EPA 542-R-13-009
August 2013
Office of Solid Waste and Emergency Response
Office of Superfund Remediation and
Technology Innovation

Optimization Review
Naval Base Kitsap OU-1

Keyport, Washington

OPTIMIZATION REVIEW

NAVAL BASE KITSAP OU-1
KEYPORT, WASHINGTON

Report of the Optimization Review
Site Visit Conducted at Naval Base Kitsap on
December 3, 2012

FINAL REPORT
August 2, 2013

EXECUTIVE SUMMARY

Optimization Background

The U.S. Environmental Protection Agency's definition of optimization is as follows:

> *"Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness."* [1]

An optimization review considers the goals of the remedy, available site data, conceptual site model, remedy performance, protectiveness, cost-effectiveness and closure strategy. A strong interest in sustainability has also developed in the private sector and within Federal, State and Municipal governments. Consistent with this interest, optimization now routinely considers green remediation and environmental footprint reduction during optimization reviews. An optimization review includes reviewing site documents, interviewing site stakeholders, potentially visiting the site for one day and compiling a report that includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site closure
- Environmental footprint reduction

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent review and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the EPA Region and other site stakeholders. Also note that while the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans and quality assurance project plans.

[1] U.S. Environmental Protection Agency. 2012 Memorandum: Transmittal of the National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion. From: James E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28, 2012.

Site-Specific Background

Naval Base Kitsap Keyport occupies 340 acres (including tidelands) adjacent to the town of Keyport in Kitsap County, Washington, on a small peninsula in the central portion of Puget Sound. Environmental cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (or Superfund) has been divided into two Operable Units (OUs). This optimization review focuses on OU-1, the former base landfill, which comprises approximately 9 acres in the western part of the base next to a wetland area and the "tide flats" that flow into Dogfish Bay. A Record of Decision for OU-1 was signed in September 1998 to address volatile organic compound (VOC) contamination present in groundwater and polychlorinated biphenyl (PCB) contamination of sediments. The primary components of the selected remedy included treating VOC hot spots with phytoremediation, removing PCB contaminated sediments and upgrading portions of the landfill cap. The planting of poplar trees for the phytoremediation remedy and the removal of the PCB-contaminated sediments occurred in 1999. A portion of the landfill cover was upgraded in 2003. The U.S. Navy (Navy), EPA, Washington State Department of Ecology (Ecology) and the Suquamish Tribe generally agree that current levels of VOC contamination in groundwater and surface water indicate that the phytoremediation remedy is not performing as intended.

Summary of Conceptual Site Model and Key Findings

Chlorinated solvents were released to the environment as a result of historic waste disposal practices at the landfill. Chlorinated solvents present in the waste, buried marsh layer and possibly underlying saturated soil continue to impact groundwater in northern and southern portions of the landfill. Groundwater in the upper aquifer discharges to surface water in the marsh. No sampling points are present in the intermediate aquifer within the footprint of the landfill, but downgradient sampling points in the intermediate aquifer demonstrate the chlorinated solvents are present in the intermediate aquifer. The site team hypothesizes that contamination has migrated in the dissolved phase from the upper aquifer into the intermediate aquifer through windows in the aquitard located in the central portion of the landfill. However, the optimization review team believes it might be possible that the contamination in the intermediate aquifer could be the result of dense non-aqueous phase liquid that historically migrated from the upper aquifer to the intermediate aquifer in the southern portion of the landfill.

Contaminant concentrations in the upper aquifer in the northern landfill have a clear decreasing trend as source material and resulting dissolved contamination attenuate. The optimization review team agrees with the Navy, EPA, Ecology and U.S. Geological Survey that the decreasing concentration trends in monitoring wells in the northern portion of the landfill indicate that some combination of the phytoremediation remedy and intrinsic biodegradation are effectively addressing the contamination in the northern landfill.

Contaminant concentrations in the upper aquifer in portions of the southern landfill (near MW1-4) remain orders of magnitude above cleanup standards, with seasonal fluctuations and no clear evidence of a decreasing trend. Contamination appears to be more widespread in the southern landfill than the northern landfill, but it is unclear how much of the contaminant extent is due to wide-spread source material and how much is due to contaminant migration in the dissolved phase. Contaminant concentration trends suggest the potential for significant contaminant mass to be present near or above the water table that provides an ongoing source of dissolved contamination to groundwater.

Intrinsic biodegradation occurs in both the northern and southern portions of the landfill and is responsible for reductions in the flux of contamination to surface water. However, the surface water downgradient of the southern landfill continues to have vinyl chloride concentrations more than an order of magnitude above the surface water remediation goal of 2.9 micrograms per liter, indicating that the phytoremediation remedy and intrinsic biodegradation are not effectively addressing contamination in the southern landfill area as intended by the 1998 Record of Decision.

Summary of Recommendations

Recommendations are provided to improve remedy effectiveness (protectiveness), provide technical improvement and assist with accelerating site closure. Specific recommendations for cost reduction and for environmental footprint reduction (green remediation) were not a primary focus for this optimization review. The optimization team's recommendations in these areas are as follows:

Improving remedy effectiveness –

Continue with efforts to characterize contamination in the southern portion of the landfill to better understand the extent of the source area. The site team is currently developing a work plan to use passive soil gas sampling and tree core sampling to conduct this characterization. The optimization review team supports this approach but offers a more conventional characterization approach for consideration.

Revisit existing data and potentially collect new data to evaluate the vapor intrusion pathway for buildings across Bradley Road.

Cost effectiveness –

No recommendations are provided in this category.

Technical improvement –

Consider testing the use of extracted contaminated water for use in the phytoremediation remedy irrigation system.

Site closure –

Revisit the surface water remediation goals and points of compliance for the marsh water.

Revisit the groundwater remediation goals.

In addition, the optimization team provides considerations for the following:

- Additional characterization and remediation if initial characterization efforts suggest a relatively focused source area
- Additional characterization and remediation if initial characterization efforts suggest a relatively diffuse source area
- Additional characterization and remediation if initial characterization efforts suggest an extensive source area

Environmental footprint reduction (green remediation) –

No specific recommendations have been provided in this category, but the technical improvement recommendation to consider testing the use of extracted contaminated water for the phytoremediation irrigation system could lead to eliminating the use of potable water for phytoremediation irrigation.

NOTICE AND DISCLAIMER

Work described herein, including preparation of this report, was performed by Tetra Tech GEO (TtGEO) for the U.S. Environmental Protection Agency under Work Assignment 2-58 of EPA contract EP-W-07-078 with Tetra Tech EM, Inc., Chicago, Illinois. The report was approved for release as an EPA document, following the Agency's administrative and expert review process.

This optimization review is an independent study funded by the EPA that focuses on protectiveness, cost-effectiveness, site closure, technical improvements and green remediation. Detailed consideration of EPA policy was not part of the scope of work for this review. This report does not impose legally binding requirements, confer legal rights, impose legal obligations, implement any statutory or regulatory provisions, or change or substitute for any statutory or regulatory provisions. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

Recommendations are based on an independent evaluation of existing site information, represent the technical views of the optimization review team, and are intended to help the site team identify opportunities for improvements in the current site remediation strategy. These recommendations do not constitute requirements for future action, rather they are provided for consideration by the EPA Region and other site stakeholders.

While certain recommendations may provide specific details to consider during implementation, these are not meant to supersede other, more comprehensive planning documents such as work plans, sampling plans and quality assurance project plans (QAPP), nor are they intended to override Applicable or Relevant and Appropriate Requirements (ARARs). Further analysis of recommendations, including review of EPA policy may be needed prior to implementation.

PREFACE

This report was prepared as part of a national strategy to expand Superfund optimization from remedial investigation to site completion implemented by the EPA Office of Superfund Remediation and Technology Innovation (OSRTI)[2]. The project contacts are as follows:

Organization	Key Contact	Contact Information
EPA OSRTI	Kirby Biggs	EPA OSRTI Technology Innovation and Field Services Division (TIFSD) 2777 Crystal Dr. Arlington, VA 22202 biggs.kirby@epa.gov phone: 703-823-3081
	Ed Gilbert	EPA OSRTI TIFSD 2777 Crystal Dr. Arlington, VA 22202 gilbert.edward@epa.gov phone: 703-603-8883
Tetra Tech (Contractor to EPA)	Jody Edwards, P.G.	Tetra Tech 1881 Campus Commons Drive, Suite 200 Reston, VA 20191 jody.edwards@tetratech.com phone: 802-288-9485
	Doug Sutton, PhD, P.E.	Tetra Tech 2 Paragon Way Freehold, NJ 07728 doug.sutton@tetratech.com phone: 732-409-0344

[2] U.S. Environmental Protection Agency. 2012. Memorandum: Transmittal of the *National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion*. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28, 2012.

LIST OF ACRONYMS

1,1-DCA	1,1 Dichloroethane
1,1-DCE	1,1-Dichloroethene
1,1,1-TCA	1,1,1-Trichloroethane
1,2-DCA	1,2-Dichloroethane
µg/kg	micrograms per kilogram
µg/L	micrograms per liter
ARARs	applicable or relevant and appropriate requirements
CERCLA	Comprehensive Environmental Response, Compensation and Liability Act
cis-1,2-DCE	cis-1,2-dichloroethene
COC	contaminant of concern
CSM	conceptual site model
DNAPL	dense non-aqueous phase liquid
DPT	direct-push technology
EPA	U.S. Environmental Protection Agency
FS	feasibility study
FFS	focused feasibility study
Ft	Feet
HSA	hollow stem auger
IC	Institutional Control
LTM	long term monitoring
MCL	maximum contaminant level
mg/kg	milligrams per kilogram
msl	mean sea level
MTCA	State of Washington Model Toxics Control Act
NAVFAC	Naval Facilities Engineering Command
NAVFAC EXWC	Naval Facilities Engineering and Expeditionary Warfare Center
NBK	Naval Base Kitsap
OSRTI	Office of Superfund Remediation and Technology Innovation
OSWER	Office of Solid Waste and Emergency Response
OU	operable unit
OU-1	operable unit with former base landfill
P&T	pump and treat
PCB	polychlorinated biphenyl
PCE	tetrachloroethene
PQL	practical quantitation level
PUD	Public Utility District
QAPP	Quality Assurance Project Plan
RAO	remedial action objective

RG	remedial goal
RI	remedial investigation
ROD	Record of Decision
RSE	remedial system evaluation
SVE	soil vapor extraction
TCE	Trichloroethene
TIFSD	Technology Innovation and Field Services Division
trans-1,2-DCE	Trans-1,2-Dichloroethene
USGS	U.S. Geological Survey
VI	vapor intrusion
VOC	volatile organic compound
WAC	Washington Administration Code

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1.0 INTRODUCTION

1.1 PURPOSE

During fiscal years 2000 and 2001, independent site optimization reviews called Remediation System Evaluations (RSEs) were conducted at 20 operating Fund-lead pump and treat (P&T) sites (i.e., those sites with P&T systems funded and managed by Superfund and the States). Due to the opportunities for system optimization that arose from those RSEs, the U.S. Environmental Protection Agency Office of Superfund Remediation and Technology Innovation (OSRTI) has incorporated RSEs into a larger post-construction completion strategy for Fund-lead remedies as documented in *OSWER Directive No. 9283.1-25, Action Plan for Ground Water Remedy Optimization*. Concurrently, the EPA developed and applied the Triad Approach to optimize site characterization and development of a conceptual site model (CSM). The EPA has since expanded the definition of optimization to encompass investigation stage optimization using Triad Approach best management practices, optimization during design and RSEs. The EPA's definition of optimization is as follows:

> *"Efforts at any phase of the removal or remedial response to identify and implement specific actions that improve the effectiveness and cost-efficiency of that phase. Such actions may also improve the remedy's protectiveness and long-term implementation which may facilitate progress towards site completion. To identify these opportunities, regions may use a systematic site review by a team of independent technical experts, apply techniques or principles from Green Remediation or Triad, or apply other approaches to identify opportunities for greater efficiency and effectiveness."* [3]

As stated in the definition, optimization refers to a "systematic site review," indicating that the site as a whole is often considered in the review. Optimization can be applied to a specific aspect of the remedy (for example, focus on long-term monitoring [LTM] optimization or focus on one particular operable unit [OU]), but other site or remedy components are still considered to the degree that they affect the focus of the optimization. An optimization review considers the goals of the remedy, available site data, CSM, remedy performance, protectiveness, cost-effectiveness and closure strategy. A strong interest in sustainability has also developed in the private sector and within Federal, State and Municipal governments. Consistent with this interest, OSRTI has developed a Green Remediation Primer (www.cluin.org/greenremediation) and now routinely considers green remediation and environmental footprint reduction during optimization reviews.

The optimization review includes reviewing site documents, potentially visiting the site for one day and compiling this report, which includes recommendations in the following categories:

- Protectiveness
- Cost-effectiveness
- Technical improvement
- Site closure
- Environmental footprint reduction

[3] U.S. Environmental Protection Agency. 2012. Memorandum: Transmittal of the *National Strategy to Expand Superfund Optimization Practices from Site Assessment to Site Completion*. From: James. E. Woolford, Director Office of Superfund Remediation and Technology Innovation. To: Superfund National Policy Managers (Regions 1 – 10). Office of Solid Waste and Emergency Response (OSWER) 9200.3-75. September 28, 2012.

The recommendations are intended to help the site team identify opportunities for improvements in these areas. In many cases, further analysis of a recommendation, beyond that provided in this report, may be needed prior to implementation of the recommendation. Note that the recommendations are based on an independent evaluation and represent the opinions of the optimization review team. These recommendations do not constitute requirements for future action, but rather are provided for consideration by the Region and other site stakeholders. Also note that while the recommendations may provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans and quality assurance project plans (QAPP).

The national optimization strategy includes a system for tracking consideration and implementation of optimization review recommendations and includes a provision for follow-up technical assistance from the optimization review team as mutually agreed upon by the site management team and EPA OSRTI.

Purpose of Optimization at Naval Base Kitsap Operable Unit (OU-1)

Naval Base Kitsap (NBK) Keyport occupies 340 acres (including tidelands) adjacent to the town of Keyport in Kitsap County, Washington, on a small peninsula in the central portion of Puget Sound. The property was acquired by the Navy in 1913, with property acquisition continuing through World War II. The Navy first used it as a quiet-water range for torpedo testing. During the early 1960s, NBK Keyport's role was expanded to include manufacturing and fabrication such as welding, metal plating, carpentry and sheet metal work. Further expansion in 1966 added a new torpedo shop; in 1978, functions broadened to include various undersea warfare weapons and systems engineering and development activities. Operations currently include engineering, fabrication, assembly and testing of underwater weapons systems.

Environmental cleanup under the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA or Superfund) at the base has been divided in two OUs. This optimization review focuses on OU-1, the former base landfill, which comprises approximately 9 acres in the western part of the base next to a wetland area and the "tide" flats that flow into Dogfish Bay. As stated in the OU-1 Record of Decision (ROD)

> "*… the OU-1 investigations revealed the potential for risks to occur via three main pathways: the drinking water pathway, the seafood ingestion (human health) pathway, and the ecological risk pathway*."

The two classes of contaminants of concern that were specified in the ROD were polychlorinated biphenyls (PCBs) and volatile organic compounds (VOCs), specifically chlorinated aliphatic hydrocarbons. The OU-1 ROD was signed in September 1998 to address VOC contamination of groundwater and PCB contamination of sediments. The selected remedy included the following components:

- Treat VOC hot spots in the landfill by phytoremediation using poplar trees.
- Remove PCB-contaminated sediments from around the seep area, which has the highest PCB concentrations.
- Upgrade the tide gate to protect the landfill from flooding and erosion during extreme tide events.
- Upgrade and maintain the landfill cover.
- Conduct LTM, including phytoremediation monitoring, intrinsic bioremediation monitoring and risk and compliance monitoring.

- Take contingent actions for off-base domestic wells, if necessary.
- Implement institutional controls (IC).

The planting of poplar trees, removal of PCB-contaminated sediments and tide gate improvements were conducted in 1999. A portion of the landfill cover was upgraded in 2003; the other remedial components are ongoing evaluations or efforts (including various sampling and analysis activities). The U.S. Navy (Navy), EPA, Washington State Department of Ecology (Ecology) and the Suquamish Tribe generally agree that current levels of VOC contamination in groundwater and surface water indicate that the phytoremediation remedy is not performing as intended. As a result, the Navy, EPA, Ecology and the Suquamish Tribe agreed to work collaboratively to conduct an optimization review of OU-1 to evaluate potential options for improving remedy performance. This optimization review focuses on OU-1, with emphasis on addressing the VOC contamination.

1.2 TEAM COMPOSITION

The optimization review team consisted of the following individuals:

Name	Affiliation	Phone	Email
Doug Sutton, PhD, PE	Tetra Tech	732-409-0344	doug.sutton@tetratech.com
Peter Rich, PE	Tetra Tech	410-990-4607	peter.rich@tetratech.com

The following individuals who are not directly associated with the site also attended site visit and contributed to the optimization review process:

- Ed Gilbert – EPA OSRTI
- Kirby Biggs – EPA OSRTI
- Tanwir Chaudhry – Consultant, Naval Facilities Engineering and Expeditionary Warfare Center (NAVFAC EXWC)
- Sarah Rollston – NAVFAC EXWC
- Tom Spriggs – NAVFAC Atlantic
- Bernie Zavala – EPA Region 10
- Kira Lynch – EPA Region 10

1.3 DOCUMENTS REVIEWED

The following documents were reviewed in support of the optimization review:

- *Second Five-Year Review* (NAVFAC – May 2005)
- *Third Five-Year Review* (NAVFAC – December 2011)
- *Record of Decision* (URS Greiner and Science Applications International Corporation – September 1998)

- *Natural Attenuation Evaluation, Operable Unit 1* (URS Group – November 2012)
- *Remedial Investigation Report* (URS Consultants, Inc. and Science Applications International Corporation – October 1993)
- *Biodegradation of Chloroethene Compounds in Groundwater at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington, 1999–2010* (USGS – 2012)
- *Annual Report, 2010, Operable Unit 1* (Sealaska Environmental Services, LLC – June 2011)
- *Annual Report, 2011, Operable Unit 1* (Sealaska Environmental Services, LLC – July 2012)
- *Phytoremediation Annual Report, 2011, Area 1, Operable Unit 1* (Sealaska Environmental Services, LLC – May 2012)
- *Soil Gas Investigation* (Tracer Research Corporation – May 1990)
- *Baseline Risk Assessment Report, Ecological Risk Assessment* (URS Consultants, Inc. and Science Applications International Corporation – October 1993)
- *Final Focused Feasibility Study for Operable Unit 1* (URS Greiner and Science Applications International Corporation – November 1997)
- *Final Summary Data Assessment Report for Operable Unit 1* (URS Greiner and Science Applications International Corporation – November 1997)
- EPA Letter to Captain Mark J. Olson, December 30, 2010
- EPA Letter to Mr. Douglas Thelin, Regarding Draft Natural Attenuation Evaluation, Operable Unit 1, Naval Base Kitsap Keyport, January 26, 2012
- Ecology Letter to Mr. Douglas Thelin, March 7, 2012, Regarding Ecology Comments on: *Natural Attenuation Evaluation, Operable Unit 1, prepared by URS Group, Inc. for the U.S. Navy Kitsap, Keyport, Washington, dated January 26, 2012*
- Ecology Letter to Mr. Douglas Thelin, March 28, 2012, Regarding Ecology Comments on: *Draft Phytoremediation Annual Report, 2011, Area 1, Operable Unit 1, NBK Keyport, Washington, Task Order 30, Prepared by Sealaska Environmental for the U.S. Navy Kitsap, Keyport, Washington, dated 21, March 2012.*

1.4 QUALITY ASSURANCE

This optimization review utilizes existing environmental data to interpret the CSM, evaluate remedy performance and make recommendations to improve the remedy. The quality of the existing data is evaluated by the optimization review team prior to using the data for these purposes. The evaluation for data quality includes a brief review of how the data were collected and managed (where practical, the site QAPP is considered), the consistency of the data with other site data and the use of the data in the optimization review. Data that are of suspect quality were either not used as part of the optimization review or used with the quality concerns noted. Where appropriate, this report provides recommendations to improve data quality.

1.5 PERSONS CONTACTED

A site visit was conducted on December 3, 2012. In addition to the optimization review team and other non-site personnel noted above, the following individuals directly associated with the site were present for the site visit and interviewed as part of the optimization review effort:

Name	Affiliation	Email Address
Aaron Lambert	EPA Region 10	lambert.aaron@epa.gov
Milton 'Gene' Clare	Navy Remedial Project Manager – Naval Facilities Engineering Command (NAVFAC) Northwest	milton.clare@navy.mil
Kwasi Boateng	EPA Region 10	
John Blacklaw	Washington State Dept. of Ecology	
Denice Taylor	Suquamish Tribe	
Richard Dinicola	United States Geological Survey (USGS)	
Mike Meyer	URS	

Email contact information is provided for the site managers only. Communication with other participants can be coordinated through the site managers.

2.0 SITE BACKGROUND

Information in the following sections is generally extracted from the following documents:

- *Final Summary Data Assessment Report* (URS Greiner and Science Applications International Corporation – November 1997), subsequently referred to as the “Data Assessment Report”;
- *Third Five-Year Review* (NAVFAC – December 2011), subsequently referred to as the “Third Five-Year Review”; and
- *2011 Annual Report* (Sealaska Environmental Services, LLC – July 2012), subsequently referred to as the 2011 Annual Report.

2.1 LOCATION

NBK Keyport occupies 340 acres (including tidelands) adjacent to the town of Keyport in Kitsap County, Washington, on a small peninsula in the central portion of Puget Sound. NBK Keyport is bordered by Liberty Bay on the east and north and Port Orchard Inlet on the southeast. Figure 1-1 from the Third Five-Year Review illustrates the NBK Keyport location (see Attachment A for this figure). The topography of the site rises gently from the shoreline to an average of 25 to 30 feet (ft) above mean sea level (msl) and then rises steeply to approximately 130 ft above msl at the southeast corner of the site.

Marine or brackish water bodies on and near the site consist of Liberty Bay, Dogfish Bay, the tide flats, a marsh and the shallow lagoon. Freshwater bodies include two creeks draining into the marsh pond and two creeks that discharge into the shallow lagoon. OU-1 consists of Area 1, the former base landfill, which comprises approximately nine acres in the western part of the base next to a wetland area and the tidal flats that flow into Dogfish Bay (see Attachment A for Figure 3-1 from the Third Five-Year Review). Most of the landfill area was formerly a marshland.

2.2 SITE HISTORY

The Navy acquired the NBK Keyport property in 1913; property acquisition continued through World War II. The landfill was the primary disposal area for domestic and industrial wastes generated by the base from the 1930s until 1973, when the landfill was closed. A burn pile for trash and demolition debris was located at the north end of the landfill from the 1930s to the 1960s. Unburned or partially burned materials from this pile were buried in the landfill or pushed into the marsh. A trash incinerator was operated at the north end of the landfill from the 1930s to the 1960s and incinerator ash was discarded in the landfill. Burning of waste continued at the landfill until the early 1970s.

Various site investigations and assessment studies occurred between 1984 and 1988. A Remedial Investigation (RI) was conducted at Area 1 between 1988 and 1993, after which human health and ecological risk assessments were conducted. Based on the results of these studies, seven remedial alternatives were evaluated in the Feasibility Study (FS) for Area 1, and the Navy, Ecology and EPA selected a preferred remedial alternative. This preferred alternative was described in the 1994 proposed plan. Because public comments were not favorable to the preferred remedial alternative, the proposed plan was withdrawn, and Area 1 was separated from the other areas to become OU-1.

The Navy, Ecology and EPA conducted further site characterization to collect data to supplement the RI. Starting in 1995 and ending in September 1996, five quarterly rounds of sampling were conducted. New data from this site characterization effort were discussed and evaluated in the Data Assessment Report, which supplemented the RI. A supplemental Focused Feasibility Study (FFS) in 1997 evaluated several additional alternatives. A new preferred remedial alternative from the FFS was selected and eventually accepted based on public comments. The OU-1 ROD was executed in September 1998. Remedial actions, including the planting of poplar trees for a phytoremediation remedy to address VOC contamination, occurred from late 1998 through 2003. Upgrading of the landfill pavement was the final remedy construction element to be completed, and it was completed in December 2003.

2.3 POTENTIAL HUMAN AND ECOLOGICAL RECEPTORS

Residents and businesses in the town of Keyport use water from two county wells. One of these Public Utility District (PUD) wells is a backup supply well located just north of the tide flats as shown by well PUD-2 in Figure 4-2 of the Third Five-Year Review. Water used at NBK Keyport originates from Base Well No. 5, located on base, just north of the Shallow Lagoon shown in Figure 1-1 of the Third Five-Year Review. The PUD backup well and the base water supply well are screened in aquifers located about 500 ft below the Clover Park aquitard (see next section). There are two additional thick aquitards that lie between the Clover Park unit and the screened zones of these supply wells. Both of these wells tap groundwater that is under flowing artesian conditions.

Homes on the south side of the tide flats and Dogfish Bay and on and near Virginia Point are generally not connected to public water supply and are instead served by private wells. A well inventory conducted for the Navy in 1996 and 1997 reportedly found that of the 69 wells in these areas, two-thirds (46 wells) were identified as being screened in deeper water-bearing zones below or within the Clover Park aquitard. The inventory categorized the other shallower wells in these areas as follows:

- Fourteen wells tap the upper aquifer. Three of these are used for domestic purposes, five are used only for non-domestic purposes (for example, irrigation), five are not used (but have not been abandoned), and the use of one well could not be determined.
- Three wells tap the intermediate aquifer. Two of these are used for domestic purposes and one is not used (but has not been abandoned).
- Six wells tap either the intermediate aquifer or a water-bearing zone within the Clover Park aquitard. All of these wells are used for domestic purposes.

Site documents report that the hydrogeology in the vicinity of the tide flats and Dogfish Bay makes it highly unlikely that groundwater from the landfill would ever flow to off-base areas where it could be tapped by these wells.

Although not specifically noted in site documents, other potential human receptors could potentially include occupants of the building across Bradley Road that might be exposed to site-related VOCs via the vapor intrusion (VI) pathway.

Potential ecological receptors include those in the marsh area, the tide flats and Dogfish Bay. According to the 1997 FFS Report, there is an ecological risk for not only aquatic organisms in these surface water bodies, but risk via the food chain, especially the human health risk for seafood ingestion. Because the site lies within the adjudicated Usual and Accustomed harvest area, the Suquamish Tribe maintains the right to harvest for ceremonial, subsistence and commercial purposes. PCBs are a main contaminant of concern (COC) for the ingestion pathway; however, the Third Five-Year Review indicates that no PCBs have been detected in clam tissue based on sampling and analysis following sediment remediation.

2.4 EXISTING DATA AND INFORMATION

The following sections summarize information provided in existing documents and do not include interpretation by the optimization review team.

2.4.1 SOURCES OF CONTAMINATION

The landfill was unlined. Waste and ash were disposed in the landfill. Typically the waste was pushed into the marsh during disposal, and or waste was placed in a burn pile for incineration. Both waste and ash serve as the sources of contamination. VOC contamination has been detected in both the southern and northern parts of the landfill indicating potential sources of VOC contamination exist in both parts of the landfill; however, the 1998 ROD refers to a “hot spot” of VOC contamination in the southern part of the landfill. This “hot spot” was identified based on the magnitude of VOC contamination in the groundwater and surface water near the southern portion of the landfill. The 1998 ROD and subsequent U.S. Geological Survey (USGS) studies indicate the potential presence of dense non-aqueous phase liquid (DNAPL) and the potential for DNAPL to have caused vertical migration of VOC contamination into the intermediate aquifer.

As discussed in site documents, the distribution of the PCB contamination, with relatively higher concentrations in the marsh sediment near the northern portion of the landfill, suggests the predominant source of PCBs is in the northern portion of the landfill.

2.4.2 GEOLOGY SETTING AND HYDROGEOLOGY

Surface Hydrology

The surface topography in the vicinity of the landfill is relatively flat, but steepens to the south, west and north. Stormwater drainage from the land areas near the OU-1 landfill flows into the marsh located west and south of the landfill. A small pond (“marsh pond”) is located in the central part of the marsh. The pond is fed by a wetland south and southeast of the pond, two small freshwater creeks that are about 1 to 2 ft wide and stormwater discharge. The pond drains through a small creek (“marsh creek”) northward through a culvert to the tide flats of Dogfish Bay. An existing tide gate was upgraded in 1999 as part of the remedy to further restrict tidal in-flows to the marsh creek. The tide flats are connected to Dogfish Bay by a narrow channel through structural fill material that forms the foundation of the Highway 308 causeway and bridge. This channel acts as a constriction to tidal flow and causes the surface water level in the tide flats to exceed that in Dogfish Bay during outgoing low tides.

Geology and Hydrogeology

The hydrostratigraphy in the vicinity of the landfill is highly heterogeneous. The Data Assessment Report identifies six general hydrostratigraphic units at the OU-1 landfill. Starting at the ground surface, these units are as follows with references to how the aquifer is noted in the Data Assessment Report:

Hydrostratigraphic Unit	As Noted on Figures B-3 through B-11 of the Data Assessment Report
Unsaturated zone	A
Upper aquifer	H1
Middle aquitard	H2 and H3
Intermediate aquifer	H4 and Jo
Clover Park aquitard	Km
Clover Park coarse-grained zone*	See Figure 3 of Data Assessment Report
Additional aquitard*	See Figure 3 of Data Assessment Report
Additional aquifer*	See Figure 3 of Data Assessment Report
Additional aquitard*	See Figure 3 of Data Assessment Report
Additional aquifer* (screened by PUD well)	See Figure 3 of Data Assessment Report

** Not shown on Figures B-3 through B-11 of the Data Assessment Report*

Cross-sections of the hydrostratigraphy are depicted on Figures 3 and B-3 through B-11 of the Data Assessment Report and are included in Attachment A of this report.

The unconfined upper aquifer is present throughout most of the area. It is generally comprised of sand, but also includes overlying silt-rich units. The water table intersects the landfill waste material beneath much of the OU-1 landfill. Roughly 5 to 10 ft of landfill material lies above the water table in the unsaturated zone, and up to about 5 ft of landfill material lies beneath the water table in the saturated zone. The middle aquitard that separates the upper and intermediate aquifers is silt-rich in most places, but is sandy in some locations. This aquitard is also locally absent in the central, eastern and northern portions of the landfill. Enhanced leakage between the two aquifers is likely to occur at locations where the middle aquitard is sandy or absent. The confined intermediate aquifer is present throughout the vicinity of the OU-1 landfill except locally southeast of the landfill and in the northern end. The intermediate aquifer is generally composed of sand with some gravel and significant silt. In a few places, silt or till layers separate the intermediate aquifer into upper and lower zones. This aquifer and overlying middle aquitard extend northwesterly from the landfill underneath the tide flats to Highway 308. The Clover Park aquitard lies below the intermediate aquifer and is very thick, extensive and fine-grained. In some locations it contains water-bearing sand and gravel. The continuity of this lower confined zone is unknown. Logs from deep supply wells, which extend to 500 to 1,000 ft below ground surface, document three additional thick aquitards beneath the Clover Park aquitard.

Figures 3-13 and 3-24 from the Data Assessment Report illustrate typical groundwater contour maps for the upper and intermediate aquifers, respectively, in the OU 1 area. The groundwater in the upper aquifer generally flows through the landfill in a westerly direction, with groundwater discharging into the marsh. In the southern part of the landfill, the groundwater discharges south or southwest toward the shore of the marsh. There is a groundwater divide in the upper aquifer east of Bradley Road, where groundwater west of the divide flows toward the landfill and groundwater east of the divide flows eastward away from the landfill. Upper aquifer groundwater from the areas south and west of the OU-1 landfill flows toward the marsh. Most of the groundwater discharges to the marsh where it flows as surface water through the marsh into the tide flats. The rest of the upper aquifer groundwater (in the northern portion of the landfill) passes through the landfill to the tide flats rather than the marsh.

The groundwater in the intermediate aquifer flows beneath the landfill mainly from the southwest, passing northward through the zone under the landfill and then moving downgradient of the landfill underneath the tide flats and Dogfish Bay. For the portion of the intermediate aquifer underneath the northern part of the landfill, the groundwater travels toward the landfill from the west and then also moves downgradient of the landfill underneath the tide flats and Dogfish Bay. The groundwater contours for the intermediate aquifer encircle the tide flats, mirroring the topography; this indicates that this groundwater ultimately discharges into the tide flats and Dogfish Bay. The groundwater levels are influenced by seasonal and tidal changes, but not enough to change the general flow patterns discussed above.

Groundwater modeling conducted by the USGS in 1997 supports the conclusion that the intermediate aquifer groundwater from beneath the landfill discharges to the tide flats and Dogfish Bay. The USGS modeling report, Ground-water Flow and Potential Contaminant Movement from the Former Base Landfill at Operable Unit 1, Naval Undersea Warfare Center, Division Keyport, Washington was prepared during assessment of the supplemental sampling data and is presented in Appendix A of the Data Assessment Report. The USGS study also concludes that, under present conditions, landfill contaminants in the groundwater would not flow beneath off-base land areas (where they could be tapped by domestic wells) before discharging to surface water. The study further concludes that it would be highly unlikely that even a hypothetical future increase in off-base groundwater withdrawal rates would alter the intermediate aquifer flow regime in a way that results in landfill contaminants being drawn to domestic wells.

Hydraulic conductivity determinations, based on slug test measurements, were made for both the upper and intermediate aquifers during the RI and supplemental data collection program. The Data Assessment Report indicates an average hydraulic conductivity based on slug tests of the upper and intermediate aquifers of 4.1 ft per day and 3.3 ft per day, respectively. Based on this information and average hydraulic gradients, the Data Assessment Report calculates groundwater velocities of approximately 0.15 ft per day in the upper aquifer and 0.1 ft per day in the intermediate aquifer and travel times along key groundwater flow paths. The Data Assessment Report calculates the travel time for groundwater to pass through the landfill in the upper aquifer is on the order of five to eight years, and the travel time for groundwater to flow from the southern landfill to the tide flats is on the order of 27 years.

Vertical gradients between the upper and intermediate aquifers presented in the Data Assessment Report indicate that a zone of upward vertical flow exists within the southern and western portions of the landfill, and a zone of downward flow exists within the northeastern part of the landfill. The vertical gradient is neutral (approximately zero) in the middle of the landfill where the middle aquitard was found to be absent.

2.4.3 GROUNDWATER CONTAMINATION

VOCs

Figure 6-3 of the Data Assessment Report, which is included in Attachment A of this report, presents the magnitude (average over five rounds of sampling) and distribution of VOC contamination at various locations in the upper aquifer prior to the September 1998ROD. VOCs shown in this figure include the following:

- Trichloroethene (TCE)
- cis-1,2-Dichloroethene (cis-1,2-DCE)

- trans-1,2-Dichloroethene (trans-1,2-DCE)
- Vinyl chloride
- 1,1,1-Trichloroethane (1,1,1-TCA)
- 1,1-Dichloroethane (1,1-DCA)
- Chloroethane
- 1,1-Dichloroethene (1,1-DCE)
- 1,2-Dichloroethane (1,2-DCA)

The VOC signature varies by sampling location. For example, at MW1-16 in the southern portion of the landfill, the VOCs were predominantly 1,1-DCA (50 percent of total presented concentration), cis-1,2-DCE (20 percent of total presented concentration), vinyl chloride (17 percent of total presented concentration) and 1,1,1-TCA (7 percent of total presented concentration). However, 100 ft away in the southern landfill at MW1-04, the VOCs were predominantly TCE (64 percent of total presented concentration), cis-1,2-DCE (26 percent of total presented concentration) and vinyl chloride (9 percent of total presented concentration).

Figure 6-3 from the 2011 Annual Report presents TCE, cis-1,2-DCE and vinyl chloride concentrations in the upper aquifer from two sampling events conducted in 2011. Table B-1 from the 2011 Annual Report provides the historic VOC data, including the data used in the development of these two figures from the Data Assessment Report and the 2011 Annual Report.

Several significant features and changes are apparent when reviewing these two figures and the data used to develop them, including the following:

- VOC contamination is generally present in the southern and northern portions of the landfill and not in between these two portions of the landfill.

- VOC contamination in the northern portion of the landfill is predominantly TCE and its daughter products. The total VOC concentrations in the northern portion of the landfill are generally lower than those in the southern portion of the landfill, and concentrations have decreased over time.

- VOC contamination in the southern portion of the landfill appears to include both 1,1,1-TCA (and its daughter products) and TCE (and its daughter products), with more 1,1,1-TCA-related contamination at MW1-16 and more TCE related contamination at MW1-04. Concentrations in the southern portion of the landfill are generally higher (both historically and at present) compared to the northern portion of the landfill.

- VOC concentrations at MW1-16 were substantially lower in 2011 than pre-ROD, even after including a 1,1-DCA concentration of 1,500 micrograms per liter (μg/L) detected in MW1-16 in October 2011 (not shown in the 2011 figure). The most significant decrease occurred around 1999.

- There are seasonal trends in the VOC data at MW1-16, with higher concentrations of VOCs detected in October compared to July.

- There are seasonal trends in the VOC data at MW1-04, with higher concentrations of VOCs detected in July compared to October (the opposite pattern of what is observed at MW1-16). The seasonal high concentrations at MW1-04 are of similar magnitude to the concentrations detected during the pre-ROD sampling events presented in the 1997 Data Assessment Report.

VOC contamination is also present in the intermediate aquifer. MW1-25 and MW1-28, located beyond the downgradient edge of the northern portion of the landfill, are impacted with cis-1,2-DCE and vinyl chloride. Pre-ROD concentrations of cis-1,2-DCE are illustrated in Figure 13 from the 1997 Keyport Area Private Well Inventory and Sampling Report (Appendix C of the Data Assessment Report). This figure is included in Attachment A of this report. Figure 6-5 of the 2010 Annual Report presents TCE, cis-1,2-DCE and vinyl chloride concentrations for the same two wells during a June 2010 sampling event. The wells were not sampled in 2011. The pre-ROD and June 2010 concentrations in these two wells are of similar magnitude. A decrease may be apparent in MW1-25, but a slight increase may be apparent in MW1-28. Table B-1 from the 2011 Annual Report and Table 6-1 of the Third Five-Year Review provide the historical sampling results for these two wells, but it appears that the pre-ROD data (1995 through 1996) presented in these tables for these two wells are not consistent with the values presented in the Data Assessment Report, suggesting the potential for data entry or data management errors in these two tables or in the Data Assessment Report. The detected VOC concentrations in the intermediate aquifer, located downgradient of the northern portion of the landfill, are currently higher than the detected VOC concentrations in the upper aquifer beneath the northern landfill. The VOC contamination in the intermediate zone appears to attenuate prior to MW1-38 and MW1-39; these wells are on the downgradient side of the tide flats. There are no monitoring wells in the intermediate aquifer within the footprint of the landfill.

PCBs

Pre-ROD PCB concentrations in groundwater (analyzed as Arochlor concentrations) are depicted in Figure 30 of the 1997 Keyport Area Private Well Inventory and Sampling Report (Appendix C of the Data Assessment Report). Groundwater is no longer sampled for PCBs, but sediments, surface water and fish tissue continue to be sampled for PCBs.

1,4-Dioxane

Groundwater samples were analyzed for 1,4-dioxane one time in 2006. The highest detections were in MW1-25 and MW1-28 (29 µg/L in both wells). These are intermediate aquifer wells located along Key Road at the western edge of the northern portion of the landfill. No remediation goal was established for 1,4-dioxane in the ROD, but the current State of Washington Model Toxics Control Act (MTCA) Method B standard is 4 µg/L. There were no detections of 1,4-dioxane above a detection limit of 1 µg/L in the southern portion of the landfill.

2.4.4 SOIL CONTAMINATION

Soil data were not reviewed by the optimization review team. It is generally understood that several organic compounds and inorganic analytes have been detected within the landfill waste. In the case of VOCs, it is generally understood that this soil contamination is serving as an ongoing source of groundwater contamination.

2.4.5 SEDIMENT AND SURFACE WATER CONTAMINATION

VOCs

Surface water sampling locations are illustrated on Figure 4-2 from the Third Five-Year Review. This figure is provided in Attachment A of this report. TCE and vinyl chloride are routinely detected at surface water sampling location MA-12 (immediately upstream of the marsh pond) above the remediation goals of 56 µg/L for TCE and 2.1 µg/L for vinyl chloride. Over the past 5 years, TCE concentrations at this location have ranged from less than 56 µg/L to as high as 170 µg/L, and vinyl chloride concentrations at MA-12 have ranged from less than 2.1 µg/L to as high as 120 µg/L. There have been no other VOC detections above standards in the annual sampling events at any other surface water or seep sampling location since 2005, and VOCs were never detected above standards at surface water sampling location DB-14 (Dogfish Bay). Sediments and fish tissue are not sampled for VOCs.

PCBs

PCBs were detected in sediment during the 1996 sampling event, but that impacted sediment was removed as part of the remedy in 1999. Since that sediment removal, PCBs have not been detected above the remedial goal of 12 micrograms per kilogram (µg/kg) in any sediment samples.

Seep location SP1-1, which is believed to have been the primary discharge location of PCBs to the marsh is sampled every two years for PCBs. Between 2000 and 2004, the total PCB concentration at SP1-1 ranged from 0.42 µg/L to 0.45 µg/L, and between 2006 and 2010, the total PCB concentrations at SP1-1 ranged from 0.27 µg/L to 0.29 µg/L. In 2010 (and possibly in earlier years), the only detected Arochlor was 1242 (0.28 µg/L). The surface water remedial goal for total PCBs is 0.04 µg/L.

With the exception of one shellfish tissue sample collected in 2000, shellfish tissue sampling results have been below the remediation goal of 15 µg/kg wet weight for seafood ingestion.

Other Analytes

With exception of one chromium exceedance at sampling location MA-11 in 2009 (269 milligrams per kilogram (mg/kg) compared to a remediation goal of 260 mg/kg), no metals have exceeded sediment remediation goals at any sampling location during any sampling event. The chromium samples collected prior to 2009 were well below the remediation goal and did not indicate an increasing trend. Additional sediment and analysis sampling to further evaluate the chromium exceedance was performed in May 2012. The data were not reviewed by the optimization review team, however, the Navy reports that chromium detections were less than the State Sediment Quality Standards. It is noted that the sediment remediation goals provided in the Third Five-Year Review are for marine sediments and that many of the sampling locations, including MA-11 are likely freshwater and not marine water sediments, which could have implications for the risk assessment and cleanup standards.

3.0 DESCRIPTION OF PLANNED OR EXISTING REMEDIES

This section is based on information available from existing site documents. Interpretations included in this section are generally those presented in the documents from which the information was obtained. The optimization review team's interpretation of this information and evaluation of remedy components are presented in Sections 4.0 and 5.0.

3.1 REMEDY AND REMEDY COMPONENTS

3.1.1 PHYTOREMEDIATION

Northern and southern areas (plantations) of hybrid poplar trees were planted in accordance with the 1998 ROD to address VOC-contaminated groundwater in the northern and southern portions of the landfill. According to the Third Five-Year Review and earlier site documents, a planting density was chosen that would: 1) avoid adverse dewatering of the wetlands adjacent to the landfill, 2) avoid adverse changes in groundwater flow such as drawing saline water from the marsh pond to the tree stands and 3) maximize contaminant removal. The hybrid trees were planted in the spring of 1999. A total of 545 trees were planted in an area between 1 and 1.5 acres in the northern plantation, and 360 trees were planted over an area of under one acre in the southern plantation. Subsequent tree maintenance and thinning has resulted in the removal of some trees. Tree spacing is arranged in a grid pattern with approximately 10 ft between each tree. An irrigation system consisting of an array of shallow buried pipe was installed and is periodically operated. Fencing was installed around each plantation to prevent unauthorized access.

3.1.2 SEDIMENT EXCAVATION

PCB-contaminated sediment was removed from the marsh creek in 1999. The Third Five-Year Review states that although the PCB concentrations were below levels requiring active cleanup, this remedial action was selected to reduce the potential for PCBs to migrate into and accumulate in the tide flats and Dogfish Bay in harmful quantities in the future. The goal of the sediment removal was to remove approximately 6 inches of surface sediments where previous sampling had shown the highest PCB concentrations. A high-pressure vacuum truck with a suction line was used to vacuum the sediment directly from the marsh into sludge boxes. Approximately 75 tons of sediment was removed from the site and transported to a Subtitle D landfill for solidification and disposal. The area of the sediment removal is shown in Figure 1-2 from the 2011 Annual Report (see Attachment A for this figure).

3.1.3 OTHER REMEDY COMPONENTS

Other remedy components included the following:

- Tide gate upgrade – This remedy component was implemented in 1999 to reduce the tidal influence on the marsh and to reduce the potential for tidal flow to influence water levels in the landfill.

- Landfill cover upgrade – This remedy component was completed between 2002 and 2003 and included upgrading stormwater facilities and regrading and paving the surface of the landfill not occupied by the phytoremediation plantations.

- LTM – This remedy component began in 1999 and is discussed further in Section 3.3.

- ICs – According to the Third Five-Year Review, the IC plan is designed to preclude the installation of wells (except those associated with the remedy) in the vicinity of the landfill and prevent development or other activity that could disturb the landfill, tide flats or adjoining marsh and shoreline. These ICs are designed to avoid actions that could lead to unacceptable risks to human health.

- Contingent remedy – A contingent remedial action plan was finalized in March 2003 and specifies the actions to be taken if monitoring identifies contamination migrating from OU-1 to water supply wells. The actions include additional sampling and providing alternate sources of water to potentially affected properties.

3.2 RAOs and Standards

This section provides a summary of remedial action objectives (RAOs) for various environmental media affected by site-related contamination as described in the 1998 ROD and the Third Five-Year Review.

RAOs for Soil, Waste and Vapor within the Landfill

- Prevent exposures to humans due to dermal contact with or ingestion of landfill soil or waste material that contains contaminants that may result in unacceptable risk. For this objective, unacceptable risk is defined by exposure of humans to concentrations of landfill contaminants above state cleanup levels for soil (MTCA Method B).

- Prevent exposures to humans due to inhalation of vapor from the landfill that contains contaminants that may result in unacceptable risk. For this objective, unacceptable risk is defined by exposure of humans to concentrations of landfill contaminants above state cleanup levels for air (MTCA Method B).

Section 11.5.3 and subsections of 11.5.3 of the 1998 ROD state that no remediation goals have been included for soil and vapor because contaminant concentrations in the landfill will not likely be decreased by the remedial actions or natural processes to a point that allows unrestricted access and unlimited use of the site.

RAOs for Groundwater

- Prevent exposures to humans due to drinking water ingestion of groundwater that contains landfill contaminants at concentrations above state and federal drinking water standards and state cleanup levels for groundwater (MTCA Method B). Section 11.5.3 and subsections of 11.5.3 of the 1998 ROD state that the points of compliance include the groundwater throughout the landfill and all groundwater that is suitable as a drinking water resource and that can be affected by the landfill contaminants. These sections and subsections of the 1998 ROD further state that the need to take additional action would be based on the contaminant concentration trends observed in the groundwater monitoring program.

- Prevent unacceptable risks to humans and aquatic organisms due to migration of landfill contaminants via groundwater into the adjacent aquatic environments, as defined in the RAOs discussed below for surface water. Section 11.5.3 and subsections of 11.5.3 of the 1998 ROD refer to the establishment of alternative or conditional points of compliance in which the point of compliance is "located within the surface water as close as technically possible to the point or points where groundwater flows into the surface water." (Washington Administration Code [WAC] 173-340-720(6)(d)).

The table below summarizes Applicable or Relevant and Appropriate Requirements (ARARS) for groundwater as presented in the Third Five-Year Review.

Groundwater ARARS for Drinking Water Pathway

Chemical	ROD RG (µg/L)	Basis of ROD RG	Current MTCA Method B (µg/L)	Current Federal and State MCL (µg/L)	Current PQL as Applicable (µg/L)
1,1- DCA	800	MTCA B, drinking water	1600	None	
1,2-DCA	5	MCL	0.48	5	
1,1-DCE	0.5	PQL	400	7	0.02
1,2-DCE (cis)	70	MCL	80	70	
1,2-DCE (trans)	100	MCL	160	100	
PCE	5	MCL	0.081	5	
1,1,1-TCA	200	MCL	7,200	200	
TCE	5	MCL	0.49	5	
Vinyl chloride	0.5	PQL	0.029	2	0.02
PCBs	0.04	PQL	0.044	0.5	0.02-0.04
1,4-Dioxane	None		4	None	

MCL = Maximum Contaminant Level; PQL = Practical Quantitation Level; RG = Remedial Goal; PCE = Tetrachloroethene; TCA = trichloroethane; DCA = dichloroethane; DCE = dichloroethene; PCBs = polychlorinated biphenyl; µg/L = microgram/liter. ROD = Record of Decision; MTCA = Washington Model Toxics Control Act.

RAOs for Surface Water

- Prevent exposures to humans due to ingestion of seafood that contains contaminants at concentrations that pose unacceptable risk as a result of chemicals migrating from the landfill via groundwater into the adjacent marine water. For this objective, unacceptable risk is defined by exposure of seafood resources to concentrations of landfill contaminants in surface water above state water quality standards, federal water quality criteria and state cleanup levels for surface water (MTCA Method B). This refers to those surface water criteria and standards developed for the protection of human health (i.e., seafood ingestion).

- Prevent exposures to aquatic organisms due to contaminants present in surface water at concentrations that pose unacceptable risk as a result of chemicals migrating from the landfill via groundwater into the adjacent surface water. For this objective, unacceptable risk is defined by concentrations in surface water above state water quality standards or federal water quality criteria developed for the protection of marine organisms.

The table below summarizes surface water ARARS as presented in the Third Five-Year Review.

ARARs for Surface Water Protection Pathway

Chemical	ROD RG Based on MTCA Method B Surface Water (µg/L)	Current NTR Organisms Only	Current MTCA Method B Surface Water Value (µg/L)	Current PQL as Applicable (µg/L)
1,1- DCA	None	None	None	NA
1,2-DCA	59	99	59.4	NA
1,1-DCE	1.9	3.2	23,100	NA
1,2-DCE (cis)	None	None	None	NA
1,2-DCE (trans)	33,000	None	32,817	NA
PCE	4.2	8.85	0.39	NA
1,1,1-TCA	41,700	None	416,666	NA
TCE	56	81	6.7	NA
Vinyl chloride	2.9	525	3.7	NA
PCBs	PQL: 0.04	0.00017	0.00011	0.02 – 0.04
1,4-Dioxane	None	None	None	

MCL = Maximum Contaminant Level, PQL = Practical Quantitation Level, RG = Remedial Goal, , PCE = Tetrachloroethene, NA = Not applicable; NTR = National Toxics Rule; TCA = trichloroethane; DCA = dichloroethane; DCE = dichloroethene; PCBs = polychlorinated biphenyl; µg/L = microgram/liter. ROD = Record of Decision; MTCA = Washington Model Toxics Control Act.

RAOs for Sediments

- Prevent exposures to humans due to ingestion of seafood that contains contaminants at concentrations that pose unacceptable risk as a result of chemicals migrating from the landfill via groundwater into the sediments of the adjacent aquatic systems and then into seafood tissues. For this objective, unacceptable risk is defined by concentrations in littleneck clam tissues, as defined in the seafood ingestion RAO discussed below for shellfish.

- Prevent exposures to aquatic organisms due to contaminants present in sediments at concentrations that pose unacceptable risk as a result of chemicals migrating from the landfill via groundwater into the adjacent aquatic systems. For this objective, unacceptable risk is defined by concentrations in sediments above state sediment quality standards (for chemistry) and by bioassays.

RAOs for Shellfish

- Prevent exposures to humans due to ingestion of seafood that contains contaminants at concentrations that pose unacceptable risk as a result of chemicals migrating from the landfill via groundwater into the adjacent aquatic systems. For this objective, unacceptable risk is defined by concentrations in littleneck clam tissues above a cumulative incremental cancer risk of 1 x 10^{-5} or above a noncancer hazard index of 1.0, using exposure assumptions for subsistence harvesters as identified in Appendix B of the ROD. These target risk levels are within EPA's acceptable risk range, which refers to an incremental cancer risk range of 10^{-6} to 10^{-4} and a noncancer hazard index of 1.0 as acceptable targets for Superfund sites. The risk levels are also in accord with the risk assessment framework used in MTCA to establish state cleanup levels for exposures to multiple hazardous substances (WAC 173-340-708). MTCA does not establish cleanup levels that are specific for shellfish samples.

- Prevent exposures of aquatic organisms to contaminants migrating from the landfill that pose unacceptable risk. For this objective, unacceptable risk is defined by concentrations of landfill contaminants in littleneck clams above the ecological risk-based screening values (i.e., the maximum acceptable tissue concentrations) in Appendix J of the Summary Data Assessment Report (U.S. Navy 1997a).

3.3 PERFORMANCE MONITORING PROGRAMS

On-going remedy-related monitoring includes the following LTM programs:

- Monitoring of tree health and nurturing activities such as fertilization, pest control, pruning and irrigation

- Water level monitoring in January, June, July and October of each year

- Groundwater and surface water quality sampling in June and October of each year

- Sentinel well sampling every two years

- Tide gate inspection and maintenance in January, June, July and October of each year

- Intrinsic bioremediation monitoring conducted by the USGS for VOCs and biodegradation parameters in up to 14 monitoring wells and nine piezometers in June of each year (for most of the sampling locations)

4.0 CONCEPTUAL SITE MODEL

This section discusses the optimization review team's interpretation of existing characterization and remedy operation data and site visit observations to explain how historic events and site characteristics have led to current conditions. This CSM may differ from that described in other site documents. CSM elements discussed are based on data obtained from EPA Region 10 and the Navy and discussed in the preceding sections of this report.

4.1 CSM OVERVIEW

Chlorinated solvents were released to the environment as a result of historic waste disposal practices at the landfill. Chlorinated solvents present in the waste, buried marsh layer and possibly underlying saturated soil continue to impact groundwater in northern and southern portions of the landfill.

Groundwater in the upper aquifer discharges to surface water in the marsh. Site documents suggest that the travel time for groundwater across the landfill is approximately seven years. The groundwater flow velocities are based on measured hydraulic gradients, assumed effective porosity values and estimates of hydraulic conductivity based on monitoring well slug tests.

Contaminant concentrations in the upper aquifer in the northern landfill have a clear decreasing trend as source material and resulting dissolved contamination attenuate. TCE concentrations are generally at or slightly above the remediation goal of 5 µg/L. Vinyl chloride (likely due to intrinsic biodegradation of TCE) is the COC for which the concentration in the northern landfill is highest relative to its remediation goal of 0.5 µg/L. Monitoring wells, 1MW-1 and MW1-2, are the two monitoring wells with the highest concentrations of vinyl chloride in groundwater in the northern landfill. There is an observable, significant decreasing trend in the vinyl chloride concentration at 1MW-1 (cis-1,2-DCE concentrations are routinely below standards at 1MW-1) and a significant decreasing trend in the cis-1,2-DCE concentration at MW1-2 as indicated in Attachment B. The optimization review team agrees with the Navy, EPA, Ecology and USGS that the decreasing trends at 1MW-1 and MW1-2 indicate that some combination of the phytoremediation remedy and intrinsic biodegradation are effectively addressing the contamination in the northern landfill.

Contaminant concentrations in the upper aquifer in portions of the southern landfill (near MW1-4) remain orders of magnitude above cleanup standards, with seasonal fluctuations and no clear evidence of a decreasing trend (see chart in Attachment B with log scale for vertical axis). Contamination appears to be more widespread in the southern landfill than the northern landfill, but it is unclear how much of the contaminant extent is due to widespread source material and how much is due to dissolved phase contaminant migration. The different contaminant signatures at MW1-4 and MW1-16 (MW1-16 has 1,1-DCA, see chart in Attachment B with log scale for vertical axis), suggest the potential of multiple localized source areas. As discussed in Section 4.2.2, contaminant concentration trends at MW1-4 and MW1-16 suggest the potential that a significant contaminant mass is present near or above the water table that provides an ongoing source of dissolved contamination to groundwater. Assuming TCE was the predominant source of contamination in the vicinity of MW1-4, the relatively high levels of cis-1,2-DCE and vinyl chloride concentrations compared to TCE concentrations at MW1-4 suggest significant reductive dechlorination is occurring before contamination reaches MW1-4. Reductive dechlorination could be happening in ponded water within the waste layer above the upper aquifer or could be happening in the upper aquifer upgradient of MW1-4 or both. Water quality in MW1-4 and piezometers downgradient of MW1-4 show somewhat higher oxidation reduction potential and lower dissolved organic carbon than other wells in the southern portion of the landfill. Therefore, reductive dechlorination appears to play a less significant a role in degrading contamination at and downgradient of MW1-4 compared with other locations within OU-1.

Surface water downgradient of the southern landfill at station MA-12 (see chart in Attachment B with log scale for vertical axis) has consistently vinyl chloride concentrations more than an order of magnitude above the surface water remediation goal of 2.9 μg/L, indicating that the phytoremediation remedy and intrinsic biodegradation are not effectively addressing contamination in the southern landfill area as expected by the 1998 ROD. The ratios of TCE to cis-1,2-DCE and of TCE to vinyl chloride in surface water at MA-12 compared to the same ratios at MW1-4 suggest intrinsic biodegradation is occurring in the upper aquifer prior to discharge to surface water; however, this attenuation is not sufficient to meet the surface water remediation goals. In addition, the presence of TCE in surface water suggests that the TCE discharge to surface water is likely along the flow path defined by P1-10, MW1-4, P1-9, P1-7 and pore water sample locations S-4/S-5.

No sampling points are present in the intermediate aquifer within the footprint of the landfill, but downgradient sampling points in the intermediate aquifer demonstrate the chlorinated solvents are present in the intermediate aquifer. The site team hypothesizes that contamination has migrated in the dissolved phase from the upper aquifer into the intermediate aquifer through “windows” in the aquitard (that is, areas where the aquitard is not present) in the central portion of the landfill. However, as discussed in Section 4.2.1, the optimization review team believes it might be possible that the contamination in the intermediate aquifer could be the result of DNAPL that historically migrated from the upper aquifer to the intermediate aquifer. Contamination in the intermediate aquifer likely discharges to the tide flats or to Dog Fish Bay after some degree of dilution from uncontaminated groundwater that converges toward the area of discharge.

Potential receptors of groundwater contamination considered at the site include users of surface water, public and potable water supply wells and occupants in the building across Bradley Road that might be exposed to contaminant vapors via the VI pathway. With respect to surface water receptors, site documents identify both ecological risks and human health risks through seafood ingestion. Because the site lies within the adjudicated Usual and Accustomed harvest area, the Suquamish Tribe maintains the right to harvest for ceremonial, subsistence and commercial purposes. All site stakeholders participating in the optimization review process agreed that additional work was required to protect the surface water of the marsh. Water level data, water quality data and geological information have helped identify contaminant migration pathways and confirm that the public and potable water supply wells are not affected. The VI pathway was evaluated during the RI with soil vapor sampling and indoor air sampling. Modular buildings previously located on the landfill were removed. Vapor migration across Bradley Road was limited with the exception of the area near the intersection of Bradley Road and Torpedo Road. ICs restrict groundwater use in the area of the landfill and prevent development or activity that could disturb the landfill.

4.2 CSM Details and Explanation

This section provides additional details and further explanation of key CSM-related review observations.

4.2.1 VERTICAL MIGRATION OF CONTAMINATION

The optimization review team believes it is unlikely that the observed contamination in the intermediate aquifer results from dissolved contamination migrating vertically from the upper aquifer into the intermediate aquifer for the following reasons:

- There is a vertically-upward hydraulic gradient between the intermediate and upper aquifers in the southern portion of the landfill and much of the central portion of the landfill.
- Groundwater in the upper aquifer generally flows from east to west, and the general absence of upper aquifer groundwater contamination in the central portion of the landfill suggests it is unlikely that contamination from the southern landfill migrated northward to the window and then vertically into the underlying intermediate aquifer.
- Although there is a vertically-downward hydraulic gradient between the upper and intermediate aquifers in the northern portion of the landfill, vinyl chloride concentrations in the intermediate aquifer at MW1-25 and MW1-28 are higher than those in the upper aquifer under the northern landfill and have not attenuated as much over time as those in the upper aquifer under the northern landfill.

An alternative scenario for contaminant transport into the intermediate aquifer is that DNAPL in the southern portion of the landfill migrated vertically downward from the upper aquifer to the intermediate aquifer and then the horizontal hydraulic gradient in the intermediate aquifer facilitated the transport of dissolved contamination toward MW1-25 and MW1-28. This scenario provides a potential pathway and also explains why cis-1,2-DCE and vinyl chloride concentrations have remained relatively persistent over time at MW1-28. There is insufficient information to confirm this suggested historic vertical migration pathway. Regardless, interpreted groundwater flow directions and water quality sampling results in the intermediate aquifer suggest that TCE is degrading to cis-1,2-DCE and vinyl chloride and that the intermediate aquifer plume is delineated and discharging to: 1) the tide flats after being diluted (to some unknown degree) by uncontaminated groundwater converging toward the tide flats from other directions, or 2) Dog Fish bay after being diluted to the concentrations observed at monitoring wells MW1-36 through MW1-39. Current surface water sampling of these water bodies suggests no exceedances of site surface water standards; therefore, the optimization review team concludes that additional investigation of the source and intermediate aquifer plume are not warranted.

4.2.2 SHALLOW ON-GOING SOURCE OF CONTAMINATION

At MW1-4, peak concentrations occur during the June sampling events. The peak TCE concentrations at MW1-4 are as high as 32,000 μg/L and are typically a factor of 4 to 10 times higher than the lower concentrations detected in the October sampling events. The cis-1,2-DCE concentrations are approximately a factor of 2 times lower and exhibit the same seasonal pattern. The vinyl chloride concentrations are 30 to 50 times lower than the TCE concentrations and also exhibit the same seasonal pattern. This seasonal fluctuation is not readily explained from dilution caused by faster groundwater flow during one season versus another season because the hydraulic gradient and groundwater flow pattern remain relatively consistent over the year. One CSM interpretation is that precipitation infiltrates during the rainy season (late fall through spring) and the infiltrated water leaches through solvent-contaminated waste, accumulates in depressions on top of the silt layer that overlies the upper aquifer and slowly leaches into the upper aquifer resulting in high concentrations that are still observable during June sampling events. During the growing season, the poplar trees extract the contaminated water accumulating above the silt and deplete it such that there is substantially lower mass flux during summer and early fall, resulting in lower groundwater concentrations during the October sampling event. This CSM interpretation would suggest that the phytoremediation remedy is relatively effective during the growing season. The site team's need to irrigate the plantations suggests further that the poplar trees are preferentially extracting this shallow (perhaps perched) water that has accumulated over several months rather than tapping the upper aquifer. The argument for perched water is also supported by TCE to cis-1,2-DCE to vinyl chloride ratios that suggest significant reductive dechlorination prior to contamination reaching MW1-4. A second CSM interpretation is that reductive dechlorination is occurring to some degree in perched water before it leaches into the upper aquifer. Although the above discussion is focused on precipitation, it is also possible that seasonal changes in groundwater elevation may also play a role in leaching contamination from the overlying waste to the upper aquifer. If this is the case, the changes in contaminant concentrations could result from a high water table in the Spring contacting solvent-contaminated waste and causing groundwater contamination that is observable in the June sampling event. Under this CSM hypothesis, the phytoremediation remedy would not necessarily be effective.

At MW1-16, concentrations decreased sharply after remedy construction in 1999 and have exhibited a seasonal trend since that time with the higher concentrations detected in October sampling events compared to June sampling events. The optimization review team does not offer a conceptual model hypothesis for this behavior other than it is apparent that changes in the land surface (resulting in more infiltration) significantly changed the contaminant distribution near MW1-16. Water from irrigation may also play a role if irrigation water is present near a source of contamination.

4.3 IMPLICATIONS FOR REMEDIAL STRATEGY

The above-described CSM has the following potential implications for a remedial strategy:

- If the actual average hydraulic conductivity of the upper aquifer is higher than suggested in existing site documents, groundwater transport times may be faster than previously thought, and changes in groundwater and surface water concentrations may respond more rapidly to remediation than previously thought.

- If density-driven DNAPL flow is the mechanism for contaminant migration from the upper to the intermediate aquifer, then it is likely that the cis-1,2-DCE and vinyl chloride at MW1-25 and MW1-28 may persist for many years.

- If the primary mass flux of contamination to upper aquifer groundwater (and hence to surface water) continues to be from a well-understood, targeted area of the overlying waste, then source area hot spot remediation may be relatively more straightforward than if the primary mass flux of contamination was smeared throughout the saturated zone and continues to reside in saturated silts and clays.

- Vinyl chloride concentrations at surface water monitoring location MA-12, situated in Marsh Creek prior to entering the pond, are approximately 18 to 30 times the remediation goal, and mass flux will need to be reduced 95 to 97 percent for the remedy to comply with the surface water remediation goal for vinyl chloride.

4.4 DATA GAPS

The primary data gap is the horizontal and vertical extent of the contaminant source in the southern portion of the landfill as it pertains to ongoing contamination of the upper aquifer and potentially ongoing contamination in the intermediate aquifer.

5.0 FINDINGS

This section presents the observations and interpretations of the optimization review team. These are not intended to imply a deficiency in the work of the remedy design or site managers, but rather are offered as constructive suggestions in the best interest of the EPA, the Navy, Ecology, the Suquamish Tribe and the general public. These observations have the benefit of being formulated based on operational data unavailable to the original design team. Furthermore, it is likely that site conditions and general knowledge of groundwater remediation have changed over time.

5.1 SOURCES

Please refer to Section 4.0 for a discussion regarding the remaining source of contamination and associated data gaps. The source area is not well characterized, and this is of particular interest in the southern portion of the landfill.

5.2 GROUNDWATER

Please refer to Section 4.0 for a discussion regarding the remaining source of contamination and associated data gaps. Contaminated groundwater continues to discharge to the surface water in the marsh, resulting in surface water concentrations that are above remedial goals.

5.3 SEDIMENT

Sediment PCB contamination was addressed in 1999 and does not appear to merit further study beyond the current monitoring program, which consistently shows that PCBs are not detected above standards in sediments. PCBs continue to discharge from seep SP1-1, resulting in surface water PCB concentrations above surface water protection standards. Continued monitoring of the seep and sediments is merited. A single recent exceedance of chromium was detected in sediment, which may merit continued monitoring of sediments in this location to determine if the chromium detection was a one-time event or if an increasing trend becomes apparent.

5.4 TREATMENT SYSTEM COMPONENT PERFORMANCE

The performance of the phytoremediation plantations is difficult to evaluate because groundwater extraction and mass removal cannot be easily quantified. The water quality data suggest that the combination of phytoremediation and intrinsic biodegradation are generally effective at addressing contamination in the northern plantation relative to remediation goals and that the source in this area is attenuating over time. By contrast, the water quality data suggest that the combination of phytoremediation and intrinsic biodegradation are not effective at meeting the remediation goals in the southern plantation and that the source is not appreciably attenuating over time.

5.5 REGULATORY COMPLIANCE

Remedy performance is described above. The current remedy is not operating under a discharge permit or an air permit.

5.6 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF ANNUAL COSTS

Costs were not discussed as a part of this evaluation. At the request of the stakeholders, the focus is on evaluating remedy effectiveness and a cost-effective approach to site closure, and current costs are not material to these optimization objectives.

5.7 APPROXIMATE ENVIRONMENTAL FOOTPRINT ASSOCIATED WITH REMEDY

The environmental footprint of the existing remedy is very low compared to many other remedies evaluated in this optimization program. The environmental footprint at this site is generally associated with personnel travel, laboratory analysis and direct potable water use for irrigation.

5.8 SAFETY RECORD

The site team did not report any safety concerns or incidents.

6.0 RECOMMENDATIONS

This section provides recommendations related to remedy effectiveness and site closure strategy. While the recommendations provide some details to consider during implementation, the recommendations are not meant to replace other, more comprehensive, planning documents such as work plans, sampling plans and QAPPs.

Cost estimates provided in this section have levels of certainty comparable to those typically prepared for CERCLA FS reports (-30 to 50 + percent), and these cost estimates have been prepared in a manner generally consistent with EPA 540-R-00-002, *A Guide to Developing and Documenting Cost Estimates During the Feasibility Study*, July, 2000. The costs presented do not include potential costs associated with community or public relations activities that may be conducted prior to field activities. Table 6-1 summarizes the costs of these recommendations. Quantification and evaluation of the remedy footprint has been deferred until more information is available about the nature and extent of the source area in the southern portion of the landfill.

6.1 RECOMMENDATIONS TO IMPROVE EFFECTIVENESS

6.1.1 CHARACTERIZE EXTENT OF CONTAMINATION IN THE SOUTHERN PORTION OF THE LANDFILL

The primary data gap to address prior to determining a path forward for site remediation is further characterization of the source material within the southern portion of the landfill. At the time of the optimization review site visit, the site team was preparing to conduct a characterization event in which tree core samples, in-plant sorbent samples and soil gas samples will be collected throughout the southern portion of the landfill. This information should help provide the site team with an understanding of the areal extent of contamination.

The root zone of the poplar trees is uncertain. The lack of an influence of the trees on the upper aquifer potentiometric surface map, and the use of irrigation suggest that the roots likely extract water from the top soil, waste and underlying silt but perhaps not significantly from the upper aquifer. If this is the case, then the tree samples (core and in-plant sorbent samples) and soil gas samples may be very effective at focusing on source material rather than a broader dissolved plume. However, if this is not the case, then the tree samples may not accurately represent source material that is present within the upper aquifer below the tree root zone.

The Navy communicated that the cost for the above-described characterization event is approximately $140,000 and that funding limitations and the need to collect tree core samples during a growing season will defer this effort until Spring/Summer 2014. An alternate option would be to take a more traditional approach to characterization by collecting groundwater samples from temporary well points, collecting passive soil gas samples and evaluating this new data alongside existing monitoring well data. One potential approach would be to collect passive soil gas samples on a 20-ft by 20-ft grid in the southern portion of the landfill (approximately 100 samples), evaluate the results and then collect soil and groundwater samples from approximately 20 to 25 locations based on the soil gas results. The soil and groundwater sample analytical results would be used to help interpret the soil gas sample results, provide information about contaminant mass in the saturated zone and determine the general extent and location of the source area. As a reasonable worst-case scenario, it is assumed that samples are collected using a hollow stem auger (HSA) with a soil sample collected from the top of the silt underlying the waste and the groundwater sample collected from a temporary well point in the upper aquifer. The optimization review team estimates that this approach would cost approximately the same amount as the tree core/soil gas sampling plan proposed by the site team (that is, $140,000), including planning, field work, oversight, laboratory analysis and reporting. Costs would decrease or the number of data points could increase if direct-push technology (DPT) sampling methods can be used in place of a HSA. If there are concerns about the limitations of using DPT or HSA rigs drilling into landfill debris, the site team might consider using a mini sonic drill rig to help overcome these issues. The data obtained from this more traditional characterization approach would be sparser than the data obtained from the tree core/soil gas sampling approach, but would provide direct information regarding soil and groundwater concentrations and would not be subject to the uncertainties associated with the tree core/soil gas sampling approach. Furthermore, the event can be conducted any time during the year, while tree core sampling must wait until the Spring/Summer 2014 growing season.

The optimization review team suggests conducting one of the above characterization events and evaluating the data before conducting further characterization efforts. If this phase of characterization suggests a focused source area, then source removal will likely be practical and additional characterization will be merited. However, if the results suggest the source is broad in extent, then source control rather than source removal may be more likely, and the goal of follow-up characterization would focus on understanding the exact distribution of the source material.

6.1.2 REVIEW POTENTIAL VAPOR INTRUSION PATHWAY FOR BUILDINGS ACROSS BRADLEY ROAD

The soil vapor data presented in the RI suggest contaminant vapors generally did not migrate across Bradley Road except at the intersection of Bradley Road and Torpedo Road. The optimization review team recommends that the site team review the RI work and the associated data quality to determine if the findings are adequate to close the VI pathway for the buildings across Bradley Road from Torpedo Road south to Gadberry Street. For some buildings, particularly near Torpedo Road, a VI evaluation potentially starting with near slab or sub-slab soil vapor sampling might be appropriate. The cost for an initial evaluation that includes review of the RI data plus planning, field work and reporting of additional vapor samples (if needed) might be approximately $20,000 but could likely be performed for less if the work can be coordinated with other field activities.

6.2 RECOMMENDATIONS TO REDUCE COSTS

No recommendations are provided for this category because the focus of this optimization review is to evaluate remedy performance and consider potential alternative paths forward to site closure.

6.3 RECOMMENDATIONS FOR TECHNICAL IMPROVEMENT

6.3.1 CONSIDER USING CONTAMINATED GROUNDWATER FOR THE IRRIGATION SYSTEM

The optimization review team agrees with the optimization review team contributors from the Navy that extracted contaminated groundwater could be used for the irrigation system instead of tap water. This approach will reduce the net amount of water flowing through the aquifer and will potentially increase the exposure of the tree roots to contaminated groundwater. If the site team decides to test this approach, the optimization review team suggests the site team install a piezometer near the extraction well and conduct an aquifer test from the well to provide a better understanding of the hydraulic conductivity of the upper aquifer. The site team might also consider installing a shallow piezometer in the waste to determine the thickness of a perched water table, if any. The hydraulic conductivity and perched water information could be key design factors when considering various remedial options. More frequent monitoring and well gauging of the southern plantation monitoring wells would be merited to evaluate the effect of this approach.

The effect of using contaminated water in the irrigation system is uncertain, so the optimization review team is only suggesting this reuse for one or two growing seasons while the site team evaluates characterization data and conducts a FFS. The optimization review team is not suggesting this change in irrigation in place of the additional characterization recommended in Section 6.1.1, in place of considering more robust treatment approaches or as a potential source of delay in addressing the contamination in the southern portion of the landfill. The optimization review team estimates that installing the wells (a shallow extraction well, upper aquifer piezometer and piezometer completed in the waste), conducting a pump test and two extra sampling and well gauging events in the southern portion of the landfill might cost approximately $30,000 to plan, conduct, evaluate and report.

6.4 CONSIDERATIONS FOR GAINING SITE CLOSE OUT

The optimization review team believes it is premature to evaluate remedial options at this site until additional characterization of the source area has been conducted and the data evaluated. A limited number of potential remedial options are discussed in this section at the request of the site stakeholders. The options presented are not intended to be a complete survey of the remedial options available or the best options available. Rather, they are conservative approaches that should be applicable for the scenarios described. The optimization review team recommends a more thorough and expanded remedial options analysis after further characterization has been completed and the CSM has been updated.

The following considerations focus on various steps and paths forward to improve performance of the remedy to protect the surface water of the marsh adjacent to and immediately downgradient of the southern portion of the landfill. The following considerations are provided assuming that site stakeholders agree with and accept the following:

- Groundwater quality within the footprint of the landfill is not expected to be restored to drinking water quality for several decades.
- Groundwater contamination in the upper aquifer underlying the northern portion of the landfill is effectively attenuating due to intrinsic biodegradation (and possibly phytoremediation) in a reasonable time frame such that additional remedial activities are not merited to address contamination from the northern portion of the landfill.
- Groundwater contamination in the intermediate aquifer appears to be stable, undergoing a degree of intrinsic reductive dechlorination and discharging to surface water after some degree of dilution from uncontaminated groundwater that is also flowing toward the tide flats. Given that surface water sampling results at the tide flats and Dog Fish Bay sampling locations for the past several years have been below the current MTCA Method B Surface Water Values, it is assumed that additional remedial activities are not merited to address contamination in the intermediate aquifer.

6.4.1 REVISIT SURFACE WATER REMEDIATION GOALS AND POINTS OF COMPLIANCE FOR THE MARSH WATER

Before evaluating various remedial strategies for this site, the site team needs to have a clear and common understanding of the remediation goals. Based on discussions with the site stakeholders and a review of the site documents, the optimization review team concludes that the primary remediation goals that require clarification and revisiting are the surface water protection goals as they apply to the marsh water. The optimization review team suggests discussing and revisiting the point of compliance and the numerical criteria for TCE and vinyl chloride for this particular surface water feature.

The 1998 ROD established the use of a conditional point of compliance within surface water, and the recent Final 2012 Natural Attenuation Report suggests extending the point of compliance to the tide gate, essentially incorporating the marsh system as a remedial component. Discussions during the site visit suggested that Ecology would not accept this proposal, and the Suquamish Tribe reiterated its rights to harvest resources from the marsh system. EPA Region 10 also later commented that the naturally occurring marsh could not be used as a treatment system. Due to the close proximity of the landfill and waste to the marsh, it likely makes sense to establish and agree upon a point of compliance within surface water, but the site stakeholders would need to agree on that location. A potential location would include MA-12 (which currently exceeds the remediation goals). MA-12 provides two benefits as a point of compliance. First, due to its location, it likely accounts for all potential discharges from the southern portion of the landfill but is also upgradient of the marsh pond. Second, it has an extensive and consistent water quality sampling record to compare groundwater quality with surface water quality historically and in the future. Discussions regarding the point of compliance could take place before or after the additional characterization work is completed, but need to occur prior to selecting a new or modified remedial approach.

With respect to numerical criteria, surface water remediation goals for TCE and vinyl chloride are set by the MTCA Method B for fish ingestion. Based on the site documents reviewed, the optimization review team could not identify all of the assumptions that were used to derive the MTCA Method B remediation goal for these contaminants, but recognizes the MTCA Method B for the ingestion pathway specifically applies to surface water that supports, or has the potential to support, fish. The optimization review team questions if the currently used remediation goals of 56 µg/L for TCE and 2.9 µg/L for vinyl chloride (or even revised values using the MTCA Method B equation) are appropriate remediation goals for the marsh given the assumptions behind MTCA Method B. If they are not appropriate, then it may be appropriate to discuss new goals with a risk assessor.

Therefore, as part of a FFS (or other process the site team undertakes to modify the remedial approach), the optimization review team recommends that the site team discuss the above items to achieve consensus on the interpretation of the remediation goals for surface water protection as they apply to the marsh. The optimization review team estimates that this recommendation (which would only be a component of a remedy options analysis or selection approach) may cost the Navy approximately $15,000 for contractor support.

6.4.2 REVISIT GROUNDWATER REMEDIATION GOALS

Shallow contaminated groundwater in OU-1 is only present beneath the landfill and discharges immediately to surface water at the edge of the landfill. The contaminated groundwater in the intermediate aquifer is present beneath the landfill and discharges to marine waters at some point offshore. As a result of these and other factors, groundwater in the known area of the plume is very unlikely to be used as drinking water even if the contamination is addressed. As a result, the optimization review team also suggests revisiting the groundwater remediation goals when revisiting the remedial approach. The optimization review team believes this could be accomplished for under $5,000 if it is performed in conjunction with the recommendation in Section 6.4.1.

6.4.3 REMEDIAL CONSIDERATIONS IF A TARGETED SOURCE IS IDENTIFIED

If results from future characterization (using either approach discussed in Section 6.1.1) show high levels of contamination in a relatively targeted area or areas, then it may be reasonable to conclude that these targeted areas are source area hot spots that might be appropriately addressed by excavation with off-site disposal. A next appropriate step would be to better understand the horizontal and vertical mass distribution in any targeted area(s) to plan excavation of the source material. It would be appropriate to conduct an additional DPT sampling event in several locations within the targeted area(s) to collect soil samples from the waste (if the waste layer is conducive to sampling via DPT methods), the silt underlying the waste, the upper aquifer and potentially the top of the silt underlying the upper aquifer. Limited DPT sampling might also be conducted in areas where tree core results are difficult to interpret or where different lines of evidence about contaminant distribution conflict. For example, if a tree core sample and soil gas sample located near P1-7 have relatively low concentrations, it may be appropriate to collect DPT samples from the waste, silt and upper aquifer in this area because the VOC concentrations from water quality sampling at P1-7 have been high (for example, 10,000 µg/L of TCE). The scope of the additional DPT sampling event would be determined once the tree core and soil gas samples have been interpreted. The optimization review team suggests that the level of effort might be on the order of five days in the field and a total cost of $60,000, including planning, DPT rig and operator, field geologist, analytical costs and reporting. Refusal caused by debris in the landfill may complicate the use of DPT sampling. Despite this potential risk, it is likely worth mobilizing a DPT rig to attempt soil sampling in the areas of interest. If refusal occurs on a relatively limited basis, the DPT sampling can continue to be used, but if refusal becomes problematic, then it might be appropriate to collect samples with a temporary well points installed with a HSA. This approach would either significantly reduce the number of locations for which data can be obtained, significantly increase the cost or both. It would also result in more investigation derived waste that requires off-site disposal.

Assuming the site team is able to refine the majority of the source material in the southern portion of the landfill to a 30-foot by 30-foot area above the water table (predominantly the waste and the underlying silt), then excavation and disposal of the waste may cost on the order of $250,000, including planning, excavation, transport and disposal of hazardous waste, backfill, oversight and reporting. If significant waste is present below the water table in the upper aquifer, then dewatering or a complementary remedial technology, such as *in situ* bioremediation through enhanced reductive dechlorination, would be needed. Based on the characterization data and excavation results, the site team would need to evaluate potential remedial options and the potential impacts of these options on the water quality of the marsh. The extent of the dewatering or applications of additional remedial technologies would depend on the above-described soil sampling results and the horizontal and vertical extent of contamination below the water table. If soil sampling results from the silt and clay underlying the upper aquifer suggest vertical migration of DNAPL is likely responsible for the contamination observed in the intermediate aquifer, the site team will need to evaluate the practicality of addressing this source material in the intermediate aquifer. The potentially complex distribution of the contamination between the upper aquifer and intermediate aquifer, the difficulty of effectively reaching contamination in the silt and clay of the middle aquitard (if present) with most available technologies and the potential for long-term back diffusion from silt and clay could make remediation of deeper contamination impractical. This potential impracticability and the absence of completed exposure pathways to contamination in the intermediate aquifer would suggest it is reasonable to limit the vertical extent of remedial efforts to the upper aquifer.

Continued monitoring of existing groundwater and surface water monitoring locations would help determine the success of the source removal. Assuming source removal occurs in the vicinity of MW1-4, based on the distance of MW1-4 and the groundwater velocities calculated in the 1997 Data Assessment Report, the site team might expect to see improvements in surface water quality in a two to four year time period. If the average hydraulic conductivity in the area between source removal and surface water is higher than that reported in site documents, then the initial influence of the source remediation on contaminant concentrations may be apparent in a shorter time frame with further influence noticeable in ensuing years.

6.4.4 REMEDIAL CONSIDERATIONS IF A DIFFUSE SOURCE IS IDENTIFIED

If results from the currently planned characterization effort show high levels of contamination over a relatively broad area or areas, then it may be reasonable to conclude that a remedial approach other than excavation is appropriate. Limited DPT sampling (on the order of $50,000 in planning, field work, laboratory analysis and reporting) might be appropriate to ascertain the distribution of the source material between the waste, the underlying silt and the upper aquifer. As stated in Section 6.4.2, if DPT sampling is not practical due to refusal, then it might be appropriate to auger through the landfill debris using an HSA to collect samples from underlying silt and the upper aquifer. Given the CSM discussed in Section 4.0, the optimization review team finds it likely that a majority of the contaminant mass is likely in the waste layer and might be readily addressed by soil vapor extraction (SVE). If this is the case, the site team might consider installing SVE trenches or wells throughout the impacted areas. Due to the relatively shallow waste layer and a permeable surface, the extraction trenches or points will have limited areal influence and a relatively high density of trenches or points may be needed.

Assuming the contaminant mass is primarily in the waste layer and covers an area greater than 10,000 square ft, a SVE remedy consisting of a network of shallow extraction trenches, a blower and granular activated carbon off-gas treatment may cost on the order of $350,000 to implement, including planning, design, construction, three years of operation and monitoring from June through September (driest months) and reporting. Although costs are generally comparable with the excavation remedy discussed in Section 6.4.2, this approach would address a broader area of contamination than the excavation remedy. However, this approach focuses only on source material in the unsaturated waste layer, whereas the excavation remedy would be able to address targeted areas of source material in the silt and possibly the upper aquifer.

Similar to the excavation remedy, continued sampling and analysis of existing groundwater and surface water monitoring locations would help determine the success of the remedy.

If this approach is selected, then shutdown criteria for the system should be established after the first summer of operation. If extracted mass for a particular summer is less than a given percentage (for example, five percent) of the mass removed during the first summer, then only incremental benefit is being realized, and the site team should not operate the system the following summer.

6.4.5 REMEDIAL CONSIDERATIONS IF SOURCE REMOVAL EFFORTS ARE NOT SUCCESSFUL OR ARE DEEMED NOT APPROPRIATE

A potential outcome of characterization efforts is an extensive source area with significant contaminant mass in the silts and clays that underlie the waste layer or upper aquifer. In this case, source material will not be easily removed by excavation or SVE, and it might be appropriate to contain the contamination rather than remove the source. Given that the intermediate aquifer plume is stable, it would appear reasonable to focus the containment effort on the contamination in the upper aquifer. Potential approaches for containment in the upper aquifer in the order of the least to the most costly option include a permeable reactive barrier, a recirculation system and a P&T system. Each option is briefly discussed below.

- A permeable reactive barrier would likely contain the plume through an enhanced biodegradation mechanism. Substrates could be applied through emplacement in a trench or periodic injection to network of wells.
- A recirculation system would provide broad area treatment through a network of injection and extraction wells. Groundwater would likely be biostimulated or bioaugmented or both before being reinjected to enhance biodegradation throughout the recirculation zone.
- A P&T system would provide hydraulic containment with extraction from a recovery trench and ex-situ treatment or disposal of the extracted groundwater. One option for disposal would be to integrate extracted water into the irrigation system for the phytoremediation remedy. This use might require no pre-treatment or might result in less stringent treatment goals than other discharge options.

Because a containment option for this site could operate for a long period, before selecting any of the above containment options, the following factors should be well understood and considered:

- A well-defined exit strategy that incorporates specific, measurable, attainable, relevant and time-bound goals
- Mass distribution of the COCs within the source area and dominant mechanisms that govern the fate and transport of these COCs
- A robust analysis of the remediation time frame
- Aquifer testing and necessary capture zone analysis for the system design
- A bench-scale and or pilot study for selecting the biostimulation and bioaugmentation amendments, refining the system design and understanding the potential impact of the operation (including groundwater oxidation-reduction conditions) to the receptors.

After completing the additional source characterization effort, the site team should perform a detailed analysis of the remediation options, including source treatment alternatives, containment and enhancement of the phytoremediation remedy.

6.5 RECOMMENDATIONS RELATED TO ENVIRONMENTAL FOOTPRINT REDUCTIONS

No specific recommendations have been provided in this category, but the technical improvement recommendation to consider testing the use of extracted contaminated water for the phytoremediation irrigation system could eliminate the use of potable water for phytoremediation irrigation.

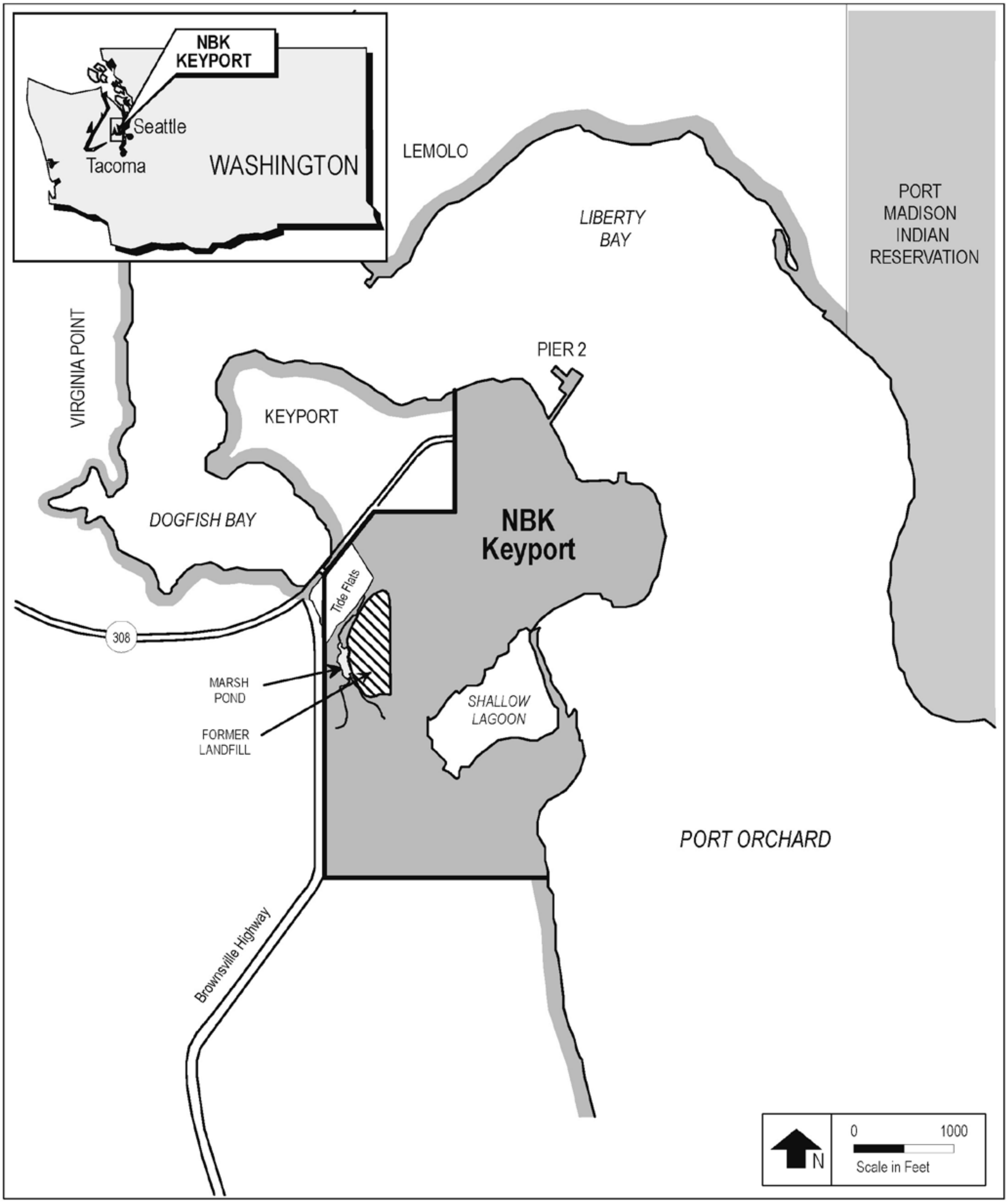
Table 6-1. Cost Summary Table

Recommendation	Category	Additional Capital Cost	Change in Annual Cost	Change in Life-Cycle Cost (30 yrs, 3 percent discount rate)
6.1.1 CHARACTERIZE EXTENT OF CONTAMINATION IN THE SOUTHERN PORTION OF THE LANDFILL	Effectiveness	$140,000	$0	$140,000
6.1.2 REVIEW POTENTIAL VAPOR INTRUSION PATHWAY FOR BUILDINGS ACROSS BRADLEY ROAD	Effectiveness	$20,000	$0	$20,000
6.3.1 CONSIDERING USING CONTAMINATED GROUNDWATER FOR THE IRRIGATION SYSTEM	Technical Improvement	$30,000	$0	$30,000
6.4.1 REVISIT SURFACE WATER REMEDIATION GOALS AND POINTS OF COMPLIANCE FOR THE MARSH WATER	Site Closure	$15,000	$0	$15,000
6.4.2 REVISIT SURFACE WATER REMEDIATION GOALS	Site Closure	$5,000	$0	$5,000
6.4.2 REMEDIAL CONSIDERATIONS IF A TARGETED SOURCE IS IDENTIFIED	Site Closure	$310,000	$0	$310,000
6.4.3 REMEDIAL CONSIDERATIONS IF A DIFFUSE SOURCE IS IDENTIFIED	Site Closure	$400,000	$0	$400,000
6.4.4 REMEDIAL CONSIDERATIONS IF SOURCE REMOVAL EFFORTS ARE NOT SUCCESSFUL OR ARE NOT APPROPRIATE	Site Closure	$250,000	$60,000	$1,426,000 discounted or $2,050,000 undiscounted

Please refer to the text of Section 6.0 for assumptions regarding costs.

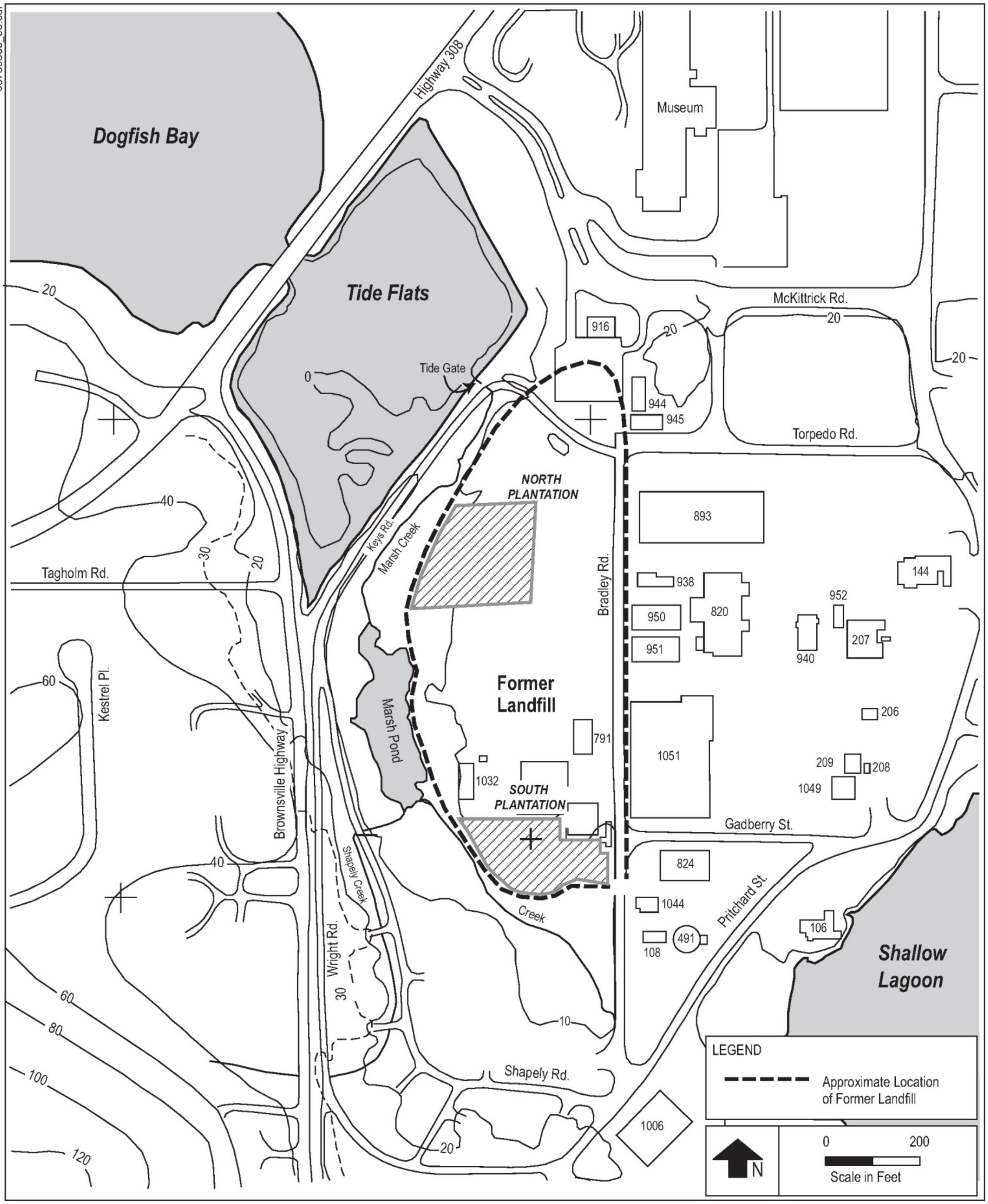
ATTACHMENT A:

Figures from Existing Site Reports

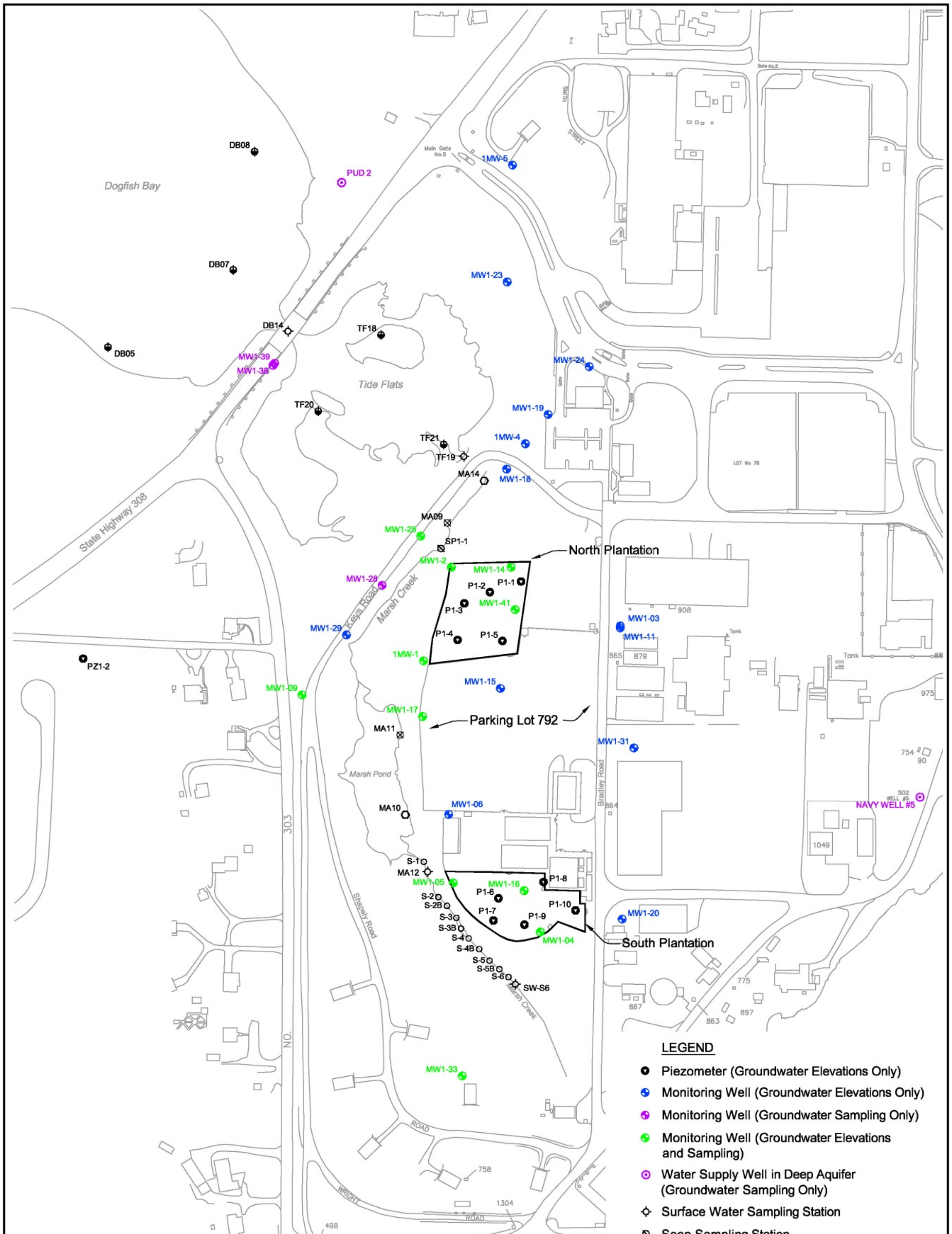


U.S. NAVY	**Figure 1-1** **NBK Keyport Vicinity Map**	NBK Keyport THIRD FIVE-YEAR REVIEW

33759568_05.cdr



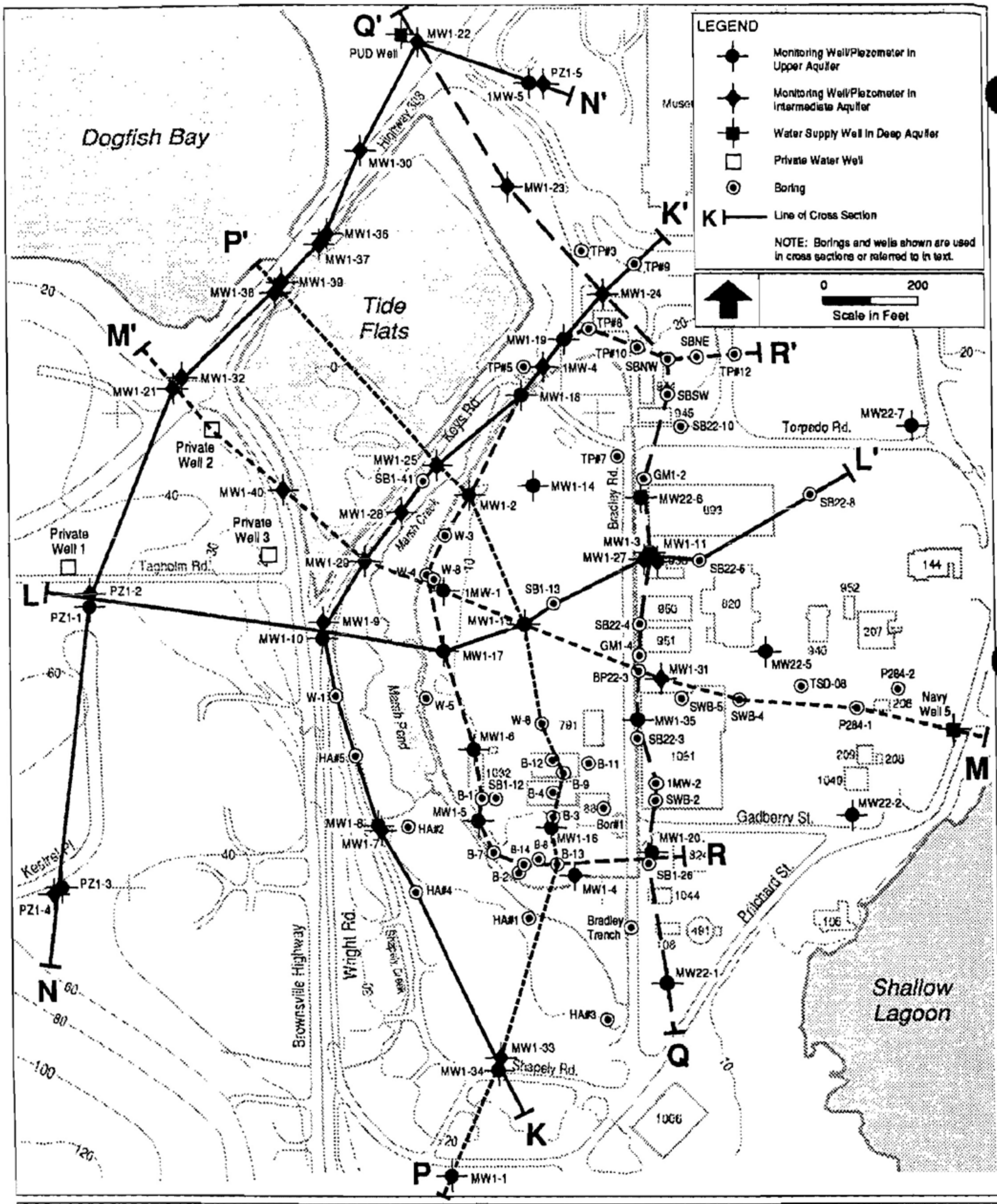
U.S. NAVY	**Figure 3-1** **Operable Unit 1**	NBK Keyport THIRD FIVE-YEAR REVIEW



Notes:
1. MA10 is a historical sampling location. It is not part of the current monitoring program.
2. All passive-diffusion sampler sites and surface water sampling station SW-S6 were sampled as part of the intrinsic bioremediation monitoring program, not the risk and compliance monitoring program.
3. MW1-33 was sampled as part of the intrinsic bioremediation monitoring program, not the risk and compliance monitoring program.

U.S. NAVY	0 100 200 SCALE IN FEET	**Figure 4-2** **Risk and Compliance Long-Term Monitoring Sampling Locations at OU 1**	NBK Keyport THIRD FIVE-YEAR REVIEW

T:\KEYPORT\Sub-Tasks\IDIQ\DO 64\5 yr Review\Fig 4-2 Risk.dwg
Mod: 11/11/2009, 15:53 | Plotted: 11/12/2009, 08:12 | john_knobbs

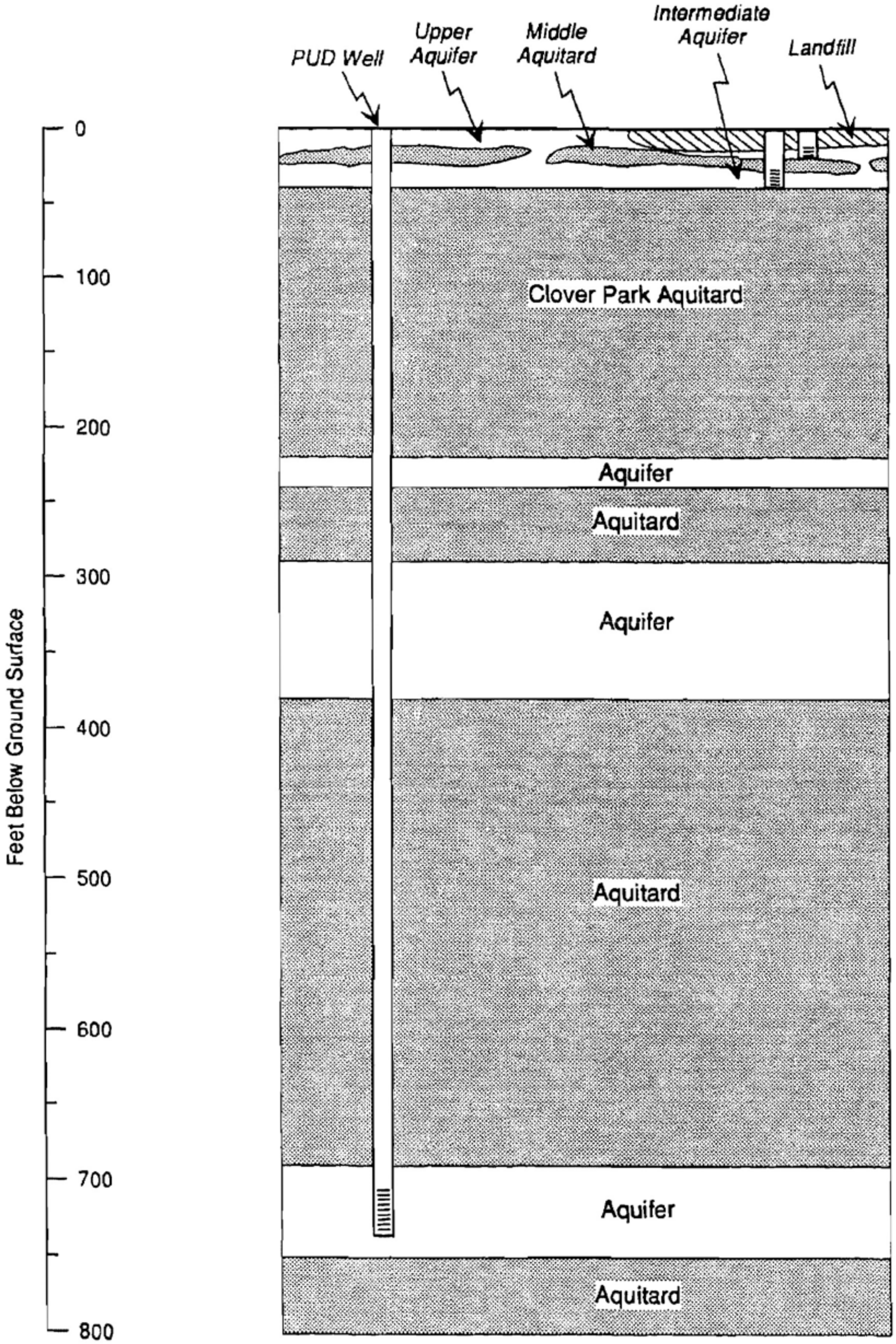


CLEAN
COMPREHENSIVE
LONG-TERM
ENVIRONMENTAL
ACTION NAVY

Figure B-3
Location Map for Geologic Cross Sections

CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\FIGB_3.DRW 11/11/97



CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	**Figure 3** **Generalized Hydrostratigraphy in Vicinity of OU 1**	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\RDR_FIG03.DSF 7/30/97

Lithologic and Hydrostratigraphic Classification

Predominantly Sand and/or Gravel (Aquifer)

Sand and/or Gravel with Local Silt (Aquifer)

Mixed Silt/Clay and Sand/Gravel (OU 1 Landfill Shown with Hatching)
(Aquifer or Leaky Aquitard)

Silt/Clay with Local Sand/Gravel (Leaky Aquitard)

Predominantly Silt/Clay with Some Local Peat
(Aquitard)

Contacts and Boreholes/Wells

Stratigraphic Contact

Stratigraphic Contact, Where Inferred
or Approximately Located

Borehole/Well

Water Level (Average for Round 4
High and Low Tides)

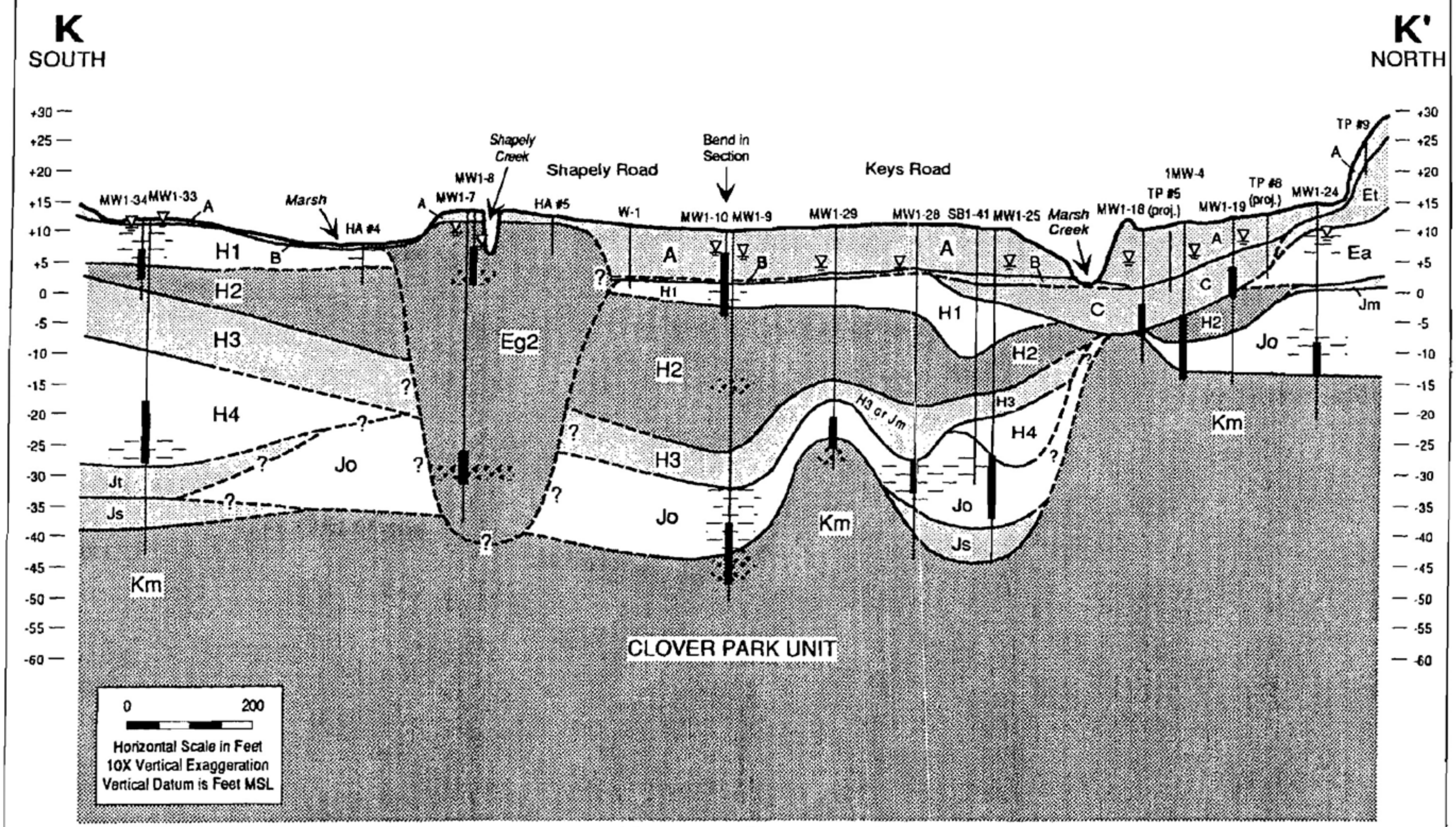
Well or Piezometer Screen Location

Total Depth of Borehole

Stratigraphic Units (see Table 3-2):

A, B, C, Er, Et, Ea, Eg1, Eg2, H1, H2, H3, H4, Jm, Jt,
Jo, Js, Km, Ks

CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	Figure B-4 Legend for Geologic Cross Sections	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION



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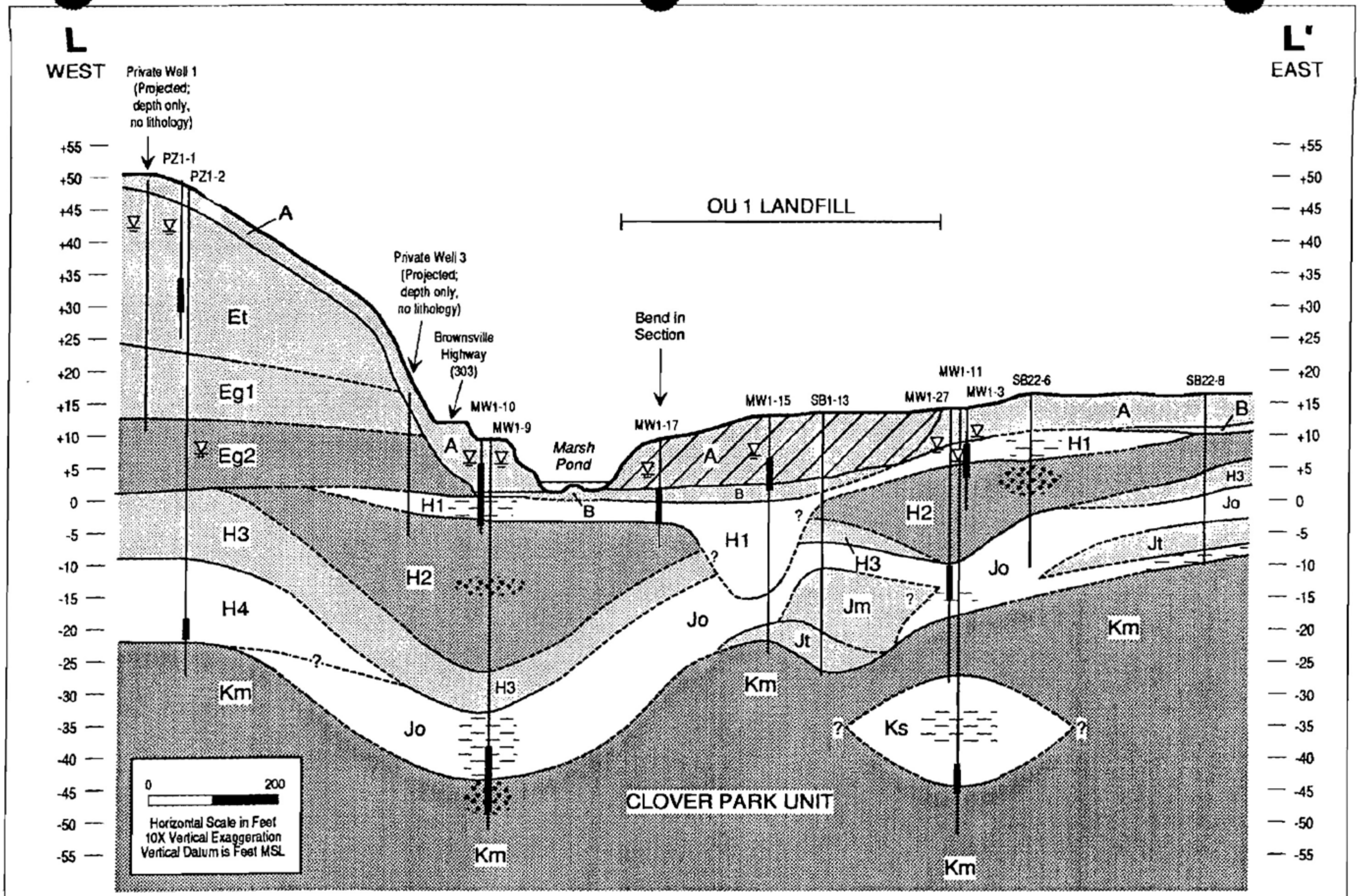
COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

Figure B-5
Geologic Cross Section K-K'

CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DARROUND\[illegible]_K.DSF 11/11/97



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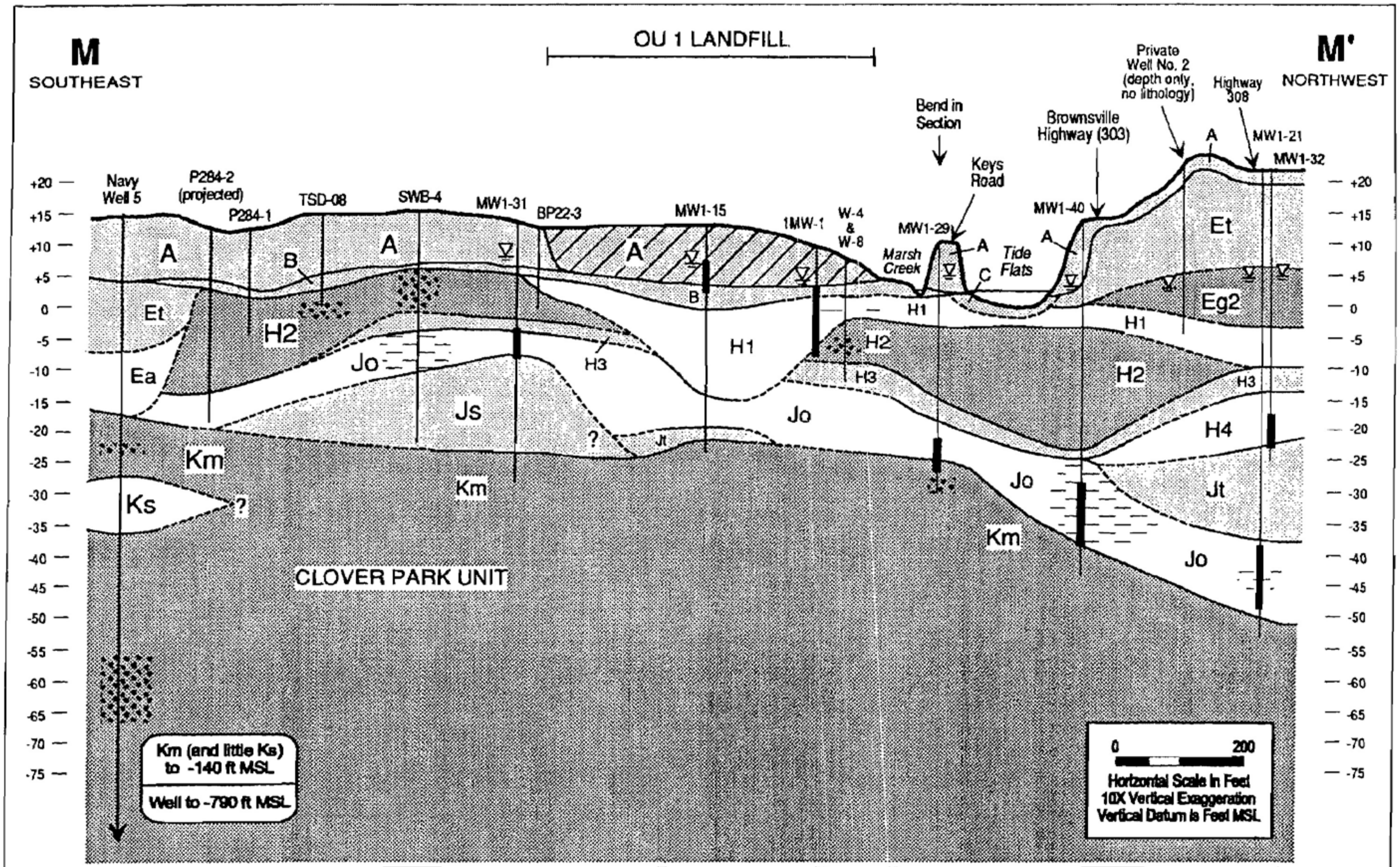
LONG-TERM
ENVIRONMENTAL
ACTION NAVY

Figure B-6
Geologic Cross Section L-L'

CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\XSEC_L.DSF 11/11/97

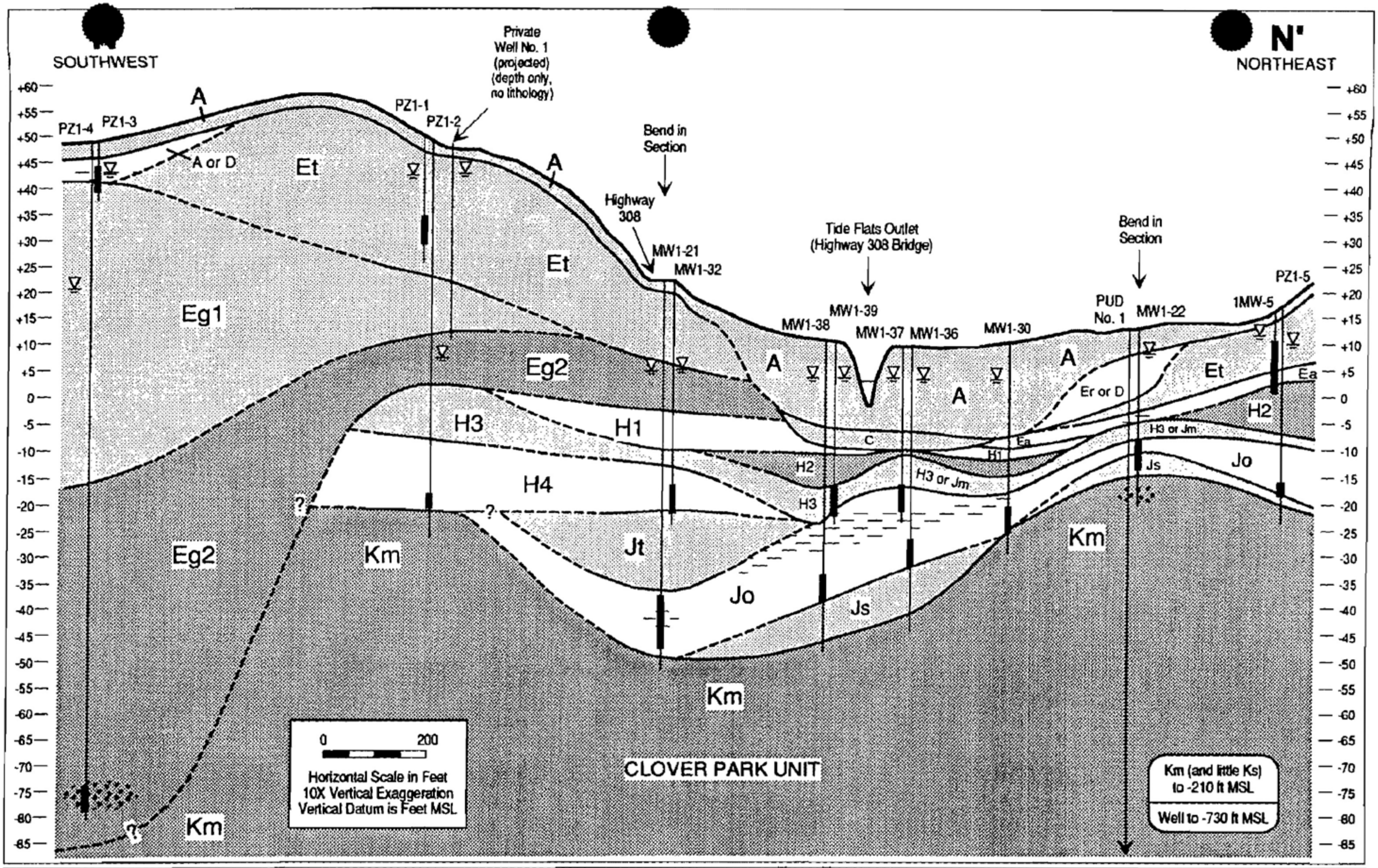


CLEAN
COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

Figure B-7
Geologic Cross Section M-M'

CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DAR\RO...XSEC_M.DSF 11/11/97

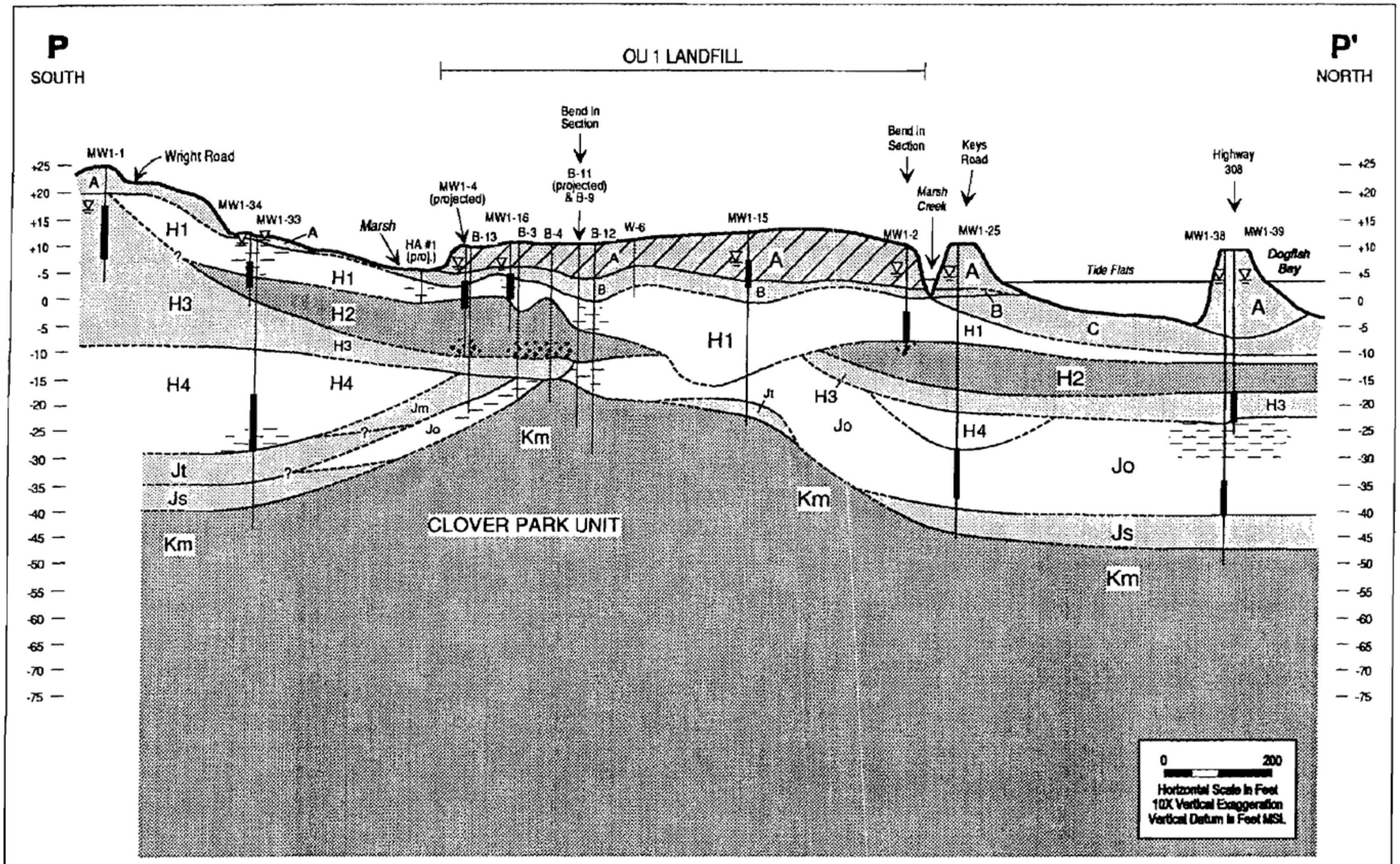


CLEAN
COMPREHENSIVE
LONG-TERM
ENVIRONMENTAL
ACTION NAVY

Figure B-8
Geologic Cross Section N-N'

CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\XSEC_N.DSF 11/11/97

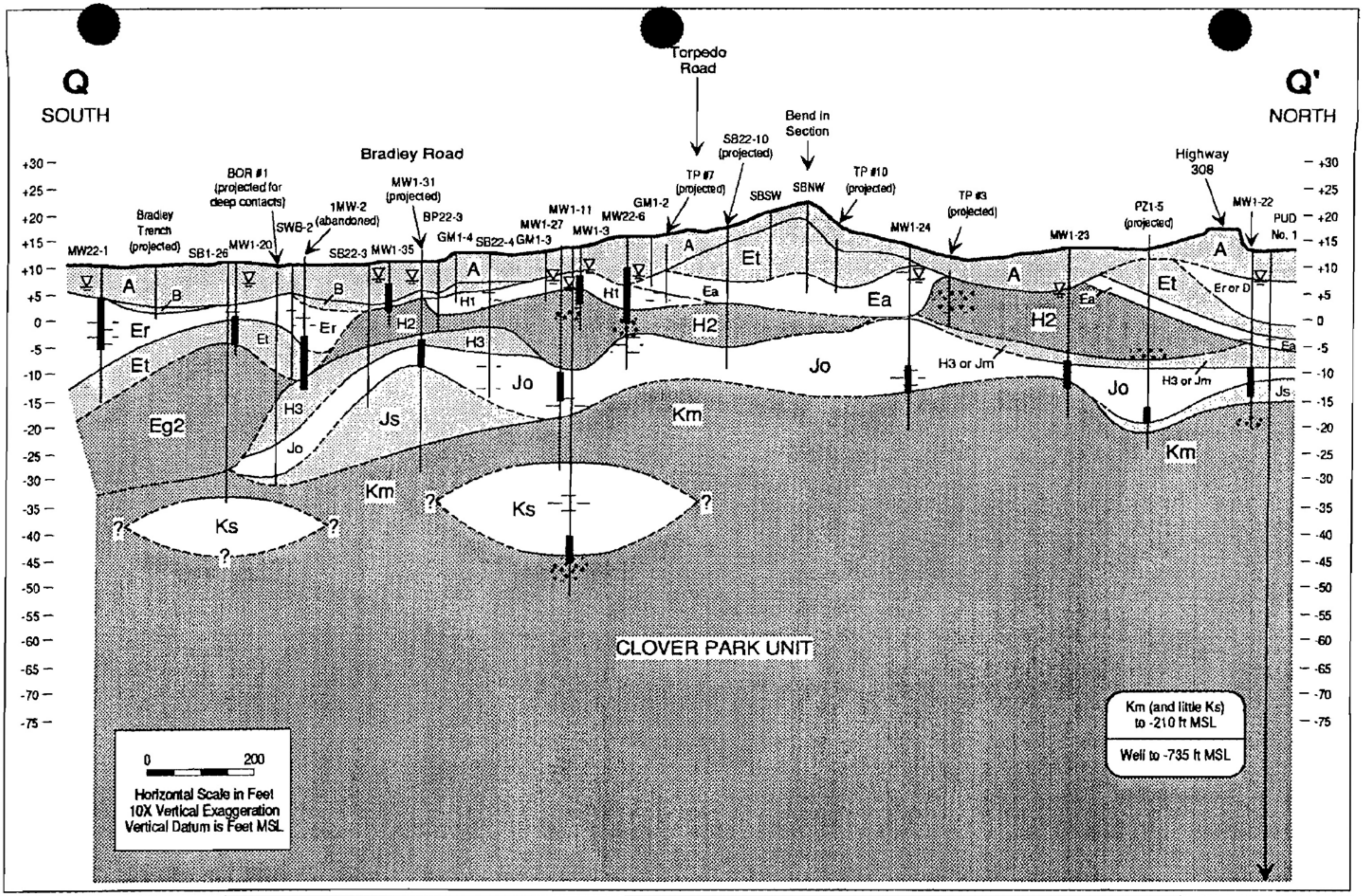


CLEAN
COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

Figure B-9
Geologic Cross Section P-P'

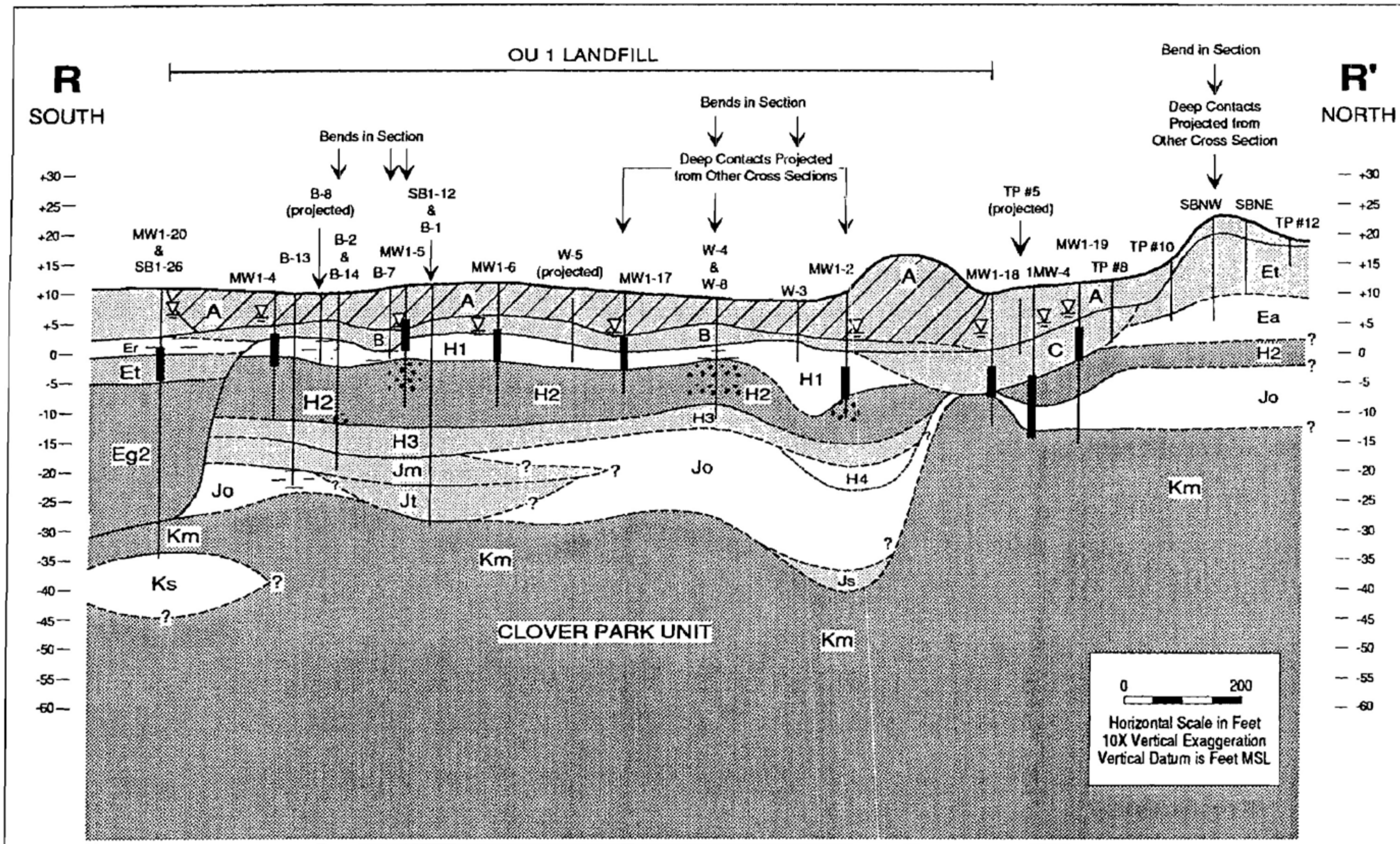
CTO 189
NUWC KEYPORT
KEYPORT, WASHINGTON
PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND...EC_P.DSF 11/11/97



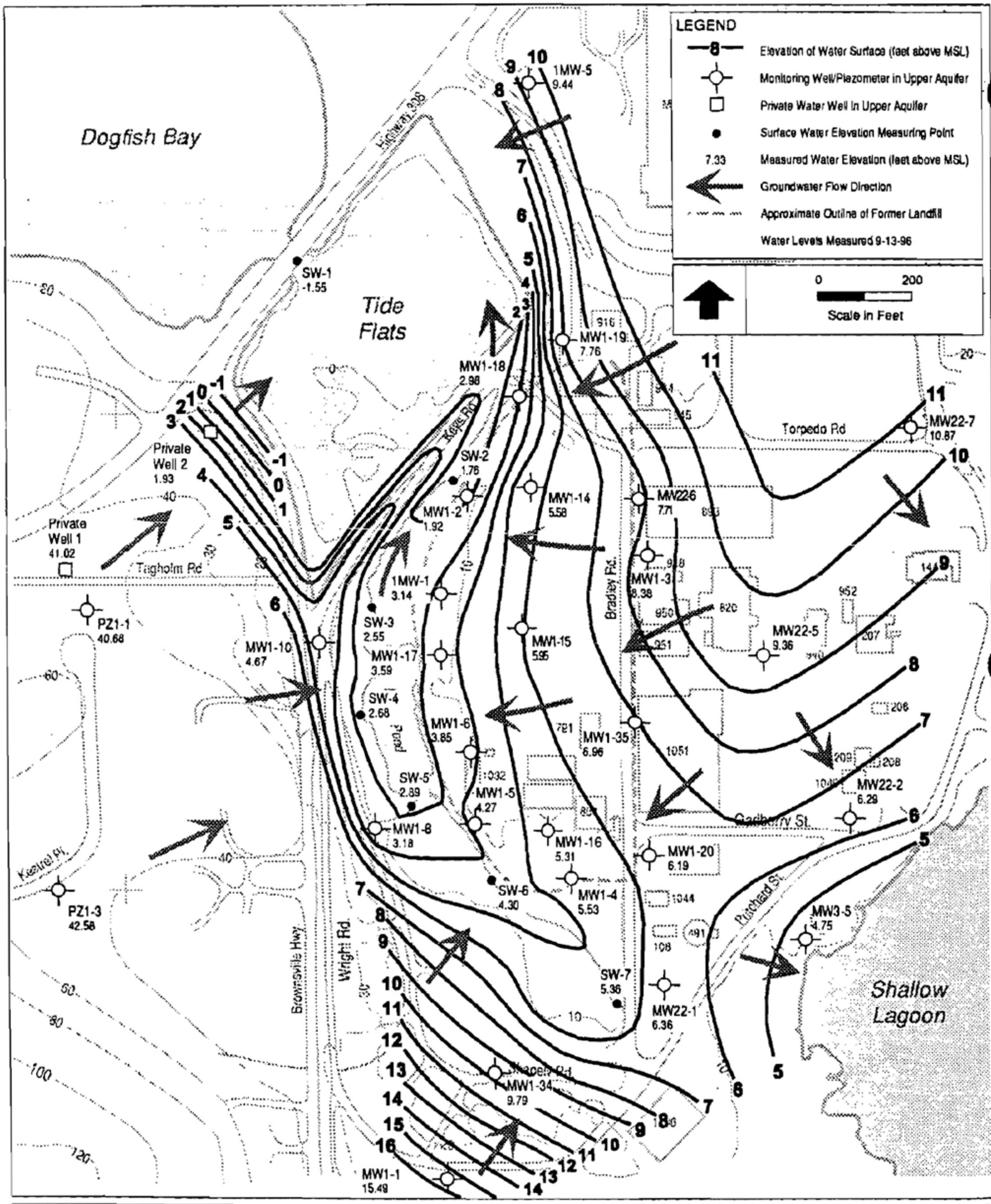
CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	**Figure B-10** **Geologic Cross Section Q-Q'**	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\XSEC_Q.DSF 11/11/97



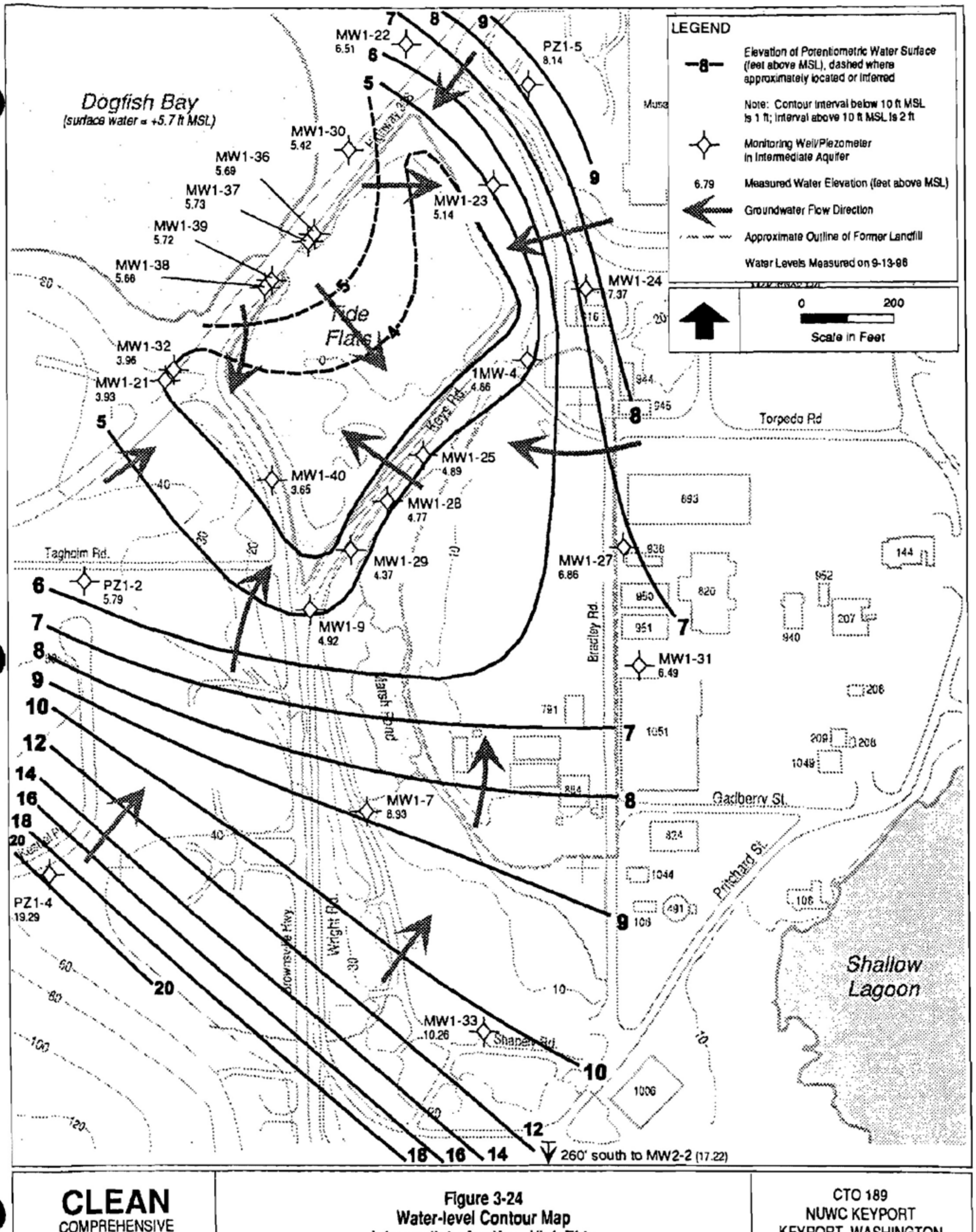
CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	**Figure B-11** **Geologic Cross Section R-R'**	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\XSEC R.DRW 11/11/97



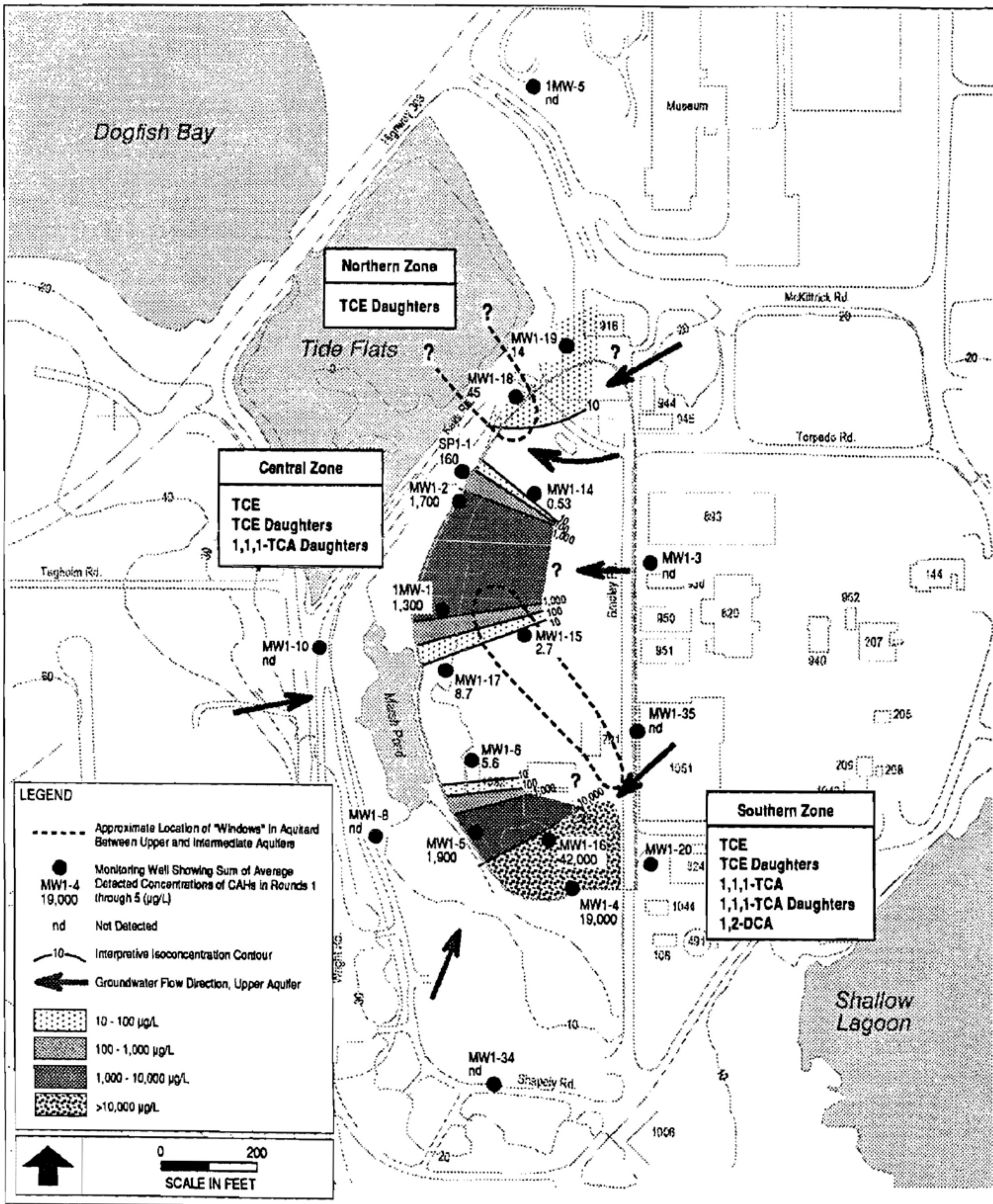
CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	Figure 3-13 Water-Level Contour Map Upper Aquifer - Low Tide Round 5	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\FIG3_13.DSF 7/21/97



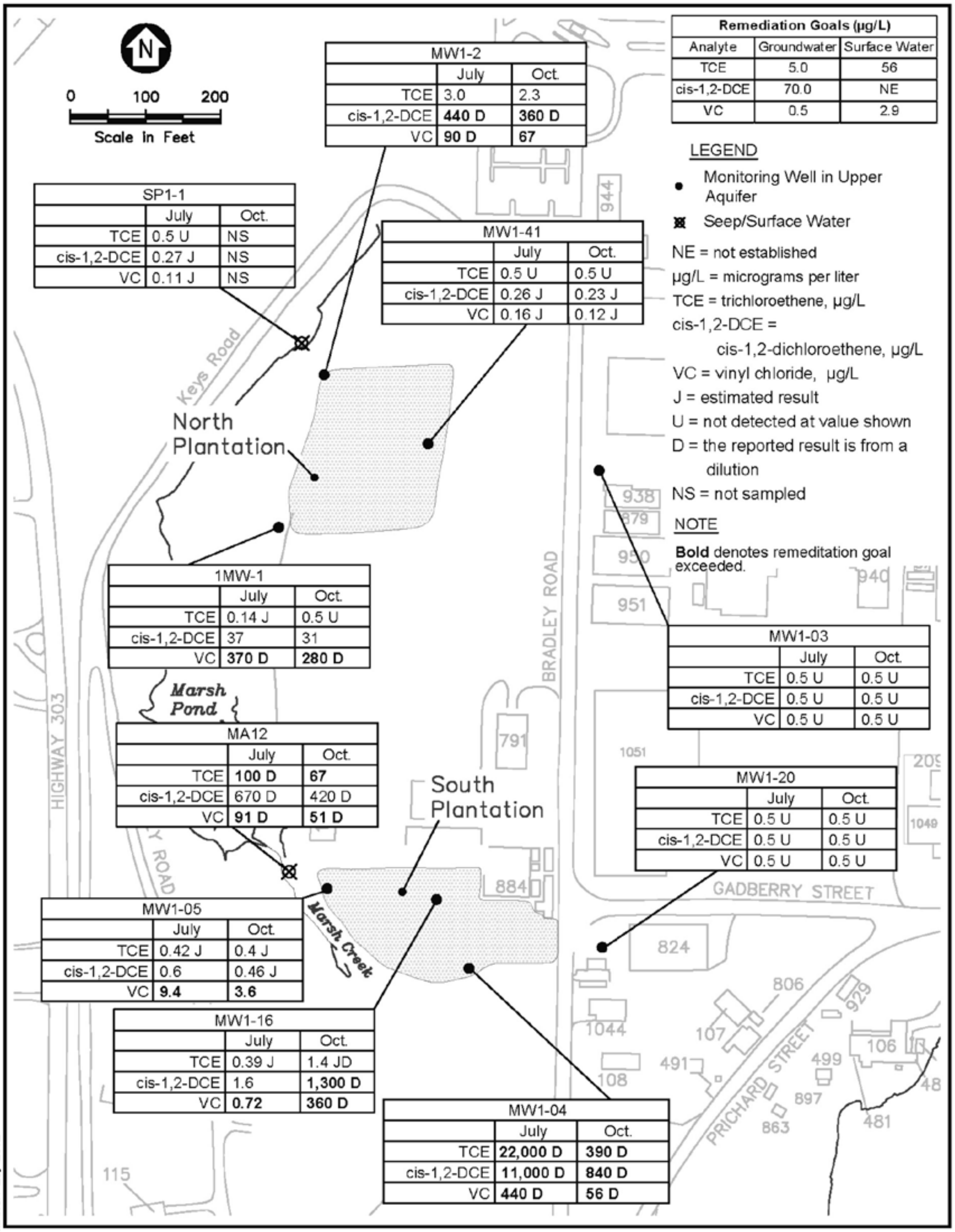
CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	**Figure 3-24** **Water-level Contour Map** **Intermediate Aquifer - High Tide** **Round 5**	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\FIG3_23.DSF 7/21/97



CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	Figure 6-3 CAH Contaminant Zones in the Upper Aquifer	CTO 189 NUWC KEYPORT KEYPORT, WASHINGTON PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\FIG6_3.DSF 6/27/97



Remediation Goals (µg/L)		
Analyte	Groundwater	Surface Water
TCE	5.0	56
cis-1,2-DCE	70.0	NE
VC	0.5	2.9

LEGEND

- ● Monitoring Well in Upper Aquifer
- ⊠ Seep/Surface Water

NE = not established
µg/L = micrograms per liter
TCE = trichloroethene, µg/L
cis-1,2-DCE = cis-1,2-dichloroethene, µg/L
VC = vinyl chloride, µg/L
J = estimated result
U = not detected at value shown
D = the reported result is from a dilution
NS = not sampled

NOTE

Bold denotes remeditation goal exceeded.

MW1-2	July	Oct.
TCE	3.0	2.3
cis-1,2-DCE	**440 D**	**360 D**
VC	**90 D**	**67**

SP1-1	July	Oct.
TCE	0.5 U	NS
cis-1,2-DCE	0.27 J	NS
VC	0.11 J	NS

MW1-41	July	Oct.
TCE	0.5 U	0.5 U
cis-1,2-DCE	0.26 J	0.23 J
VC	0.16 J	0.12 J

1MW-1	July	Oct.
TCE	0.14 J	0.5 U
cis-1,2-DCE	37	31
VC	**370 D**	**280 D**

MW1-03	July	Oct.
TCE	0.5 U	0.5 U
cis-1,2-DCE	0.5 U	0.5 U
VC	0.5 U	0.5 U

MA12	July	Oct.
TCE	**100 D**	**67**
cis-1,2-DCE	670 D	420 D
VC	**91 D**	**51 D**

MW1-20	July	Oct.
TCE	0.5 U	0.5 U
cis-1,2-DCE	0.5 U	0.5 U
VC	0.5 U	0.5 U

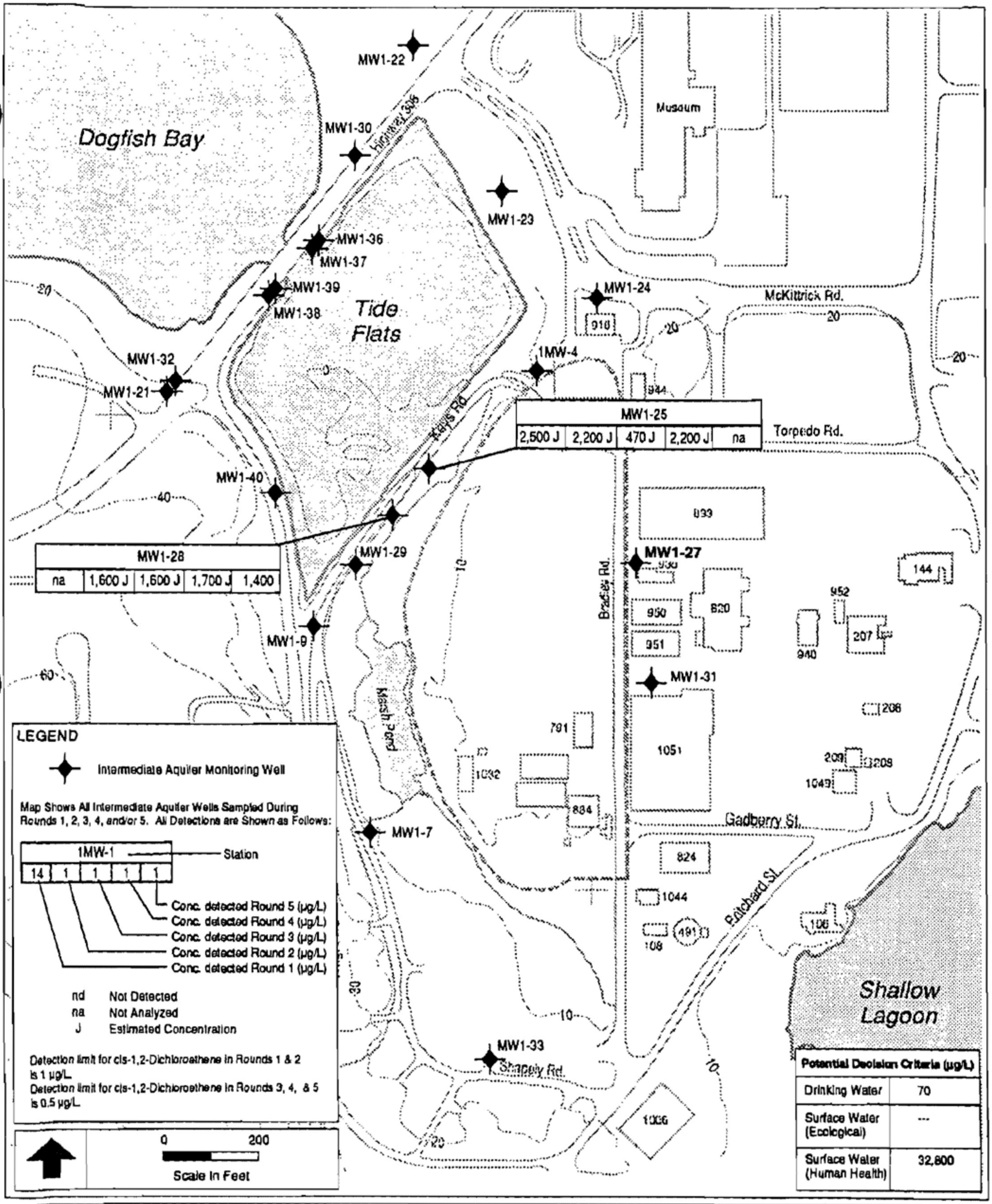
MW1-05	July	Oct.
TCE	0.42 J	0.4 J
cis-1,2-DCE	0.6	0.46 J
VC	**9.4**	**3.6**

MW1-16	July	Oct.
TCE	0.39 J	1.4 JD
cis-1,2-DCE	1.6	**1,300 D**
VC	**0.72**	**360 D**

MW1-04	July	Oct.
TCE	**22,000 D**	**390 D**
cis-1,2-DCE	**11,000 D**	**840 D**
VC	**440 D**	**56 D**

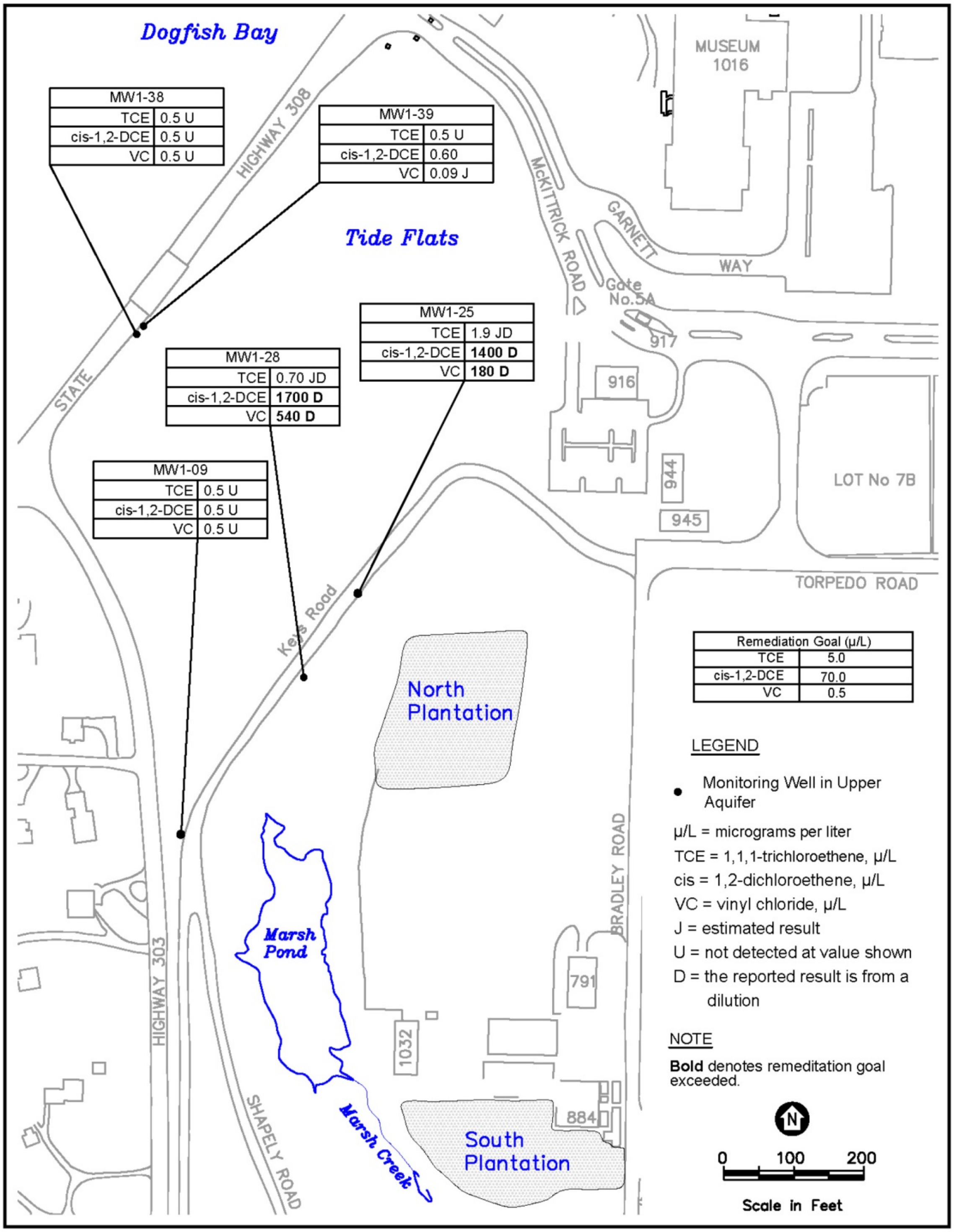
P:\SEALASKA\KEYPORT\TO30\OU 1 \ AR 2011\FIG 6-3.DWG
PLOT/UPDATE: MARCH 26, 2012

U.S.NAVY	SEALASKA	Figure 6-3 Distribution of Selected Target VOCs For Upper Aquifer July and October 2011	Task Order 30 NBK Keyport OU 1 Annual Report 2011



CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	Figure 13 Distribution of cis-1,2-Dichloroethene in Intermediate Aquifer	CTO 189 NUWC KEYPORT OU 1 KEYPORT, WA PRE-ROD DATA COLLECTION

CTO189\DAR\ROUND5\DISTINT1.DRW 4/10/97



MW1-38	
TCE	0.5 U
cis-1,2-DCE	0.5 U
VC	0.5 U

MW1-39	
TCE	0.5 U
cis-1,2-DCE	0.60
VC	0.09 J

MW1-25	
TCE	1.9 JD
cis-1,2-DCE	**1400 D**
VC	**180 D**

MW1-28	
TCE	0.70 JD
cis-1,2-DCE	**1700 D**
VC	**540 D**

MW1-09	
TCE	0.5 U
cis-1,2-DCE	0.5 U
VC	0.5 U

Remediation Goal (μ/L)	
TCE	5.0
cis-1,2-DCE	70.0
VC	0.5

LEGEND

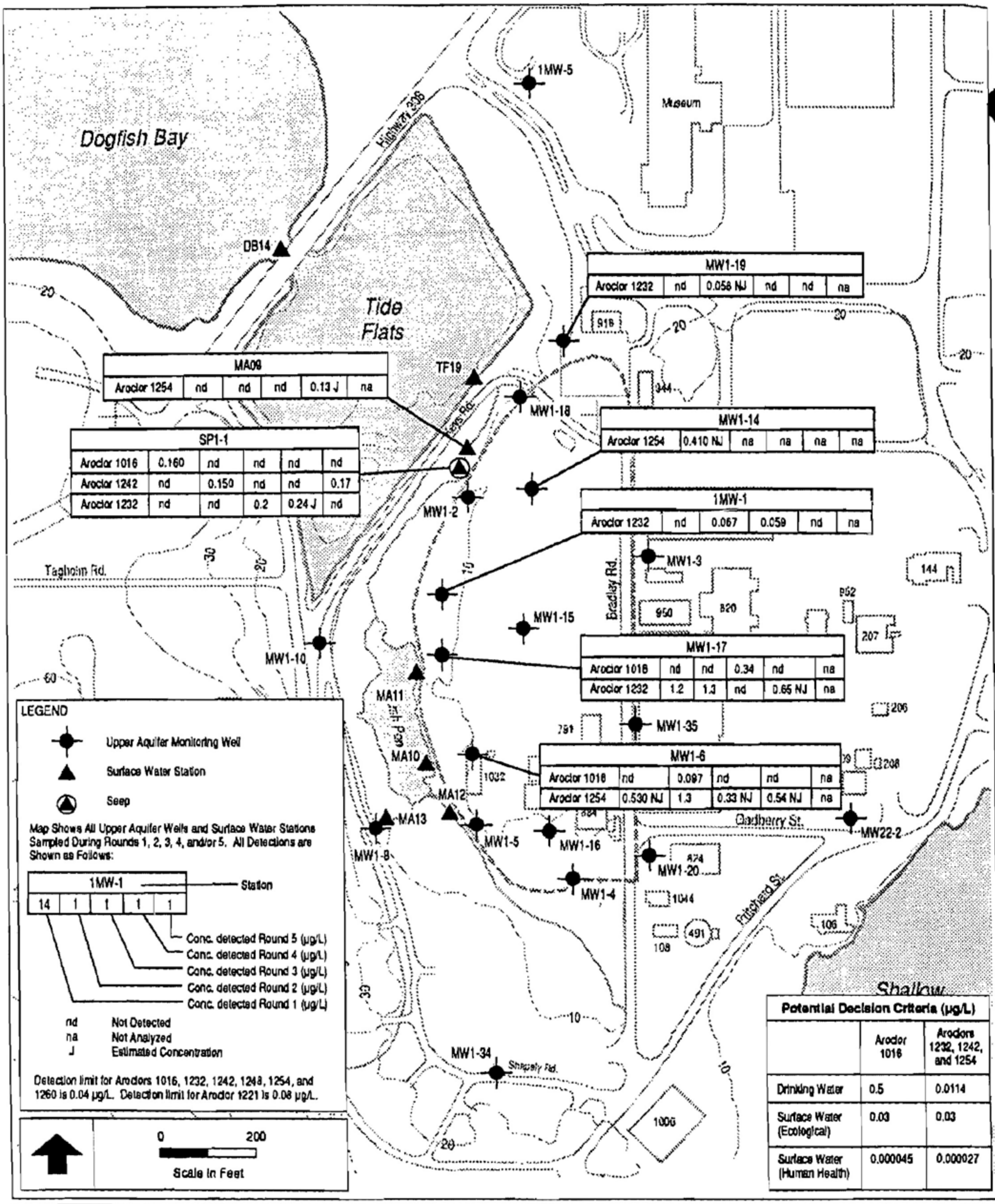
● Monitoring Well in Upper Aquifer

μ/L = micrograms per liter
TCE = 1,1,1-trichloroethene, μ/L
cis = 1,2-dichloroethene, μ/L
VC = vinyl chloride, μ/L
J = estimated result
U = not detected at value shown
D = the reported result is from a dilution

NOTE

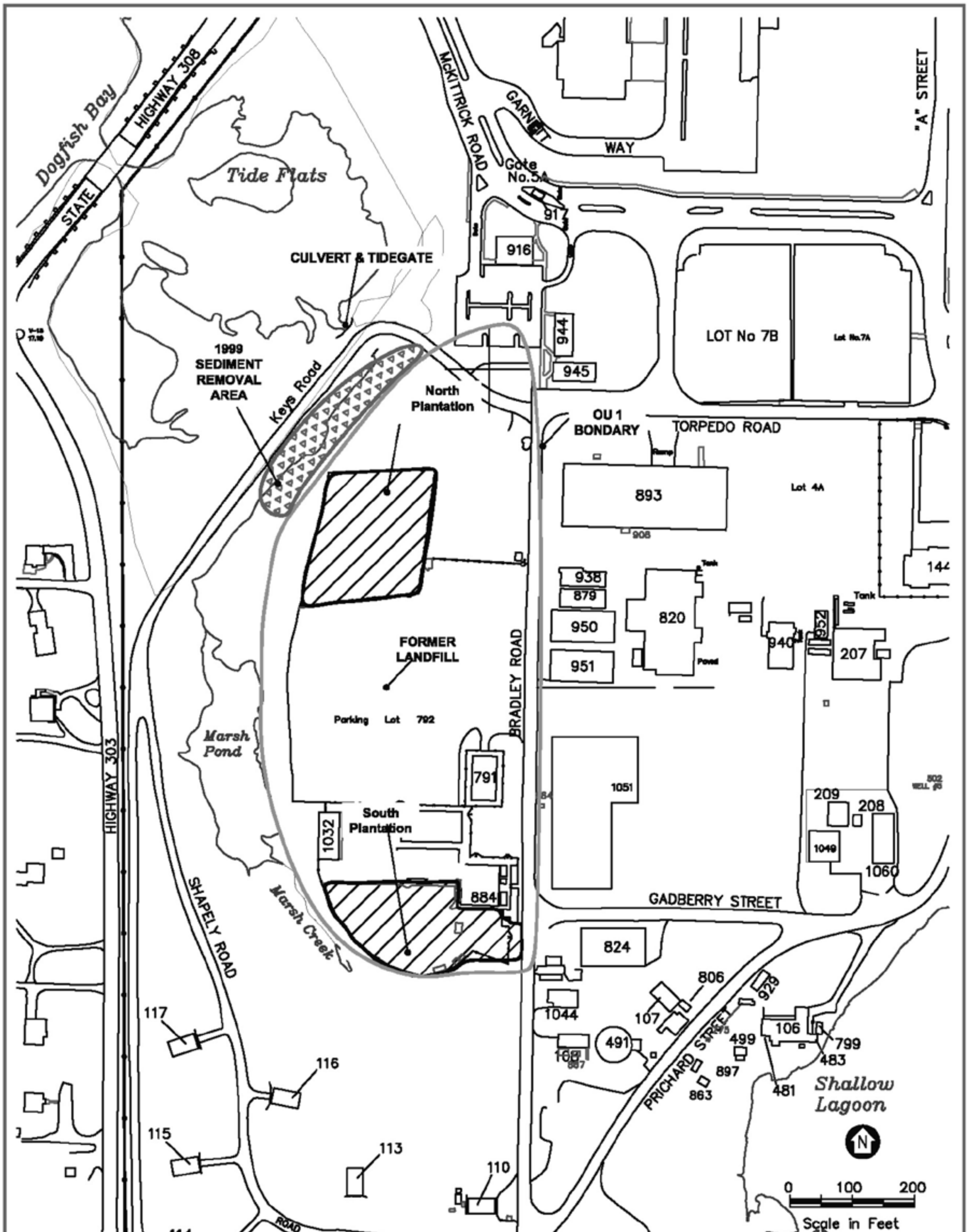
Bold denotes remeditation goal exceeded.

U.S.NAVY	SEALASKA	**Figure 6-5 Distribution of Selected Target VOCs For Intermediate Aquifer June 2010**	Task Order 18 NBK Keyport Area 1 Annual Report 2010



CLEAN COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY	Figure 30 Distribution of Aroclors in Upper Aquifer and Surface Water	CTO 189 NUWC KEYPORT OU 1 KEYPORT, WA PRE-ROD DATA COLLECTION

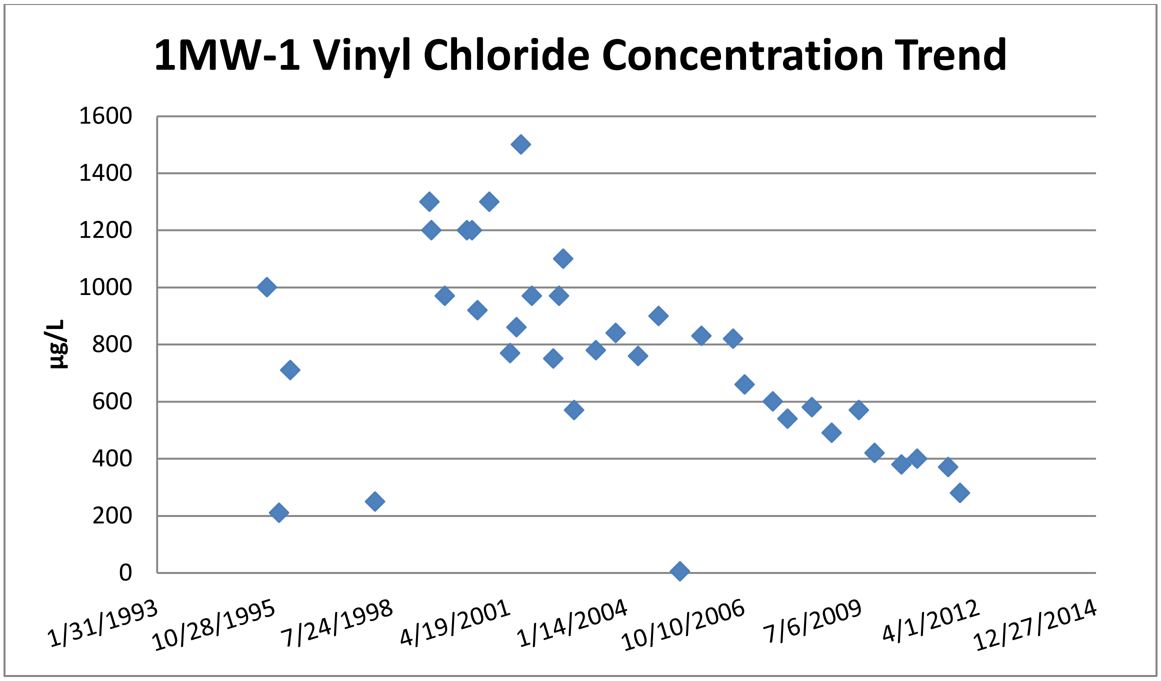
CTO189\DAR\ROUND5\DISTUPR1.DSF 5/7/97

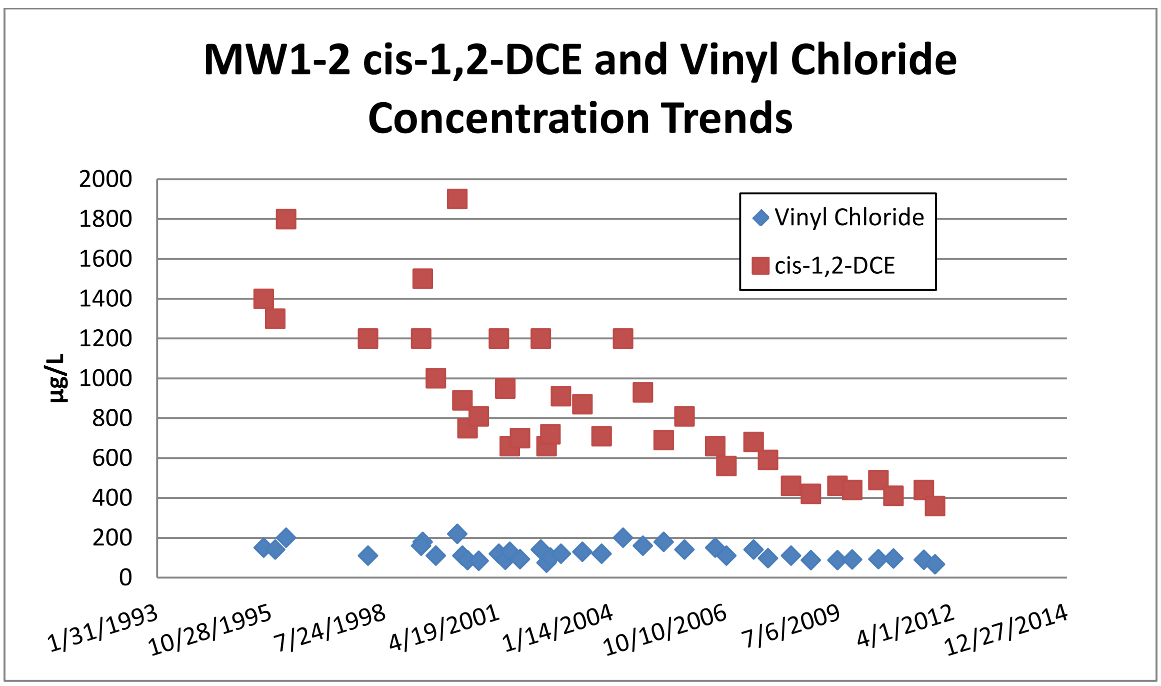


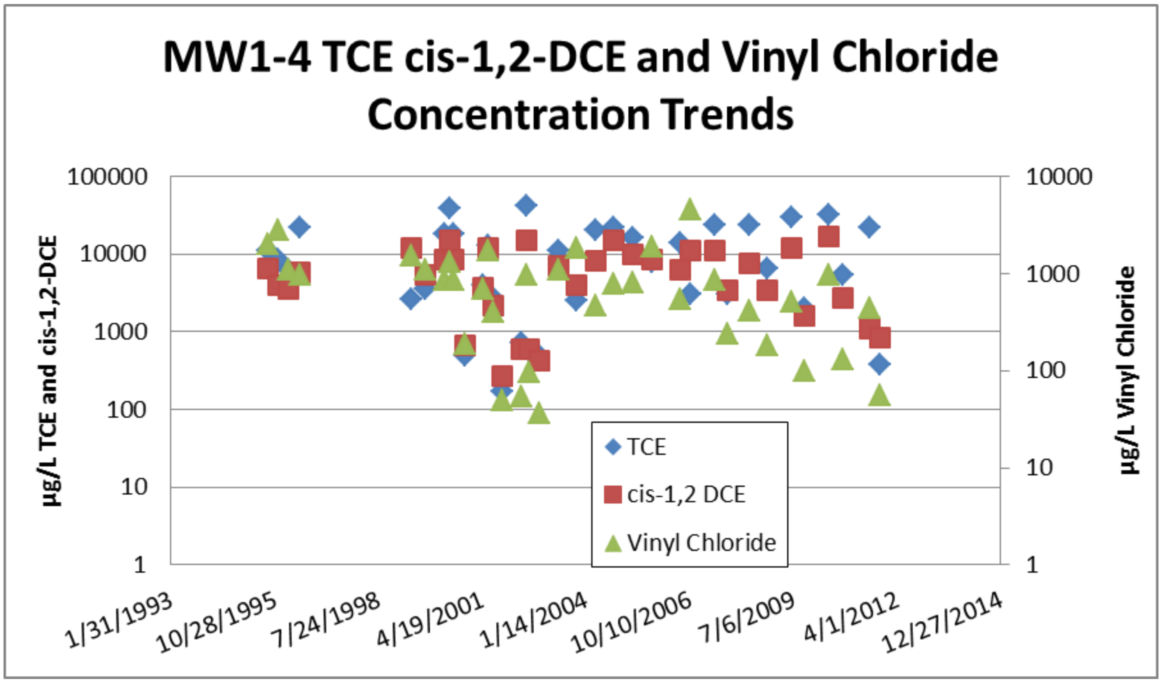
U.S.NAVY	SEALASKA	**Figure 1-2** **Location of OU 1, Area 1**	Task Order 30 NBK Keyport OU 1 Annual Report 2011

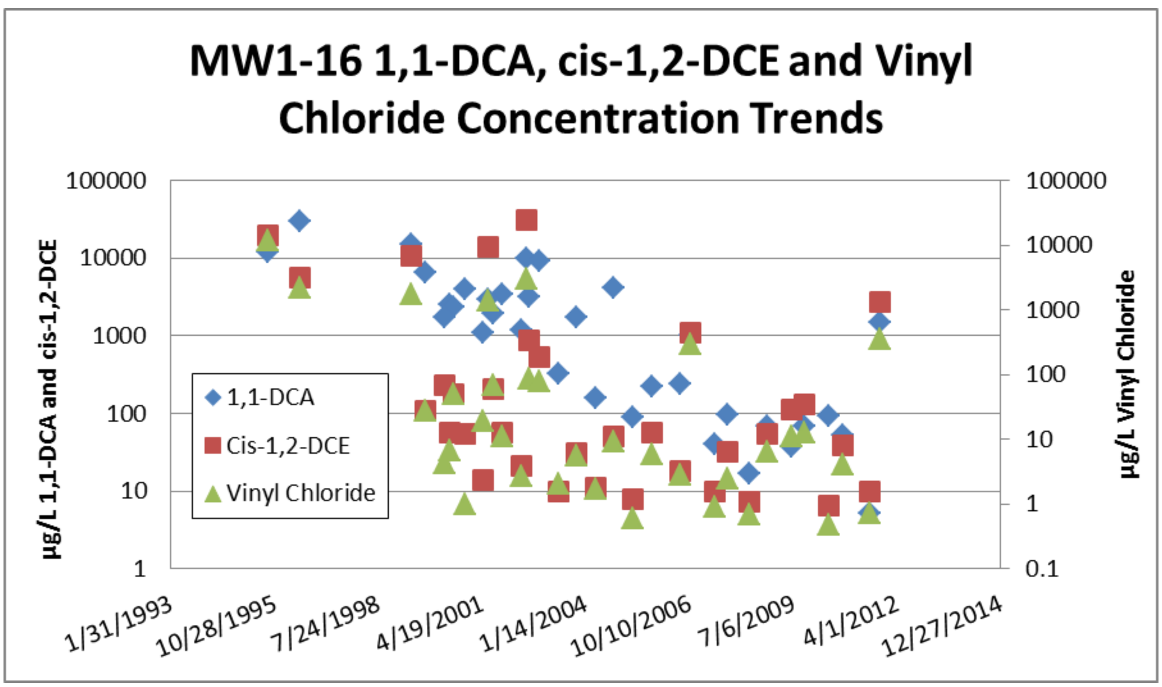
ATTACHMENT B

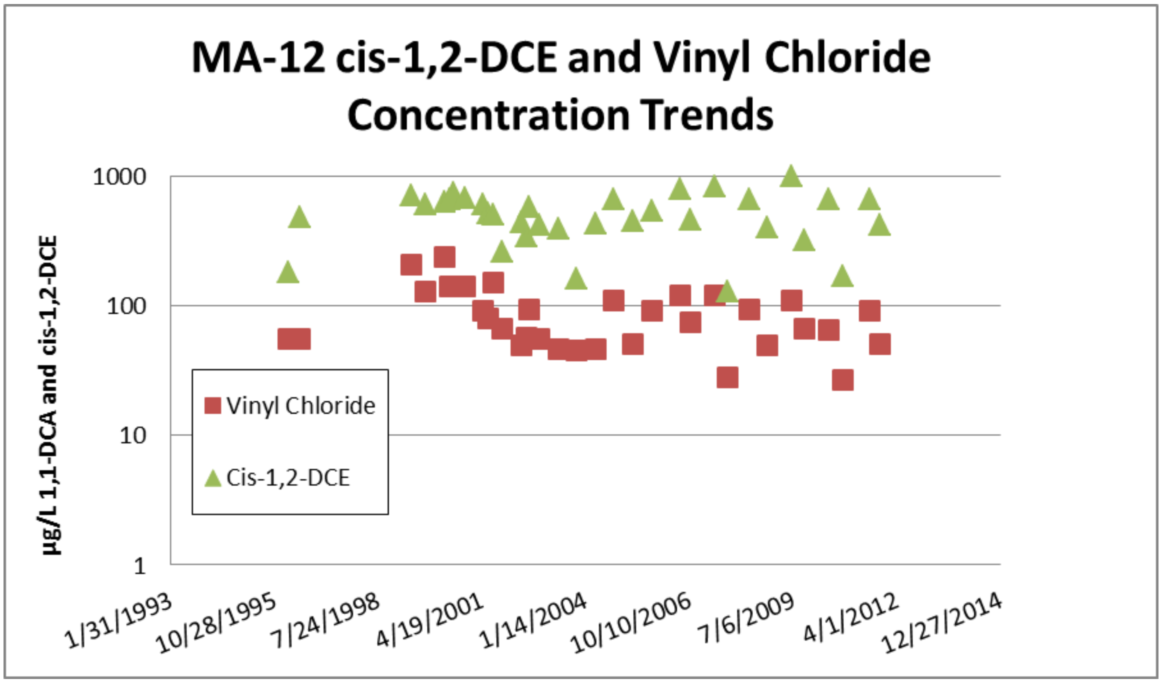
Concentration Trend Charts Prepared by the Optimization Review Team


1MW-1 Vinyl Chloride Concentration Trend
µg/L
1600
1400
1200
1000
800
600
400
200
0
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014


MW1-2 cis-1,2-DCE and Vinyl Chloride Concentration Trends
µg/L
2000
1800
1600
1400
1200
1000
800
600
400
200
0
Vinyl Chloride
cis-1,2-DCE
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014


MW1-4 TCE cis-1,2-DCE and Vinyl Chloride Concentration Trends
µg/L TCE and cis-1,2-DCE
µg/L Vinyl Chloride
100000
10000
1000
100
10
1
10000
1000
100
10
1
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
TCE
cis-1,2 DCE
Vinyl Chloride


MW1-16 1,1-DCA, cis-1,2-DCE and Vinyl Chloride Concentration Trends
µg/L 1,1-DCA and cis-1,2-DCE
µg/L Vinyl Chloride
100000
10000
1000
100
10
1
100000
10000
1000
100
10
1
0.1
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014
1,1-DCA
Cis-1,2-DCE
Vinyl Chloride


MA-12 cis-1,2-DCE and Vinyl Chloride Concentration Trends
1000
100
10
1
µg/L 1,1-DCA and cis-1,2-DCE
Vinyl Chloride
Cis-1,2-DCE
1/31/1993
10/28/1995
7/24/1998
4/19/2001
1/14/2004
10/10/2006
7/6/2009
4/1/2012
12/27/2014