to map product distribution and to estimate site-wide NAPL volumes. Measured concentrations of TCE, cis-1,2-DCE, and TPH from soil samples collected from NAPL-contaminated soils were used to estimate the mass of each of these major compounds of the NAPL mixture. The total number of feet at each subsurface location where NAPL was observed was used to generate a net NAPL thickness contour map for each NAPL area (Figures 5-28 through 5-30). The net thickness of NAPL is not necessarily equal to the distance between the top of NAPL (Figures 5-22, 5-24, and 5-26) and the bottom of NAPL (Figures 5-23, 5-25 and 5-27) at any individual location because intervals of non-NAPL-contaminated soil were sometimes encountered between the top and bottom of observed NAPL. When the observed net NAPL thickness data were interpolated for contouring purposes, the boundary of each NAPL area was set to zero NAPL thickness to prevent the interpolation software from extrapolating positive values of NAPL thickness beyond the area boundaries.

The net thickness of NAPL was used to estimate the volume of liquid NAPL present in subsurface soil within each of the three main NAPL areas. The volumes of soil contaminated with NAPL represented by the net thickness maps are approximately 235,000 ft^3 (8,700 yd^3) for NAPL Area 1, 462,500 ft^3 (17,100 yd^3) for NAPL Area 2, and 122,000 ft^3 (4,500 yd^3) for NAPL Area 3. Using the average site porosity value of 0.3 (Table 3-4) and a value of NAPL saturation in the pore space of 5 percent (Table 3-4) yields a volume estimate of NAPL in the subsurface of 26,000 gallons for NAPL Area 1, 52,000 gallons for NAPL Area 2, and 13,000 gallons for NAPL Area 3. These values are considered rough estimates because of uncertainties in the total thickness of NAPL-contaminated soil and the large measured range of NAPL saturation. The NAPL volume estimates should therefore be considered accurate (±50 percent). Also, the isolated small pockets of DNAPL observed outside the three main NAPL areas are not included in this estimate, thus potentially biasing estimates of total NAPL for the EGDY slightly low.

Measurements of the weight percentages of the compounds TCE, cis-1,2-DCE, TPH-O, and TPH-D were calculated from the analytical results of soil samples collected from NAPL-contaminated soil. It was assumed that these four compounds made up the majority of the mass of the NAPL for each sample. The weight percentages were averaged for each NAPL area to determine the proportions of the NAPL mixture for each area (Tables 5-4 through 5-6). A total estimated mass of each compound was then calculated for each area using the estimated NAPL volume (see Table 5-7). For Area 2, weighted mass percentages (from Subarea 2a) of 5.7 percent for TCE, 0.3 percent for cis-1,2-DCE, and 93.9 percent for combined TPH were used to represent the entire NAPL Area 2 rather than subdividing the mass by subtreatment areas.

5.3.5 Treatment Volumes for Thermal Treatment Areas

Plans and specifications for thermal treatment of the three major NAPL source areas were developed concurrent with the Phase II RI. For ease of treatment system construction and to avoid missing the bottom of NAPL-contaminated media, the bases of the treatment areas were set at a constant elevation for each area and subarea to be treated. The depth chosen for each treatment area and subarea was below the deepest NAPL observed during the RI. The total volume of soil to be treated for each treatment area is given in Table 5-10. The areal extent of thermal treatment for each NAPL area is shown on Plate 1. The treatment depths for each NAPL area are shown on the EGDY NAPL area cross-sections (Figures 5-6 through 5-12).

NAPL Area 1 surrounds an area where numerous disposal trenches were located. Therefore, NAPL is potentially present in the vadose zone throughout the treatment area. Thermal treatment for this area will be required from the ground surface to the maximum depth of NAPL (elevation 245 feet NGVD 29). The total treatment volume is approximately 30,900 cubic yards.

NAPL Area 2 has been divided into three smaller adjacent treatment areas based on the differing vertical distribution of NAPL within each of the subareas. Subarea 2a is located below disposal trenches and therefore requires treatment from the ground surface to the maximum depth of observed NAPL in this area (elevation 230 feet NGVD 29). The total volume of soil to be treated is 26,000 cubic yards. Subarea 2b is also located below disposal trenches and therefore requires treatment from the ground surface to the maximum depth of observed NAPL in this area (elevation 259 feet NGVD 29). The total volume of soil to be treated in Subarea 2b is 6,300 cubic yards. Subarea 2c is not located below disposal trenches and therefore requires treatment only from the highest groundwater surface to the maximum depth of observed NAPL in this area (elevation 253 feet NGVD 29). The highest groundwater elevation measured in this portion of the EGDY was approximately 273 feet NGVD 29. The total volume of soil to be treated in Subarea 2c is 19,900 cubic yards.

NAPL Area 3 surrounds an area where numerous disposal trenches were located. Therefore, NAPL is potentially present in the vadose zone throughout the treatment area. Thermal treatment for this area will be required from the ground surface to the maximum depth of NAPL (elevation 247 feet NGVD 29). The total treatment volume is approximately 20,100 cubic yards.

5.4 DESCRIPTION OF GROUNDWATER AND SURFACE WATER CONTAMINATION

5.4.1 Summary of Extent of VOC Groundwater and Surface Water Contamination

5.4.1.1 Vashon Aquifer and Associated Surface Water Bodies

TCE and cis-1,2-DCE are the two COCs that have traveled with groundwater beyond the EGDY source area. TCE has traveled the farthest and at the greatest concentration. In the Vashon aquifer, TCE (at concentrations above 5 µg/L) extends from the source area 2 miles downgradient to American Lake (Figures 5-31a and 5-31b). It is not known whether American Lake fully intersects the Vashon aquifer TCE plume in a vertical direction or whether all TCE reaching American Lake within the Vashon aquifer discharges to American Lake. TCE and cis-1,2-DCE were detected in American Lake during the 1988 RI (Envirosphere 1988) at concentrations that ranged from less than 0.15 to 1.3 µg/L and less than 0.10 to 0.23 µg/L, respectively. TCE was detected in both deep and shallow American Lake samples. The compound cis-1,2-DCE was detected only in shallow American Lake samples.

TCE also extends from the source area toward the west-southwest approximately 3,000 feet. TCE from NAPL Areas 1 and 2 follows the local westward gradient (see Section 5.1.2) to the west-southwest before turning north near the Madigan Family Housing Area. A portion of this westward lobe of the TCE plume extends to intercept Murray Creek, where TCE enters the streambed. TCE enters Murray Creek at a low concentration (approximately 2 µg/L) and remains at that concentration in the creek at least up to sampling location SW-MC-4 (located in Murray Creek near MAMC). TCE concentrations in Murray Creek are therefore well below the cleanup goal of 80 µg/L. During the initial RI (Envirosphere 1988), TCE and cis-1,2-DCE were detected in Lynn Lake at concentrations ranging from less than 0.1 to 39 µg/L and less than 0.15 to 23 µg/L, respectively.

The 5 µg/L margin of the TCE plume has remained relatively stable since it was defined during the 1988 RI. The margin of the western lobe of the plume, however, was poorly defined until recently. Therefore, it is not known if this portion of the plume is stable, expanding, or contracting.

The concentration of cis-1,2-DCE is approximately 10 percent that of TCE. The cis-1,2-DCE plume in the Vashon aquifer (Figure 5-32) begins in the source area and extends throughout the TCE plume. Concentrations of cis-1,2-DCE above the cleanup goal of 70 µg/L are in a relatively small plume that extends from the source area west-northwest to the secondary EGDY extraction well field.

Vinyl chloride has been detected in groundwater at a few select locations within the EGDY but never downgradient of East Lincoln Drive, which is the northernmost edge of the EGDY.

Concentrations of TCE and cis-1,2-DCE have remained relatively constant in most monitored wells since the late 1980s. Some wells (e.g., extraction wells and wells near extraction wells) have shown slightly decreasing trends, while other wells within the interior of the plume have shown slightly increasing trends with time.

5.4.1.2 Sea Level Aquifer

TCE enters the Sea Level aquifer through a window of permeable Vashon Drift deposits in the trough that was eroded through the Second Non-Glacial aquitard. The Sea Level aquifer TCE plume extends from the window generally west and northwest. The lateral extent of TCE contamination is presently estimated to be limited to that shown in Figure 5-33. Five new Sea Level aquifer monitoring wells have been recently installed outside the perimeter of the estimated Sea Level aquifer plume boundary to confirm the extent of the TCE plume. These wells are expected to be sampled in October 2002.

TCE contamination appears to remain within the upper portion of the TCE plume above the till layer that may separate the Sea Level aquifer into upper and lower portions (Figure 5-4). TCE has been detected at very low levels in well T-09E, which is screened within the lower portion of the Sea Level aquifer. Vashon-aquifer-type tracer signature (see Section 5.1.2.5) was detected in this well, suggesting that the seals in the annulus of well T-09E may be leaking and thus allowing TCE from Vashon aquifer contamination to migrate down into this well. The well construction indicates that the annulus was filled with gravel with only 5-foot-thick sections of bentonite to isolate the various water-bearing zones. A Vashon-aquifer-type tracer signature was also observed in a second contaminated well that was previously presumed to be screened in the lower unit of the Sea Level aquifer (LC-74D). Subsequent review of the borehole geologic log gave little support that the well was actually screened in the lower unit of the Sea Level aquifer. Well LC-74D is screened at an elevation of 54 to 64 feet, which is approximately the elevation of the Third Glacial Drift till unit in this portion of the study area. Well construction records show that this well has an adequate annular seal to prevent vertical migration of contamination.

Concentrations of cis-1,2-DCE have been detected well below the cleanup goal of 70 µg/L in the Sea Level aquifer (Figure 5-34). Concentrations of TCE and cis-1,2-DCE have remained relatively constant in most monitored wells within the Sea Level aquifer since the early to mid-1990s. Well LC-74D was the most notable exception, showing an increasing trend in TCE up until production well 13 was shut down in 2000. Because of the inadequate number of monitoring wells near the perimeter of the plume, it is unknown whether the Sea Level aquifer plume is expanding, stable, or contracting.

5.4.2 Fate and Transport of VOCs

Based on the evidence collected as of this writing, NAPL disposed of at the EGDY was primarily TCE mixed with waste petroleum hydrocarbons. The ratio of hydrocarbons to TCE likely varied considerably. TCE may even have been disposed of as pure phase product to a limited extent. PCE has been detected at very few locations, suggesting that it was disposed of in only small quantities. VC and cis-1,2-DCE were not likely used for Logistics Center activities. Thus, TCE is the primary starting point for dissolved-phase chlorinated solvent contamination in groundwater.

5.4.2.1 TCE Solubility

Dissolved-phase TCE begins immediately beyond the limits of the source area NAPL in both the vadose and saturated zones. The concentration of TCE dissolved in groundwater adjacent to the NAPL sources is dependent upon the proportion of TCE to other components (e.g., diesel, oil, and grease). For pure TCE NAPL, dissolved-phase TCE will be present at the solubility limit of TCE (e.g., 1,600 mg/L at 10°C). For mixed-constituent NAPL, TCE will dissolve into groundwater at a lower effective solubility proportional to TCE's mass percentage of the NAPL mixture. Because most, or all, of the chlorinated NAPL present in the EGDY is mixed NAPL-containing petroleum hydrocarbons, TCE is likely to dissolve into groundwater at some fraction of its pure phase solubility. TCE has commonly been measured at concentrations ranging from 1,000 μg/L to more than 1,000,000 μg/L in groundwater near NAPL sources.

5.4.2.2 TCE Biodegradation

Under anaerobic conditions with a suitable electron donor present, bacteria can transform TCE through reductive dechlorination into less chlorinated compounds by transferring electrons and replacing a chlorine atom with a hydrogen atom (hydrogenolysis). Sequential dechlorination of TCE and chlorinated intermediate DCE isomers and VC result in production of ethene gas as a final product.

Anaerobic biotransformation of a variety of chloroethene compounds has been studied and well documented for the past 15 years (e.g., DeBruin et al. 1992; DiStefano, Gossett, and Zinder 1991; Egli et al. 1988; Fathepure and Boyd 1988a, 1988b; Freedman and Gossett 1989; Holliger and Schumacher 1994; Vogel and McCarty 1985). Reductive dechlorination reactions are facilitated by a number of anaerobic microorganisms either co-metabolically or directly.

Co-metabolic reactions are dechlorination reactions that occur in the presence of a main energy-producing reaction such as methanogenesis or acetogenesis. Contaminant destruction occurs as a fortuitous reaction (co-metabolic) to the main energy-producing reactions. A suitable substrate is needed to stimulate this activity. Typically, only a small fraction of the available reducing equivalents in the substrate (e.g., electron transfers) are used for contaminant transformation. Reducing equivalent yield is defined as the ratio of the number of reducing equivalents used in dechlorination to the total number used by a culture.

Some organisms are known to directly use chlorinated ethenes as an electron acceptor in energy and growth reactions. A suitable electron donor is necessary as a substrate for these reactions. This activity, termed chlororespiration, is orders of magnitude more efficient at dechlorination than co-metabolic dechlorination (i.e., has a better reducing equivalent yield). Chlororespiring organisms have been shown to thrive in the presence concentrations of chloroethenes up to 150 mg/L, whereas organisms such as methanogens are inhibited at one tenth the concentration (Ballapragada et al. 1995; Ballapragada et al. 1997; Holliger et al. 1993; Scholz-Muramatzsu et al. 1995; Sharma and McCarty 1996). This type of activity at high chloroethene concentration provides support for possible use of bioremediation in DNAPL source areas.

Unfortunately, there is no a priori method to predict the dechlorination activity (chlororespiring or co-metabolic) at a given site. Thus, it is still necessary to develop site-specific reaction stoichiometry and rate information. Published rates of reductive dechlorination vary widely and indicate a strong dependence on site-specific conditions.

Degradation pathways for most organic compounds including TCE are complex, involving multiple series and potentially parallel reaction steps. Of the possible biologically catalyzed degradation pathways for TCE, the most common is hydrogenolysis.

The following hydrogenolysis pathway occurs with a substitution of a chloride ion for a proton and includes DCE and VC intermediates:

$$\text{TCE} + H^+ + 2e^- \Rightarrow \text{1,1-DCE or 1,2-DCE} + Cl^-$$
$$\text{1,1-DCE or 1,2-DCE} + H^+ + 2e^- \Rightarrow \text{vinyl chloride} + Cl^-$$
$$\text{vinyl chloride} + H^+ + 2e^- \Rightarrow \text{ethene} + Cl^-$$

Petroleum co-contaminants are present in many parts of the EGDY. It is likely that these co-contaminants are the reason that some portions of the EGDY source area are anoxic and that reductive dechlorination products (e.g., DCE and VC) have been observed. Outside of these petroleum-contaminated areas, the aquifer is generally oxic. In the petroleum-contaminated areas, the presence of fermentation products and contaminants produces conditions favorable for developing microbial communities capable of dechlorination.

Previous TCE bioremediation-related work has provided some valuable information about the microbial ecology and effect of amendments on dechlorination at the EGDY site. The discussion below focuses primarily on the information gained through microcosm and field testing at Fort Lewis as part of the reductive anaerobic biological in situ treatment technology (RABITT) project.

Microbial dechlorination activity occurs at the EGDY site when appropriate substrate and nutrients are present. Microcosm tests demonstrated that although the dechlorination rates are slow, TCE can be fully dechlorinated to ethene in the EGDY sediments using either lactate, butyrate, or a complex (yeast extract) substrate. This result is important because it establishes that the fermentative bacteria can transform multiple substrates into hydrogen and that dechlorinating bacteria at the EGDY can compete with other hydrogen users and dechlorinate TCE, DCE, and VC. This activity is not necessarily present at all sites. The dechlorination process does not appear to be facilitated by highly efficient dechlorinating bacteria such as Dehalococcidies ethenogens, even though the microcosm conditions included the high concentration of initial TCE that favors this type of activity.

TCE was dechlorinated during the RABITT bioremediation field test. The primary product of dechlorination observed within the test area was cis-1,2-DCE. Only a small amount of DCE dechlorination to VC was observed. Several factors may have contributed to this result. The dechlorination rate for DCE at the EGDY is significantly slower than the rate for TCE. The in situ temperature is lower than what was used in the microcosm tests, and the low temperature could result in slower dechlorination rates. The field test was configured to inject TCE-contaminated water and nutrients into a treatment zone, but the contaminated groundwater only passed through the treatment zone once. In this configuration, TCE was always present in the most biologically active area of the treatment zone (i.e., near the nutrient injection point). Because TCE is a preferred electron acceptor and is dechlorinated at a much higher rate than for DCE, TCE would be dechlorinated in preference to DCE or VC.

Although some level of biodegradation occurs within the EGDY source area, dissolved-phase TCE and cis-1,2-DCE have migrated outside the source area and continue to migrate beyond the source area.

5.4.2.3 TCE Migration Outside the EGDY

Areas of the aquifer that are contaminated with TCE but still contain oxygen will not have a developed microbial community for reductive dechlorination. Vashon aquifer materials are low in TOC and relatively high in dissolved oxygen outside of the source area, thus resulting in geochemical conditions that are not conducive for reductive dechlorination of dissolved-phase solvents leaving the EGDY. Thus, TCE that successfully migrates to outside the source area is unlikely to degrade further as it travels through the low-carbon, high-oxygen aquifers typical of the study area. The fact that measured TCE to cis-1,2-DCE ratios remain relatively constant from the source area to the downgradient margin of the plume indicates that little measurable degradation of TCE occurs outside of the anoxic portions of the EGDY. Since cis-1,2-DCE is present at lower concentrations than TCE and has a higher cleanup goal, it is not specifically discussed in the following text. Vinyl chloride is not detected outside of the EGDY most likely because it can degrade readily under aerobic conditions.

Dissolved TCE leaves the EGDY at concentrations between 100 and 1,000 μg/L. At these concentrations, the density of contaminated groundwater is not measurably different from noncontaminated groundwater, and TCE will travel along the natural groundwater travel paths. TCE will not, however, move at the same rate as groundwater, nor will TCE concentrations remain constant throughout the plume due to the effects of sorption and dispersion. Dispersion causes TCE to be spread out at lower concentrations toward the lateral and forward margins of the plume. Sorption retards the velocity of TCE relative to groundwater as the contaminant partitions between its sorbed and dissolved phases as it migrates with groundwater. Calibration results from previous groundwater contaminant fate and transport modeling studies (USACE 1998b) predict that TCE likely migrates at approximately one third of the groundwater velocity.

Within the EGDY, four extraction wells are withdrawing water from the upper Vashon aquifer in the vicinity of NAPL Area 3. These four extraction wells appear to create hydraulic capture of the area surrounding NAPL Area 3 (Figures 5-18 and 5-19). Thus, dissolved-phase contamination from NAPL Area 3 may be completely captured by the pump-and-treat system, resulting in isolation of this source area from the downgradient plume. The nearby small-volume source areas discussed in Section 5.3 also appear to be within the hydraulic capture zone of the EGDY extraction wells.

Dissolved-phase TCE from NAPL Areas 1 and 2 may be partially captured and treated by the EGDY extraction well system. However, a portion of the dissolved-phase TCE from source areas 1 and 2 is not captured and migrates to the west-southwest. Some of this plume enters Murray Creek at low concentrations. The remainder appears to eventually migrate toward the north to rejoin the main body of the plume. Lynn Lake is within this migration path. Because Lynn Lake is fed entirely by groundwater, TCE likely enters Lynn Lake as the water table periodically rises to intersect the lakebed.

Some of the TCE that is not captured by the primary EGDY well field is likely captured by the secondary EGDY well field (LX-16 and RW-01). However, an analysis of flow paths based on groundwater gradient data indicates that some of the TCE plume may be able to pass by the secondary EGDY well field to the south and continue on to the I-5 extraction well field or move down through the permeable window in the Non-Glacial aquitard into the Sea Level aquifer.

As discussed in Sections 5.1.2 and 5.4.1, it is possible that there may be a high-permeability connection between the Vashon and Sea Level aquifers near the Madigan Family Housing area based on the projected trend of the trough at the base of the Vashon Drift (Figure 5-15). If a permeable window exists in this area, some TCE may enter the Sea Level aquifer in this region. Detections of TCE at well LC-50D (less than 0.1 to 8 μg/L) indicate that some TCE enters the Sea Level aquifer here, but the migration pathway is unknown.

TCE that bypasses the secondary EGDY extraction well field or that was already present downgradient of the secondary EGDY well field prior to pump-and-treat operations continues to move downgradient over the permeable window (Figures 5-31a and 5-4) that is a hydraulic connection between the Vashon and Sea Level aquifers. TCE moves into the Sea Level aquifer at this permeable window and also continues to move downgradient within the Vashon aquifer toward the I-5 extraction well field.

TCE-contaminated groundwater that continues to migrate downgradient within the Vashon aquifer is captured by the I-5 extraction well field. Based on the presence of TCE in extraction well LX-1 at concentrations greater than 5 μg/L, it is possible that a very small amount of TCE may be able to bypass the I-5 extraction well field along the southern end of the I-5 extraction well field. TCE does not pass under the I-5 extraction well system, as confirmed by wells screened in permeable units below the extraction wells.

A portion of the TCE plume that was present downgradient of the I-5 extraction well field before initiation of pump-and-treat operations is captured by the extraction well system. However, the infiltration galleries located just south of I-5 do not provide sufficient flow of water to reverse the natural gradient (Figure 5-17). Therefore, much of this downgradient portion of the TCE plume is not captured and continues to migrate toward American Lake, where it enters the lake and is rapidly diluted with surface water.

The bottom of American Lake is at an approximate elevation of 180 feet (NGVD 29) where the TCE plume reaches the lake. The deepest portion of the lake, north of Silcox Island, is 90 feet deep (elevation 132 feet NGVD 29). TCE contamination above 180 feet elevation (NGVD 29) likely enters American Lake. However, contamination has been detected in well LC-128 (screened elevation 120 to 140 feet NGVD 29). The extent of this deep Vashon aquifer contamination is unknown due to the small number of monitoring wells screened in this interval. Therefore, it is unknown whether this portion of the TCE plume flows to deeper portions of American Lake north of Silcox Island or downward into the Sea Level aquifer with American Lake water.

TCE that enters the Sea Level aquifer through the permeable window near LC-41D appears to remain within the upper portion of the Sea Level aquifer above the Second Pre-Olympia Drift till throughout the plume based on available evidence (e.g., contaminant concentration measurements from wells screened in the lower portion of the Sea Level aquifer). The length of the permeable window over which TCE enters the Sea Level aquifer is unknown, but the window may extend from the southern to northern edges of the Vashon aquifer plume based on consistent TCE presence at wells LC-41D and LC-66D (Figure 5-33). From the permeable window, TCE migrates toward American Lake, then possibly toward the west as it encounters a groundwater gradient reversal from American Lake water entering the Sea Level aquifer. Additional groundwater elevation data and TCE concentration data should provide a better understanding of the Sea Level aquifer migration pathways.

It is unknown whether the Sea Level aquifer plume is expanding, contracting, or remaining relatively constant. Data collected over the last 15 years indicate that the Vashon aquifer plume has achieved a steady-state condition over most of its volume. Pump-and-treat operations are locally reducing contaminant concentrations slowly and steadily. The stability of the western lobe of the TCE plume near the Madigan Family Housing area is unknown.

5.5 STUDY AREA CONTAMINANT MASS BALANCE ESTIMATES

Contaminant mass within the study area exists or existed in buried drums within the EGDY, in unsaturated and saturated soils within the EGDY, and as a dissolved phase in the Vashon and Sea Level aquifers. All known drummed contaminant has been removed from the EGDY, and the pump-and-treat system continues to remove contaminant mass from the Vashon aquifer. TCE and cis-1,2-DCE are the primary dissolved-phase contaminants of concern, and petroleum hydrocarbons (TPH) make up a large portion of the NAPL contaminant mass; other contaminants (e.g., PCE) are present at very small fractions of the NAPL mass. Therefore, TCE, cis-1,2-DCE, and TPH were the only contaminants whose masses were estimated (Table 5-11). All mass estimate totals are rounded to one significant figure due to the high level of uncertainty inherent in the estimations. The methods used to estimate mass of contamination are presented below.

5.5.1 Drummed NAPL and Incidental NAPL-Contaminated Soil

Estimates of drummed NAPL mass were derived from data collected during the trenching/drum removal program (GSA 2001). The mass estimates were calculated from the total volume of overpacked liquid waste and drum carcasses mixed with contaminated soil that were removed from the site. Limited analytical samples taken of liquid waste and soil were extrapolated to the entire mass of materials removed. The total estimated mass of contaminants removed with drums and incidental contaminated soil was 100,000 lb (50,000 kg) for TPH, 50,000 lb

(20,000 kg) for TCE, and 4,000 lb (2,000 kg) for cis-1,2-DCE. These wastes, which were removed from the subsurface and incinerated, are no longer part of the study area contaminant mass.

5.5.2 Remaining Source Area NAPL (Saturated and Unsaturated Zones)

Mass estimates for the NAPL remaining in the saturated and unsaturated zones at the EGDY are described in Section 5.3.4. The total estimated volume of NAPL remaining in the source area is estimated to be 90,000 gallons (300,000 liters) (Table 5-8). The total estimated mass of contaminants comprising this NAPL volume is 600,000 lb (300,000 kg) for TPH, 100,000 lb (60,000 kg) for TCE, and 20,000 lb (8,000 kg) for cis-1,2-DCE (Table 5-11). These contaminants are still present within the subsurface of the EGDY. Thermal remediation is planned to begin in 2003 to remove this contaminant mass.

5.5.3 Mass Removed by the Pump-and-Treat System

Mass removed by the pump-and-treat system is estimated by combining analytical measurements of treatment plant monthly influent and effluent with measurements of the total flow of water through the system. The total estimated mass removed as of June 2002 is 7,000 lb (3,000 kg) for TCE and 700 lb (300 kg) for cis-1,2-DCE. TPH mass removal is assumed nonexistent for the I-5 treatment plant and negligible for the EGDY treatment plant due to the low dissolved-phase mobility of TPH compounds in the aquifer. Approximate mass removal rates for TCE at the I-5 and EGDY treatment plants for the quarterly period ending March 2002 were 0.7 and 1 lb/day, respectively. The rate of mass removal is slowly declining, as is expected for a system where mass removal is reducing the total mass of the dissolved-phase plume.

5.5.4 Dissolved and Sorbed Phase Mass

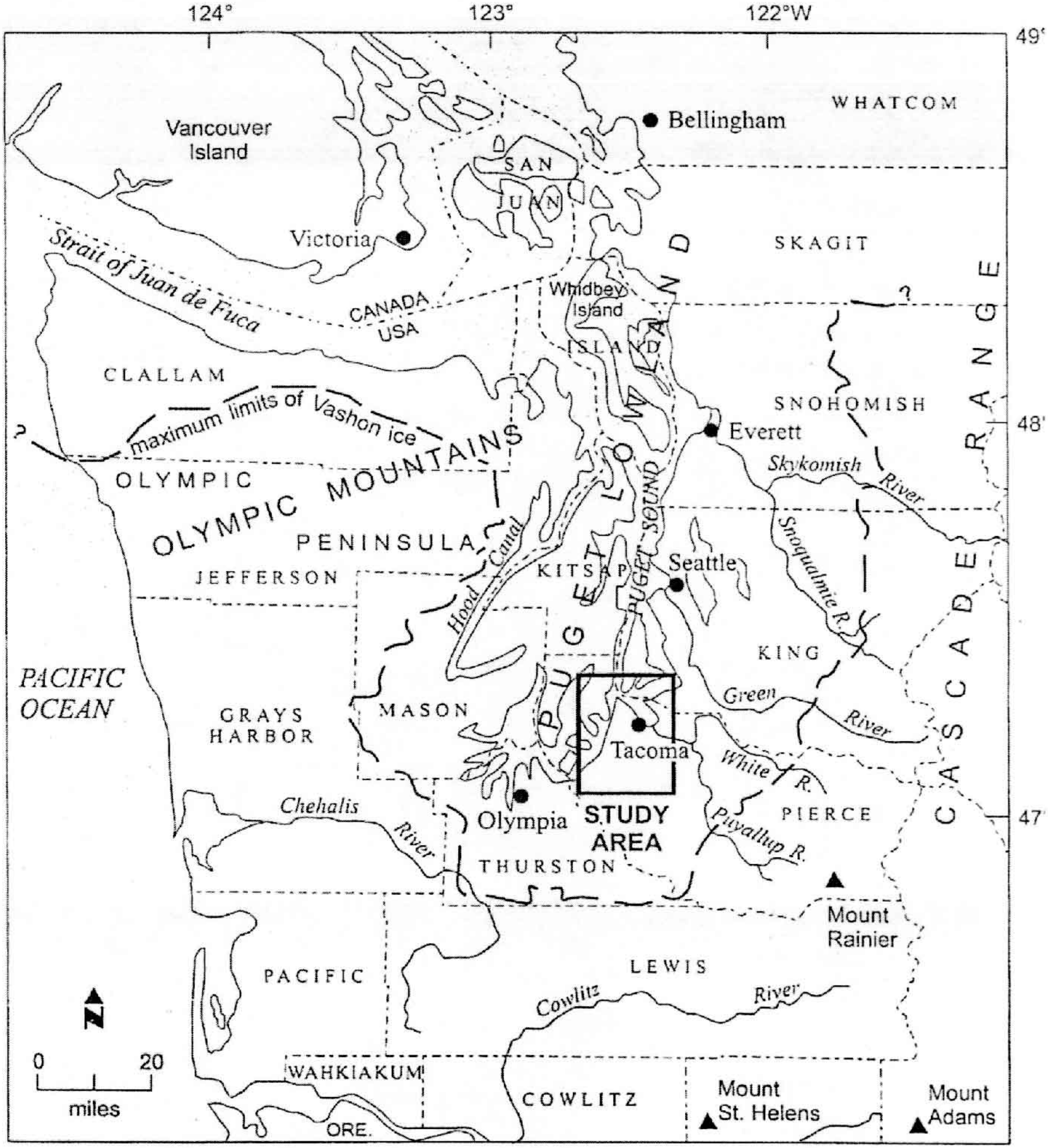
The mass of TCE and cis-1,2-DCE present in the dissolved phase within the Vashon and Sea Level aquifers was estimated using the areal extent of the plumes (Figures 5-31 through 5-34) and estimates of the thickness of the portion of each aquifer containing the contaminants. For the Vashon aquifer, the thickness of the aquifer containing dissolved-phase contaminants was assumed to be 50 feet for all concentrations less than 1,000 μg/L and 30 feet for contamination concentrations greater than or equal to 1,000 μg/L. For the Sea Level aquifer, thickness was assumed to be 50 feet for all concentration values. Surface areas of various concentration ranges within each plume (i.e., 5 to 10 μg/L, 10 to 100 μg/L, 100 to 1,000 μg/L, 1,000 to 10,000 μg/L, 10,000 to 100,000 μg/L, and greater than 100,000 μg/L) were determined using a data contouring package (SURFER). The surface area for each concentration interval was multiplied by the assumed aquifer thickness, an arithmetic average concentration for the interval, and an average site porosity of 0.3 to produce an estimate of the mass of contaminant within that concentration interval. The total mass was summed for all concentration intervals to produce a total of 8,000 lb (4,000 kg) of TCE and 800 lb (400 kg) of cis-1,2-DCE.

The mass of contaminants sorbed to the soil phase was similarly estimated assuming equilibrium partitioning of TCE between soil and water and a partitioning coefficient of 0.24 mL/g (USACE 1998b). The volume of soil affected by sorption was assumed to be equal to the average porosity. The total estimated sorbed mass within the aquifers is 4,000 lb (2,000 kg) for TCE and 400 lb (200 kg) for cis-1,2-DCE. The estimated combined total dissolved and sorbed mass for both aquifers is 13,000 lb (6,000 kg) for TCE and 1,000 lb (600 kg) for cis-1,2-DCE. Approximately 1,000 lb (500 kg) of the dissolved and sorbed phase mass of TCE and cis-1,2-DCE is estimated to be present within the Sea Level aquifer. The remainder is within the Vashon aquifer.

5.5.5 Total Study Area Contaminant Mass

The combined mass of contaminants estimated to remain within the subsurface of the study area is 600,000 lb (300,000 kg) of TPH (in the NAPL source area only), 113,000 lb (66,000 kg) of TCE and 21,000 lb (8,600 kg) of cis-1,2-DCE (Table 5-11). Approximately 90 percent of the estimated remaining mass of TCE and cis-1,2-DCE is contained within the NAPL in NAPL Areas 1, 2, and 3.

Until the NAPL is remediated or contained, TCE and cis-1,2-DCE will continue to partition into the dissolved phase and contribute to the mass of the dissolved-phase plume for an unknown period of time. If the source area mass is removed and/or contained, the total mass of dissolved and sorbed phase TCE and cis-1,2-DCE should diminish as the contaminants are extracted and treated by the pump-and-treat system and by natural dispersion within the aquifers. Based on modeling results (USACE 1998b), it is estimated that TCE would take up to 45 years to be reduced to below 5 μg/L everywhere in the Vashon aquifer once the source area no longer contributes to the plume downgradient of the EGDY. The fate and transport of TCE within the Sea Level aquifer has not been modeled. However, when the primary source area is no longer contributing a significant amount of TCE to the dissolved-phase plume, concentrations entering the Sea Level aquifer will decline with time as the concentrations within the Vashon aquifer above the window decline, until no contaminated water is entering the Sea Level aquifer through the window after approximately 40 years.



Source: Borden and Troost 2001

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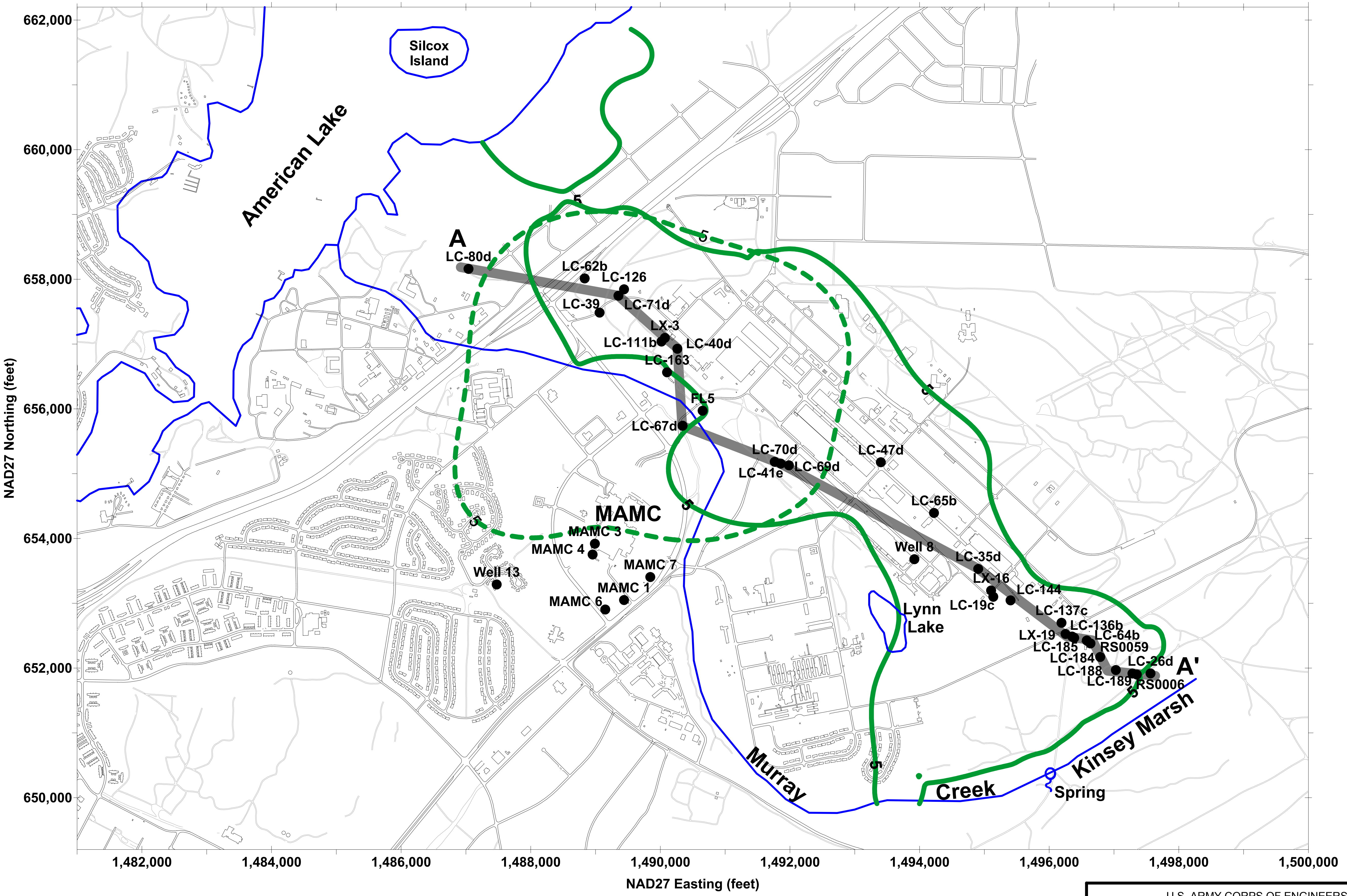
Fort Lewis Logistics Center Superfund Site

Regional Setting

Fort Lewis	**Figure 5-1**	Washington



LEGEND

Vashon aquifer March 2002 TCE 5 ug/l isocontour

Sea Level aquifer March 2002 TCE 5 ug/l isocontour

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EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Map of Logistics Center Longitudinal Cross Section A-A' Location

Fort Lewis	**Figure 5-2**	Washington

GEOLOGIC UNITS

Qv Vashon Drift

Qvr: Vashon Recessional Outwash/Steilacoom Gravel. Loose, well-graded, brown to gray sandy, cobbly gravel or gravelly sand.

Qvt: Vashon Till and Ice Contact Deposits. Loose to dense, brown to gray, silty sandy gravel w/some clay, gravel often supported in sandy, silty matrix when dense.

Qvl: Vashon Glacial Lacustrine Silt. Very stiff to hard, dark gray clayey massive silt and sandy silt.

Qva: Vashon Advance Outwash. Loose, brown to gray, medium to coarse sandy gravel or gravelly sand w/cobbles and loose, brown, fine to medium sand.

Qob: Olympia Beds (not present on cross-sections). Alluvial sand and gravel w/silt, dense silty gravel, stiff silt, scattered wood and peat.

Qpog: Pre-Olympia Drift. Medium to coarse, light brown to gray-brown sandy gravel w/cobbles or very fine to coarse sand w/discontinuous lenses of gravelly sand (glacio-fluvial); and thin, discontinuous layers and lenses of sandy silt, or dense, light brown to gray-brown clay seams and matrix-supported gravel (till).

Qpon: Second Non-Glacial Deposits. Stiff, lavender to pink, clayey, often organic silt, silty sand and sandy silt w/occasional fine gravel. Often contains dark gray to black peat.

Qpog$_2$: Third Glacial Drift. Interbedded, orange to dark gray sandy gravel and sand w/minor silt interbeds, intensively iron oxide-stained at top; dense, gray, silty sandy gravel and gravelly sandy silt, generally matrix supported; and interbedded gray to brown, to dark gray sandy gravel and sand.

Qpon$_2$: Third Non-Glacial Deposits. Lavender silt, peat, sand and gravelly sand.

GENERALIZED MATERIAL TYPES

▨ Disturbed material containing waste metal and construction debris, ash, sand and gravel.

⁘ Loose, sandy gravel or gravelly sand w/low (<10%) fines content.

▨ Loose to dense, silty sandy gravel or silty, gravelly sand.

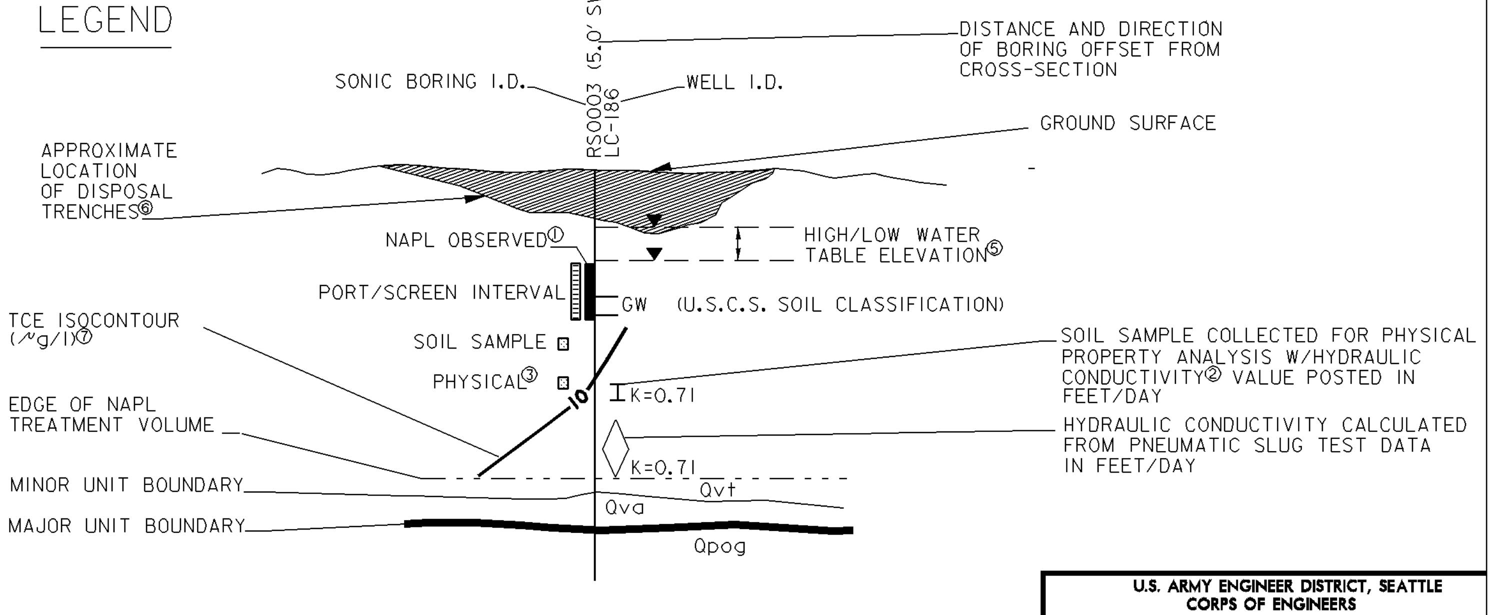
⁘ Loose sand w/generally low (<10%) fines content.

▨ Stiff to hard, clayey silt.

NOTES:

1. PRESENCE OF NAPL IS BASED ON COMBINED LINES OF EVIDENCE, INCLUDING UV FLUORESCENCE, VISIBLE NAPL STAINING/COATING, HYDROPHOBIC DYE TEST AND SHEEN TEST IN WATER.
2. VALUE IS VERTICAL HYDRAULIC CONDUCTIVITY.
3. SOIL SAMPLE COLLECTED FOR PHYSICAL PROPERTIES, BUT NOT PERMEABILITY.
4. NA = NOT ANALYZED.
5. HIGH/LOW GROUNDWATER TABLE ELEVATIONS BASED UPON QUARTERLY DATA COLLECTED 1996 THROUGH 2000.
6. LOCATIONS OF DISPOSAL MATERIAL BASED UPON EM SURVEY. DEPTHS OF TRENCHES BASED UPON DRUM EXCAVATION CONTRACT OBSERVATIONS.
7. LOCATION OF TCE ISOCONTOURS ESTIMATED FROM COMPOSITE DATA SET OF NUMEROUS SAMPLING EVENTS.

LEGEND



SOIL SAMPLE ANALYSIS: $(\underbrace{\text{TCE, CiS-1, 2-DCE}}_{\mu\text{g/Kg}}, \underbrace{\text{TPH-DX, TPH-O}}_{\text{mg/Kg}}$

GROUNDWATER SAMPLE ANALYSIS④: $[\underbrace{\text{TCE, CiS-1, 2-DCE}}_{\mu\text{g/L}}, \underbrace{\text{TPH-DX, TPH-O}}_{\text{mg/L}}]$

GROUNDWATER ANALYSIS THAT IS "J" FLAGGED: 0.372

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CROSS-SECTIONS
LEGEND AND NOTES

FORT LEWIS			WASHINGTON	
SIZE F	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH/ POWERS	SHEET FIGURE 5-3	

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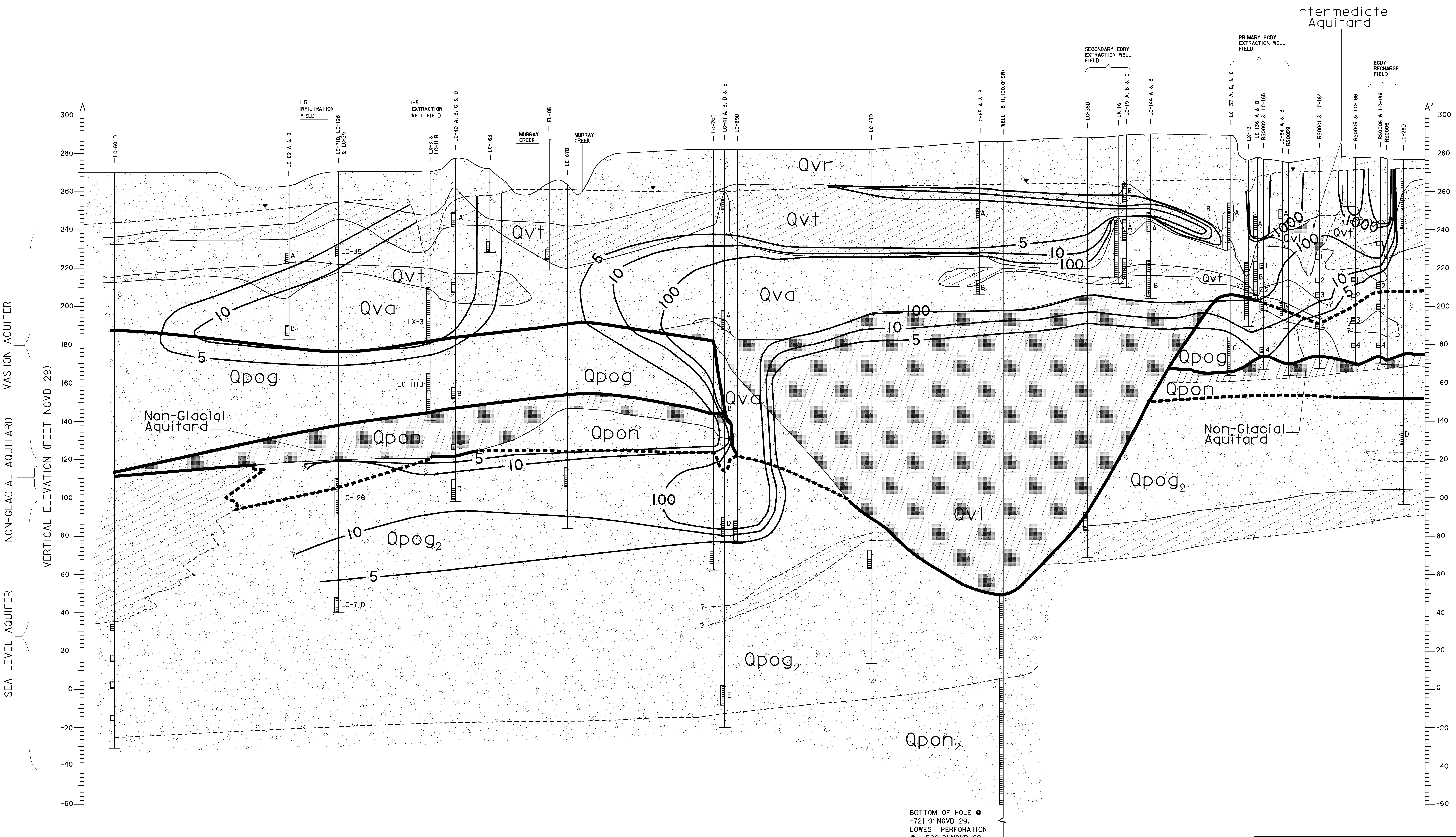

BOTTOM OF HOLE @ -721.0' NGVD 29.
LOWEST PERFORATION @ -500.0' NGVD 29.

VERTICAL EXAGGERATION = 20X

1" = 400' 400' 200' 0 400' 800'

COMPUTER AIDED DESIGN & DRAFTING

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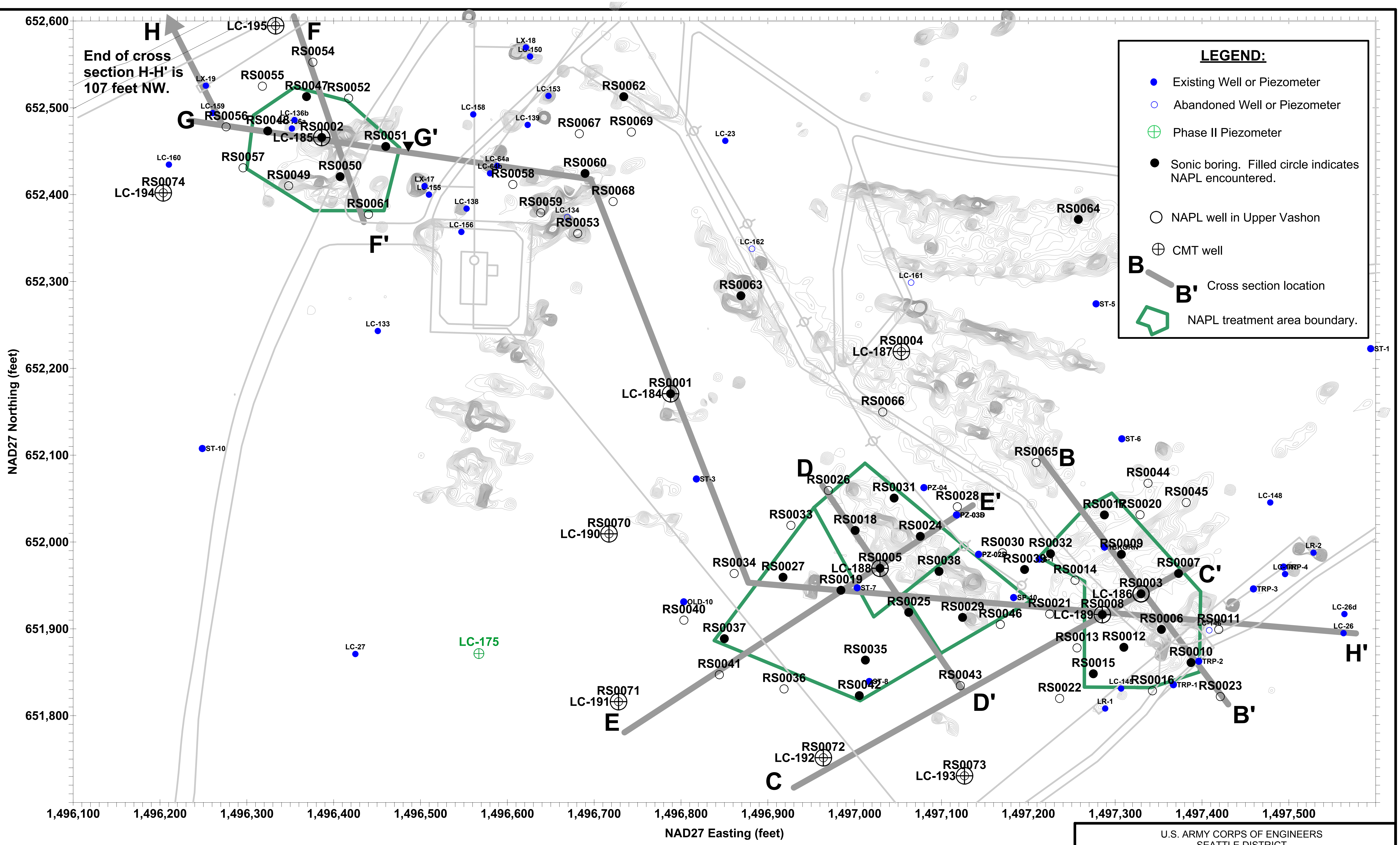
CROSS-SECTION A - A'

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-4	



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EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Map of EGDY Area Cross-Section Locations

Fort Lewis	**Figure 5-5**	Washington

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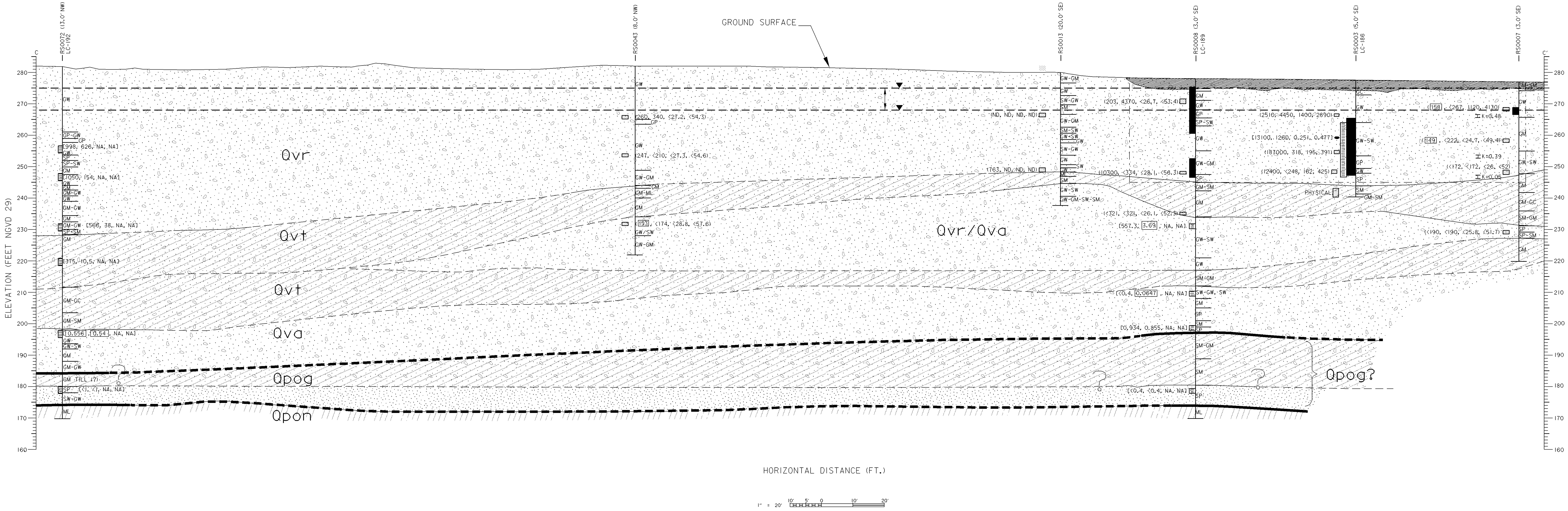

NO VERTICAL EXAGGERATION

REDUCED TO 50% OF FULL SIZE

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CROSS–SECTION C – C'

FORT LEWIS WASHINGTON

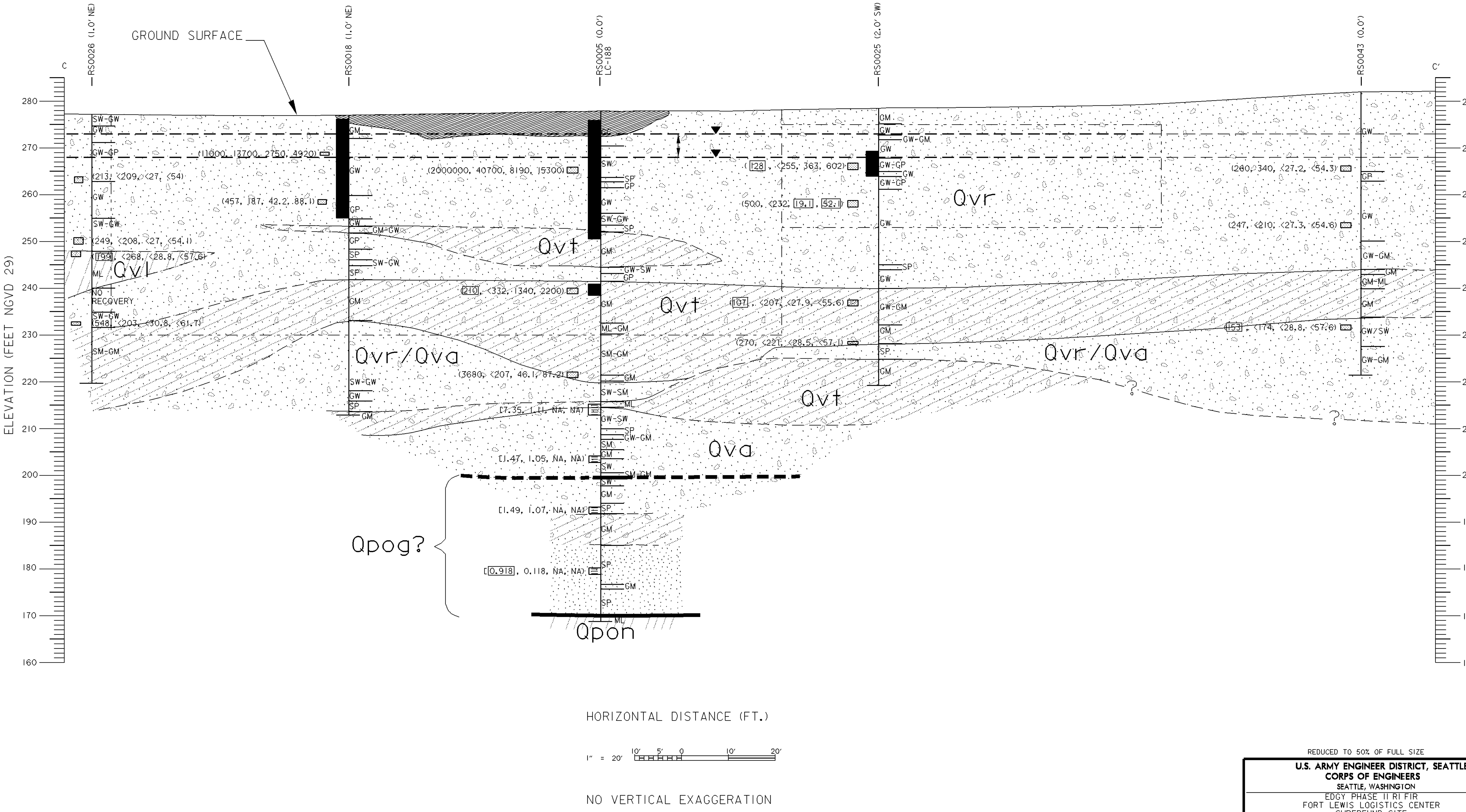
SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-7	

Computer
Aided
Design &
Drafting

A

B

C



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CROSS–SECTION D – D′

FORT LEWIS WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-8	

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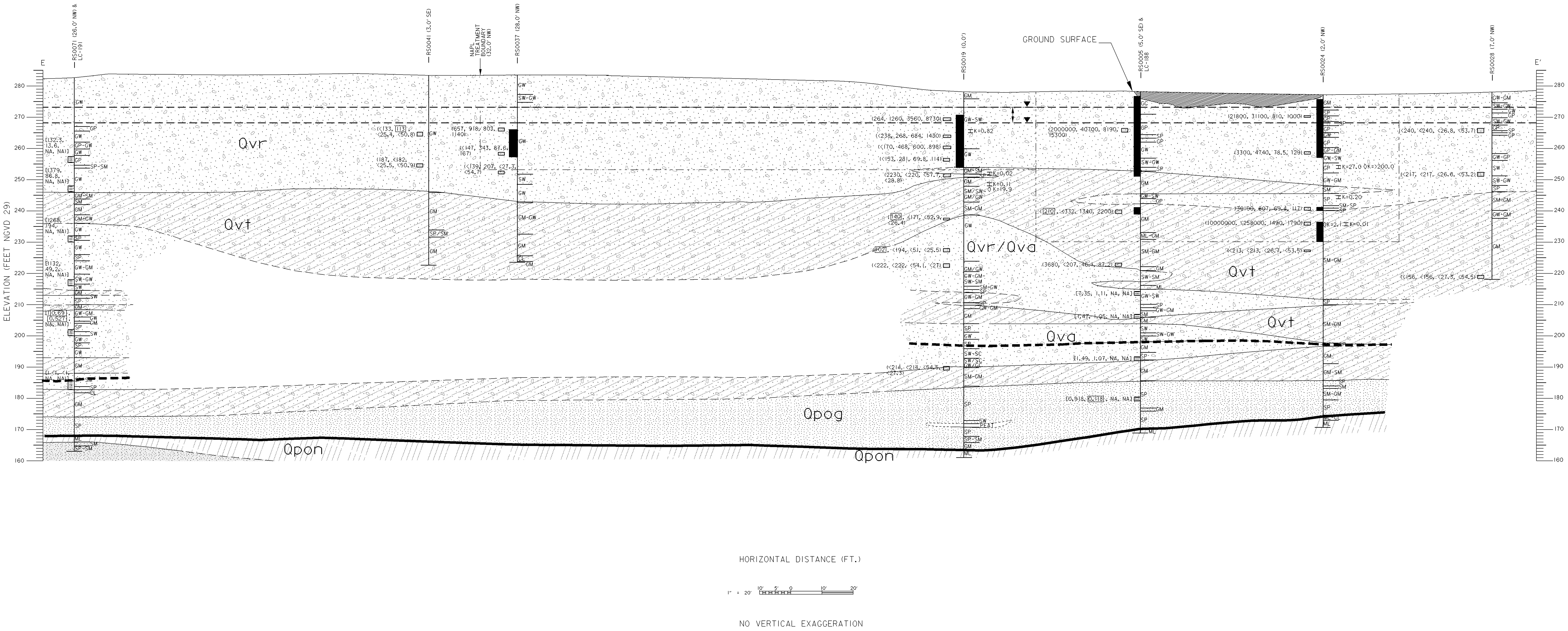
Computer Aided Design & Drafting



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CROSS-SECTION E - E'

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SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-9	

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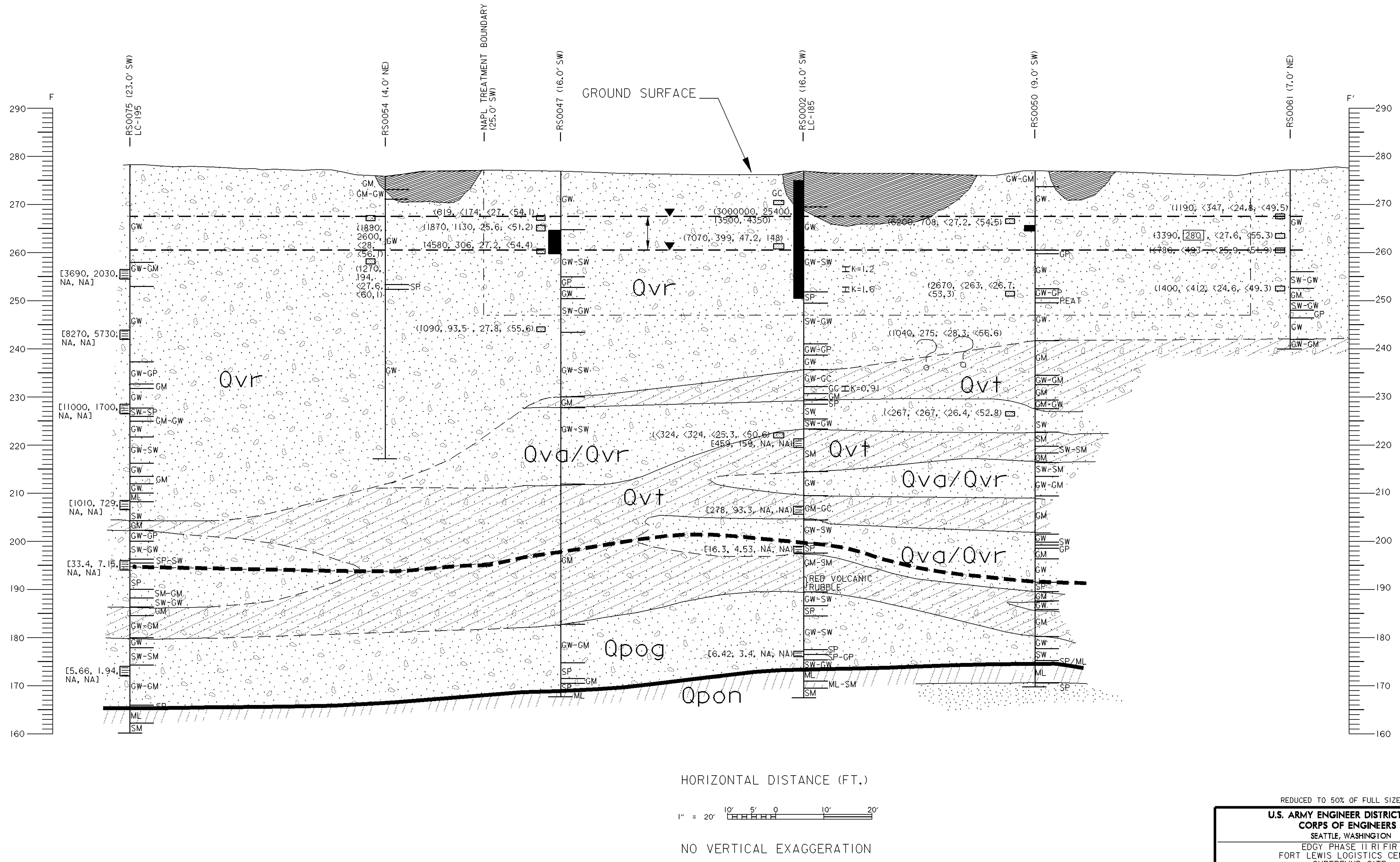
Computer Aided Design & Drafting



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CROSS-SECTION F – F′

FORT LEWIS WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-10	

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DATE AND TIME PLOTTED: 30-SEP-2002 13:30
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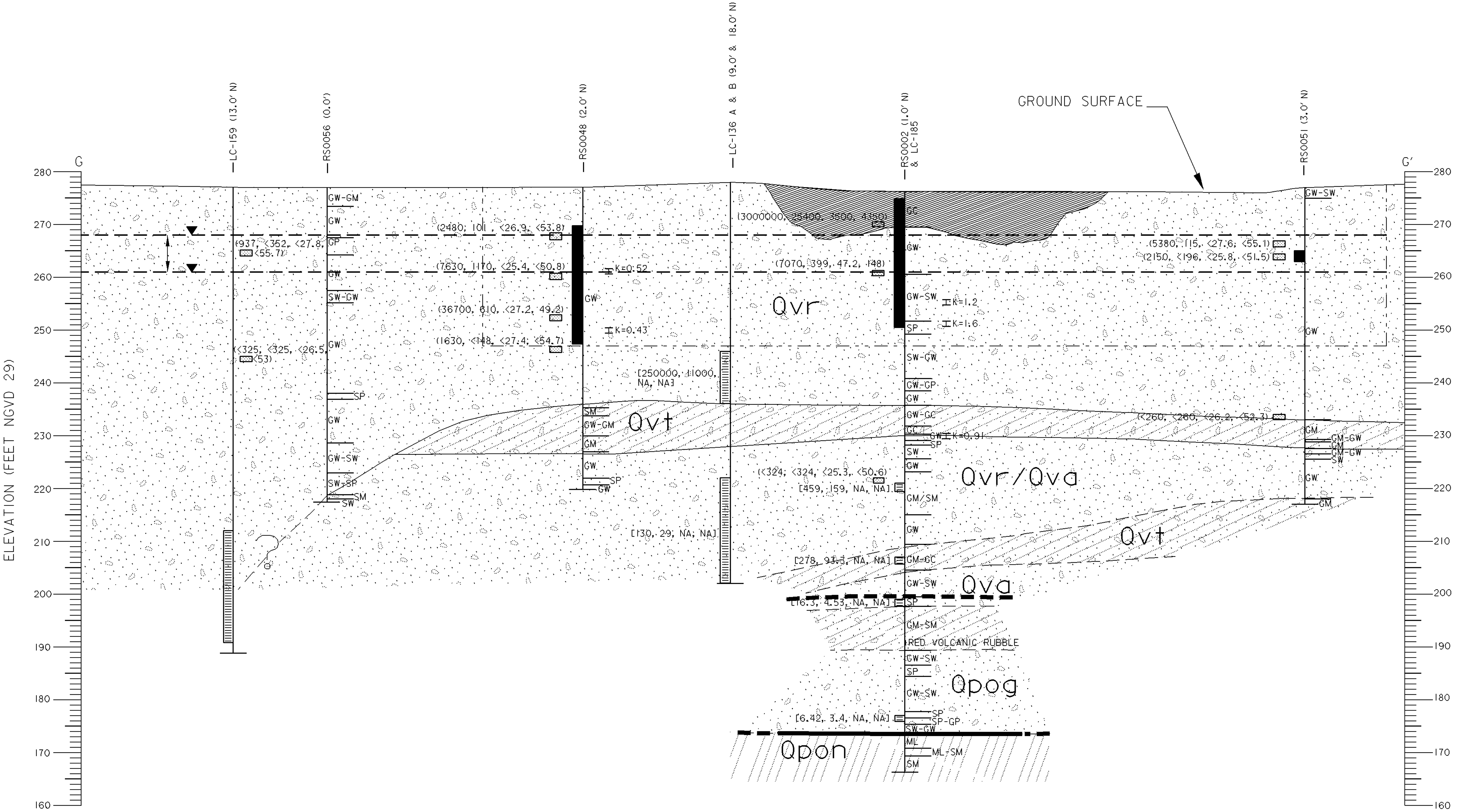
COMPUTER AIDED DESIGN & DRAFTING



HORIZONTAL DISTANCE (FT.)

1" = 20′ 10′ 5′ 0 10′ 20′

NO VERTICAL EXAGGERATION

REDUCED TO 50% OF FULL SIZE

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CROSS-SECTION G – G′

FORT LEWIS WASHINGTON

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE

DSGN. SMITH/ SCHIEFELBEIN
CHK. SMITH
SHEET FIGURE 5-11

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CROSS-SECTION H - H′

SIZE	INVITATION NO.	FILE NO.	DATE:	PLATE
DSGN. SMITH/ SCHIEFELBEIN		CHK. SMITH	SHEET FIGURE 5-12	

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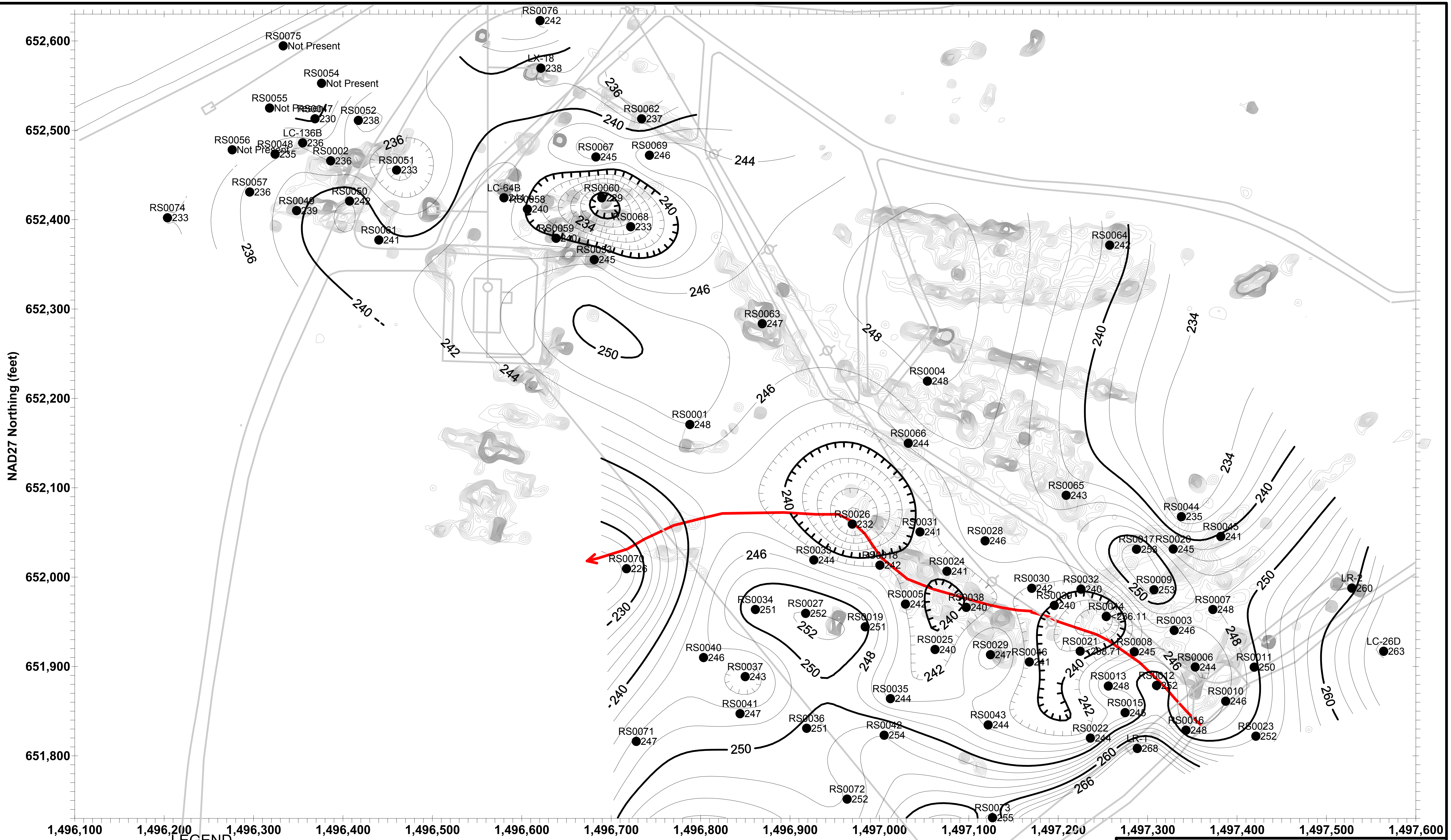

LEGEND

LC-182 ● 245	Boring location with top of till and lacustrine unit elevation (feet NGVD 29).
240	Top of till and lacustrine unit elevation contour.
←	Possible erosional channel on top of till and lacustrine unit.

NOTES:

1. Contour values represent the estimated top of till and lacustrine unit surface elevation (feet NGVD 29)
2. Contour Interval is 2 feet.
3. Contours were computer generated by SURFER using minimum curvature.
4. Contours are provided for visualization purposes only.

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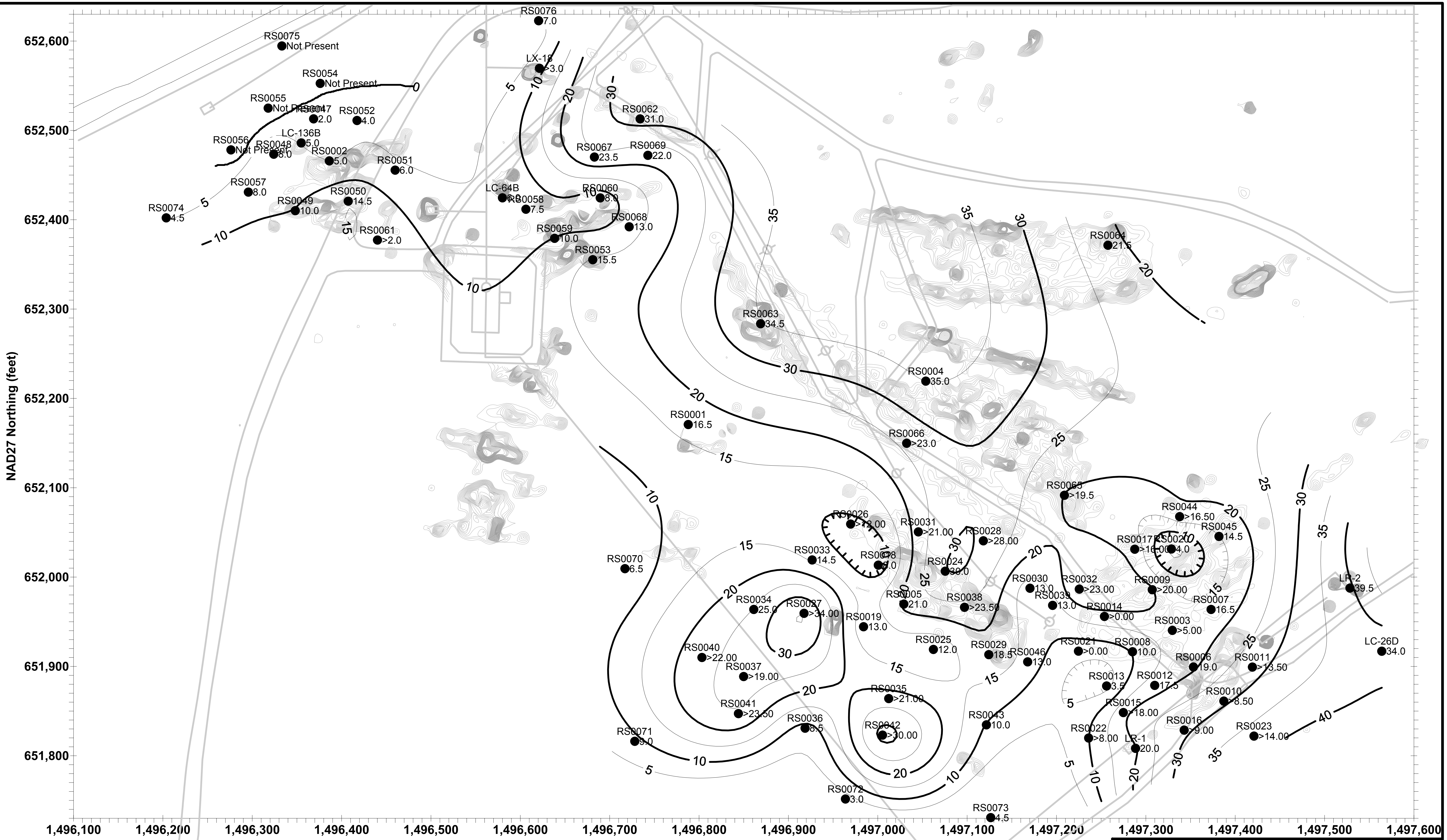
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Surface Elevation Map of the Top of Vashon Till and Glaciolacustrine Silt

Fort Lewis	**Figure 5-13**	Washington



LEGEND

LC-182
● 19.5 Stratigraphic location with thickness of till and lacustrine unit (feet).

20 Till and lacustrine unit isopach contour.

NOTES:

1. Contour values represent the estimated thickness of the till and lacustrine unit (feet).
2. Contour Interval is 5 feet.
3. Contours were computer generated by SURFER using minimum curvature.
4. For data points where total thickness is unknown, a value up to 1 foot thicker than the minimum was used as necessary to prevent contouring below minimum thickness.
5. Contours are provided for visualization purposes only.

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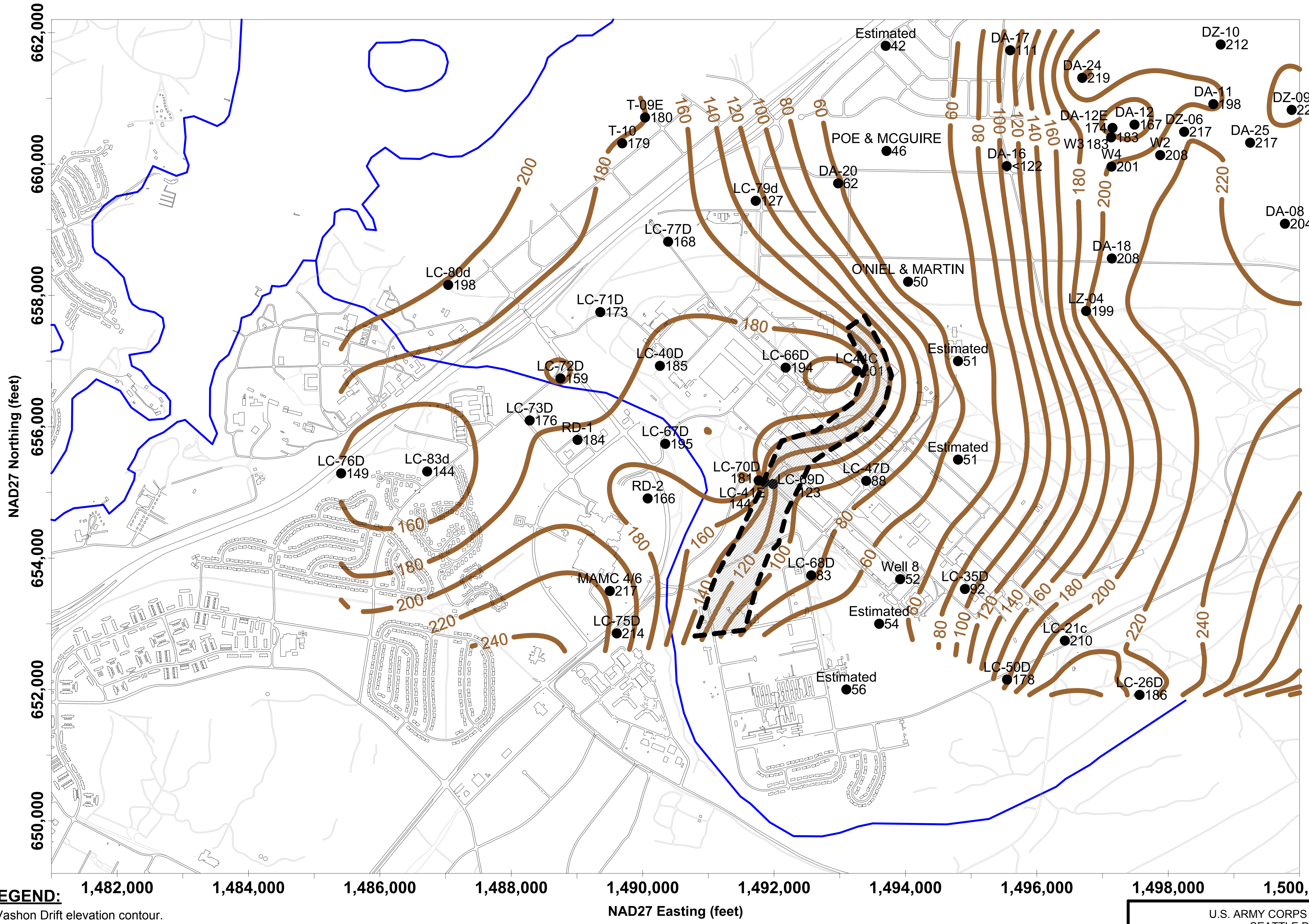
Fort Lewis Logistics Center Superfund Site

Isopach Map of Vashon Till and Glaciolacustrine Silt - EGDY

Fort Lewis	**Figure 5-14**	Washington



LEGEND:

Base of Vashon Drift elevation contour.

LC-182 ● 194 Stratigraphic location with base of the Vashon Drift elevation (feet NGVD 29).

▨ Possible extent of permeable sedments connecting the Vashon and Sea Level aquifers across the Vashon aquifer TCE plume.

NOTES:

1. Contour values represent the estimated elevation (feet NGVD 29) for the base of the Vashon Drift.
2. Contour Interval is 20 feet.
3. Lithologic contact picks from Borden and Troost (2001) used in conjunction with data from new lower aquifer wells not available to Borden and Troost.
4. Elevation of the base of the Vashon Drift estimated where indicated.
5. Contours were computer generated by SURFER using linear kriging with linear drift.
6. Contours are provided for visualization purposes only.

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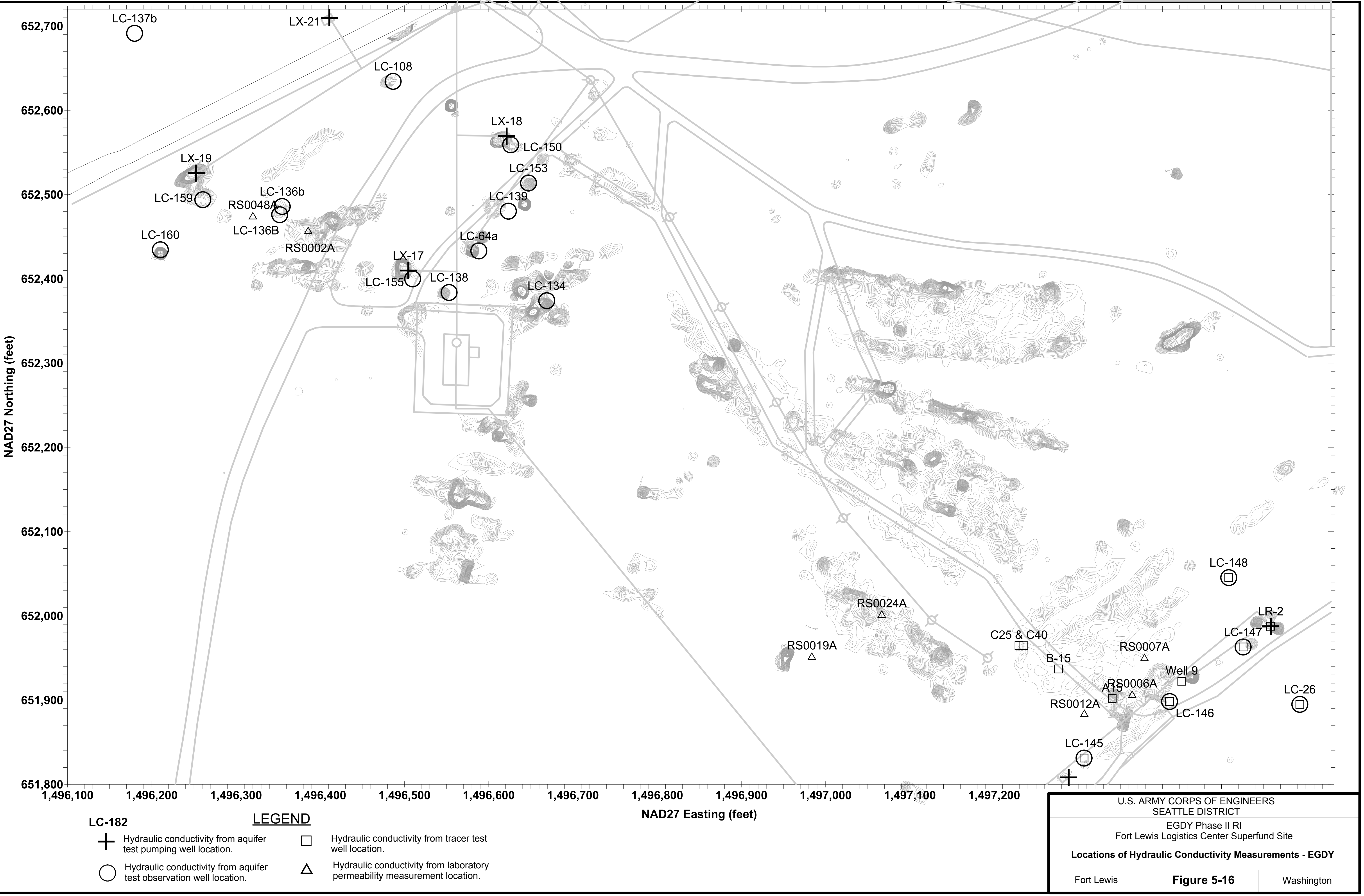
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Surface Elevation Map of the Base of the Vashon Drift

Fort Lewis	**Figure 5-15**	Washington



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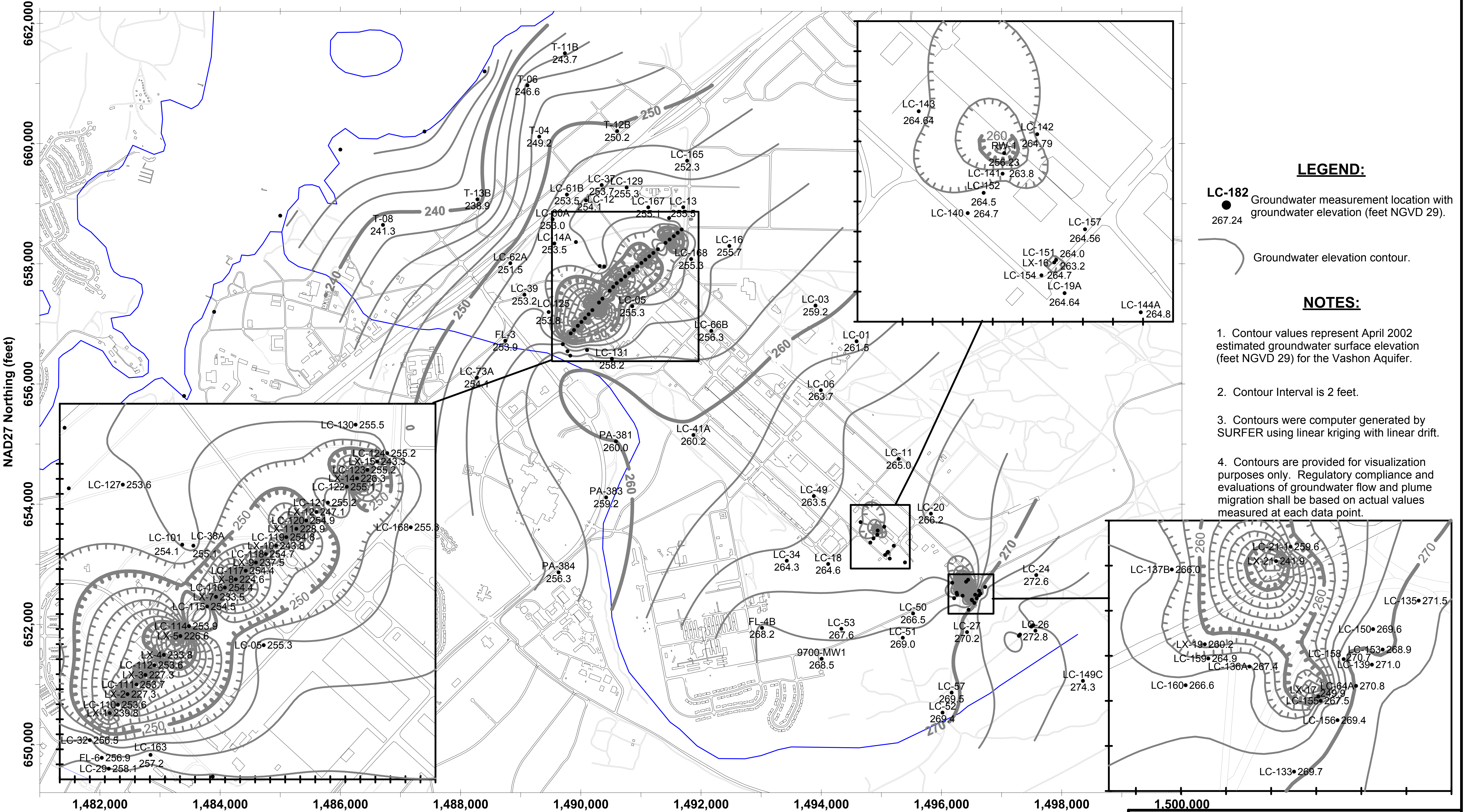
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Locations of Hydraulic Conductivity Measurements - EGDY

Fort Lewis	**Figure 5-16**	Washington



LEGEND:

LC-182 ● 267.24	Groundwater measurement location with groundwater elevation (feet NGVD 29).
⌒	Groundwater elevation contour.

NOTES:

1. Contour values represent April 2002 estimated groundwater surface elevation (feet NGVD 29) for the Vashon Aquifer.

2. Contour Interval is 2 feet.

3. Contours were computer generated by SURFER using linear kriging with linear drift.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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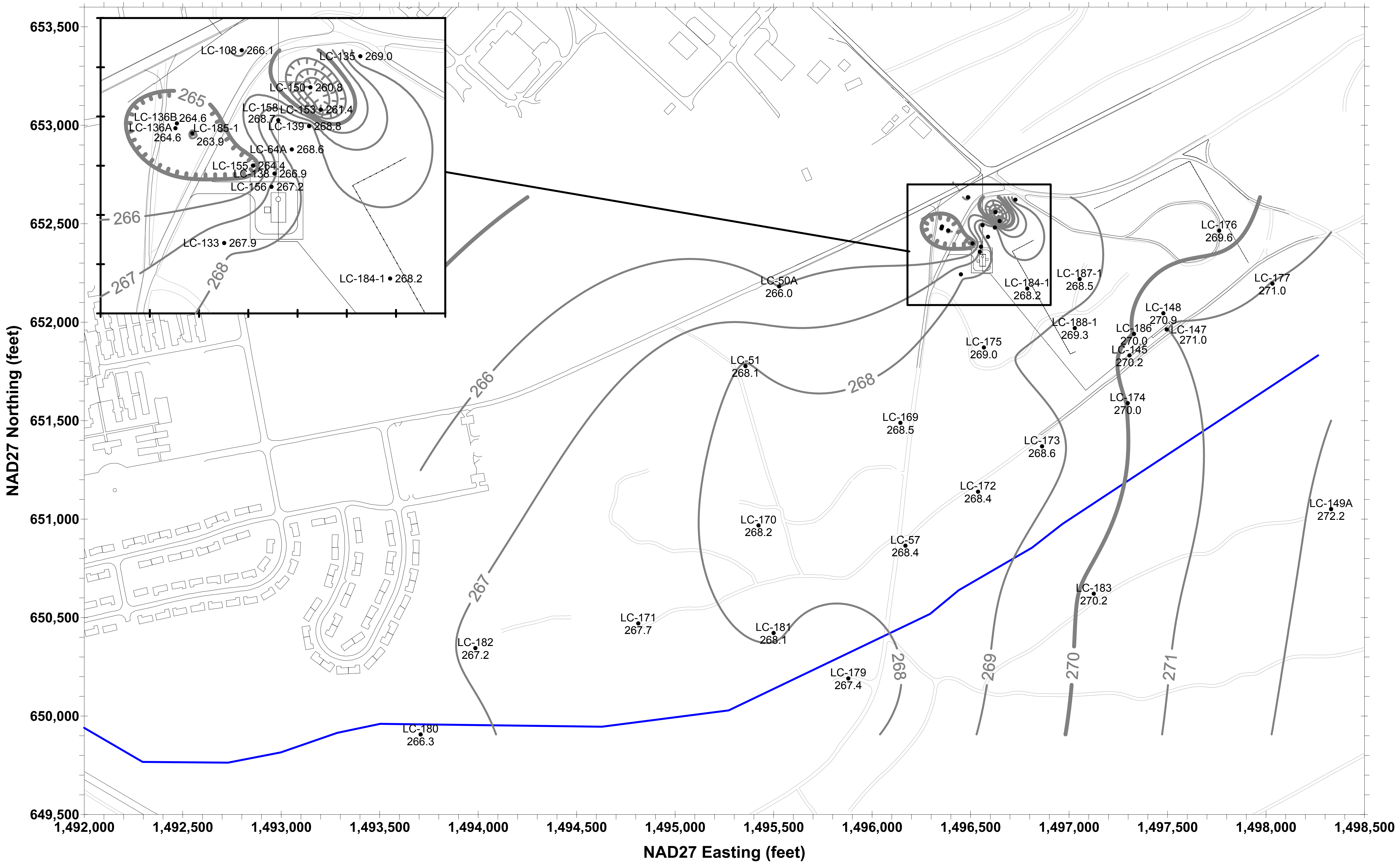
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
April 2002 Water Table Surface Contours for the Vashon Aquifer

Fort Lewis	**Figure 5-17**	Washington



LEGEND

LC-182 ● 267.24 Groundwater measurement location with groundwater elevation (feet NGVD 29).

Groundwater elevation contour.

NOTES:

1. Contour values represent November 2001 estimated groundwater surface elevation (feet NGVD 29) for the Upper Vashon Aquifer.

2. Contour Interval is 1 foot.

3. Contours were computer generated by SURFER using linear kriging with linear drift.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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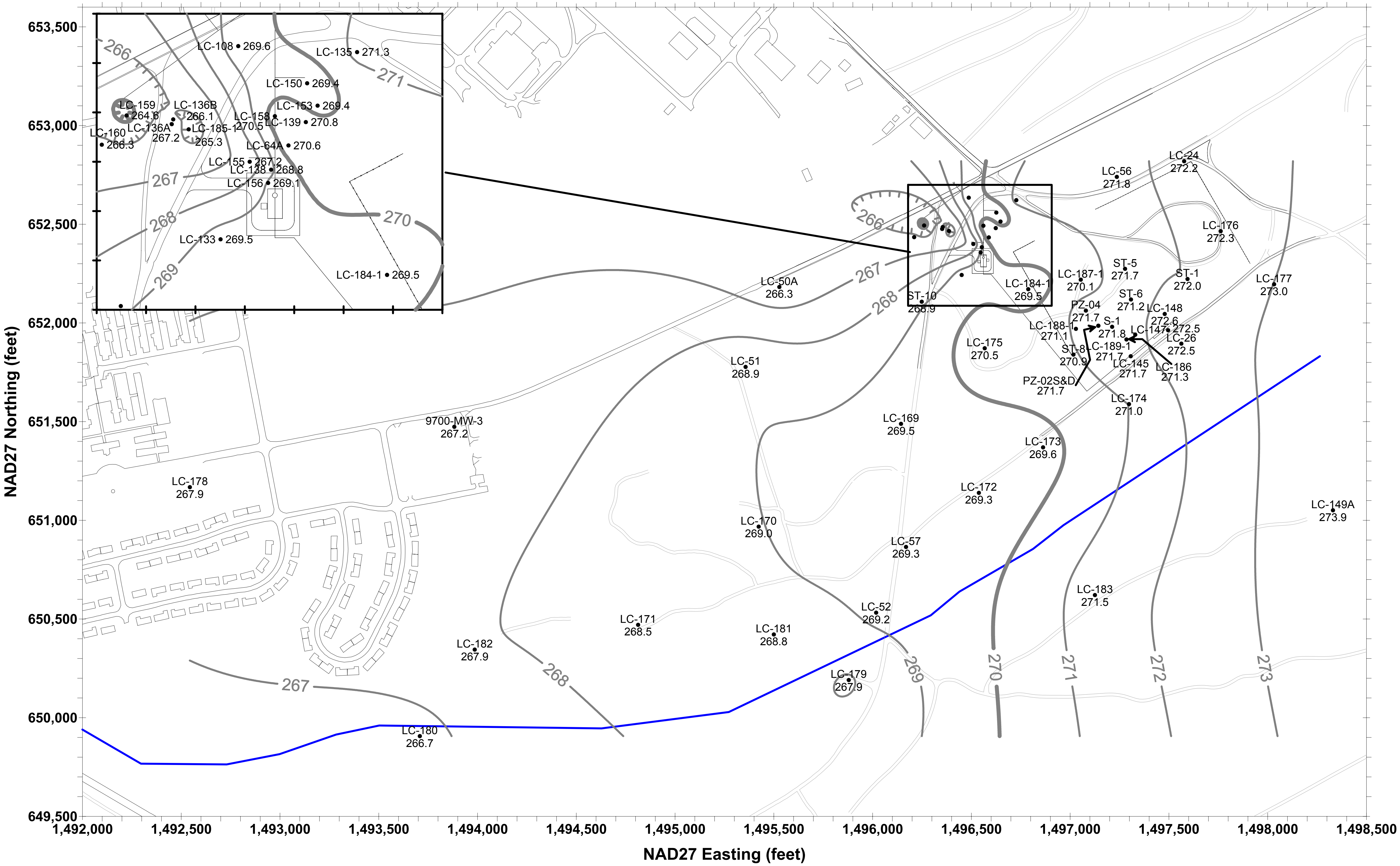
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

November 2001 Water Table Surface Contours
for the Vashon Aquifer - EGDY Area

Fort Lewis	**Figure 5-18**	Washington



LEGEND

LC-182
●
267.24 Groundwater measurement location with groundwater elevation (feet NGVD 29).

Groundwater elevation contour.

NOTES:

1. Contour values represent March 2002 estimated groundwater surface elevation (feet NGVD 29) for the Upper Vashon Aquifer.

2. Contour Interval is 1 foot.

3. Contours were computer generated by SURFER using linear kriging with linear drift.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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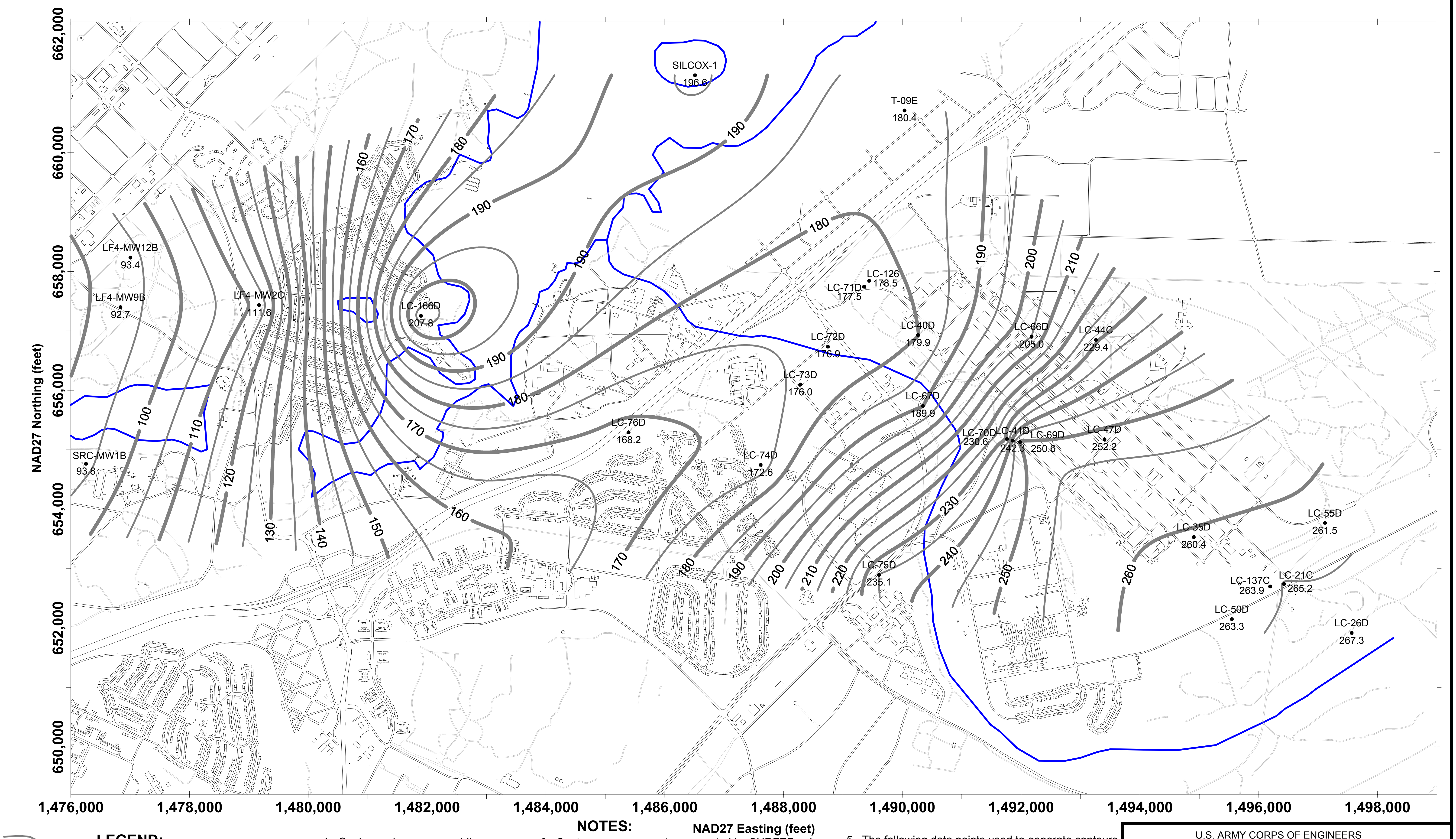
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

March 2002 Water Table Surface Contours
for the Vashon Aquifer - EGDY Area

Fort Lewis	**Figure 5-19**	Washington



LEGEND:

Groundwater potentiometric surface elevation contour.

LC-76D
● 168.2
Sea Level aquifer groundwater level measurement location with water level elevation (feet NGVD 29).

NOTES:

1. Contour values represent the November 2001 estimated potentiometric surface elevations (feet NGVD29) for the Sea Level aquifer.
2. Contour Interval is 5 feet.
3. Contours were computer generated by SURFER using linear kriging with linear drift. An estimated artificial data point of 160 feet elevation (E1484000, N654000) was used to make contours match hydrogeologic interpretation.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at field locations.
5. The following data points used to generate contours are not plotted: well 88-1-SS, 81.1 feet (E1471543, N657079); and well LF4-MW16B, 85.8 feet (E1475180, N657238).

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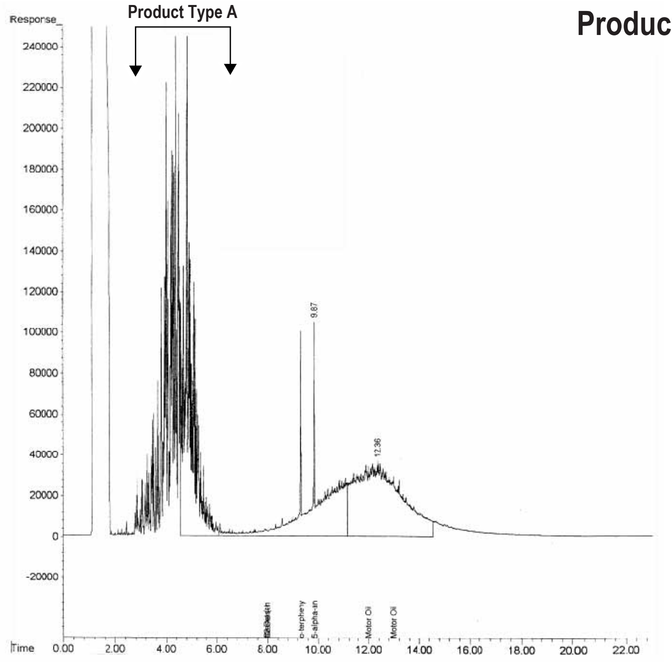
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

November 2001 Potentiometric Surface Contours
for the Sea Level Aquifer

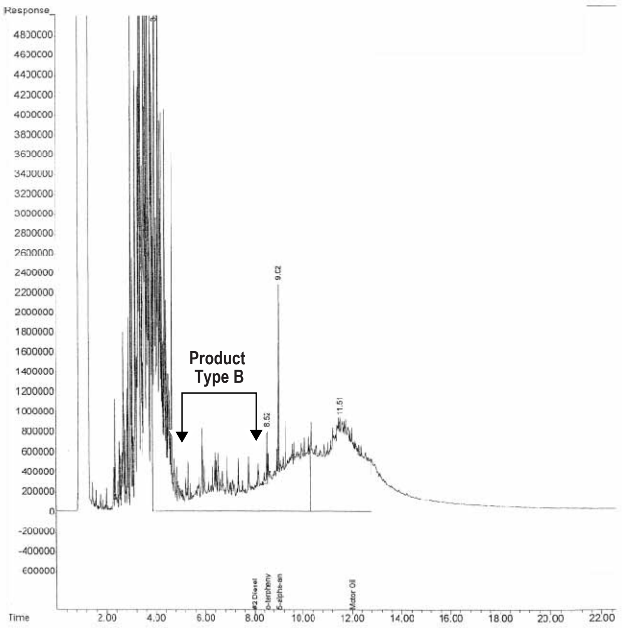
Fort Lewis	**Figure 5-20**	Washington

33750026-1

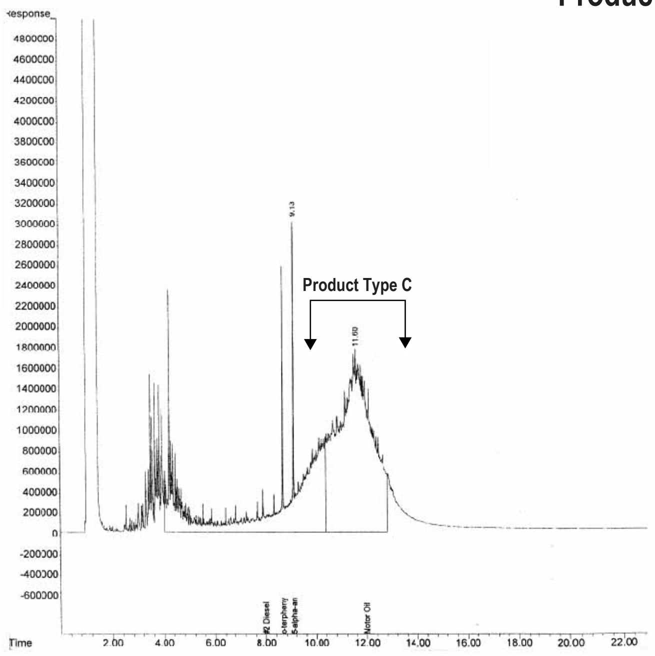
Product Type A
RS0017



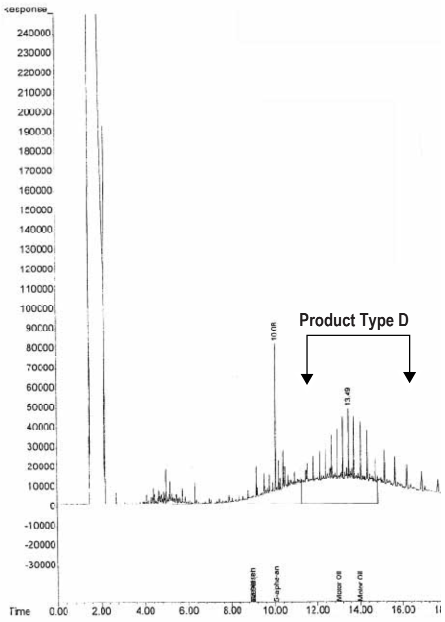
Product Type B
RS0038



Product Type C
RS0064



Product Type D
RS0002



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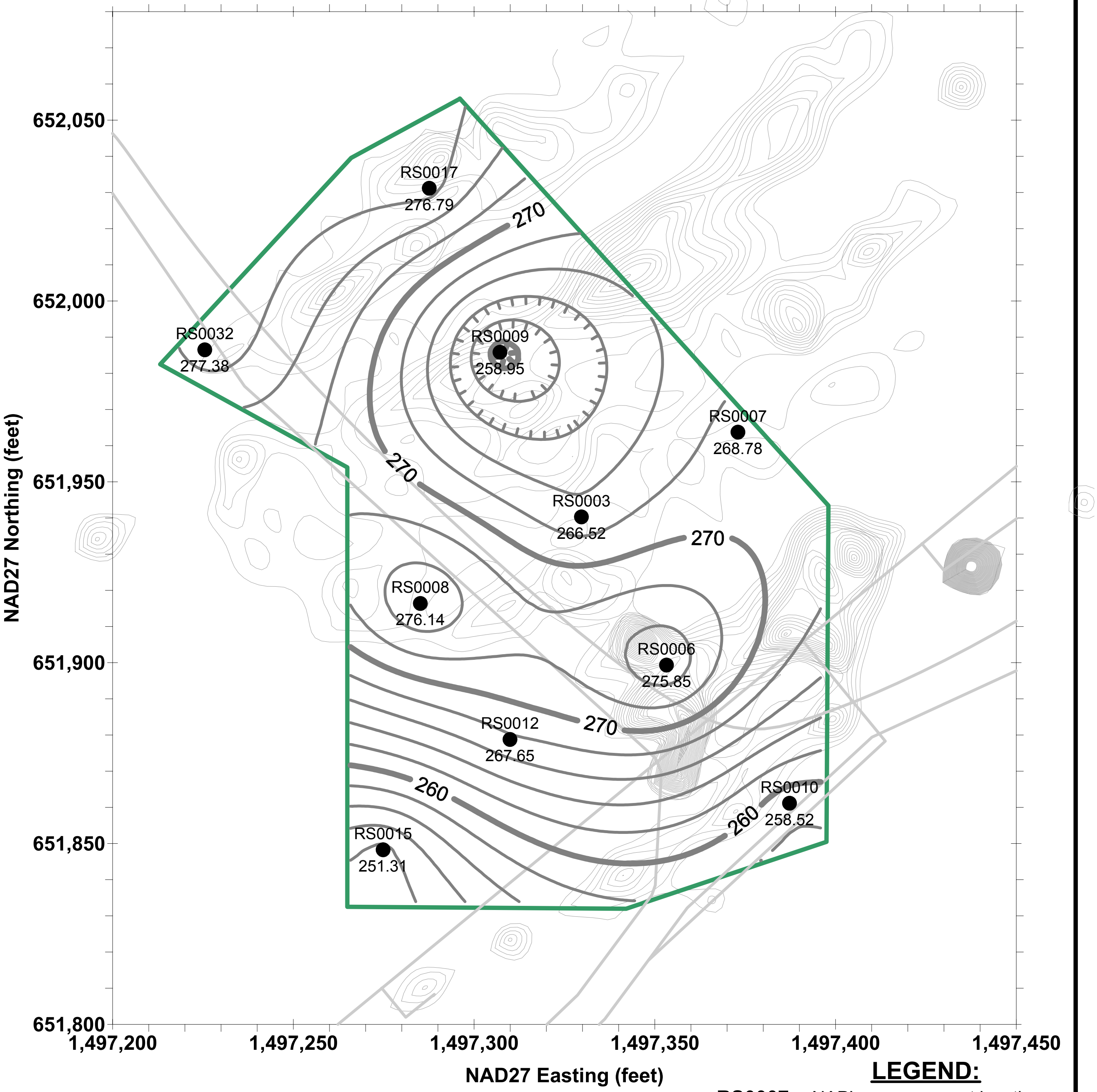
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

NWTPH-Dx Chromatograms

Fort Lewis	**Figure 5-21**	Washington



LEGEND:

RS0007 ● 267.2 NAPL measurement location with top of NAPL elevation (feet NGVD 29).

Top of NAPL elevation contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated top of NAPL elevation (feet NGVD 29) for NAPL Area 1.

2. Contour Interval is 2 feet.

3. Contours were computer generated by SURFER using linear kriging.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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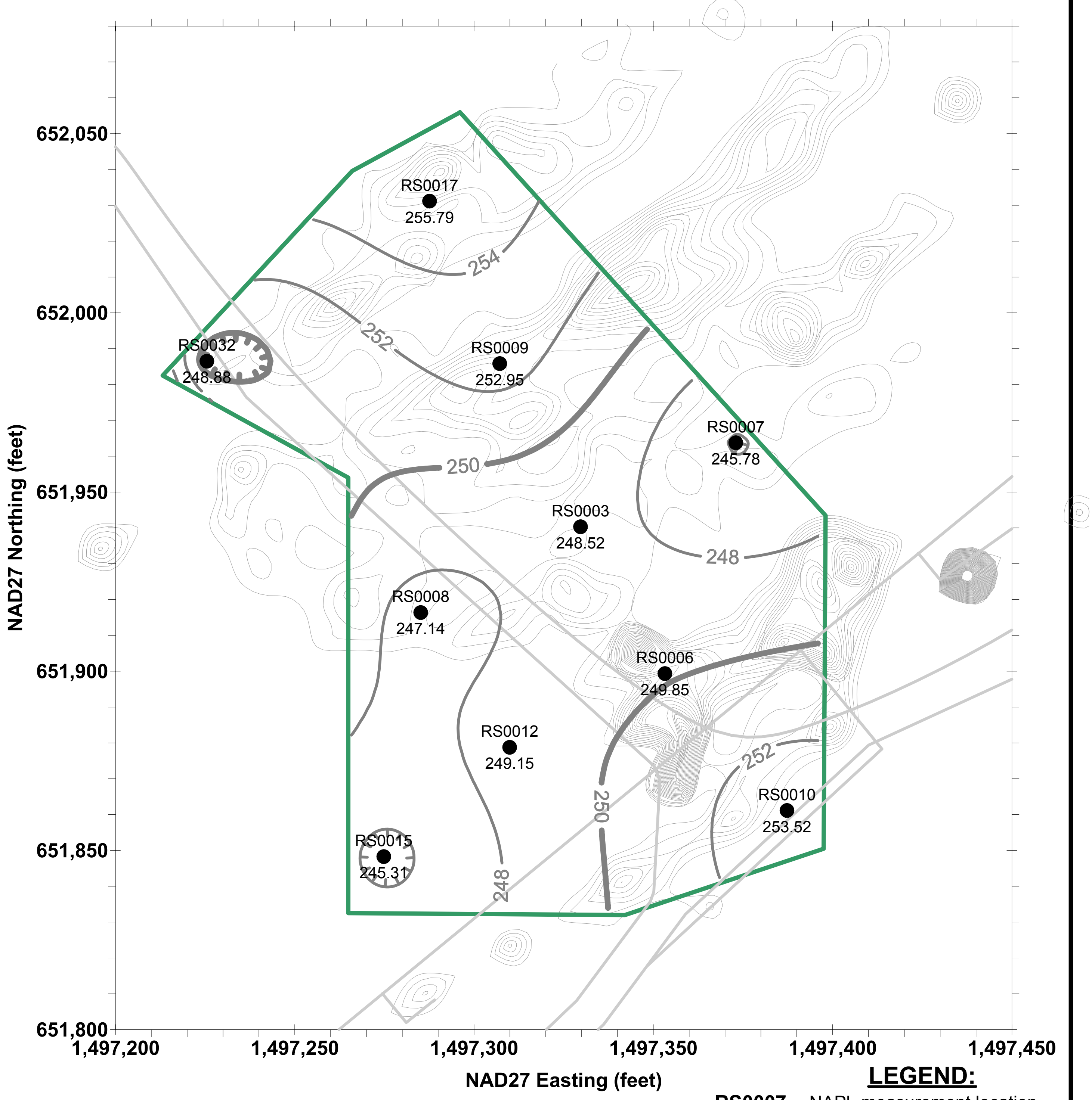
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Elevation of the Interpreted Upper Boundary of NAPL - NAPL Area 1

Fort Lewis	**Figure 5-22**	Washington



LEGEND:

RS0007 ● 267.2 NAPL measurement location with base of NAPL elevation (feet NGVD 29).

Base of NAPL elevation contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated base of NAPL elevation (feet NGVD 29) for NAPL Area 1.

2. Contour Interval is 2 feet.

3. Contours were computer generated by SURFER using linear kriging.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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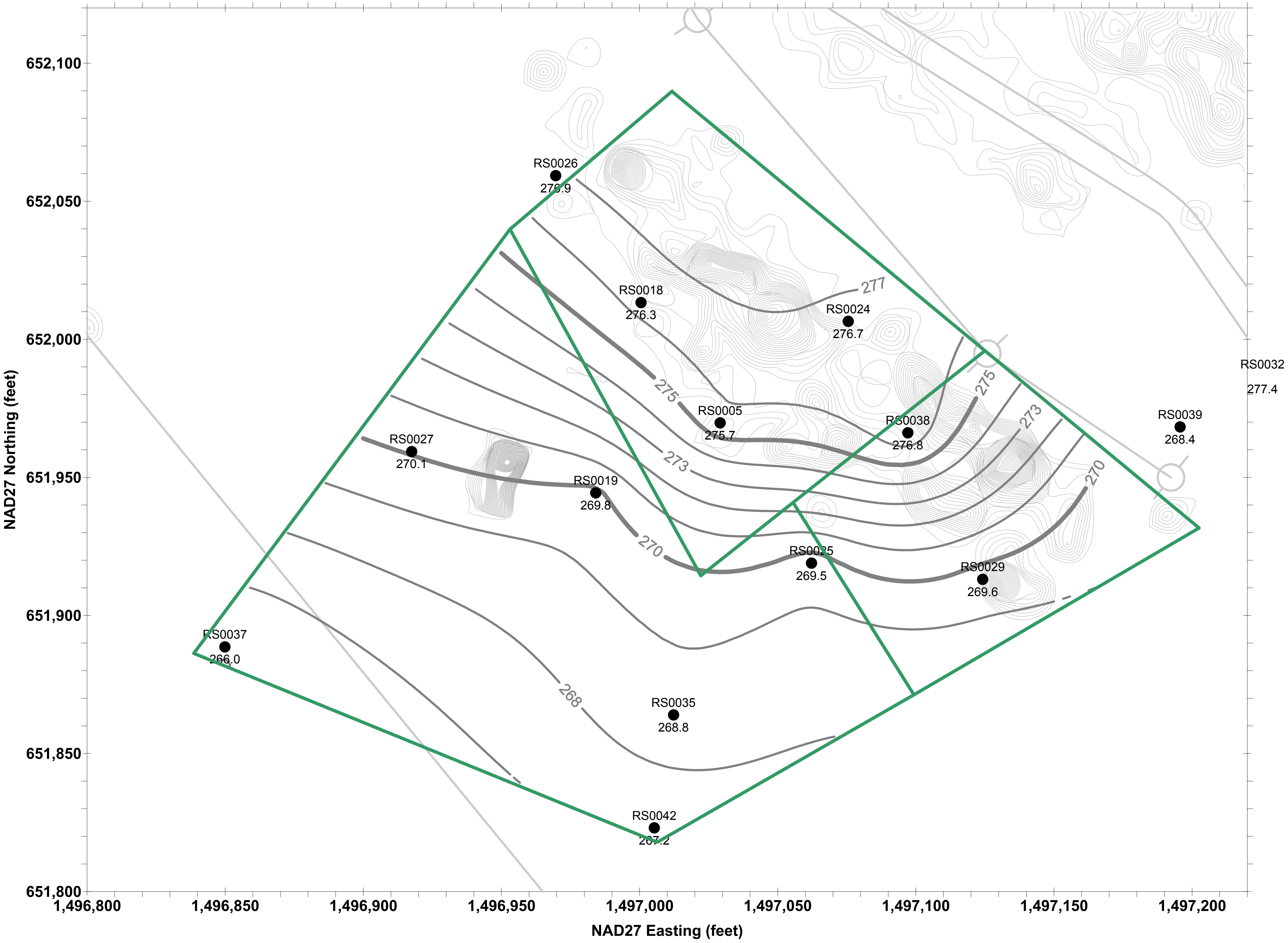
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Elevation of the Interpreted Lower Boundary of NAPL - NAPL Area 1

Fort Lewis	**Figure 5-23**	Washington



LEGEND:

RS0007 ● 267.2 NAPL measurement location with top of NAPL elevation (feet NGVD 29).

Top of NAPL elevation contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated top of NAPL elevation (feet NGVD 29) for NAPL Area 2.
2. Contour Interval is 1 foot.
3. Contours were computer generated by SURFER using linear kriging.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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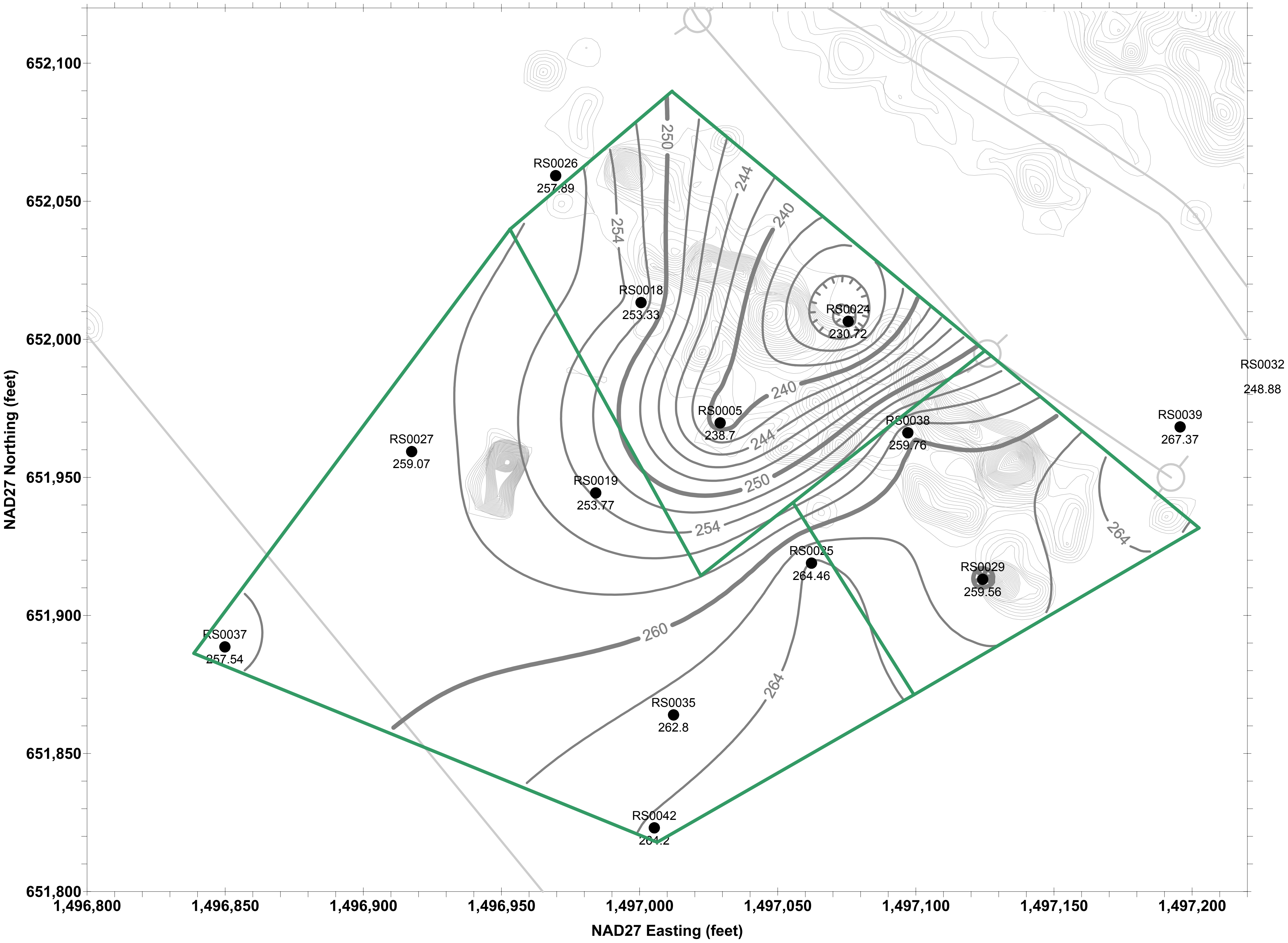
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Elevation of the Interpreted Upper Boundary of NAPL - NAPL Area 2

Fort Lewis	**Figure 5-24**	Washington



LEGEND:

RS0007 ● 267.2 — NAPL measurement location with base of NAPL elevation (feet NGVD 29).

Base of NAPL elevation contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated base of NAPL elevation (feet NGVD 29) for NAPL Area 2.
2. Contour Interval is 2 feet.
3. Contours were computer generated by SURFER using linear kriging.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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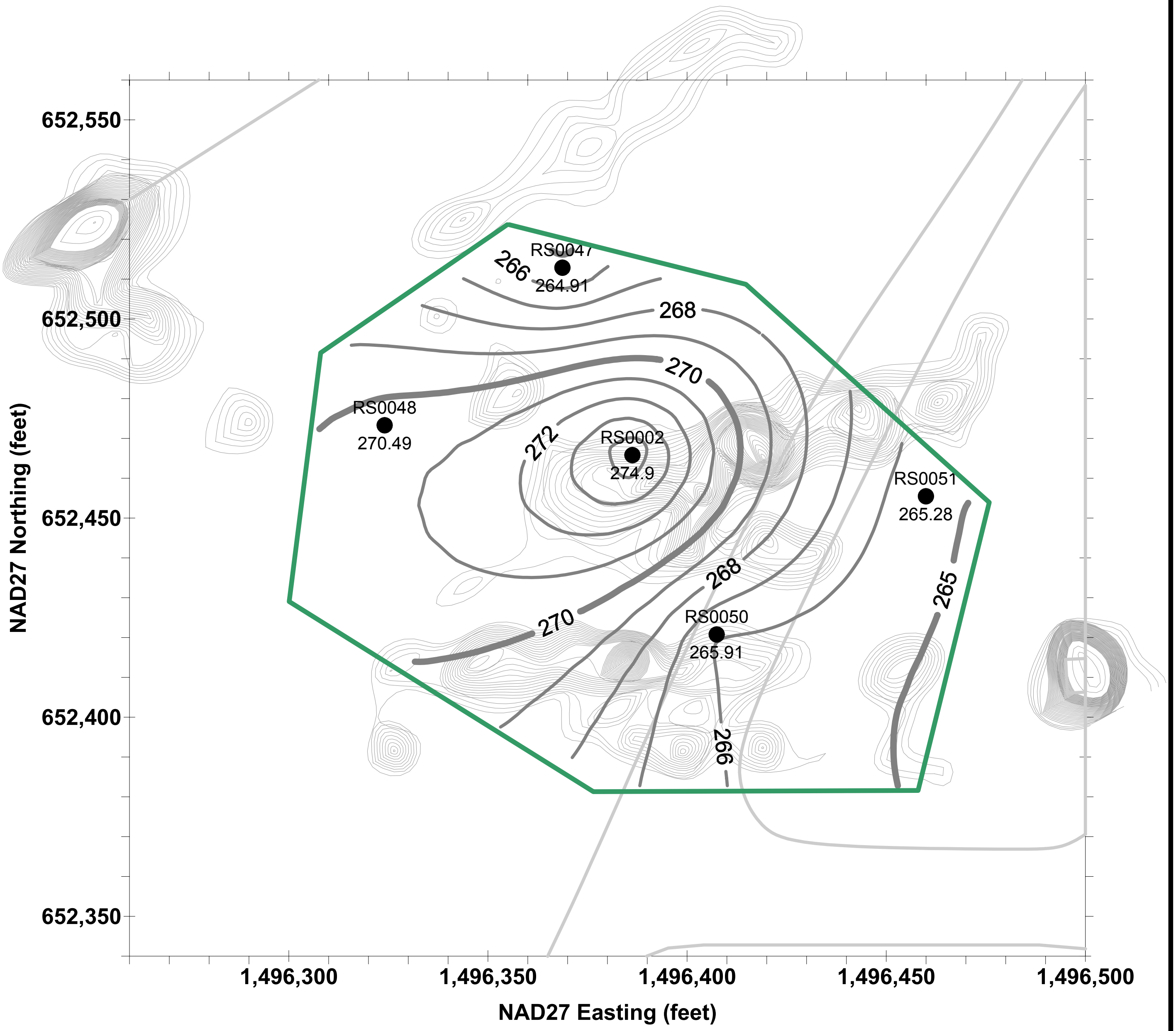
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Surface Elevation of the Interpreted Lower Boundary of NAPL - NAPL Area 2

Fort Lewis	**Figure 5-25**	Washington



LEGEND:

RS0007 ● 267.2 NAPL measurement location with top of NAPL elevation (feet NGVD 29).

Top of NAPL elevation contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated top of NAPL elevation (feet NGVD 29) for NAPL Area 3.

2. Contour Interval is 1 foot.

3. Contours were computer generated by SURFER using linear kriging.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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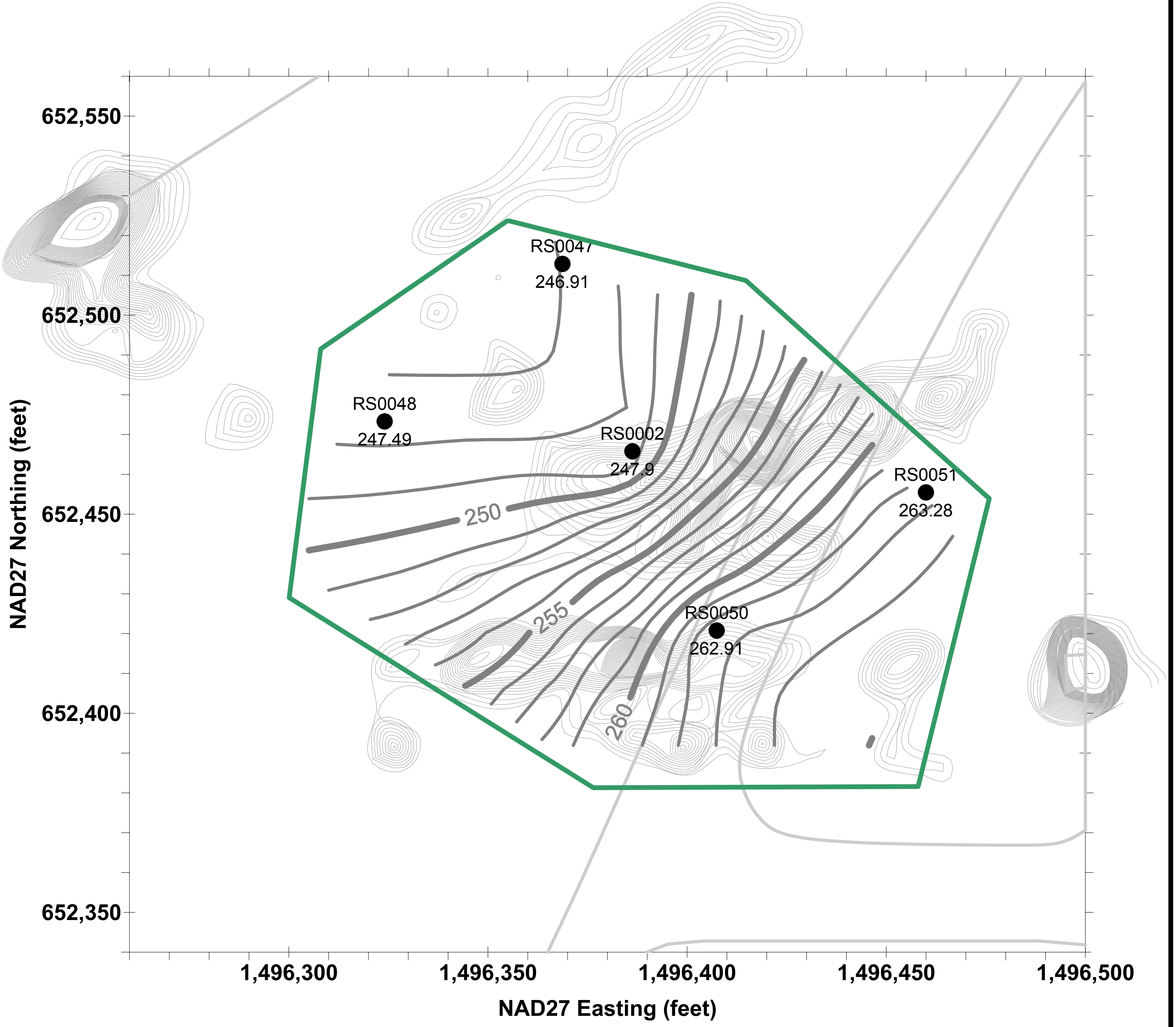
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Elevation of the Interpreted Upper Boundary of NAPL - NAPL Area 3

Fort Lewis	**Figure 5-26**	Washington



LEGEND:

RS0007 ● 267.2	NAPL measurement location with bottom of NAPL elevation (feet NGVD 29).
∼	Bottom of NAPL elevation contour.
⬠	NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated base of NAPL elevation (feet NGVD 29) for NAPL Area 3.

2. Contour Interval is 1 foot.

3. Contours were computer generated by SURFER using linear kriging.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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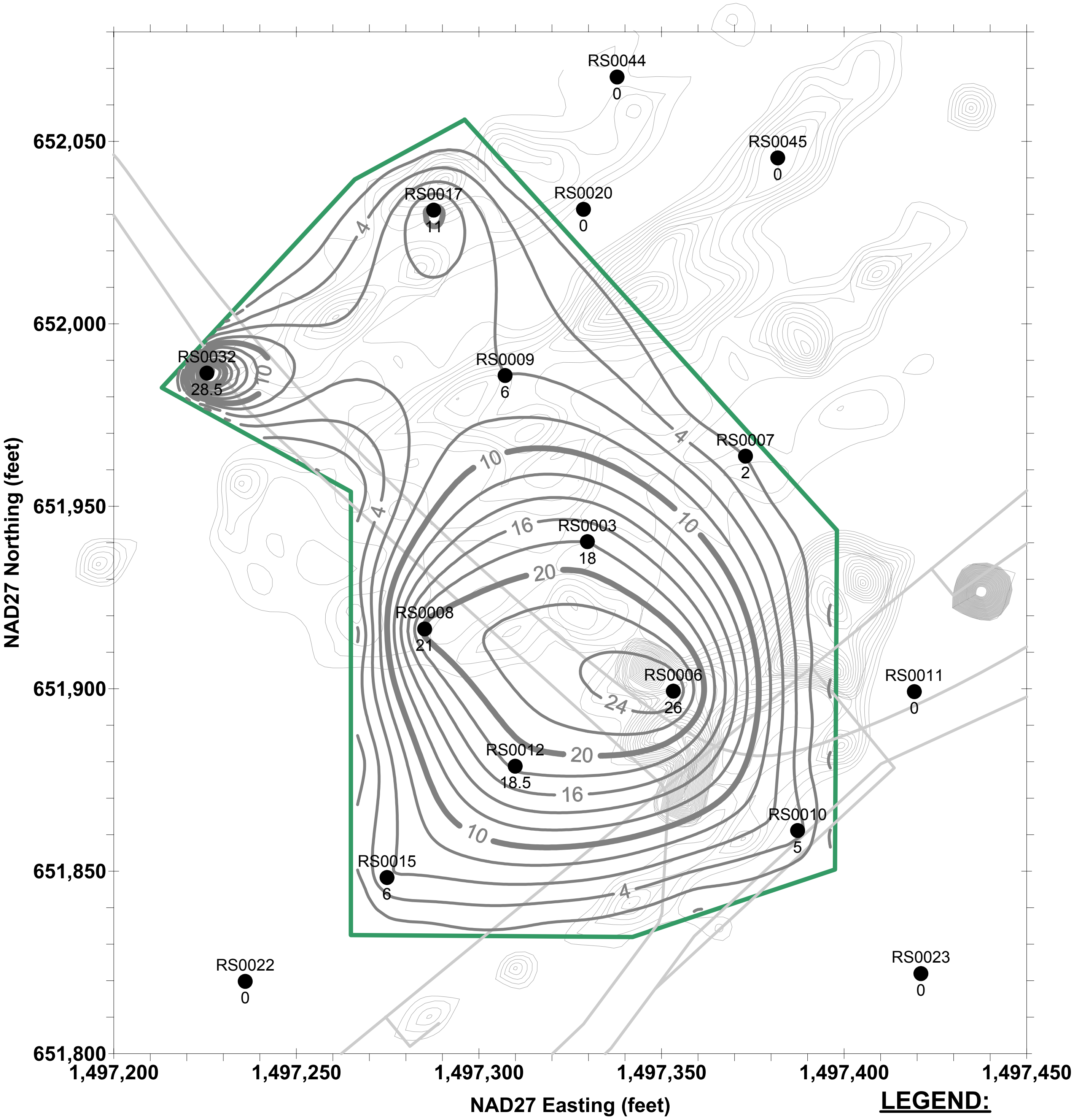
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Surface Elevation of the Interpreted Lower Boundary of NAPL - NAPL Area 3

Fort Lewis	**Figure 5-27**	Washington



LEGEND:

RS0007 ● 267.2	NAPL measurement location with estimated net NAPL thickness (feet).
∿	NAPL thickness contour.
⬠	NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated net NAPL thickness(feet) for NAPL Area 1.

2. Contour Interval is 2 feet.

3. Contours were computer generated by SURFER using linear kriging.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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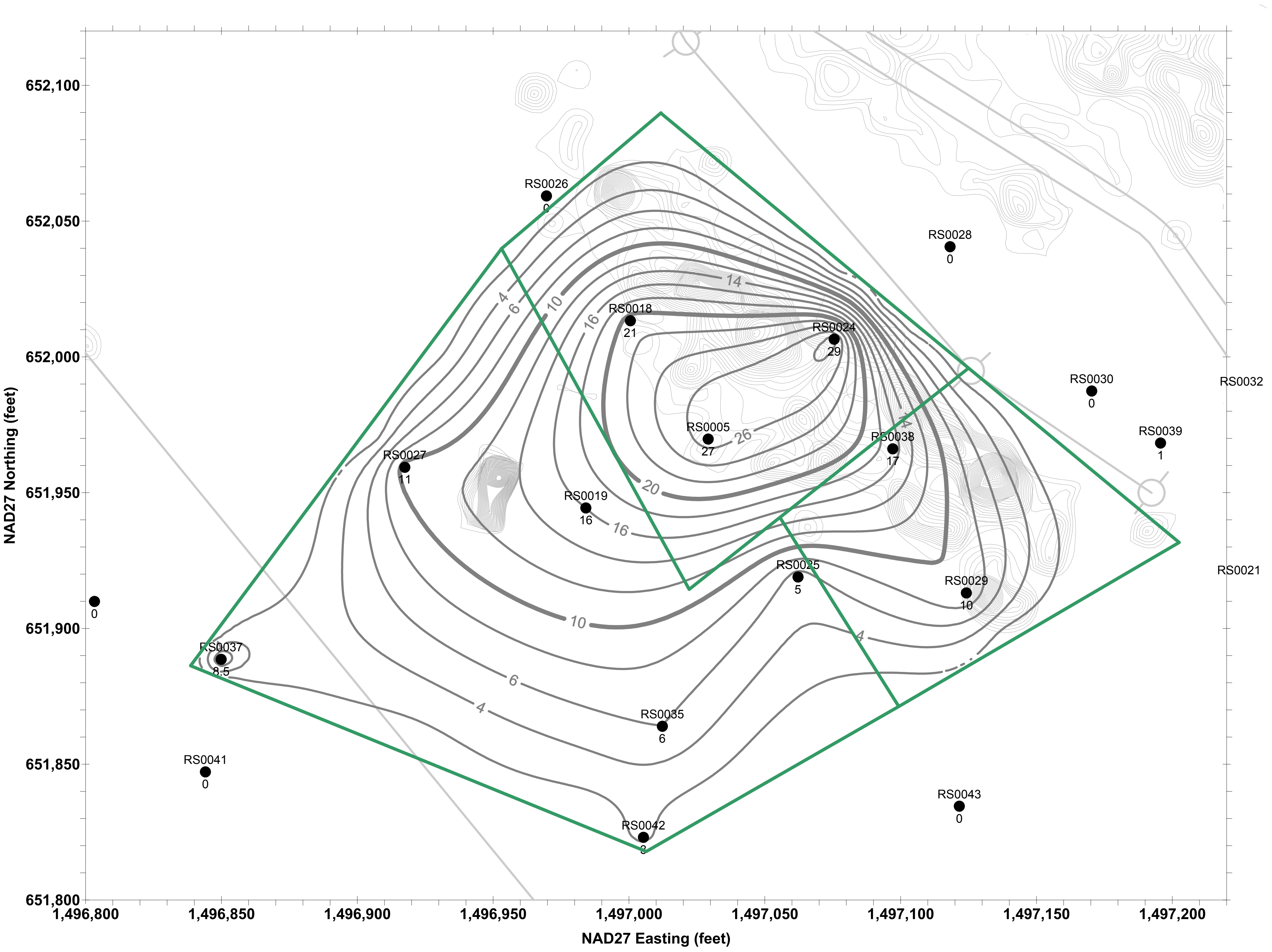
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Interpreted Net NAPL Thickness - NAPL Area 1

Fort Lewis	**Figure 5-28**	Washington



LEGEND:

RS0007 ● 267.2 — NAPL measurement location with estimated net NAPL thickness (feet).

NAPL thickness contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated net NAPL thickness (feet) for NAPL Area 2.
2. Contour Interval is 2 feet.
3. Contours were computer generated by SURFER using linear kriging.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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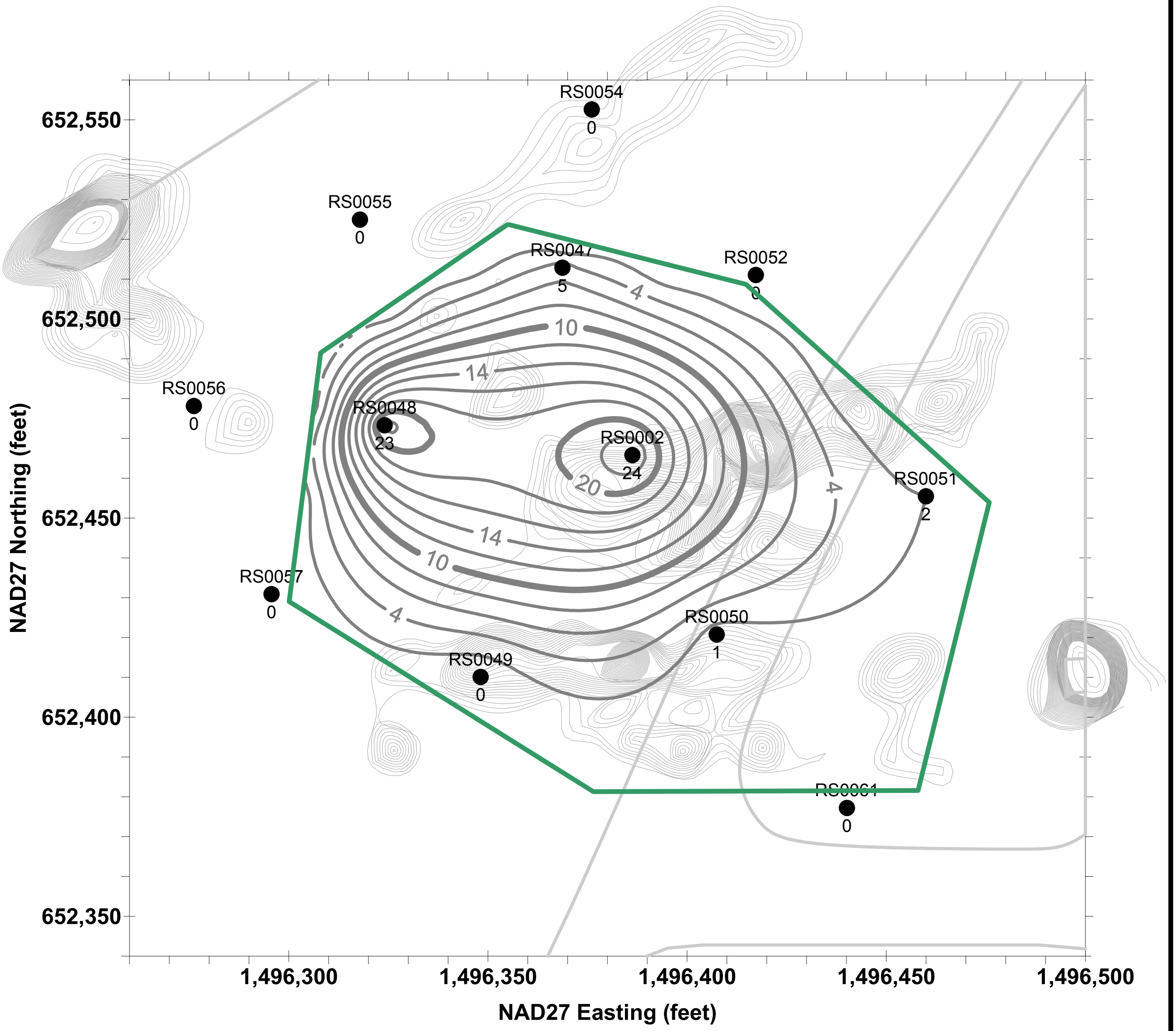
Fort Lewis Logistics Center Superfund Site

Interpreted Net NAPL Thickness - NAPL Area 2

Fort Lewis | **Figure 5-29** | Washington



LEGEND:

RS0007 ● 267.2 NAPL measurement location with estimated net NAPL thickness (feet).

NAPL thickness contour.

NAPL treatment area boundary.

NOTES:

1. Contour values represent estimated net NAPL thickness (feet) for NAPL Area 3.
2. Contour Interval is 2 feet.
3. Contours were computer generated by SURFER using linear kriging.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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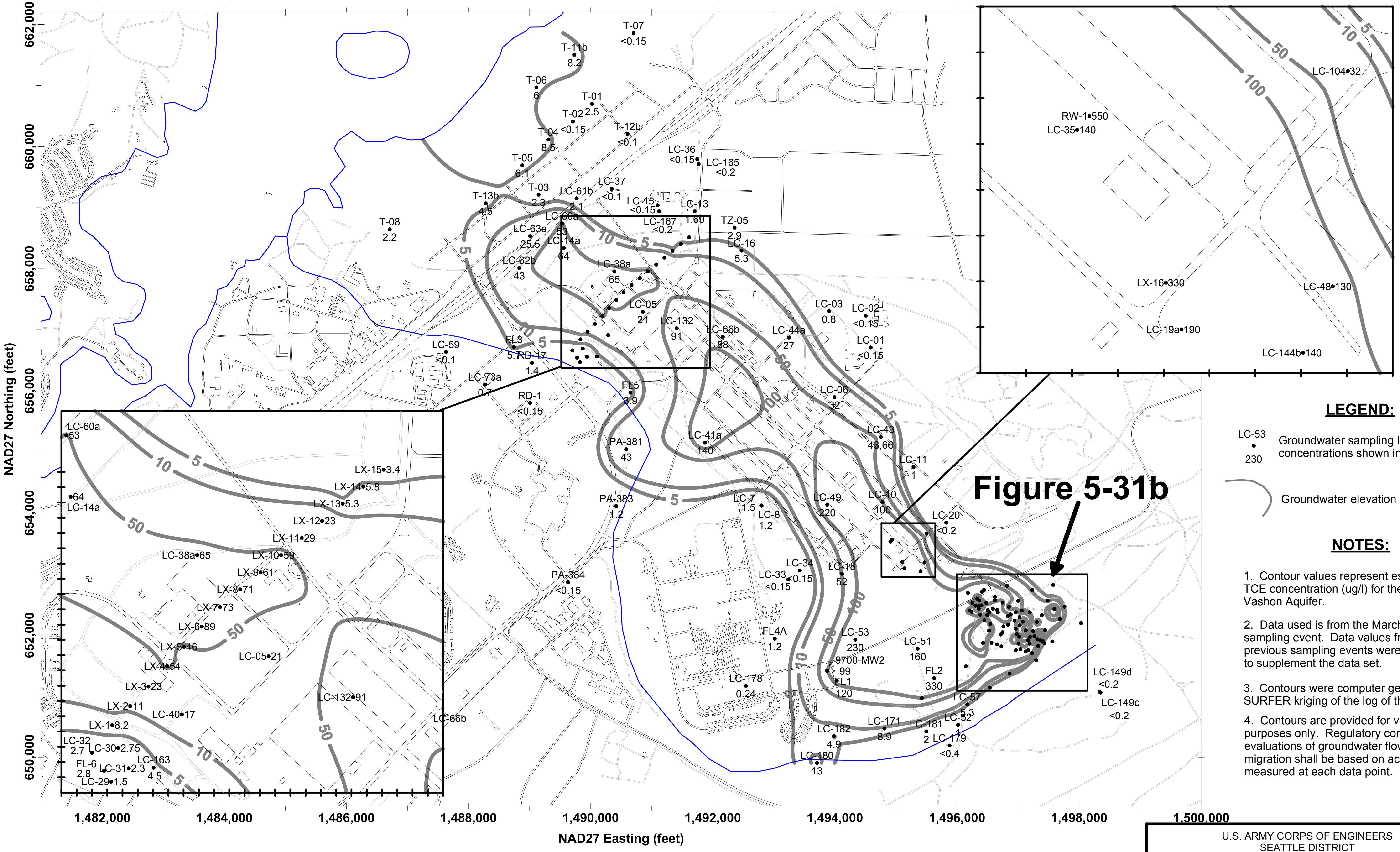
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Interpreted Net NAPL Thickness -
NAPL Area 3

Fort Lewis	**Figure 5-30**	Washington



LEGEND:

LC-53 ● 230 — Groundwater sampling location. TCE concentrations shown in ug/l.

Groundwater elevation contour.

NOTES:

1. Contour values represent estimated TCE concentration (ug/l) for the Vashon Aquifer.
2. Data used is from the March, 2002 sampling event. Data values from previous sampling events were used to supplement the data set.
3. Contours were computer generated by SURFER kriging of the log of the data set.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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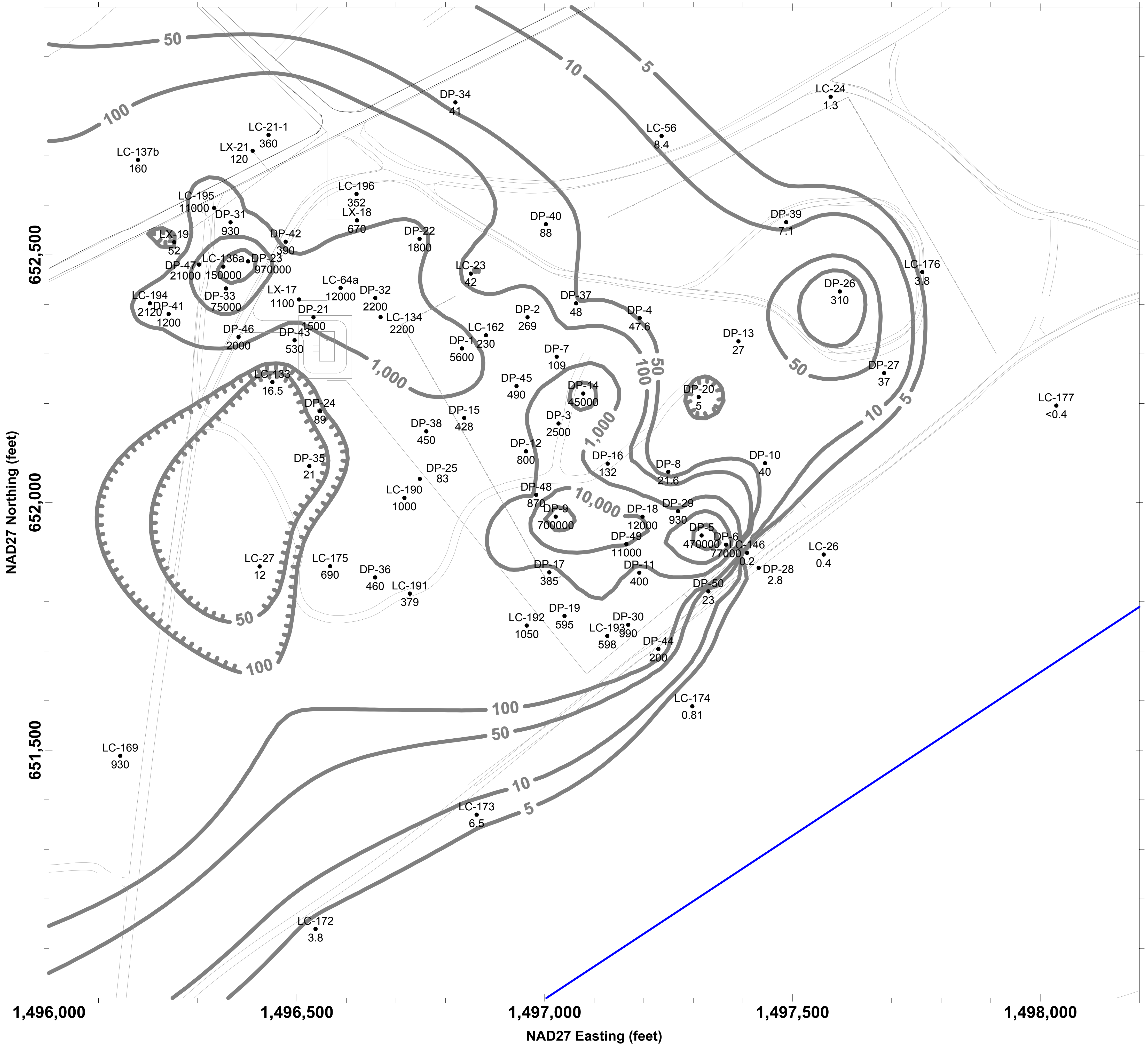
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Vashon Aquifer TCE Plume Map - March 2002

Fort Lewis | **Figure 5-31a** | Washington



LEGEND:

LC-53 ● 230	Groundwater sampling location. TCE concentrations shown in ug/l.
⌒	Groundwater elevation contour.

NOTES:

1. Contour values represent estimated TCE concentration (ug/l) for the Vashon Aquifer.
2. Data used is from the March, 2002 sampling event. Data values from previous sampling events were used to supplement the data set.
3. Contours were computer generated by SURFER kriging of the log of the data set.
4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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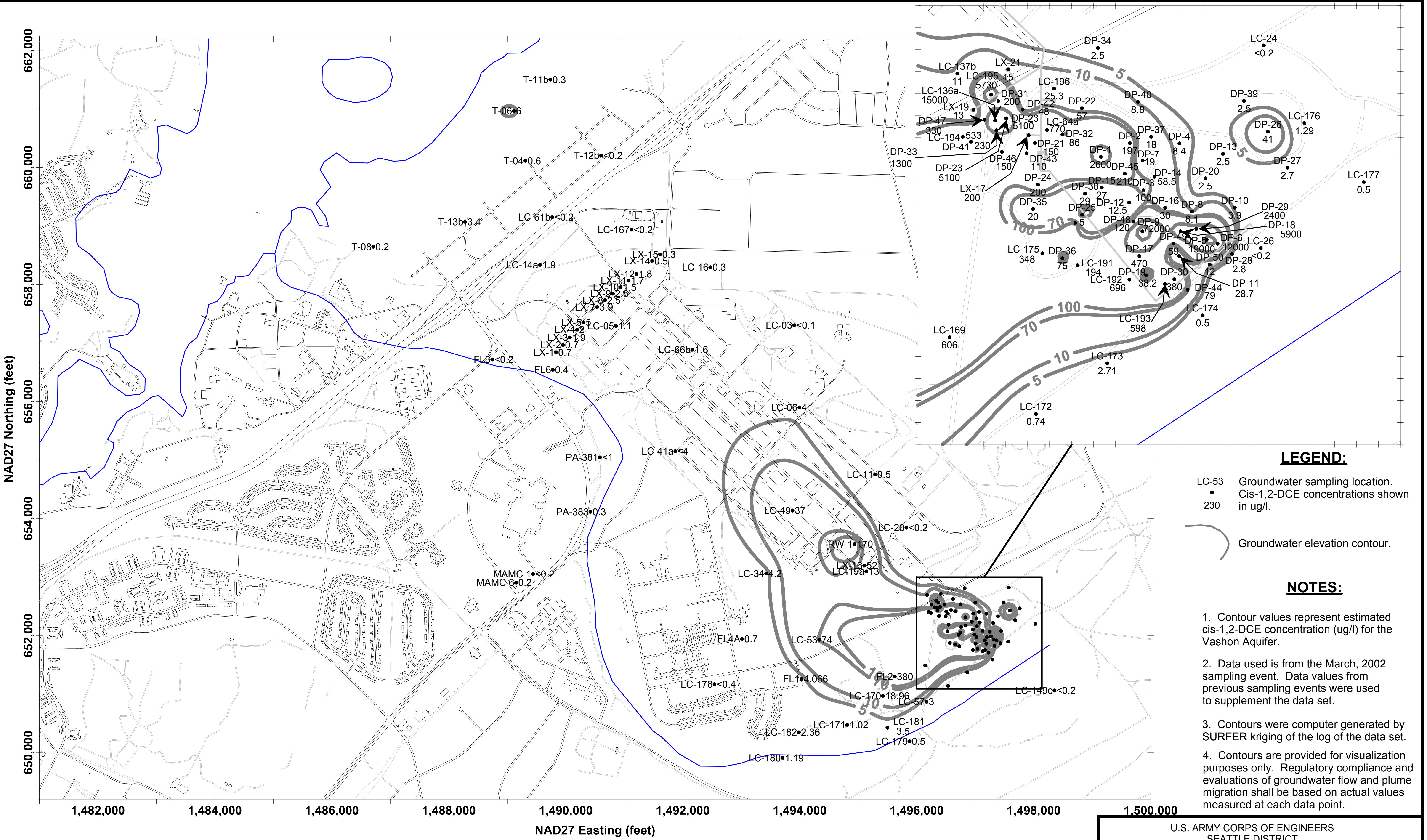
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Vashon Aquifer TCE Plume Map - March 2002 (EDGY Inset)

Fort Lewis | **Figure 5-31b** | Washington



LEGEND:

LC-53 • 230	Groundwater sampling location. Cis-1,2-DCE concentrations shown in ug/l.
	Groundwater elevation contour.

NOTES:

1. Contour values represent estimated cis-1,2-DCE concentration (ug/l) for the Vashon Aquifer.

2. Data used is from the March, 2002 sampling event. Data values from previous sampling events were used to supplement the data set.

3. Contours were computer generated by SURFER kriging of the log of the data set.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluations of groundwater flow and plume migration shall be based on actual values measured at each data point.

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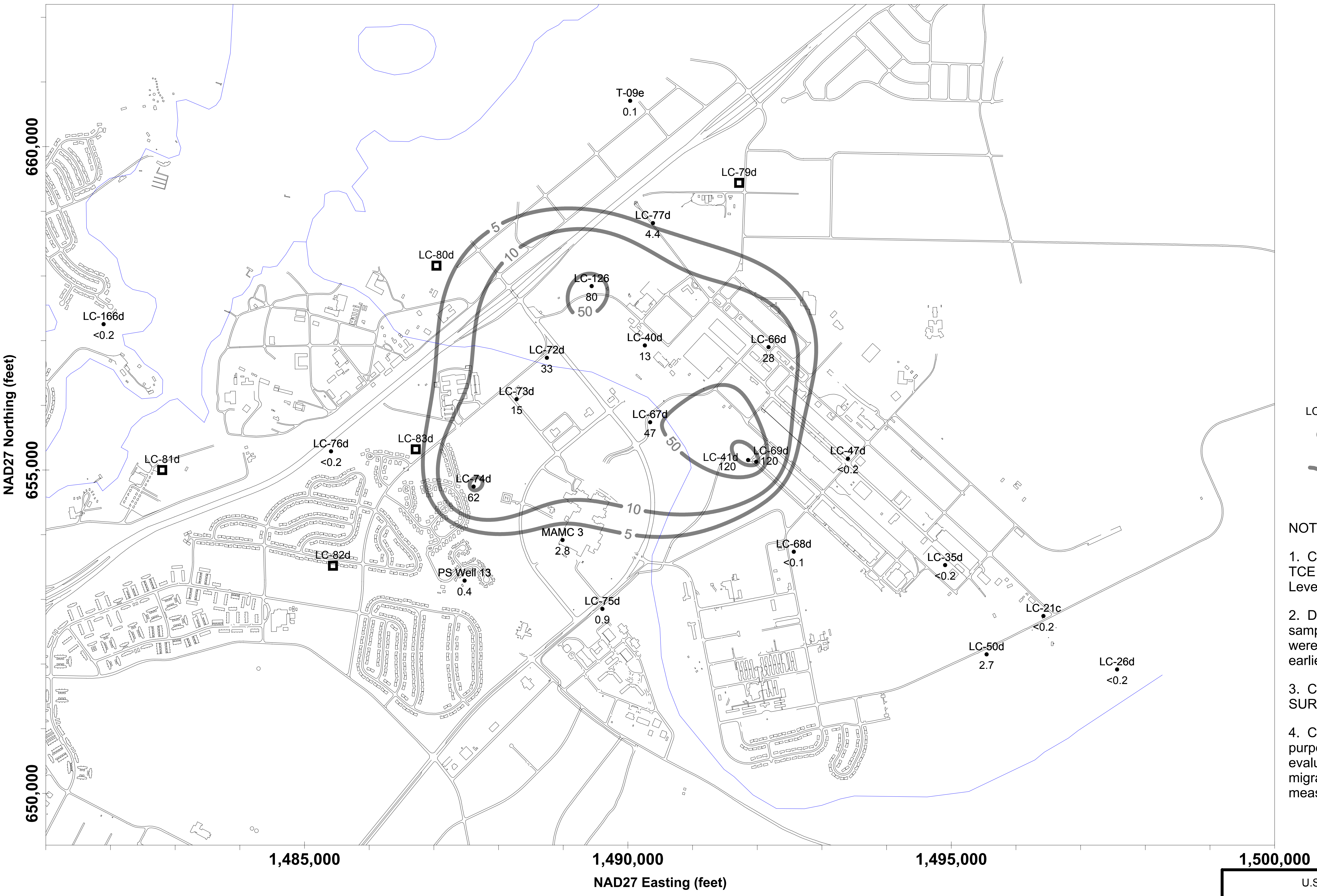
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site
Vashon Aquifer cis-1,2-DCE Plume Map - March 2002

Fort Lewis	**Figure 5-32**	Washington



LEGEND:

□ New Lower Aquifer well

LC-76D
● 0.8 March 2002 groundwater sampling point. TCE concentration values shown in ug/l.

Groundwater TCE concentration contour.

NOTES:

1. Contour values represent estimated TCE concentrations (ug/l) for the Sea Level Aquifer.

2. Data used is from the March 2002 sampling event. The March 2002 data were supplemented with data values from earlier sampling events.

3. Contours were computer generated by SURFER kriging of the log of the data set.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluation of groundwater flow and plume migration shall be based on actual values measured at each data point.

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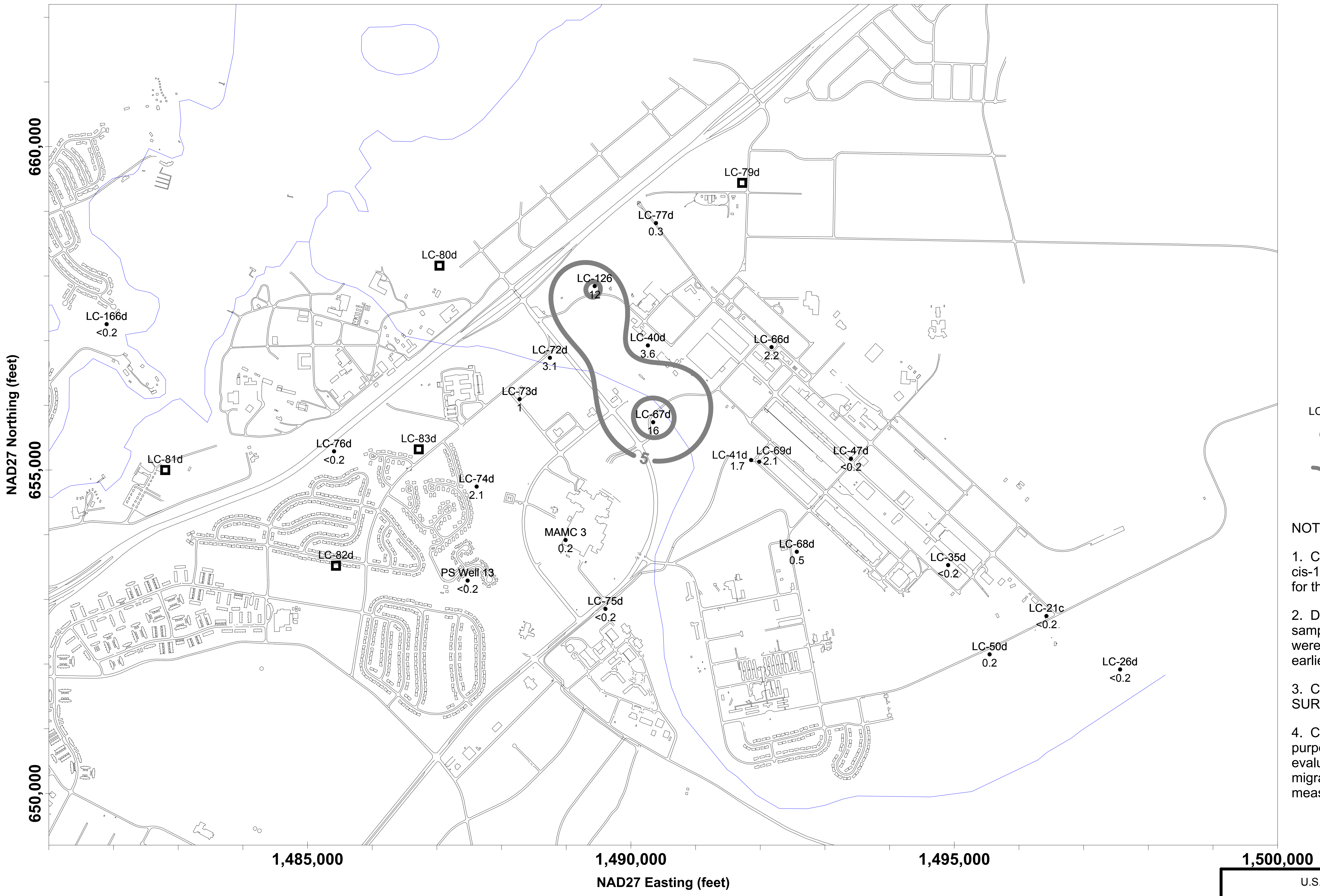
EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Sea Level Aquifer TCE Plume Map - March 2002

Fort Lewis | **Figure 5-33** | Washington



LEGEND:

▫ New Lower Aquifer well. Locations approximate pending survey.

LC-76D • 0.8 March 2002 groundwater sampling point. Cis-1,2-DCE concentration values shown in ug/l.

⌒ Groundwater cis-1,2-DCE concentration contour.

NOTES:

1. Contour values represent estimated cis-1,2-DCE concentrations (ug/l) for the Sea Level Aquifer.

2. Data used is from the March 2002 sampling event. The March 2002 data were supplemented with data values from earlier sampling events.

3. Contours were computer generated by SURFER kriging of the log of the data set.

4. Contours are provided for visualization purposes only. Regulatory compliance and evaluation of groundwater flow and plume migration shall be based on actual values measured at each data point.

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EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

Sea Level Aquifer cis-1,2-DCE Plume Map - March 2002

Fort Lewis

Figure 5-34

Washington

Table 5-1
STRATIGRAPHIC CONTACT ELEVATION DATA FOR SELECTED SITE BOREHOLES

Boring ID	Northing	Easting	Ground Surface	Top Vashon Till/Silt	Bottom Vashon Till/Silt	Thickness Vashon Till/Silt	Base Qv	Top Qpon
	(feet, NAD27)		Elevation (feet, NGVD 29)					
RS0001	652171	1496788	277.93	247.9	231.4	16.5	IND	173.4
RS0002	652466	1496386	276.90	235.9	230.9	5.0	IND	173.4
RS0003	651940	1497330	277.52	245.5	<240.52	>5.00	IND	IND
RS0004	652219	1497054	279.03	248.0	213.0	35.0	IND	175.5
RS0005	651970	1497029	277.70	241.7	220.7	21.0	IND	169.7
RS0006	651899	1497353	276.85	243.9	224.9	19.0	IND	172.9
RS0007	651964	1497373	276.78	247.8	231.3	16.5	IND	IND
RS0008	651916	1497285	278.14	245.1	235.1	10.0	IND	175.1
RS0009	651986	1497307	277.95	253.0	<232.95	>20.00	IND	IND
RS0010	651861	1497387	278.52	246.0	<237.52	>8.50	IND	IND
RS0011	651899	1497419	277.12	249.6	<236.12	>13.50	IND	IND
RS0012	651879	1497310	277.65	252.2	234.7	17.5	IND	IND
RS0013	651878	1497256	279.67	248.2	244.7	3.5	IND	IND
RS0014	651956	1497254	278.11	<236.11	<236.11	>0.00	IND	IND
RS0015	651848	1497275	279.31	245.3	<227.31	>18.00	IND	IND
RS0016	651829	1497343	279.69	247.7	<238.69	>9.00	IND	IND
RS0017	652031	1497288	277.79	252.8	<236.79	>16.00	IND	IND
RS0018	652013	1497001	277.33	241.8	233.8	8.0	IND	IND
RS0019	651944	1496984	277.77	250.8	237.8	13.0	IND	163.3
RS0020	652031	1497329	278.71	244.7	240.7	4.0	IND	IND
RS0021	651917	1497225	278.71	<238.71	<238.71	>0.00	IND	IND
RS0022	651820	1497236	282.20	244.2	<236.20	>8.00	IND	IND
RS0023	651822	1497421	278.06	252.1	<238.06	>14.00	IND	IND
RS0024	652007	1497076	276.72	240.7	210.7	30.0	IND	173.7
RS0025	651919	1497062	278.46	240.5	228.5	12.0	IND	IND
RS0026	652059	1496970	276.89	231.9	<219.89	>12.00	IND	IND
RS0027	651959	1496918	278.07	252.1	<218.07	>34.00	IND	IND
RS0028	652041	1497118	277.54	245.5	<217.54	>28.00	IND	IND
RS0029	651913	1497124	276.56	247.1	228.6	18.5	IND	IND
RS0030	651987	1497170	277.33	241.8	228.8	13.0	IND	IND
RS0031	652051	1497045	276.67	240.7	<219.67	>21.00	IND	IND
RS0032	651987	1497225	277.38	240.4	<217.38	>23.00	IND	IND
RS0033	652019	1496927	277.25	244.3	229.8	14.5	IND	IND
RS0034	651964	1496861	278.36	251.4	226.4	25.0	IND	IND
RS0035	651864	1497012	282.80	243.8	<222.80	>21.00	IND	IND
RS0036	651831	1496919	283.61	250.6	242.1	8.5	IND	IND
RS0037	651889	1496850	283.54	242.5	<223.54	>19.00	IND	IND
RS0038	651966	1497097	276.76	240.3	<216.76	>23.50	IND	IND
RS0039	651968	1497196	277.37	239.9	226.9	13.0	IND	IND
RS0040	651910	1496803	283.68	245.7	<223.68	>22.00	IND	IND
RS0041	651847	1496844	283.30	246.8	<223.30	>23.50	IND	IND
RS0042	651823	1497005	283.70	253.7	<223.70	>30.00	IND	IND
RS0043	651835	1497122	281.83	243.8	233.8	10.0	IND	IND
RS0044	652068	1497338	278.28	234.8	<218.28	>16.50	IND	IND

Table 5-1 (Continued)
STRATIGRAPHIC CONTACT ELEVATION DATA FOR SELECTED SITE BOREHOLES

	Northing	Easting	Ground Surface	Top Vashon Till/Silt	Bottom Vashon Till/Silt	Thickness Vashon Till/Silt	Base Qv	Top Qpon
Boring ID	(feet, NAD27)		Elevation (feet, NGVD 29)					
RS0045	652045	1497382	279.04	240.5	226.0	14.5	IND	IND
RS0046	651905	1497168	278.22	241.2	228.2	13.0	IND	IND
RS0047	652513	1496369	276.91	229.9	227.9	2.0	IND	168.9
RS0048	652473	1496324	277.49	235.5	227.5	8.0	IND	IND
RS0049	652410	1496348	277.34	239.3	229.3	10.0	IND	IND
RS0050	652421	1496407	276.91	241.9	227.4	14.5	IND	175.4
RS0051	652455	1496460	277.28	233.3	227.3	6.0	IND	IND
RS0052	652511	1496417	276.06	238.1	234.1	4.0	IND	IND
RS0053	652355	1496681	276.09	245.1	229.6	15.5	IND	IND
RS0054	652553	1496376	276.39	Not Present	Not Present	Not Present	IND	IND
RS0055	652525	1496318	277.69	Not Present	Not Present	Not Present	IND	IND
RS0056	652478	1496276	277.46	Not Present	Not Present	Not Present	IND	IND
RS0057	652431	1496296	278.31	236.3	228.3	8.0	IND	IND
RS0058	652412	1496606	275.55	239.6	232.1	7.5	IND	IND
RS0059	652379	1496638	274.94	239.9	229.9	10.0	IND	169.4
RS0060	652424	1496689	275.61	228.6	220.6	8.0	IND	IND
RS0061	652377	1496440	275.74	240.7	<238.74	>2.00	IND	IND
RS0062	652513	1496734	280.25	237.2	206.2	31.0	IND	IND
RS0063	652284	1496869	276.68	247.2	212.7	34.5	IND	IND
RS0064	652371	1497258	282.01	241.5	220.0	21.5	IND	178.5
RS0065	652092	1497209	277.44	242.9	<223.44	>19.50	IND	IND
RS0066	652150	1497032	278.01	244.0	<221.01	>23.00	IND	IND
RS0067	652470	1496683	276.71	244.7	221.2	23.5	IND	IND
RS0068	652392	1496722	276.70	232.7	219.7	13.0	IND	IND
RS0069	652472	1496743	280.32	245.8	223.8	22.0	IND	IND
RS0070	652009	1496717	279.42	226.4	219.9	6.5	IND	172.4
RS0071	651816	1496728	282.62	246.6	237.6	9.0	IND	168.6
RS0072	651752	1496964	283.13	252.1	249.1	3.0	IND	175.6
RS0073	651731	1497126	283.79	254.8	250.3	4.5	IND	173.3
RS0074	652402	1496204	276.73	232.7	228.2	4.5	IND	167.2
RS0075	652594	1496333	278.23	Not Present	Not Present	Not Present	IND	166.2
RS0076	652623	1496620	279.25	241.7	234.7	7.0	IND	169.7
LC-26D	651917	1497564	276.89	262.9	228.9	34.0	186.0	IND
LC-64B	652424	1496580	276.63	243.6	237.6	6.0	IND	IND
LC-136B	652486	1496355	277.60	235.6	230.6	5.0	IND	IND
LR-1	651808	1497288	281.87	267.9	247.9	20.0	IND	IND
LR-2	651988	1497528	278.58	259.6	220.1	39.5	IND	IND
LX-18	652569	1496621	279.09	238.1	<235.09	>3.00	IND	IND
LC-79D	659440	1491720	272.00	IND	IND	IND	127.0	113.0
LC-80D	658160	1487040	280.00	IND	IND	IND	198.0	124.0
LC-81D	655000	1482800	280.00	IND	IND	IND	IND	122.0
LC-82D	653520	1485440	280.00	IND	IND	IND	IND	121.0
LC-83D	655320	1486720	280.00	IND	IND	IND	144.0	124.5

Table 5-1 (Continued)
STRATIGRAPHIC CONTACT ELEVATION DATA FOR SELECTED SITE BOREHOLES

	Northing	Easting	Ground Surface	Top Vashon Till/Silt	Bottom Vashon Till/Silt	Thickness Vashon Till/Silt	Base Qv	Top Qpon
Boring ID	**(feet, NAD27)**		**Elevation (feet, NGVD 29)**					
DA-02	659250	1502672	IND	IND	IND	IND	215.0	IND
DA-04	658044	1500926	IND	IND	IND	IND	223.0	IND
DA-07	660135	1500344	IND	IND	IND	IND	200.0	IND
DA-08	659091	1499776	IND	IND	IND	IND	204.0	IND
DA-11	660912	1498687	IND	IND	IND	IND	198.0	IND
DA-12	660600	1497486	IND	IND	IND	IND	167.0	IND
DA-12E	660550	1497151	IND	IND	IND	IND	174.0	IND
DA-15	664272	1497688	IND	IND	IND	IND	192.0	IND
DA-16	659968	1495541	IND	IND	IND	IND	<122	IND
DA-26	663535	1497677	IND	IND	IND	IND	184.0	IND
DA-17	661732	1495595	IND	IND	IND	IND	111.0	IND
DA-18	658562	1497141	IND	IND	IND	IND	208.0	IND
DA-20	659706	1492975	IND	IND	IND	IND	62.0	IND
DA-24	661312	1496692	IND	IND	IND	IND	219.0	IND
DA-25	660324	1499246	IND	IND	IND	IND	217.0	IND
DZ-01	661521	1501278	IND	IND	IND	IND	199.0	IND
DZ-06	660491	1498243	IND	IND	IND	IND	217.0	IND
DZ-09	660824	1499879	IND	IND	IND	IND	224.0	IND
DZ-10	661820	1498799	IND	IND	IND	IND	212.0	IND
GC	659610	1501870	IND	IND	IND	IND	214.0	IND
LC-21C	652743	1496426	279.89	IND	IND	IND	210.0	IND
LC-35D	653530	1494905	288.00	IND	IND	IND	92.0	IND
LC-40D	656927	1490263	277.30	IND	IND	IND	185.0	IND
LC-41E	655154	1491859	281.69	IND	IND	IND	144.0	IND
LC44C	656849	1493259	271.24	IND	IND	IND	201.0	IND
LC-50D	652150	1495547	271.68	IND	IND	IND	178.0	IND
LC-66D	656900	1492176	281.56	IND	IND	IND	194.0	IND
LC-67D	655739	1490344	264.18	IND	IND	IND	195.0	IND
LC-68D	653737	1492566	IND	IND	IND	IND	83.0	IND
LC-69D	655128	1491985	282.20	IND	IND	IND	123.0	IND
LC-70D	655182	1491765	280.70	IND	IND	IND	181.0	IND
LC-71D	657746	1489355	269.50	IND	IND	IND	173.0	IND
LC-72D	656736	1488749	263.90	IND	IND	IND	159.0	IND
LC-73D	656095	1488280	269.60	IND	IND	IND	176.0	IND
LC-75D	652853	1489607	278.60	IND	IND	IND	213.6	IND
LC-76D	655289	1485410	279.14	IND	IND	IND	149.1	IND
LC-77D	658818	1490388	275.42	IND	IND	IND	168.4	IND
LZ-04	657762	1496750	277.20	IND	IND	IND	199.0	IND
MAMC 4/6	653500	1489500	IND	IND	IND	IND	217.0	IND
O'NIEL & MARTIN	658208	1494040	IND	IND	IND	IND	50.0	IND
POE & MCGUIRE	660200	1493712	IND	IND	IND	IND	46.0	IND
RD-1	655799	1489009	272.30	IND	IND	IND	184.0	IND
RD-2	654908	1490076	IND	IND	IND	IND	166.0	IND

Table 5-1 (Continued)
STRATIGRAPHIC CONTACT ELEVATION DATA FOR SELECTED SITE BOREHOLES

Boring ID	Northing	Easting	Ground Surface	Top Vashon Till/Silt	Bottom Vashon Till/Silt	Thickness Vashon Till/Silt	Base Qv	Top Qpon
	(feet, NAD27)		Elevation (feet, NGVD 29)					
Silcox Island	661600	1486600	245.00	IND	IND	IND	IND	IND
T-09E	660709	1490036	272.66	IND	IND	IND	180.0	IND
T-10	660316	1489689	270.65	IND	IND	IND	179.0	IND
W2	660136	1497878	IND	IND	IND	IND	208.0	IND
W3	660406	1497130	IND	IND	IND	IND	183.0	IND
W4	659961	1497137	IND	IND	IND	IND	201.0	IND
Well 8	653680	1493920	IND	IND	IND	IND	52.0	IND

Notes:
See Section 5.1 of this report for description of Qv and Qpon
IND = indeterminate (information not determined or not available)
NAD27 = North American Datum of 1927
NGVD 29 = National Geodetic Vertical Datum of 1929

Table 5-2
PUMPING TEST HYDRAULIC CONDUCTIVITY SUMMARY

Pumping Well	K_h (ft/day)	Kh/Kv
I-5 WELL FIELD		
LX-1	96	36
LX-2	53	9
LX-3	167	35
LX-4	248	28
LX-5	337	38
LX-6	511	99
LX-7	283	60
LX-8	377	39
LX-9	704	267
LX-10	561	312
LX-11	1,141	51
LX-12	691	37
LX-13	895	219
LX-14	585	36
LX-15	827	16
Average	**498**	**86**
SECONDARY EAST GATE WELL FIELD		
RW-1	168	94
LX-16	238	73
Average	**203**	**83**
PRIMARY EAST GATE WELL FIELD		
LX-17	37	12
LX-18	16	24
LX-19	114	159
LX-21	50	N/D
Average	**54**	**65**
EAST GATE RECHARGE WELL FIELD		
LR-1	232	163
LR-2	171	60
Average	**201**	**112**

Notes:
ft/day = feet per day
K_h = horizontal hydraulic conductivity
K_v = vertical hydraulic conductivity
N/D = not determined

Table 5-3
TRACER TEST HYDRAULIC CONDUCTIVITY SUMMARY

Upgradient Measurement Point				Downgradient Measurement Point					
	Easting	Northing	Depth[1]		Easting	Northing	Depth[1]	K_h	K_v
ID	(NAD27)		(feet)	ID	(NAD27)		(feet)	(ft/day)	(ft/day)
Gallery 5	1497382	651849		A15	1497340	651902	15	>840 to <2,400	
Gallery 5	1497382	651849		LC-145	1497307	651831	29-48.6		>8 to <19
Gallery 6	1497477	651959		LC-148	1497479	652045	29-49	>260 to <3,100	
Gallery 6	1497477	651959		LC-26	1497563	651895	11.5-36	>69 to <490	
Gallery 6	1497477	651959		Well 9	1497423	651922		>110	
Gallery 6	1497477	651959		LC-147	1497496	651963	29-49		>8 to <80
A15	1497340	651902	15	B15	1497276	651937	15	3,100	
B15	1497276	651937	15	C25	1497230	651965	25	2,300	
B15	1497276	651937	15	C40	1497235	651965	40	540	
LR-1	1497288	651808	78-108	LR-2	1497528	651988	68-98	2,300 to 3,800	
Well 9	1497423	651922		LC-146	1497408	651898	29.5-49.1		590

Notes:

Data summarized from USGS 1999: *A Tracer Test to Estimate Hydraulic Conductivities and Dispersivities of Sediment*
in the Shallow Aquifer at the East Gate Disposal Yard, Fort Lewis, Washington.
Water-Resources Investigations Report 99-4244

[1] Well screen depth interval (feet below ground surface); infiltration galleries 5 and 6 constructed above water table;
Well 9 is 30 feet deep - the screened interval is unknown

ft/day = feet per day

K_h = horizontal hydraulic conductivity

K_v = vertical hydraulic conductivity

NAD27 = North American Datum of 1927

Table 5-4
NAPL CHEMICAL COMPOSITION BY NAPL AREA

Boring Location	**RS0002**	**RS0003**	**RS0005**	**RS0006**	**RS0017**	**RS0018**	**RS0019**	**RS0024**	**RS0032**	**RS0038**	**RS0048**	**RS0062**	**RS0063**	**RS0064**
NAPL Area	**Area 1**	**Area 3**	**Area 2a**	**Area 1**	**Area 1**	**Area 2a**	**Area 2c**	**Area 2a**	**Area 1**	**Area 2b**	**Area 3**	**Und.**	**Und.**	**Und.**
VOCs Reported														
1,1,1-trichloroethane			x										x	
1,1-dichloroethane													x	
1,1-dichloroethene			x											
1,2,4-trimethylbenzene	x	x	x	x	x	x	x	x	x	x	x	x	x	x
1,2-dichlorobenzene			x				x							x
1,2-dichloroethane			x											
1,3,5-trimethylbenzene	x	x	x	x	x	x	x	x	x	x		x	x	
4-isopropyltoluene			x	x	x	x	x		x	x		x	x	
benzene	x		x											
carbon tetrachloride			x											
ethyl benzene			x	x	x				x	x		x	x	
isopropylbenzene			x	x	x					x				
m.p-xylene	x		x	x	x		x	x	x	x		x	x	
methylene chloride			x											
n-butylbenzene					x	x	x							
n-propylbenzene			x	x	x	x	x		x	x		x	x	
napthalene	x		x	x	x					x		x	x	
o-xylene			x	x	x	x		x	x	x		x	x	
sec-butylbenzene			x	x	x	x	x		x	x		x	x	
tetrachloroethene	x	x	x	x								x		
toluene	x		x							x			x	
trans 1,2-dichloroethene				x								x		
trans 1,3-dichloropropene	x													
vinyl chloride				x	x	x			x	x				

Notes:
NAPL = nonaqueous-phase liquid
Und. = undefined

Table 5-5
CALCULATED ANALYTE WEIGHT PERCENTAGES OF NAPL - NAPL AREA

Analyte	Weight (Mass) Percentage of NAPL
	Area 1
TPH-D	24.6%
TPH-O	57.7%
cis-1,2-DCE	5.5%
TCE	12.3%
TOTAL	100.0%

Notes:
Results based on 20 analytical results from 12 borings in NAPL Area 1
Percentage estimates assume 100% of contaminant mass comes from 4 analytes in table
Field duplicates averaged
Non-detects deleted (not included in averages)
cis-1,2-DCE = cis-1,2-dichloroethene
NAPL = nonaqueous-phase liquid
TCE = trichloroethene
TPH-D = total petroleum hydrocarbons - diesel
TPH-O = total petroleum hydrocarbons - oil

Table 5-6
CALCULATED ANALYTE WEIGHT PERCENTAGES OF NAPL - NAPL AREA

Analyte	Weight (Mass) Percentage of NAPL			
	Area 2a	Area 2b	Area 2c	Area 2
TPH-D	32.8%	39.8%	36.5%	35.0%
TPH-O	55.2%	60.0%	63.4%	58.9%
cis-1,2-DCE	0.5%	0.1%	0.04%	0.3%
TCE	11.5%	0.1%	0.01%	5.7%
TOTAL	100%	100%	100%	100.0%

Notes:
Results of NAPL Area 2a based on 9 analytical results from 4 borings in NAPL Area 2a
Results of NAPL Area 2b based on 4 analytical results from 2 borings in NAPL Area 2b
Results of NAPL Area 2c based on 11 analytical results from 6 borings in NAPL Area 2c
Results of NAPL Area 2 as a whole weighted based on volumetric percentages that each NAPL Area 2 portion contributes
Percentage estimates assume 100% of contaminant mass comes from 4 analytes in table
Field duplicates averaged
Non-detects deleted (not included in averages)
cis-1,2-DCE = cis-1,2-dichloroethene
NAPL = nonaqueous-phase liquid
TCE = trichloroethene
TPH-D = total petroleum hydrocarbons - diesel
TPH-O = total petroleum hydrocarbons - oil

Table 5-7
CALCULATED ANALYTE WEIGHT PERCENTAGES OF NAPL - NAPL AREA 3

Analyte	Weight (Mass) Percentage of NAPL
	Area 3
TPH-D	6.3%
TPH-O	27.5%
cis-1,2-DCE	3.5%
TCE	62.7%
TOTAL	100.0%

Notes:
Results based on 7 analytical results from 4 borings in NAPL Area 3
Percentage estimates assume 100% of contaminant mass comes from 4 analytes in table
Field duplicates averaged
Non-detects deleted (not included in averages)
cis-1,2-DCE = cis-1,2-dichloroethene
NAPL = nonaqueous-phase liquid
TCE = trichloroethene
TPH-D = total petroleum hydrocarbons - diesel
TPH-O = total petroleum hydrocarbons - oil

Table 5-8
ESTIMATED TOTAL AND COMPOUND-SPECIFIC VOLUME AND MASS OF NAPL CONTAMINATION BY NAPL AREA

NAPL Area	Volume (ft^3)	NAPL Volume			NAPL Mass		
		(ft^3)	(gal)	(liters)	(g)	(kg)	(lb)
1	235,047	3,526	26,407	99,953	95,668,806	95,669	210,910
2	462,463	6,937	51,958	196,661	181,296,552	181,297	399,684
3	122,028	1,830	13,710	51,892	64,628,823	64,629	142,480
TOTAL			90,000	300,000	300,000,000	300,000	800,000

NAPL Area	Volume by Compound						Mass by Compound					
	TPH		TCE		cis-1,2-DCE		TPH		TCE		cis-1,2-DCE	
	(gal)	(liters)	(gal)	(liters)	(gal)	(liters)	(kg)	(lb)	(kg)	(lb)	(kg)	(lb)
1	23,523	89,033	1,974	7,472	880	3,331	80,130	176,654	11,208	24,710	4,330	9,547
2	49,843	188,654	1,844	6,980	211	798	169,789	374,313	10,470	23,082	1,038	2,288
3	5,612	21,242	7,588	28,720	494	1,870	19,118	42,146	43,081	94,975	2,431	5,359
TOTAL	80,000	300,000	10,000	40,000	2,000	6,000	300,000	600,000	60,000	100,000	8,000	20,000

Notes:
Estimates assume mean porosity of 0.3 and NAPL saturation of 0.05
Estimates use analyte weight percentages provided in Tables 5-5, 5-6, and 5-7
Totals have been rounded to 1 significant digit
Units: ft^3 = cubic feet, gal = gallons, g = grams, kg = kilogram, lb = pound
cis-1,2-DCE = cis-1,2-dichloroethene
NAPL = nonaqueous-phase liquid
TCE = trichloroethene
TPH = total petroleum hydrocarbons

Table 5-9
TPH PRODUCT TYPES AND LOCATIONS

EGDY Area	Location	Product Type A	Product Type B	Product Type C	Product Type D
NAPL Treatment Area 1	RS0003	X		X	X
NAPL Treatment Area 1	RS0006	X		X	X
NAPL Treatment Area 1	RS0006a	X		X	
NAPL Treatment Area 1	RS0007	X		X	
NAPL Treatment Area 1	RS0007a	X		X	
NAPL Treatment Area 1	RS0009	X		X	
NAPL Treatment Area 1	RS0012	X		X	X
NAPL Treatment Area 1	RS0015	X		X	X
NAPL Treatment Area 1	RS0017	X		X	
NAPL Treatment Area 1	RS0020			X	
NAPL Treatment Area 1	RS0032	X		X	X
NAPL Treatment Area 2	RS0005	X	X	X	
NAPL Treatment Area 2	RS0018	X	X	X	
NAPL Treatment Area 2	RS0019	X	X	X	
NAPL Treatment Area 2	RS0024	X	X	X	
NAPL Treatment Area 2	RS0025	X	X	X	
NAPL Treatment Area 2	RS0027	X	X	X	
NAPL Treatment Area 2	RS0029	X	X	X	
NAPL Treatment Area 2	RS0031	X		X	
NAPL Treatment Area 2	RS0035	X	X	X	
NAPL Treatment Area 2	RS0037	X	X	X	
NAPL Treatment Area 2	RS0038	X	X	X	
NAPL Treatment Area 3	RS0002	X		X	X
Area E and NE of Treatment Plant	RS0060	X	X	X	X
Area E and NE of Treatment Plant	RS0062	X	X	X	
Area E and NE of Treatment Plant	RS0063	X	X	X	
Area E and NE of Treatment Plant	RS0064	X		X	

Note:
NAPL = nonaqueous-phase liquid
TPH = total petroleum hydrocarbons

Table 5-10
TREATMENT VOLUMES FOR NAPL TREATMENT AREAS

NAPL Treatment Area	Area (ft^2)	Treatment Elevation (feet NGVD 29)	Volume (ft^3)	Volume (yd^3)
1	25,400	From GS to 245	834,300	30,900
2a	14,900	From GS to 230	702,000	26,000
2b	9,300	From GS to 259	170,100	6,300
2c	26,900	From 273 to 253	537,300	19,900
TOTAL 2 (2a+2b+2c)	51,100	Varies	1,409,400	52,200
3	18,200	From GS to 247	542,700	20,100
TOTAL (1+2+3)	94,700	Varies	2,786,400	103,200

Notes:
GS = ground surface
NAPL = nonaqueous-phase liquid
NGVD 29 = National Geodetic Vertical Datum of 1929
Units: ft^2 = square feet, ft^3 = cubic feet, yd^3 = cubic yards

Table 5-11
STUDY AREA CONTAMINANT MASS SUMMARY

Source	**TPH**				**TCE**				**cis-1,2-DCE**			
	Volume		**Mass**		**Volume**		**Mass**		**Volume**		**Mass**	
	(gal)	**(liters)**	**(lb)**	**(kg)**	**(gal)**	**(liters)**	**(lb)**	**(kg)**	**(gal)**	**(liters)**	**(lb)**	**(kg)**
Drum Removal[1]	20,000	60,000	100,000	50,000	4,000	10,000	50,000	20,000	400	2,000	4,000	2,000
Remaining Source NAPL[2]	80,000	300,000	600,000	300,000	10,000	40,000	100,000	60,000	2,000	6,000	20,000	8,000
Pump & Treat[3]	NA	NA	NA	NA	500	2,000	7,000	3,000	50	200	700	300
Remaining Dissolved Phase[4]	NA	NA	NA	NA	1,000	4,000	13,000	6,000	100	500	1,000	600
TOTAL	100,000	360,000	700,000	350,000	16,000	56,000	170,000	90,000	3,000	8,700	26,000	10,900
TOTAL REMAINING	80,000	300,000	600,000	300,000	11,000	44,000	113,000	66,000	2,100	6,500	21,000	8,600

Notes:

[1] Based on TCE estimates from Garry Struthers Associates, Inc. (GSA). 2001: *Closure Report for Trenching/Drum Removal, East Gate Disposal Yard, Fort Lewis, Washington* ; cis-1,2-DCE estimates determined using DCE/TCE ratios of analyticals; TPH estimates determined using TPH/TCE ratios of remaining source NAPL

[2] Estimated value assuming 5% average NAPL saturation and 30% average porosity

[3] Based on calculated value from February 2002 extrapolated to June 2002; cis-1,2-DCE assumed to be 10% of TCE

[4] Preliminary estimate using surface areas of plume concentration regions with averaged values for each region; cis-1,2-DCE assumed to be 10% of TCE

Units: gal = gallon, lb = pound, kg = kilogram
cis-1,2-DCE = cis-1,2-dichloroethene
NA = not applicable
NAPL = nonaqueous phase liquid
TCE = trichloroethene
TPH = total petroleum hydrocarbons

6.0 POST-FIELD-INVESTIGATION DATA GAPS AND UNCERTAINTIES

This section discusses data gaps and uncertainties associated with the Phase II RI conducted at the Fort Lewis EGDY and Logistics Center. Data gaps and uncertainties have been separated by data use. The two primary uses for data collected as part of the Phase II RI are (1) design of the EGDY thermal treatment and (2) optimization of the Logistics Center groundwater treatment system. Additionally, data may be used in the future to evaluate reactive barrier wall placement options. Therefore, reactive wall data gaps have also been included in this section.

6.1 DATA USE—EGDY THERMAL TREATMENT

No known significant data gaps exist at the EGDY with regard to the basis for thermal treatment design. The three main NAPL areas at the EGDY have been adequately characterized in three-dimensional space. Minor data gaps are discussed in the following sections.

6.1.1 Small-Volume Source Areas

Other small-volume NAPL source areas are likely to exist at the EGDY besides the three main NAPL areas defined during this RI. The sonic drilling program included 12 borings that were located in areas of the EGDY other than the three main NAPL areas. These borings were numbered RS0053, RS0058 through RS0060, and RS0062 through RS0069. Of these 12 borings, 4 contained NAPL and are outside the three main NAPL areas that are scheduled for thermal treatment. The four borings and their respective NAPL intervals are RS0060 (2 feet to 25 feet bgs), RS0062 (5 feet to 20 feet bgs), RS0063 (5 feet to 16 feet bgs), and RS0064 (6 feet to 16 feet bgs). Figure 3-3 and Plate 1 show these borings with filled-in circles, which indicates NAPL was observed in the sonic soil cores. NAPL at all borings except RS0064 appeared to be a combination of LNAPL and DNAPL. The water table depth at RS0064 was deeper (14.7 feet bgs) because this boring was located at a slightly higher elevation than the other borings. The NAPL at RS0064 likely is LNAPL because it is not present below the historical seasonal low groundwater elevation and because minimal TCE or cis-1,2-DCE was detected. TCE concentrations in soil at RS0060, RS0062, and RS0063 were elevated and indicative of potential small-volume TCE NAPL source areas. Borings within 50 to 60 feet of RS0060 and RS0062 contained no NAPL based on visual and analytical results, indicating the NAPL is limited in horizontal extent at these two locations. Elevated TPH motor oil concentrations at borings RS0063 and RS0064 are indicative of other small-volume petroleum NAPL source areas within the EGDY, not a part of the three main NAPL areas. There were no adjacent borings beside RS0063 or RS0064 to bound the extents of NAPL at these locations.

Other areas of small-volume NAPL sources that were not investigated as part of this study may exist at the EGDY adjacent to historical disposal trenches. Source areas exhibit high dissolved-phase TCE concentrations in groundwater (i.e., greater than 1,000 μg/L). There are no areas in the EGDY with dissolved-phase TCE concentrations that exceed 1,000 μg/L and that have not been investigated. Therefore, it is unlikely that large NAPL sources have been overlooked. However, small sources of NAPL with low TCE concentrations may be present, which could then contribute to lower-level TCE concentrations (i.e., less than 1,000 μg/L) in groundwater.

Even though small-volume NAPL source areas likely exist at the EGDY outside of the three main NAPL areas, these areas are not slated for thermal treatment and hence have no impact on thermal treatment design.

6.1.2 Density of Site Data

As with any investigation, a trade-off is recognized between the cost of collecting data points and the confidence in a complete and accurate site characterization. The more data points, the greater the confidence that the site has been characterized accurately and adequately. However, the more data points collected, the more costly the investigation. Even though a total of 76 sonic borings were drilled and the materials encountered were characterized by visual observations and laboratory testing, this represents a density of one boring for every 0.46 acre of land at the EGDY (assuming a total EGDY land area of 35 acres, as discussed in Section 1.1.1). Even when all sonic and MIP borings are considered together, the density is only one boring for every 0.33 acre. If all sonic and MIP borings located within just the three main defined NAPL areas are considered, the density is one boring for every 0.03 acre (1,300 ft^2) (53 sonic borings and 24 MIP borings in the 2.2 total acres of the three main NAPL areas). The density of data collected from the Phase II investigation allows for characterization only to the scale investigated. Because most borings within the three NAPL areas were on the order of 50 feet apart, the horizontal NAPL boundaries are considered accurate to within ±25 feet.

6.1.3 Stratigraphic Correlations

Based on the ample data obtained from the EGDY sonic borings, physical properties tests, previous borings, and numerous studies, good stratigraphic control has been established within the three main NAPL areas at the EGDY. Outside these NAPL areas, erosional and/or permeable windows within the low-permeability tills and silts could be present. Thus, contaminant migration pathways for vertical migration of dissolved-phase contamination may exist. The goal of the geophysical investigation was to close this data gap by obtaining detailed three-dimensional stratigraphic control at the EGDY site. This goal was not achieved due to the limitations associated with each geophysical method used (Appendix F).

6.2 DATA USE—LOGISTICS CENTER GROUNDWATER TREATMENT SYSTEM

Data gaps and uncertainties related to small-volume source areas, density of site data, and stratigraphic correlation are more significant for data uses associated with the Logistics Center groundwater treatment system than for the EGDY thermal treatment and design. This is so because the Logistics Center is much larger in area than the EGDY and hence the complexities of the system are increased relative to the size of the area under consideration.

6.2.1 Small-Volume Source Areas

The small-volume NAPL sources not fully investigated at the EGDY represent data gaps for future dissolved-phase TCE contaminant distribution. After thermal treatment has been conducted on the three main NAPL areas at the EGDY, and assuming the thermal treatment has been successful at removing the vast majority of TCE-containing NAPL, these small-volume NAPL sources would then be the primary contributors to the dissolution and subsequent transport of TCE downgradient in the Logistics Center plume.

Other source areas, such as small-volume NAPL or elevated concentrations of dissolved-phase TCE, may exist outside the EGDY but within the upgradient portions of the Logistics Center that were not investigated during this study. The primary “other area” not fully investigated is a Logistics Center stormwater outfall located approximately 1,000 feet west of the intersection of McKinley Avenue and South L Street. Beneath this location, the upper aquifer dissolved-phase TCE plume bulges outward from the main axis of the plume. A surface water grab sample for VOCs was collected on May 14, 2001, after a rainfall event from the outfall culvert; however, the TCE concentration was an estimated value of 0.13 µg/L—just above method detection limits. No subsurface investigation was conducted at this location to determine the cause of the bulge in the plume; hence, no conclusion has been made regarding this potential source area.

6.2.2 Density of Site Data

Obtaining groundwater flow and contaminant transport data in the greater EGDY area of the Logistics Center was a secondary objective of the Phase II RI. The data gaps associated with the bulge in the TCE plume southwest of the EGDY (in the greater EGDY area) have been filled by the groundwater grab sampling, piezometer installation, and groundwater measurements performed as part of this investigation. The current density of site data pertaining to the entire Logistics Center is insufficient to fully understand the hydrogeologic system, in particular with regard to the size, shape, and nature of the permeable window that allows TCE to enter the Sea Level aquifer. This, however, was not an objective of the Phase II RI.

6.2.3 Stratigraphic Correlations

The stratigraphic correlations made as part of the updated CSM described in Section 5 are interpretations subject to some degree of error. Because the data density is less for the greater EGDY area and the Logistics Center than it is for the EGDY, stratigraphic unit correlation over the larger area contains some uncertainty. Additionally, the geology and hydrogeology associated with the glacial and interglacial depositional environments beneath the Logistics Center are very complex. The density of collected data is such that correlations between the geologic and hydrogeologic units must be inferred based on similarities between material types, compositions, inclusions, contacts, and other factors. Some stratigraphic correlations remain unresolved due to a lack of understanding of geologic and hydrogeologic conditions between boring locations within the Logistics Center.

6.3 DATA USE—REACTIVE BARRIER WALL

6.3.1 Stratigraphy

A stratigraphic data gap remains near the EGDY with regard to future potential reactive barrier wall placement. Although sufficient stratigraphic data were collected to characterize the EGDY NAPL distribution, sufficient data were not gathered pertaining to reactive wall placement (DQO 3) because it is assumed that the wall would be placed some distance from the NAPL areas in an area not specifically investigated during the Phase II RI. Sonic boring locations and collected stratigraphic data did not specifically target reactive barrier wall locations. Critical in the design of an effective barrier wall is a well-defined lower permeability stratigraphic unit in which to tie in the bottom of the wall.

6.3.2 Hydrogeology

Another important consideration in reactive barrier wall design is a detailed and specific understanding of the behavior of groundwater at the wall location. Groundwater velocities (and hence contaminant velocities) at the proposed wall alignment should be determined in order to design an effective reactive barrier wall.

6.4 DATA GAP CONCLUSIONS

Although data gaps associated with potential small-volume NAPL source areas, density of site data, and stratigraphic correlations still exist, it is believed that these data gaps are primarily related not to the EGDY but to the Logistics Center beyond the EGDY and do not prevent the EGDY site from being adequately characterized. The predesign site characterization data collected is considered sufficient to complete the evaluation of in situ thermal technologies and to select and design a thermal remediation system based on the collected data. If a reactive barrier wall is to be considered further for dissolved-phase TCE treatment downgradient of the EGDY, further stratigraphic and hydrogeologic investigation is warranted. The potential small-volume NAPL source areas at the EGDY likely will require further limited investigation and characterization to remediate by hot-spot treating (polishing) after thermal treatment of the three main NAPL areas is completed. The small-volume source area characterization may depend on the success of the thermal treatment remediation as a whole.

7.0 CONCLUSIONS

Newly acquired data from the sonic and MIP boring programs, coupled with historical line-of-evidence data, indicate that there are three main separate and distinct NAPL source areas at the EGDY contributing to the overall Logistics Center dissolved-phase TCE contaminant plume. These areas have been designated as NAPL Areas 1 through 3. NAPL Area 1 is located in the southernmost portion of the EGDY adjacent to the East Gate infiltration galleries. NAPL Area 2 is located approximately 300 feet west-northwest of NAPL Area 1 in the center of the site, and NAPL Area 3 is located in the northern portion of the EGDY between East Lincoln Drive and the East Gate groundwater treatment plant.

NAPL Area 1 is approximately 25,400 square feet (0.6 acre) in size and up to 34 feet in depth, for a total volume of approximately 30,900 cubic yards. Chlorinated solvents and oils were the primary contaminants found within NAPL Area 1.

NAPL Area 2 is approximately 51,100 square feet (1.2 acres) in size and up to 47 feet in depth, averaging approximately 28 feet in depth. The total volume of NAPL Area 2 is approximately 52,200 cubic yards. A component of NAPL Area 2 has migrated with groundwater flow toward the southwest; hence, the downgradient NAPL is generally shallower than the NAPL beneath the disposal trenches associated with NAPL Area 2. The primary contaminants found within NAPL Area 2 were those in a complex petroleum hydrocarbon mixture. The compound cis-1,2-DCE and, to a lesser extent, TCE are also COCs in NAPL Area 2.

NAPL Area 3 is approximately 18,200 square feet (0.4 acre) in size and up to 30 feet in depth, for a total volume of approximately 20,100 cubic yards. Chlorinated solvents, primarily TCE, were the predominant contaminants found within NAPL Area 3. NAPL associated with NAPL Area 3 is present in lower percent NAPL saturated conditions than at NAPL Areas 1 and 2 and is more interspersed throughout the soil matrix in globules or ganglia than in the other two areas.

The total remaining mass of source area NAPL is estimated at 800,000 lb, assuming a 5 percent average NAPL saturation and 30 percent average porosity. Specifically, at NAPL Area 1, an estimated 210,000 lb of NAPL remain in the subsurface; at NAPL Area 2, an estimated 400,000 lb; and at NAPL Area 3, and estimated 140,000 lb.

NAPL outside the three main areas was observed in four sonic boring locations. These observations are in agreement with observations made during the previous drum removal and trenching operations and with observations from other activities associated with the ESI, which also denoted several small-volume NAPL areas besides the three main areas. Other potential areas of small-volume NAPL sources that were not investigated as part of this study may exist at the EGDY adjacent to historical disposal trenches. Several small-volume source areas are likely present and constitute a data gap; however, the vast majority of NAPL-containing soil at the site has been adequately characterized for subsequent follow-on thermal treatment.

VOC analytical results and groundwater elevation data obtained during this investigation in the greater EGDY area suggest a component of groundwater flow and TCE plume transport is to the southwest from the upgradient portions of the EGDY corresponding to NAPL Areas 1 and 2. Groundwater flow and contaminant transport direction changes from southwesterly to the regional northwesterly direction as the Vashon TCE plume intersects Murray Creek, a surface expression of shallow groundwater. This behavior was hypothesized prior to the Phase II RI but was corroborated by newly installed piezometers and data acquired from these locations.

Excavation of six potential source areas other than the EGDY-related NAPL source areas was conducted in the greater EGDY area as part of the Phase II RI. No evidence of past hazardous waste disposal was observed at any of the investigated locations. Therefore, these areas are no longer considered potential contributing source areas to the greater Logistics Center TCE plume.

The primary DQO for the project was successfully met: Data of sufficient quality and quantity were obtained from this Phase II RI to be used in the design of a thermal remediation action for NAPL source area treatment (DQO 1). These data included characterization of the chemical composition of contaminated soil and water phases, physical properties of the contaminated and uncontaminated soils, geologic and hydrogeologic properties of the subsurface, and distribution of NAPL in the subsurface.

Additionally, the remaining DQOs for this project were met except for the data gaps discussed in Section 6.4. Sufficient analytical data were obtained to segregate and classify IDW according to RCRA and Washington State Dangerous Waste Regulations (DQO 4). Also, data were generated quickly to ensure that the field-generated data supported the real-time decision-making needs of the dynamic work plan (DQO 5). Despite data gaps associated with DQOs 2 and 3, adequate data were collected to allow further evaluation of options for optimizing the existing groundwater treatment system and possibly for placing a reactive barrier wall. The data obtained on depth of dissolved-phase contamination, stratigraphy, and groundwater flow direction can be used to optimize the groundwater treatment system and determine reactive barrier wall placement options if this technology is considered in the future.

The Phase II RI investigation scope was developed to meet the above DQOs. It allowed collection of a sufficient volume and quality of data to complete the EGDY site characterization for in situ thermal technologies evaluation and subsequent design. Further stratigraphic and hydrogeologic investigation downgradient of the EGDY may be warranted for design of a reactive barrier wall. Limited characterization of potential small-volume NAPL source areas at the EGDY also may be warranted following completion of thermal treatment at the three main NAPL areas.

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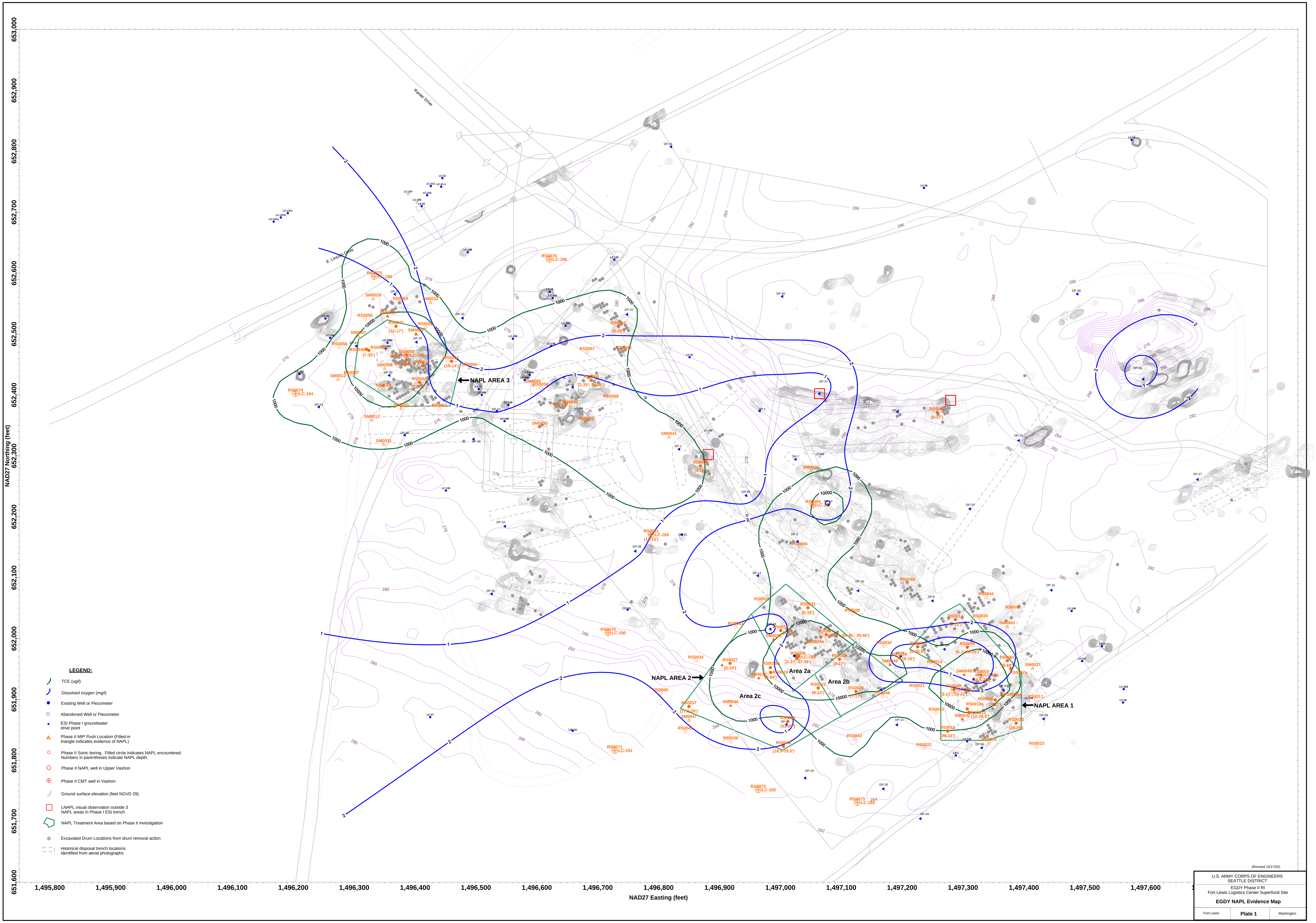

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SEATTLE DISTRICT

EGDY Phase II RI
Fort Lewis Logistics Center Superfund Site

EGDY NAPL Evidence Map

Fort Lewis
Plate 1
Washington