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EPA Superfund
Record of Decision:

NAVAL UNDERSEA WARFARE ENGINEERING STATION (4 WASTE AREAS)
EPA ID: WA1170023419
OU 01
KEYPORT, WA
09/28/1998

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FINAL
RECORD OF DECISION
FOR OPERABLE UNIT 1

Naval Undersea Warfare Center Division
Keyport, Washington
CTO-0010

September 1998

FINAL

RECORD OF DECISION FOR OPERABLE UNIT 1
NAVAL UNDERSEA WARFARE CENTER DIVISION
KEYPORT, WASHINGTON

Comprehensive Long-term Environmental Action Navy
(CLEAN) Contract, Northwest Area
Contract Task Order 0010

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September 1998

DECLARATION OF THE RECORD OF DECISION

SITE NAME AND LOCATION

Naval Undersea Warfare Center, Division Keyport (NUWC Keyport)
Operable Unit 1 (Area 1)
Keyport, Washington

STATEMENT OF BASIS AND PURPOSE

The NUWC Keyport site consists of two operable units. Operable Unit 1 (OU 1) addresses Area 1 (the former base landfill), while Operable Unit 2 (OU 2) addresses the remaining Areas (Areas 2, 3, 5, 8 and 9). The site was split into two operable units because of public concerns about the Area 1 landfill. This was done to allow more time to consider alternatives for Area 1 while proceeding to a decision for the other Areas. A separate Record of Decision was previously approved for OU 2 in September 1994, so the remedial actions for OU 2 have been selected and their implementation is underway.

This decision document presents the selected remedial action for OU 1, chosen in accordance with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), as amended by the Superfund Amendments and Reauthorization Act (SARA) and, to the extent practicable, the National Contingency Plan. This decision is based on the administrative record file for this site.

The lead agency for this decision is the United States Navy (Navy). The United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) have participated in scoping the site investigation and in evaluating alternatives for remedial action. Ecology and EPA concur with the selected remedy.

ASSESSMENT OF THE SITE

Actual or threatened releases of hazardous substances from this site, if not addressed by implementing the response action selected in this Record of Decision (ROD), may present an imminent and substantial endangerment to human health or the environment

DESCRIPTION OF THE SELECTED REMEDIES

The remedial actions for OU 1 address potential human health and ecological risks posed by the landfill. The chemicals of concern are chlorinated aliphatic hydrocarbons (CAHs) and polychlorinated biphenyls (PCBs). Direct exposures to chemicals within the landfill could cause human health risks above acceptable risk levels. PCBs currently exceed chemical criteria of the state sediment quality standards in a part of the marsh adjacent to the landfill. However, the chemical and sediment bioassay results taken together predict no current adverse effects to the sediment benthic organisms. PCBs and CAHs are present in groundwater downgradient of the site and in some surface water samples, and PCBs could accumulate in the downgradient marsh and marine environment. Hydrogeologic conditions direct groundwater into the adjacent surface water and away from areas where drinking water wells exist or could exist in the future, and these conditions are not expected to change. If hydrogeologic conditions were to change in the future, or concentrations of chemicals of concern were to increase downgradient of the landfill, unacceptable risks could occur to human health or the environment

The major components of the selected remedy are as follows:

- Treat CAH hot spot in the landfill by phytoremediation (using poplar trees)
- Remove PCB-contaminated sediments
- Upgrade the tide gate
- Upgrade and maintain the landfill cover
- Conduct long-term monitoring
- Take contingent actions for off-base domestic wells, if necessary
- Implement institutional controls

The phytoremediation action is aimed at reducing the main sources of CAH contamination in order to improve conditions over the long term, and reduce the potential for these chemicals of concern to cause unacceptable risks in the future. The sediment removal action is intended to reduce the amount of PCB-contaminated sediment in the part of the marsh having the highest PCB concentrations, in order to reduce the potential for PCB discharges in the seep or groundwater to accumulate to unacceptable risk levels in the marsh sediments, and to reduce the potential for PCB-contaminated sediments to migrate from the marsh to the tide flats where the PCBs could accumulate in shellfish tissues. The institutional controls and landfill cover actions will be used to prevent human health risks at the landfill that could otherwise occur from groundwater use or contact with soil or landfill material. Upgrading the tide gate will be done to protect the landfill from flooding and long-term erosion by tidal action. The long-term monitoring will be used to check expectations that contaminants will not cause unacceptable future risks, and determine if more action is needed or if actions can be decreased or discontinued in the future. The contingent actions will be used to prevent potential drinking water risks and will be taken if the monitoring results show that hydrogeologic conditions change such that the groundwater plume from the landfill is moving toward, and may contaminate, an off-base domestic well or wells. The contingent actions will involve installing a new well in a deeper, uncontaminated aquifer on properties located within the projected flow path of the plume, or connecting them to the public water supply.

STATUTORY DETERMINATIONS

The selected remedy is protective of human health and the environment, is in compliance with federal and state requirements that are legally applicable or relevant and appropriate to the remedial action, and is cost-effective. The remedy utilizes permanent solutions and treatment technologies to the maximum extent practicable and satisfies the statutory preference for remediation that employs treatment that reduces toxicity, mobility, or volume as a principal element for this site. Hazardous substances will be left on site above risk-based levels; therefore, the five-year review will apply to this action. The five-year review for OU 1 will be made to coincide with the five-year review schedule for OU 2.

Signature sheet for the Naval Undersea Warfare Center, Division Keyport Operable Unit 1 Record of Decision between the United States Navy, The United States Environmental Protection Agency, and the Washington Department of Ecology.

<IMG SRC 98183A>

Signature sheet for the Naval Undersea Warfare Center, Division Keyport Operable Unit 1 Record of Decision between the United States Navy, the United States Environmental Protection Agency, and the Washington State Department of Ecology.

<IMG SRC 98183B>

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ABBREVIATIONS AND ACRONYMS

ARAR - applicable or relevant and appropriate requirement
ASIL - acceptable source impact level
ATSDR - Agency for Toxic Substances and Disease Registry
CAH - chlorinated aliphatic hydrocarbon
CERCLA - Comprehensive Environmental Response, Compensation, and Liability Act
CFR - Code of Federal Regulations
CLEAN - Comprehensive Long-Term Environmental Action Navy
COC - chemical of concern
COI - chemical of interest
COPC - chemical of potential concern
CSL - cleanup screening level
DCA - dichloroethane
DCE - dichloroethene
DNAPL - dense non-aqueous phase liquid
Ecology - Washington State Department of Ecology
EPA - U.S. Environmental Protection Agency
FS - feasibility study
HEAST - Health Effects Assessment Summary Table
HI - hazard index
HQ - hazard quotient
IAS - Initial Assessment Study
IRIS - Integrated Risk Information System
PPT - parts per thousand
PUD - public utility district
RAB - Restoration Advisory Board
RAO - remedial action objective
RBSC - risk-based screening concentration
RCRA - Resource Conservation and Recovery Act
RfD - reference dose
RG - remediation goal
RI - remedial investigation
RME - reasonable maximum exposure
ROD - Record of Decision
SARA - Superfund Amendments and Reauthorization Act
SDAR - Summary Data Assessment Report
SF - slope factor
SMS - sediment management standard
SQS - sediment quality standard
SVOC - semivolatile organic compound
TCA - trichloroethane
TCE - trichloroethene
TRV - toxicological reference value
UCL - upper confidence limit
USC - United States Code
USGS - U.S. Geological Survey
VC - vinyl chloride
VOC - volatile organic compound
WAC - Washington Administrative Code

MATC - maximum acceptable tissue concentration
MTCA - Model Toxics Control Act
NAPL - non-aqueous phase liquid
NCP - National Contingency Plan
NPL - National Priorities List
NUWC - Naval Undersea Warfare Center
NUWES - Naval Undersea Warfare Engineering Station
O&M - operation and maintenance
OU - operable unit
PCB - polychlorinated biphenyl
PCE - perchloroethene (same as tetrachloroethene)
WQC - water quality criteria
WQS - water quality standard

1.0 INTRODUCTION

In accordance with Executive Order 12580, the Comprehensive Environmental Response, Compensation, and Liability Act of 1980 (CERCLA) as amended by the Superfund Amendments and Reauthorization Act of 1986 (SARA), and, to the extent practicable, the National Oil and Hazardous Substances Pollution Contingency Plan, the United States Navy (Navy) is addressing environmental contamination at the Naval Undersea Warfare Center, Division Keyport (NUWC Keyport) by undertaking remedial action. The selected remedial action has the approval of the United States Environmental Protection Agency (EPA) and the Washington State Department of Ecology (Ecology) and is responsive to the expressed concerns of the public. The selected remedial actions will comply with applicable or relevant and appropriate requirements (ARARs) promulgated by Ecology, EPA, and other state and federal agencies.

2.0 SITE NAME, LOCATION, AND DESCRIPTION

NUWC Keyport is located in Kitsap County in the central portion of Puget Sound (Figure 2-1). The facility occupies about 340 acres of a small peninsula in Liberty Bay (Figure 2-2). A small shallow lagoon occupies the southeastern portion of the naval property. The tide flats and Dogfish Bay, which is an extension of Liberty Bay, are located on the western side of the base. Historic photographs show that, prior to 1912, the shallow lagoon and Dogfish Bay were connected by the tide flats or marshy lowlands. By the 1940s, much of this marsh had been filled by the Navy.

Nearby communities include the town of Keyport, which is immediately adjacent to NUWC Keyport; the Port Madison Indian Reservation, which lies northeasterly of the base across Liberty Bay; Poulsbo, which is about three miles to the north of the base; and Silverdale, which is about six miles southwest of the base (Figure 2-1). Most land in the vicinity of NUWC Keyport is used for low-density residential or light industrial purposes.

The former base landfill comprises about nine acres in the western part of the base next to the tide flats and Dogfish Bay (Figure 2-2). This landfill was referred to in the Navy's early site investigation studies as the NUWES Keyport Landfill. The site, including the adjacent, potentially-contaminated environment, was also called Area 1 and is currently designated Operable Unit (OU) 1. Most of the landfill area was formerly a marshland that extended from the tide flats toward the shallow lagoon. A portion of this marsh remains on the western and southern sides of the landfill. The landfill is unlined at the bottom and the majority of the top is covered with asphalt. The rest is covered with soil, so that landfill waste material is not exposed at the surface.

Most of the northern part of the OU 1 landfill is unpaved; it was occupied by office trailers until 1994. Ground cover in this part of the site includes gravel, fine-grained soil, and grassy areas. The central portion of the OU 1 landfill is currently paved with asphalt and serves as a parking or material storage area. It has an elevation of about ten feet above mean sea level. The southern end of the landfill is paved with asphalt and several buildings used for above-ground storage of hazardous wastes and materials are located there. Several years ago, the Navy constructed a new facility for management of hazardous wastes off the landfill and moved almost all of these operations to the new location.

The approximate boundary of the landfill, based on the Initial Assessment Study (IAS) by SCS Engineers (1984), is indicated in Figure 2-3. The data collected during the remedial investigation (RI) and the supplemental field studies in 1995 and 1996 are in general agreement with this boundary. The eastern boundary of the landfill was confirmed by a site investigation (URS 1992) showing that the landfill does not extend beyond the eastern side of Bradley Road. This study did not include the northern boundary of the landfill, the exact location of which is not certain. The boundaries of the landfill to the south and west are immediately adjacent to a marsh pond and associated wetland areas that lie between the landfill and Shapely Road. The landfill boundary next to the marsh generally coincides with the location of an embankment sloping from the top of the landfill down to shoreline of the wetland. The elevation difference between the landfill surface and the shoreline is typically about 5 feet, except in the northern end of the marsh near Torpedo Road, where there is a small knoll on the landfill and the elevation drop to the wetland is about 15 feet. Field investigations (e.g., soil borings) have not been performed to verify the northern, southern and western boundaries of the landfill.

Although much of the landfill area itself is paved and fenced, the areas of grass and exposed soil that do remain provide terrestrial habitat. Scotch broom and blackberry are the dominant species in disturbed areas between the landfill and marsh. Forest habitat south of the landfill is represented by a dense stand of red alder interspersed with Douglas fir. Red alder is also found along the slopes on the western side of the marsh. Within the wooded areas there is a dense understory of salal, ferns, blackberry, Oregon grape, rhododendron, various vines, and coarse grasses.

The forested areas provide habitat for rodents, small amphibians such as salamanders, snakes, and possibly deer or coyote. Birds associated with the forest habitat include sparrows, chickadees, goldfinches, hummingbirds, crows, and occasional hawks. An eagles nest was discovered in August 1996 on the hill south of the shallow lagoon. The eagle's raised three fledglings, and the pair returned in 1997. Eagles have also been observed in this area during 1998.

Marsh vegetation is dominated by pickleweed and saltgrass. Additional marsh plants include saltmarsh bulrush, seaside arrowgrass, Douglas aster, and velvet grass. Stands of cattail are confined to the southern end of the marsh pond where fresh water mixes with brackish pond water. Floating mats of epiphytic algae are present in the open water zone. Small crustacea such as amphipods are common in the marsh creek. Other marsh wildlife includes otters, muskrats, voles, barn swallows, belted kingfishers, mallards, gulls, great blue herons, and hawks. Shapely Creek probably once supported a small spawning population of salmonids, although access restrictions and habitat degradation caused by development have eliminated the viability of a sustained population. The stream reach below the marsh contains estuarine fish species such as stickleback and sculpin.

The tide flats and much of Dogfish Bay are tidally exposed areas representing primarily fine-grained sediment habitat. Typical Puget Sound invertebrates such as polychaetes, snails, and crustacea, are present. Several species of clams were also identified, including native littleneck clam, bent-nosed clam, mud clam, Manila clam, Washington clam, and basket cockle.

The entire OU 1 landfill lies within the 100 year floodplain (URS 1993d). The marsh area, including the pond and the streams that feed and drain the pond up to an elevation of approximately five ft MSL, were identified as wetlands in a 1992 delineation (Wiltermood 1992). No rare, threatened, or endangered species are known to inhabit OU 1 itself, however, as mentioned above, an eagle's nest was observed in 1996 elsewhere on the NUWC facility and eagles were observed in 1996, 1997 and 1998. No historic areas that are eligible for listing on the National Register are known to exist at OU 1.

3.0 SITE HISTORY AND ENFORCEMENT ACTIVITIES

3.1 SITE HISTORY

The NUWC Keyport property was acquired by the Navy in 1913 and first used as a quiet-water range for torpedo testing. The first range facility was located in Port Orchard inlet to the southeast of the site. The first building was constructed in 1915. During and soon after World War I, some minor additions were made to the base. The largest expansion in activities and acquisition of additional property occurred during World War II.

During the early 1960s, the role of the base was expanded from torpedo testing to include manufacturing and fabrication operations, such as welding, metal plating, carpentry, and sheet metal work. More expansion took place in 1966, including the building of a new torpedo shop. In 1978, the facility changed names from Naval Torpedo Station Keyport to Naval Undersea Warfare Engineering Station (NUWES) Keyport in recognition that the functions had broadened to include various undersea warfare weapons and systems engineering and development activities. In 1992, the name of the facility was changed again, becoming NUWC Keyport. Operations currently include test and evaluation, in-service engineering, maintenance, and repair, Fleet readiness and industrial base support for undersea weapons systems, counter-measures, and sonar systems.

The OU 1 landfill was the primary disposal area for both 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 (south of Torpedo Road) 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, with the ash disposed of in the landfill. Burning continued at the landfill until the early 1970s. Based on interviews of base personnel, the IAS identified the following types of industrial wastes that were likely disposed of in the landfill:

- Paints, lacquers, thinners, ketones, enamel, and deflocculant from the paint shop
- Paint residues and solvents such as TURCO, methyl ethyl ketone, trichloroethene (TCE), alcohol, and toluene from the paint stripping shop
- Residue from burning torpedo fuel (Otto fuel) and solids contaminated with torpedo fuel
- Cutting oils, acids, caustics, and lead slag from metal shops
- Dried bacterial sludge from the industrial wastewater treatment plant
- Pesticide rinsate from pest control shops.

The IAS also states that liquid plating bath wastes from the on-base plating shop (located on the eastern side of the base) were treated at the landfill from 1962 to 1984. From 1962 to 1972, the pliting bath wastes were treated in tanks at Building 439, which was located next to where Building 884 currently stands at OU 1. After treatment, the effluent was discharged to the marsh via a drain. Discharge of the treated effluent to the marsh was discontinued in 1972, at which time the base began sending the treated effluent to an off-site disposal facility. This was approximately the same time that the landfill was closed. In the 1980s, treatment was conducted in Building 884. Treatment at the landfill was discontinued in 1984.

The IAS also identified general locations at the landfill where these activities took place; these locations are noted in Figure 3-1, using the terminology of the IAS. The "acid treatment area" coincides with the location of former Building 439. The "waste paint disposal area" in the southern part of the landfill is a location where the IAS indicated painting-related wastes and solvents were disposed of from the 1930s until the 1970s. This location coincides with the highest concentrations of solvent-type contaminants detected in groundwater at OU 1

The IAS also describes management and disposal of drummed wastes at the base. It states that barrels of painting wastes and stripping solutions were disposed of at the landfill, and that "most of the waste was reportedly poured out of the barrels and the barrels were reused or recycled." Empty barrels were stored, managed, and recycled at Area 2, the former drum storage area, (located in the southwestern part of the base) from the 1940s through the 1960s. The IAS states that drums that were not completely empty were reportedly drained onto the ground at the former drum storage area. Since February 1994, the Navy interviewed over 50 former and current employees to learn whether intact drums of liquid wastes were placed in the landfill. Eight of these people had been directly involved in landfill operations. One person remembered that 12 or 14 pallets of 5-gallon cans of paint and some 55-gallon drums were buried whole. The remaining people believe that whole drums were not buried intact. Some of them said that drums were emptied into the landfill or crushed before burial. Emptied drums were stored for reuse at Area 2. Overall, the interviews indicated that disposal of liquids in drums was not a common practice and substantial amounts of drummed liquid wastes are unlikely to be in the landfill.

3.2 PREVIOUS INVESTIGATIONS

The IAS was conducted in September 1984, under the Navy Assessment and Control of Installation Pollutants program, to identify areas of possible environmental contamination resulting from past methods of storage, handling, and disposal of hazardous substances at NUWC Keyport. Subsequent studies, documented in a Current Situation Report (SCS 1987), evaluated these and other areas to determine locations of potential or significant contamination that may require remedial action and should be studied further. As a result, six specific Areas (formerly referred to as "sites") were recommended for further investigation in the remediation process.

In 1988, under its Installation Restoration Program, the Navy began the RI and feasibility study (FS) phases of the remediation process for the six Areas of potential concern that were identified in the earlier studies. EPA placed NUWC Keyport on the National Priorities List (NPL) in 1989.

The RI Report (URS 1993a) and the Human Health and Ecological Risk Assessment Reports (URS 1993b and 1993c) were completed in October 1993. The FS Report (URS 1993d) was completed in November 1993. The FS Report included a summary of the RI and evaluated seven remedial alternatives for OU 1. The alternatives ranged from no action to comprehensive measures for complete containment of the landfill.

The Navy, EPA, and Ecology used the information in the RI and FS Reports to select a preferred remedial alternative for each of the six Areas of the NUWC Keyport site. The preferred alternative for each Area was described in a proposed plan (Navy 1994) that was distributed to the public for comment in January 1994.

A public meeting was held in February 1994 to present the proposed plan and receive public comments. Many of the public comments were not favorable with respect to the preferred alternative for Area 1 in the proposed plan. Because of this, Area 1 was separated, for administrative purposes, from the other Areas of the site and became OU 1.

3.3 SUPPLEMENTAL DATA COLLECTION ACTIVITIES

For OU 1, the concerns expressed by the public on the proposed plan during the public comment period led to a number of subsequent discussions among the Navy, EPA, and Ecology to further evaluate the preferred alternative for OU 1. From these discussions, it was agreed that the RI data should be supplemented with additional site characterization data to improve the understanding of current conditions at OU 1 prior to reaching a remedial decision. As a result, the Navy implemented a supplemental sampling program, consisting of five quarterly sampling rounds conducted from August 1995 through September 1996. The Navy, Ecology, and EPA agreed that additional data should be collected to improve the understanding of potential risks from the following three key pathways of potential concern at OU 1:

- Drinking water pathway (human health risk)
- Seafood ingestion pathway (human health risk)
- Ecological pathway (risk to aquatic organisms).

These pathways are shown schematically in Figures 3-2 through 3-5. As shown in Figure 3-2, all of these pathways start with groundwater becoming contaminated with chemicals present in the landfill. Figures 3-3 through 3-5 show each of the pathways in greater detail, and also identify how specific sampling locations relate to points along each pathway.

The drinking water pathway (Figure 3-3) is concerned with the possibility of contaminants from the landfill migrating in the groundwater of the intermediate aquifer and then traveling toward off-base land areas where drinking water wells are located or could be installed in the future. The main concern for this pathway is whether the groundwater in the intermediate aquifer could flow to off-base land areas before discharging into the marine water (i.e., tide flats and Dogfish Bay). Based on data available at the time, the RI concluded that it was unlikely that intermediate aquifer groundwater from the landfill would flow to off-base land areas where it could be tapped by drinking water wells. However, following the 1994 public comment period, it was decided that the supplemental sampling effort would gather additional information to address this pathway.

The seafood ingestion pathway (Figure 3-4) is concerned with the possibility of chemicals from the landfill migrating with the groundwater and surface water into the adjacent marine water or sediments where they could contaminate edible species and cause human health risk. The main concern is whether landfill contaminants have made or will make the seafood in the tide flats, and Dogfish Bay unsafe to eat.

The ecological pathway (Figure 3-5) is concerned with the possibility of contaminants from the landfill causing harm to the aquatic life, comprising the ecosystem downstream of the landfill in the marsh, tide flats and Dogfish Bay. The main concern is whether concentrations of landfill contaminants in the surface water or sediments are at levels that pose risk to aquatic organisms in these surface water bodies or may cause other ecological risk via the food chain.

The supplemental sampling program has successfully increased understanding among the Navy and regulatory personnel concerning the nature of the contamination and the risks posed by the site. The new data from these additional field investigations were discussed and evaluated in the Summary Data Assessment Report (URS 1997a), which served as a supplement to the RI Report. In addition, a supplemental focused FS (URS 1997b) was conducted in which several additional remedial alternatives beyond those considered in the original FS were evaluated. The focused FS summarized the principal results and conclusions of the RI and the supplemental sampling program, developed remedial action objectives based on these results, and evaluated remedial alternatives to achieve these objectives. The remedial objectives were developed based on the evaluations of potential contaminants and risks to human health and the environment. The remedial alternatives were compared to the nine evaluation criteria for protectiveness and impacts as required by CERCLA

The Navy, Ecology, and EPA used the information in the RI, the Summary Data Assessment Report, the FS, and the focused FS to select the preferred remedial alternative for OU 1. The preferred alternative was described in a new proposed plan for OU 1 (Navy 1997) that was distributed to the public for comment in November 1997. A public meeting was held in December 1997 to present the new proposed plan and receive public comments. Because the public response to the preferred alternative was positive (over 80 percent of the comments expressed support for the plan), this record of decision (ROD) reflects the preferred alternative presented in the Navy's 1997 proposed plan for OU 1.

4.0 COMMUNITY RELATIONS

The original community relations plan for NUWC Keyport was prepared in 1990 (URS 1990). The plan was updated and revised in 1997 (URS 1997c) to document that a ROD was complete for OU 2 and that OU 1 had been separated from the other NPL Areas. A copy of the revised CRP is in the repositories listed at the end of this section.

In March 1995, a Restoration Advisory Board (RAB) was established. The RAB met monthly, and for several months in 1995, bi-weekly. The RAB members and interested community members have contributed significantly to the remedial process and the selected remedy for OU 1. The RAB continues to meet at pre-determined milestones.

The Summary Data Assessment Report (URS 1997a) and the Focused Feasibility Study (URS 1997b) for OU 1 were completed and released to the public through the administrative record and information repositories in November 1997. In the development of both reports, the Navy considered the input of the members of the RAB and Keyport community. The proposed plan for OU 1 was mailed to all interested parties on November 13, 1997.

Public notices were published on November 12, 1997, in the North Kitsap Herald and on November 16, 1997, in The Sun. These notices contained information on the proposed plan, the 30-day comment period, and the public meeting. The public comment period was held November 16 through December 15, 1997. The public meeting, preceded by an availability and poster session, was held December 3, 1997 at the Naval Undersea Museum, Keyport, Washington. At the meeting, representatives of the Navy presented the proposed plan and answered questions about OU 1. At the conclusion of the public comment period, 26 written and verbal comments had been received. Public comments were taken into consideration in developing the remedial decision for this site. This decision is based on the administrative record for this site. The Responsiveness Summary at the end of this ROD (Appendix A) summarizes the comments and responses.

Since 1994, the following activities have occurred regarding OU 1:

- In February 1994, the original proposed plan was presented to the community in a public meeting. The community did not accept the Navy's preferred alternative for OU 1 and wanted to know more about what was in the landfill and how it would affect the environment and be managed in future years.
- In July 1994., three workshops were held to provide an open forum of dialogue with the community about information on groundwater, health, and other information about the landfill.
- Quarterly Community Update newsletters have been sent to a mailing list of about 230 people since October 1994, providing meeting notices and an ongoing status of activities at OU 1.
- On November 9, 1996, a four-hour informal workshop was held in the community to share new information about the landfill.
- In October, November, and December 1996, Navy and Ecology representatives visited the Keyport Improvement Club to share information.

Information repositories are located at:

Kitsap Regional Library
1301 Sylvan Way
Bremerton, Washington
Phone: (360) 377-7601

Poulsbo Branch Library
700 NE Lincoln Road
Poulsbo, Washington
Phone: (360) 779-2915

Kitsap Public Utility District
1431 Finn Hill Road
Poulsbo, Washington
Phone: (360) 779-7656

Washington State Department of Ecology
300 Desmond Drive SE
Lacey, Washington
Phone: (360) 407-7200

The Administrative Record is on file at:

Engineering Field Activity, Northwest
Naval Facilities Engineering Command
19917 Seventh Avenue NE
Poulsbo, Washington
Phone: (360) 396-0002.

5.0 SCOPE AND ROLE OF OPERABLE UNIT

This ROD addresses OU 1. Following the public comment period on the original proposed plan (Navy 1994), the NUWC Keyport NPL site was organized into two OUs in the following manner:

- Operable Unit 1:
  Area 1-Keyport Landfill

- Operable Unit 2:
  Area 2 - Van Meter Road Spill/Drum Storage Area
  Area 3 - Otto Fuel Leak Area
  Area 5 - Sludge Disposal Area
  Area 8 - Plating Shop Waste/Oil Spill Area
  Area 9 - Liberty Bay.

OU 2 has been addressed in a separate ROD and remedial measures (including soil removal, building demolition, long-term monitoring, and institutional controls) are currently in progress. The ROD for OU 1 is the last ROD that is planned for NUWC Keyport.

6.0 SUMMARY OF SITE CHARACTERISTICS

This section provides an overview of the site characterization information that was developed during the RI and the supplemental data collection program. Tables 6-1 and 6-2 summarize the major investigative activities that were conducted for these field programs. The locations of the sampling stations listed in these tables are shown in Figures 6-1 through 6-3. Tables 6-1 and 6-2 indicate the general scope of these investigations, but do not list all the field activities that have been performed. Details of the investigations can be found in the RI Report (URS 1993a) and the Summary Data Assessment Report (URS 1997a).

6.1 PHYSICAL AND ENVIRONMENTAL SETTING

6.1.1 Surface Hydrology

The landfill is located in the western part of the base (Figure 6-4). The surface topography is relatively flat in the immediate vicinity of the landfill, but steepens to the south, west, and north. Stormwater drainage from the land areas near the OU 1 landfill flows into the marshlands located west and south of the landfill. This wetland area drains northward into the tide flats of Dogfish Bay through a culvert under Keys Road. 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.

The marshlands adjacent to the landfill include most of the area bounded by the landfill, Keys Road, Shapely Road, and Bradley Road (Figure 6-4). A small pond is located in the central part of the marshlands. The pond is drained by a small creek northward to the tide flats. The pond is fed by the wetland in the remainder of the marshlands located south and southeast of the pond. In this document, the entire marshlands area is referred to as "the marsh," including the pond, the creek that drains the pond, and the wetland area upstream of the pond. In this document, the pond is referred to as "the marsh pond," and the creek that drains the marsh pond is referred to as "the marsh creek."

Surface water inputs to the marsh pond include two freshwater creeks; these enter the pond at points A and B in Figure 6-4. Both of these creeks are small. The stream entering the pond from the west is only about two ft wide at point A. The other stream is of similar size, but braids near the pond at point B. The stream entering the pond at point A drains an area west of Highway 303 and then follows Shapely Road before turning toward the marsh pond. This stream is believed to be unnamed. For the sake of convenience, this stream is referred to as "Shapely Creek" in this document.

The creeks feeding the marsh pond are small drainages, with stream beds that are about one to two ft wide. Shapely Creek flows year-round and has the appearance of a drainage ditch where it parallels Shapely Road. Upstream of the base, it flows through a dense thicket just south of the county pump station on Highway 303. The strewn bed in this area and on the base consists mainly of silty clay with little sand or gravel. Above the pump station, the creek flows through a subdivision, following the gravel drainage ditches that front the residences along the streets, before entering a stormwater retention basin that is part of the development. The flow discharges from the retention basin via a grating and an underground pipe that drains in the direction of the county pump station.

The marsh also receives inputs from stormwater drainage systems that discharge through culverts located at points C and D in Figure 6-4. Other inputs to the marsh include shallow groundwater flowing toward the marsh from all sides in the water table aquifer.

The water from the marsh drains to the tide flats through a culvert under Keys Road, with the discharge at point E in Figure 6-4. In this document, this discharge is referred to as the "outlet of the marsh" or the "marsh outlet." A tide gate is located at the marsh outlet to control tidal flow into the marsh. The tide gate consists of a hinged metal flange on the end of the culvert. At low tide, the outflow from the marsh can swing the flange partially open to allow outflow from the marsh to drain. At high tide, the flange swings against the culvert to restrict inflow to the marsh. The surface water bodies near the landfill constitute a complex, tidally influenced hydrologic system. Tidal fluctuations in Dogfish Bay influence the water levels in the tide flats, marsh creek, marsh pond, and groundwater in the northwestern part of the landfill. The typical range in tide level, at a measuring point close to the southeast side of the Highway 308 bridge, is about ten ft from higher-high to lower-low tide. Because the elevation of the upstream end of the channel between the tide flats and Dogfish Bay is considerably higher than the low-tide level of Dogfish Bay, the water level in Dogfish Bay is considerably lower than that in the tide flats during low tide. At high tide, the tide flats and Dogfish Bay have the same water surface elevation.

High tides in Dogfish Bay and the tide flats cause seawater to flow through the tide gate into the creek area and typically flood the area as far south as the marsh pond. The tide gate controls the inflow so there is only a small tidal influence on the water surface elevation in the pond, and little or no influence upstream of the pond. Salinity measurements throughout the hydrologic system illustrate the degree of upstream tidal influence. The salinity of Dogfish Bay measured during the RI was 29.8 parts per thousand (ppt). The salinity was 23 ppt in the tide flats and about 13 ppt in the brackish water of the marsh pond. Tidal backflow does not affect the salinity of the two freshwater creeks flowing into the pond except for the first few feet upstream into their channels.

6.1.2 Geology And Hydrogeology

The geology and hydrogeology in the vicinity of the OU 1 landfill have been studied during the RI and the subsequent supplemental data collection program. This section provides a brief overview of the hydrogeologic information presented in the RI Report and the Summary Data Assessment Report. The reader is referred to these reports for additional details. Because a considerable amount of new data were collected during the supplemental program, the Summary Data Assessment Report is the better source of hydrogeologic information and interpretations for the site.

The history of glacial and interglacial deposition and erosion that has occurred in the Puget Sound area over the last two million years has created a complex stratigraphy beneath the site. Stratigraphic units in the vicinity of the OU 1 landfill are vertically and laterally variable and complex. They include interbedded glacial deposits and nonglacial fluvial/floodplain deposits, plus post-glacial estuary/marsh deposits and fill.

The hydrostratigraphy in the vicinity of the OU 1 landfill is highly variable due to the complexity and distribution of the geologic units. The Summary Data Assessment Report identifies six general hydrostratigraphic units at the OU 1 landfill. These units are, in downward sequential order starting at the ground surface:

- Unsaturated zone
- Upper aquifer
- Middle aquitard
- Intermediate aquifer
- Clover Park aquitard
- Clover Park coarse-grained zone.

Table 6-3 shows the stratigraphic units that compose each of these hydrostratigraphic units and identifies the primary units within each aquifer and aquitard. Cross sectional diagrams were developed in the Summary Data Assessment Report to illustrate the hydrostratigraphy at the OU 1 landfill. Figure 6-5 shows the alignment of each of these cross sections and the locations of the soil borings used to develop the cross sectional diagrams. The cross sections are presented as Figures 6-6 and 6-7.

The hydrostratigraphy beneath the landfill includes two main aquifers that are separated by the middle aquitard. The unconfined upper aquifer is present throughout virtually all of the area. It is generally composed of a sand-rich unit, but also includes overlying silt-rich units. This sand zone is locally not present and is replaced by silt-rich units in the eastern parts of the tide flats, in the area southwest of the marsh pond, and in areas east of the landfill. As shown in Figure 6-7,the water table intersects the landfill waste material beneath much of the OU 1 landfill. That is, roughly five to ten feet of landfill material lie above the water table in the unsaturated zone, and up to about five feet of landfill material lie 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 locally is quite sandy. More significantly, this aquitard is locally absent in the central, eastern and northern portions of the landfill (Figure 6-8). 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 near MW1-18. This aquifer is generally composed of sand with some gravel and significant silt, and 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. However, it locally contains water-bearing sand and gravel, which has been designated in Table 6-3 as the Clover Park coarse-grained zone. The continuity of this lower confined zone is unknown. Logs from deep supply wells (extending to 500 to 1000 feet below land surface) show the existence of three additional thick aquitards beneath the Clover Park aquitard.

6.1.3 Groundwater Flow

Groundwater level measurements were taken during the RI and the supplemental data collection program for both the upper aquifer and the intermediate aquifer. Typical groundwater contour maps are shown in Figures 6-9 and 6-10 for these two aquifers.

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 passing through the landfill discharges to the tide flats rather than the marsh (e.g., at the northern section of the landfill).

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, and thus indicate 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 U.S. Geological Survey (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, NUWC, Division Keyport, Washington was prepared during assessment of the supplemental sampling data and is presented in Appendix A of the Summary 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 such a way as to allow landfill contaminants to ever be 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. Hydrogeologic parameters and conditions at the landfill are summarized in Table 6-4 for these two aquifers. This table includes estimates of groundwater velocity and discharge passing through the landfill that were developed in the Summary Data Assessment Report. Based on the averaged conditions for the upper aquifer, the travel time for groundwater to pass through the landfill (i.e., from Bradley Road to the marsh) is on the order of five to eight years (see Figure 6-11 for location of groundwater streamlines used for calculating travel times). For the intermediate aquifer, based on averaged conditions, the travel time from the southern end of the landfill to the tide flats is on the order of 27 years, and the travel time across the tide flats is on the order of 50 years (see Figure 6-12 for location of groundwater streamlines used for calculating travel times). Considering the range of groundwater gradients and hydraulic conductivities in the intermediate aquifer, these estimated travel times in the intermediate aquifer are generally consistent with tritium measurements of groundwater samples from the site that suggest the age of the intermediate aquifer groundwater in the area of the Highway 308 bridge is on the order of about 40 years old (see Appendix A of the Summary Data Assessment Report [URS 1997a]).

Vertical gradients between the upper and intermediate aquifers are indicated in Figure 6-13. These contours 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) at MW1 - 15 in the middle of the landfill; a minimal head difference is not surprising in this area since the middle aquitard was found to be absent at this well location.

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, and is located just north of the tide flats (Figure 6-3). Water used at NUWC Keyport originates from Base Well No. 5, located on base, just north of the shallow lagoon (Figure 6-3). The PUD backup well and the base water supply well are screened in aquifers located about 500 ft below the Clover Park aquitard. There are two additional thick aquitards that lie between the Clover Park unit and the screen zones of these supply wells. Both of these wells tap groundwater that is under flowing artesian conditions (i.e., the water level in the well rises above the ground surface when the well pump is turned off).

Homes on the south side of the tide flats and Dogfish Bay and on and near Virginia Point (Figure 2-2) are generally not hooked up to public water supply and are instead served by private wells. A well inventory conducted for the Navy in 1996 and 1997 (see Appendix C of the Summary Data Assessment Report) 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 (e.g., 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 (could not tell which). All of these wells are used for domestic purposes.

As discussed earlier in this section, 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.

6.1.4 Habitats and Biota

The following text summarizes information obtained during the RI regarding the terrestrial and marine habitats and biota associated with OU 1. Additional detail can be found in the Ecological Risk Assessment (URS 1993d).

Most of the landfill area is paved and fenced. Although some areas of grass and exposed soil remain in the northern portion of the OU 1 landfill, the potential habitat at the landfill is limited. Forest habitat surrounding the marsh is represented by a dense stand of red alder (Alnus rubus) located along the southern border of the landfill. Red alder is also found along the slopes on the western side of the marsh. Red alder is interspersed with Douglas fir (Pseudotsuga menziesii). A dense understory includes salal (Gaultheria shallon), ferns, blackberry (Rubus spp.), Oregon grape (Mahonia sp.), rhododendron (Rhododendron macrophyllum), various vines, and coarse grasses. Scotch broom (Cytisus scoparius) and blackberry are the dominant species in disturbed areas between the landfill and marsh (SCS 1984).

Wildlife associated with the forested areas at NUWC Keyport includes rodents, small amphibians such as salamanders, snakes, and possibly deer or coyote. Birds associated with the forest habitat include sparrows, chickadees, goldfinches, hummingbirds, crows, and occasional hawks. An eagle's nest was discovered in August 1996 on the hill south of the shallow lagoon. The eagles raised three fledglings, and the pair returned in 1997.

Marsh vegetation is dominated by pickleweed (Salicornia virginica) and saltgrass (Distichlis spicata). Additional marsh plants include saltmarsh bulrush (Scirpus maritimus), seaside arrowgrass (Triglochin maritimum), Douglas aster (Aster subspicatus), and velvet grass (Holcus lanatus). Stands of cattail (Typha latifolia) are confined to the southern end of the marsh pond where fresh water mixes with brackish pond water. Floating mats of epiphytic algae are present in the open water zone.

Small crustacea such as amphipods are common in the marsh creek. Other marsh wildlife that would be typical for this area would include otters, muskrats, voles, barn swallows, belted kingfishers, mallards, gulls, great blue herons, and hawks.

The tide flats and much of Dogfish Bay are tidally exposed areas representing primarily fine-grained sediment habitat. Typical Puget Sound invertebrates such as polychaetes, snails, and crustacea are present. Although systematic surveys were not conducted, several species of clams were identified in the August 1989 sampling event, including native littleneck clam (Protothaca staminea), bent-nosed clam (Macoma nasuta), mud clam

(Macoma inquinata, which is synonymous with M. irus), Manila clam (Tapes japonica), Washington clam (Saxidomus giganteus), and basket cockle (Clinocardium nuttallii). In 1992, the Pacific oyster (Crassostrea gigas) was identified in commercial harvest beds in Dogfish Bay. In contrast to the marsh, epiphytic algae are not abundant in the tidally exposed areas of the tide flats and Dogfish Bay.

Biological surveys conducted by the Navy (see Appendix A of the Summary Data Assessment Report [URS 1997a]) concluded that, although Shapely Creek probably once supported a small spawning population of salmonids, access restrictions and habitat degradation caused by development have eliminated the viability of a sustained population. The surveys further concluded that the stream reach below the marsh (i.e., the marsh creek) contains estuarine fish species such as stickleback and sculpin.

6.2 NATURE AND EXTENT OF CONTAMINANTS

As described below in Section 7, two classes of contaminants were identified as chemicals of concern (COCs) for the three main potential exposure pathways of interest: chlorinated aliphatic hydrocarbons (CAHs) and polychlorinated biphenyls (PCBs). CAHs comprise a class of volatile organic compounds (VOCs) that consist of straight-chain hydrocarbons that contain one or more chlorine atoms. The CAHs that were identified as COCs at OU 1 are:

- 1,1-dichloroethane (1,1-DCA)(CAS# 75-34-3)
- 1,2-dichloroethane (1,2-DCA)(CAS# 107-06-2)
- 1,1-dichloroethene (1,1-DCE)(CAS# 75-35-4)
- cis-1,2-dichloroethene (cis-1,2-DCE)(CAS# 156-59-2)
- trans-1,2-dichloroethene (trans-1,2-DCE)(CAS# 156-60-5)
- tetrachloroethene (PCE)(CAS# 127-18-4)
- 1,1,1-trichloroethane (1,1,1-TCA)(CAS# 71-55-6)
- trichloroethene (TCE)(CAS# 79-01-6)
- vinyl chloride (CAS# 75-01-4).

The compounds PCE, 1,1,1-TCA, and TCE are known as "parent compounds" because they break down into the other CAHs on the list, known as "daughter compounds." Because TCE is the most prevalent parent compound at the landfill, the CAHs listed above are sometimes referred to as "TCE-family compounds."

There are 209 individual chemicals (or "congeners") that fall under the generic classification of "PCBs." They all have the same basic chemical structure, consisting of various numbers of chlorine atoms attached to a biphenyl molecule. The biphenyl molecule consists of two benzene rings connected to each other by a single carbon bond and has ten different locations where chlorine atoms can be attached. Commercially produced PCBs were manufactured as different mixtures that contained differing amounts of the 209 individual congeners. The tradename used for these different mixtures was "Aroclors." The following Aroclors have been detected at OU-1:

- Aroclor 1016 (CAS# 12674-11-2)
- Aroclor 1232 (CAS# 11141-16-5)
- Aroclor 1242 (CAS# 53469-21-9)
- Aroclor 1254 (CAS# 11097-69-1)
- Aroclor 1260 (CAS# 11096-82-5).

The CAHs were identified as COCs because of the drinking water pathway and the seafood ingestion pathway. The PCBs were identified as COCs because of the seafood ingestion pathway and the ecological pathway. Details of the screening process and rationale for identifying these compounds as COCs for these pathways are given in the Summary Data Assessment Report and are summarized below in Section 7.

Other chemicals, while not identified as COCs, were judged to be appropriate for inclusion in the long-term monitoring of sediment and shellfish tissue along with the COCs (see section 11.5). Chemicals in this category include acenaphthene, bis(2-ethylhexyl) phthalate, and several metals. These chemicals were generally detected in much lower concentrations relative to regulatory or risk-based levels and were judged to pose even lower potential future human health or ecological risks than the COCs. However, long-term monitoring of these chemicals in sediment and shellfish tissue is warranted because they exhibited spatial distributions that suggested the landfill might be a source and they could potentially build up in the marine environment over time.

6.2.1 Distribution of Chemicals of Concern

6.2.1.1 Distribution of CAHs

CAHs are present in both the upper and intermediate aquifers, with concentrations in the upper aquifer greater than those in the intermediate aquifer by an order of magnitude or more. Figure 6-14 shows the distribution in the upper aquifer of the three most prevalent TCE-family compounds, TCE, cis-1,2-DCE, and vinyl chloride. Figure 6-15 shows the general pattern of TCE-family compounds in the upper aquifer as inferred from the chemical results from the eight monitoring wells on the downgradient margin of the landfill and the three monitoring wells in the interior of the landfill. The contours in Figure 6-15 represent the sum of the concentrations of the individual TCE-family compounds in each well, averaged over all rounds. These contours show that concentrations of TCE-family compounds are ten times higher in the southern part of the landfill than they are elsewhere throughout the landfill. The distribution of individual CAHs that are most prevalent at OU 1 illustrate this same spatial pattern, indicating that the southern part of the landfill is the most significant source, or "hot spot" for CAHs.

Certain CAHs, such as the solvents PCE, TCE, and 1,1,1-TCA, are, in their non-dissolved phase, denser than water and capable of forming "dense non-aqueous phase liquids" (DNAPLs). DNAPLs can sink through aquifers under the influence of gravity and create discrete DNAPL pools and stringers some distance from the original solvent disposal site. Such disconnected DNAPLs can form secondary sources of dissolved contaminants within aquifer. Once dissolved in groundwater, these solvents no longer behave like DNAPLs. Based upon the disposal history of the site and on the observed concentrations of CAHs in groundwater, the presence of DNAPLs cannot be ruled out at OU 1.

Some of the CAHs have been detected in the adjacent surface water, particularly close to the landfill in the marsh (Figures 6-14 and 6-16). The presence of these compounds in the marsh water appear to be the direct result of on-going discharge from the upper aquifer into the marsh.

The most prevalent compounds detected in the surface water are cis-1,2-DCE and vinyl chloride, which are among the more soluble and mobile of the daughter products from degradation of TCE. The concentrations in the marsh surface water decrease in the downstream direction as the water moves from the southern part of the marsh, which is near the hot spot area of the landfill described above, to the outlet of the marsh into the tide flats (i.e., at station TF18 near the northern end of the marsh). CAHs are also present in the seep that discharges into the marsh creek (in the northern part of the marsh). The discharge from the seep does not substantially alter the decreasing trend in concentrations from the southern part of the marsh to the marsh outlet, indicating that the seep is not as significant a source of CAHs as is the southern part of the landfill.

CAHs have migrated from the landfill into the intermediate aquifer and formed a plume as evidenced by detection of TCE and its daughter products in three monitoring wells immediately downgradient of the landfill and detection of vinyl chloride in one of the wells located farther downgradient at the Highway 308 bridge. The general pattern of the intermediate aquifer plume is illustrated by the plot of TCE-family compounds (Figures 6-17 and 6-18). CAHs may have been transported downward to the intermediate aquifer as DNAPLs or were advected downward in the dissolved phase in places where the upper and intermediate aquifers are connected.

The detection of vinyl chloride at the bridge (MW1-39) was at a low concentration, close to the detection limit, but was consistent in all rounds in which this well was sampled. This result, plus the observation that vinyl chloride and other CAHs were analyzed for but were not detected in nearby wells, suggests that the leading edge of the plume is probably in the vicinity of the bridge. Vinyl chloride is expected at the leading edge of the plume because it is more soluble and has less affinity for soils than most other CAHs. The detection of vinyl chloride at the bridge (and not other CAHs) may also be indicative of efficient degradation of TCE and DCEs in the intermediate aquifer beneath the tide flats. A low-concentration detection (near the detection limit) of TCE in well MW1-32 in the second of three supplemental sampling rounds is probably a spurious result and is not considered part of the plume. (This conclusion was further supported by results of the March 1998 sampling round that again found that no CAHs were detected in this well.)

The intermediate aquifer plume appears to be narrow, as expected based on the groundwater flow direction toward the center of the tide flats (Figure 6-10). The data indicate the ultimate fate of all mobile contaminants in the intermediate aquifer is to discharge to surface water in the tide flats or Dogfish Bay.

6.2.1.2 Distribution of PCBs

PCBs were detected in the groundwater of the upper aquifer, the seep, the aquatic sediments, and the clam tissue samples. PCBs were not detected in the intermediate aquifer. The distribution of PCBs is illustrated in Figure 6-19. PCBs were detected in some of the upper aquifer monitoring wells and in the seep samples, but were not detected in the surface water samples from the marsh, tide flats, and Dogfish Bay (except for one round at MA09, the marsh water station next to the seep). Many of the results were close to the detection limit and not consistent from round to round. However, PCBs were detected in every round in the samples from the seep and the two monitoring wells closest to the marsh pond (MW1-6 and MW1-17). Because the PCBs measured in the seep are discharging directly into the marsh, it is likely that much of the PCBs currently migrating from the landfill into the marsh are coming from the seep. For the groundwater, soil adsorption probably reduces the concentrations of PCBs before they discharge into the marsh, given that PCBs have a strong affinity for soil particles.

Figure 6-19 shows the distribution of PCBs in aquatic sediments downstream of the landfill. The highest concentration was detected at MA09, the marsh sediment station closest to the seep. This station is also located in the northern (downstream) portion of the marsh, which receives the drainage from the remainder of the marsh. Concentrations of PCBs detected in the marsh pond sediment were an order of magnitude less than the results for MA09. The only detections of PCBs in the sediments downstream of the marsh were at TF21, the tide flats station closest to the marsh outlet. Concentrations at TF21 were about one-sixth those at MA09.

Figure 6-19 shows the PCBs results for clam tissue samples collected from the tide flats and Dogfish Bay during Round 3 of the supplemental data collection program. The highest detected concentration was at TF21, the clam tissue station located closest to the landfill. A detection also occurred in one of the remote stations in Dogfish Bay, but the concentration was very close to the detection limit. The distribution pattern in the tissue results is in agreement with the pattern described above for sediments. In both cases, the results show a spatial trend of decreasing concentration with increased distance downstream of the seep. This trend suggests that the PCBs in sediments and clam tissue have probably come from the landfill. This could be the result of past practices and operations at the landfill before it was closed or may be the result of ongoing discharges over the history of the landfill. The landfill is currently releasing low concentrations of PCBs into the marsh via the seep (seep concentrations range from not detected at a detection limit of 0.04 Ig/L to detected at 0.24 Ig/L) and possibly other groundwater discharges.

6.2.2 Environmental Fate of Chemicals of Concern

Table 6-5 lists transport and fate properties of PCBs and CAHs. Aqueous solubilities for CAHs are on the order of 100 to 10,000 mg/L, while the PCBs detected at OU 1 have solubilities on the order of 1 mg/L or less. The PCBs are much more strongly attracted to solid particles than the CAHs, with soil/water partition coefficients for PCBs on the order of 1,000 mL/g or more, compared to partition coefficients for CAHs on the order of 1 mL/g or even less. Because of these properties, CAHs are relatively mobile in the environment. PCBs, on the other hand, are much less mobile and their migration in groundwater is strongly retarded by soil adsorption.

When contaminated groundwater discharges into a surface water body, PCBs tend to accumulate in the sediments near the source or discharge point, while CAHs tend to remain dissolved and move downstream with the water phase. Because PCBs are relatively insoluble in water, they tend to be more readily dissolved in organic liquids such as the oils in animal tissues. For this reason, they tend to bioaccumulate in the tissues of aquatic organisms including seafood such as clams. CAHs have much lower affinity for oils and do not tend to bioaccumulate.

The CAHs are extremely volatile, while the heavier PCBs are considered to be nearly non-volatile. Henry's Law constants (dimensionless) for CAHs are on the order of 0.1 to 1.0, while those for PCBs are on the order of about 0.01 to 0.1. This means that CAHs tend to vaporize from water when exposed to the atmosphere, such as at the surface of a water body or at the top of the water table in the case of groundwater. Vaporization rates are more rapid from surface water bodies than groundwater because of the turbulence that occurs at the surface of water bodies from currents, winds, and stream flow. For CAHs, volatilization is a primary fate process in surface water bodies.

Naturally occurring bacteria and other microorganisms have the ability to degrade a wide variety of synthetic organic compounds. PCBs are among the most resistant chemicals to this kind of degradation, and natural biodegradation rates are normally assumed to be insignificant. Bacteria are much better able to adapt to the presence of CAHs and break them down as a consequence of their metabolic activity. While different environmental conditions are needed for efficient biodegradation of different chemicals in the TCE-family, naturally occurring bacteria are capable of converting each of the TCE-family compounds to harmless chemical forms.

The CAHs detected at Area 1 are members of chemical transformation series in which parent solvents degrade in groundwater into daughter compounds. For example, the parent solvents PCE and TCE can degrade into the daughter compounds cis- and trans-1,2-DCE. Similarly, the parent solvent 1,1,1-TCA can degrade to the daughter compounds 1,1-DCA and 1,1-DCE. The three DCEs can degrade further to vinyl chloride which, under the right conditions, can degrade completely. The compound 1,1-DCA can degrade into chloroethane. The parent solvent 1,2-DCA can also degrade to chloroethane. Vinyl chloride and cloroethane can degrade completely to ethane, carbon dioxide, and chloride. Some daughter compounds (e.g., vinyl chloride) are more toxic and more mobile in groundwater than the parent compounds. In general, degradation of the more highly-chlorinated compounds, such as PCE and TCE, is favored by highly reducing groundwater conditions. Degradation of less-chlorinated compounds, such as the DCEs, and vinyl chloride, is favored by less-reducing or oxidizing groundwater conditions.

The natural breakdown processes described above have been referred to in the scientific literature as "natural" or "intrinsic" bioremediation (especially when the processes are effective in helping to control the COCs at a contaminated site). The term "natural attenuation" includes intrinsic bioremediation, but also includes non-biological chemical breakdown as well as other processes

that act naturally to retard migration rates or reduce concentrations of contaminants, such as volatilization, mixing, dispersion, photo-oxidation, and adsorption to particles.

Conditions at OU 1 have been studied to determine the degree to which natural biodegradation may be active at the landfill. The results of these studies, which were conducted for the Navy by the USGS, suggest that low oxygen conditions exist within the landfill that are conducive to breaking down parent compounds such as TCE, while conditions ranging from mildly reducing to oxidizing are present in the groundwater downgradient of the landfill that appear to be conducive to the degradation of daughter products such as DCEs and vinyl chloride. Similar conditions were measured in the monitoring wells at the Highway 308 bridge, indicating that conditions in the intermediate aquifer under the tide flats may also be conducive to bacterial breakdown of TCE daughter products such as vinyl chloride. These findings were documented in the report, Natural Attenuation of Chlorinated Solvents in Ground Water at Operable Unit 1, NUWC, Division Keyport, Washington which was included in Appendix A of the Summary Data Assessment Report. The USGS studies also included microcosm tests that provided demonstration of the existence and approximate rates of bacterial degradation under aerobic and anaerobic conditions, as well as soil adsorption measurements to determine sorption isotherms for the chlorinated ethenes in the intermediate aquifer.

The chemical distribution patterns of the COCs, as discussed in the previous section, are in general accord with these environmental fate processes. For example, CAHs were detected in the surface water samples while PCBs were not, reflecting the higher solubilities and lesser adsorption tendency of the CAHs. In surface water, attenuation of CAHs can be caused by processes including volatilization, dilution, and, in the case of cis-1,2-DCE and vinyl chloride, biodegradation under aerobic conditions. The decreasing concentrations of CAHs observed in the surface water as it moves downstream from the landfill probably reflects, primarily, their tendency to vaporize from the surfaces of the water bodies, as well as dilution by additional surface water inputs such as that from Shapely Creek and possibly some from tidal intrusion from the tide flats during high tide. PCBs were detected in the sediments and clam tissue samples nearest the landfill, reflecting their strong attraction to solid particles and their tendency for bioaccumulation.

CAHs have migrated into the intermediate aquifer while PCBs have not been detected in this aquifer, reflecting the greater solubility and mobility of CAHs and the stronger affinity PCBs have for adsorption to soils. The presence of CAHs in the intermediate aquifer may also be due to the downward migration potential, or sinking behavior, of pure liquid phase TCE, since it has a density as a pure liquid that is heavier than water. The presence of daughter products such as DCE and vinyl chloride in upper and intermediate aquifer monitoring wells downgradient of the landfill suggests that natural degradation processes are at work breaking down the parent compounds of the TCE-family. The absence of DCE and the detection of vinyl chloride at low concentrations at the Highway 308 bridge may indicate the greater mobility of vinyl chloride compared to other daughter products such as DCE that are more retarded by soil adsorption; these results may also reflect the ability of natural bacterial degradation in helping to minimize the downgradient spread of the TCE-family plume in the intermediate aquifer.

Regardless of the extent to which the natural degradation processes described above are active, TCE-family contaminants from the landfill that are dissolved in the upper aquifer groundwater are constrained by the hydrology of the site to discharge surface water or to migrate to the intermediate aquifer. Those that migrate to the intermediate aquifer are constrained by the hydrology to discharge to surface water. Once in surface waters these chemicals tend to be volatilized and degraded in the atmosphere.

7.0 SUMMARY OF SITE RISKS

Remedial actions at NUWC Keyport OU 1, as described later in this ROD, are intended to protect human health and the environment from current and potential future exposure to hazardous substances associated with the site.

Potential risks to human health and the environment from chemicals detected at OU 1 were evaluated initially as part of the 1993 RI and then again as part of the 1995/1996 post-RI supplemental sampling program. Risk assessments conducted as part of the RI were documented in the Baseline Human Health Risk Assessment report

(URS 1993b) and the Baseline Ecological Risk Assessment report (URS 1993c). Risks evaluated as part of the post-RI supplemental sampling program were documented in the Summary Data Assessment Report (URS 1997a) and the Focused Feasibility Study Report (URS 1997b). The following sections summarize the results of these assessments of human health and ecological risk.

7.1 HUMAN HEALTH RISKS

A quantitative human health risk assessment, using CERCLA guidance, was conducted in 1993 as part of the RI for OU 1. Details of the calculations and assumptions used in this risk assessment can be found in the 1993 baseline human health risk assessment report.

Human health risks from selected exposure pathways were subsequently reevaluated using the large amount of additional data that was collected during the 1995/1996 supplemental sampling program. Because this later sampling generally found the same classes of contaminants and the same patterns of results as the RI, a CERCLA-type human health risk assessment, like that performed during the RI, was not repeated. Instead, human health risks were evaluated by comparing chemical results to regulatory criteria and calculated risk-based concentrations.

7.1.1 Summary of the 1993 Human Health Risk Assessment

A baseline human health risk assessment was performed for OU 1 using EPA guidance and data collected during the RI. The risk assessment was reviewed by EPA. The risk assessment report incorporated EPA comments and was finalized October 25, 1993 (URS 1993b). The risk assessment included the following five components:

- The identification of chemicals of potential concern (COPCs)
- An exposure assessment that identified existing and potential future exposure pathways and quantified exposures
- A toxicity assessment that considered both cancer and non-cancer effects
- A characterization of risk
- An evaluation of the effects of various uncertainties on the results of the assessment.

These five components are summarized in the following sections.

7.1.1.1 Chemicals of Potential Concern

COPCs were identified in the baseline risk assessment using the following two-step evaluation process:

First, inorganic chemicals in each environmental medium (e.g., soil, groundwater, surface water) were compared to background concentrations. Chemicals whose maximum concentrations exceeded background were carried forward in the COPC evaluation process. Organic chemicals and some inorganics for which no background values were available were not compared to background concentrations; all of these chemicals were carried forward.

Second, the chemicals carried forward from the first step were compared to conservative risk-based screening concentrations (RBSCs). These screening concentrations were derived assuming residential exposures and acceptable cancer risk levels of 1x10 -7 for soil and 1x10 -6 for water and acceptable hazard quotients (HQs) of 0.1. Chemicals whose maximum concentrations exceeded these RBSCs were identified as COPCs. In addition, all Class A carcinogenic chemicals (known human carcinogens) and those chemicals for which no screening concentrations were available were identified as COPCs regardless of their concentrations.

The COPCs identified by the above process are listed by medium in Table 7-1.

7.1.1.2 Exposure Assessment

The exposure assessment characterized the exposure scenarios, identified potentially exposed populations and their exposure pathways and routes of exposure, and quantified exposure in terms of chronic daily dose. Exposure is a function of both the intake of a contaminant (e.g., how much is ingested per day) as well as the contaminant concentration.

For both current and future land use, exposures to onsite workers, site visitors, and nearby residents were evaluated. For worker exposures, the following pathways were evaluated: (1)exposure to soil contaminants through soil ingestion and (2) exposure to indoor or outdoor airborne contaminants, either in the form of volatilized compounds or suspended particulates. For site visitors and nearby residents, the following pathways were evaluated: (1) exposure to contaminants in the surface water of nearby water bodies through ingestion, (2) exposure to contaminants in the sediment of nearby surface water bodies through ingestion, and (3) exposure to contaminants in seafood from nearby surface water bodies through ingestion (for this pathway, the evaluation included both recreational and subsistence use).

Exposure of hypothetical future onsite residents to shallow groundwater (i.e., from the upper and intermediate aquifers) was also evaluated and quantified during the development of the 1993 risk assessment and are presented in this ROD. This pathway was not included in the risk assessment report, however, because future residential use of the landfill was judged to be extremely unlikely.

Table 7-2 summarizes the exposure pathways and scenarios evaluated during the 1993 risk assessment including future onsite residential use of shallow groundwater.

Risks to then current and hypothetical future onsite workers to airborne landfill contaminants via inhalation of indoor air were evaluated in the 1993 risk assessment. These evaluations are summarized in this section of the ROD. However, since 1993, all buildings on the landfill have either been removed or are no longer occupied. Because of this, the risks calculated and presented for "current" workers in the 1993 risk assessment do not presently exist.

CERCLA guidance recommends that both reasonable maximum exposures (RMEs) and average exposures be calculated in risk assessments. RME exposures are intended to estimate the value of the highest dose that could reasonably be expected to occur for a given pathway and are calculated using RME intake assumptions and exposure concentrations. Average exposures were calculated using average intake assumptions and exposure concentrations.

As detailed in the 1993 Human Health Risk Assessment Report (URS 1993b), RME and average intake assumptions were generally based on values from EPA guidance documents (e.g., EPA's standard default assumptions). However, where EPA values were not available, best professional judgement was used. These cases are listed below:

- For worker exposure to soil (via ingestion) and airborne contaminants (via inhalation), average exposure duration was judged to be ten years.

- For subsistence seafood users, the fraction of seafood derived from OU 1-contaminated shellfish was judged to be 0.25 for RME exposure and 0. 10 for average exposure.

- For site visitors and nearby residents, ingestion of marine sediments during recreational activities was judged to have an exposure frequency of 52 days per year for RME exposure and 26 days per year for average exposure.

RME exposure concentrations were calculated using the 95 percent upper confidence limit (UCL) on the arithmetic mean of the sample results. In cases where the 95 percent UCL exceeded the maximum value observed, the maximum value was used to calculate the RME. Average exposure concentrations were calculated using the arithmetic mean of the sample results.

Exposure concentrations in soil were estimated by using soil sample results (i.e., concentrations at receptors were not estimated using modeling or other indirect means). For current land use scenarios, surface soil sample results were used. Because future land use scenarios included construction activity (e.g., construction of residences), it was assumed that soil from all horizons could be excavated, stockpiled, and reused onsite and thus could be placed at or near the ground surface and cause exposure to workers. Therefore, to quantify future scenarios, soil sampling results from all depths were combined.

Exposure concentrations in groundwater were estimated by using groundwater sampling results. Results from all RI sampling rounds of groundwater from the upper and intermediate aquifers were used as exposure concentrations to evaluate the risks from use of this water.

Indoor air exposure concentrations were estimated by use of ambient air monitoring data from several buildings that were located on the landfill at the time the RI was done. These buildings have since been removed or are no longer occupied. To estimate outdoor exposure concentrations for VOCs, the following techniques were used. Emission flux measurements were used to evaluate volatile emissions from the landfill. Dispersion modeling was then used to calculate exposure concentrations at receptor locations. The model was run using worst-case meteorological input assumptions. To estimate current outdoor exposure concentrations for metals, data from suspended particulate samples were used. Exposure concentrations were also calculated for future scenarios in which fugitive dust emissions from soil could result in exposure to airborne particulates. A model was used to estimate airborne contaminant concentrations based on measured concentrations of contaminants in soil.

Exposure concentrations for surface water were estimated by using surface water sampling results. Surface water sampling was conducted as part of the RI during both dry and wet seasons to account for seasonal changes in contaminant concentrations. Samples were collected near the surface to evaluate exposure scenarios involving ingestion of water while swimming. Surface water data were evaluated separately for the marsh, tide flats, and Dogfish Bay.

Exposure concentrations for sediment were estimated by using sediment sampling results. Concentrations were based on all samples collected within a surface water body (e.g., the marsh, tide flats, and Dogfish Bay).

Exposure concentrations for seafood were estimated using clam tissue sampling results from native littleneck clams (Protothaca staminea), manila clams (Tapes japonica), bent-nose clams (Macoma nasuta) and mud clams (Macoma inquinata). Concentrations were based on all samples collected within a surface water body (e.g., the tide flats and Dogfish Bay).

7.1.1.3 Toxicity Assessment

Toxicity information was provided in the 1993 risk assessment for the COPCs. Generally, cancer risks are calculated using toxicity factors known as slope factors (SFs), while noncancer risks are assessed using reference doses (RfDs).

EPA develops SFs for estimating excess lifetime cancer risks associated with exposure to potential carcinogens. SFs are multiplied by the estimated intake of a potential carcinogen to provide an upper-bound estimate of the excess lifetime cancer risk associated with exposure at that intake level. Estimated intakes are determined using the exposure concentrations which were calculated as discussed above in Section 7.1.1.2. The term "upper-bound" reflects the protective (i.e., conservative) estimate of the risks calculated from the SF. Use of this approach makes underestimates of the actual cancer risk highly unlikely. SFs are derived from the results of human epidemiological studies, or chronic animal bioassay data, to which mathematical interpolation from high to low doses, and from animals to humans, have been applied.

EPA develops RfDs to indicate the potential for adverse health effects from exposure to chemicals exhibiting noncancer effects. RfDs are estimates of lifetime daily exposure for humans, including sensitive subpopulations, likely to be without risk of adverse effect. Estimated intakes of contaminants of concern from environmental media can be compared to the RfD. RfDs are derived from human epidemiological studies or animal studies to which protective safety factors have been applied.

The risk assessment used oral and inhalation SFs and RfDs. Toxicity factors were obtained from the Integrated Risk Information System (IRIS) or, if no IRIS values were available, from the Health Effects Assessment Summary Table (HEAST). For the few chemicals which did not have toxicity values available from either source, sources other than IRIS and HEAST were used. EPA does not provide toxicity data for lead because of unique considerations related to the toxicology of this element. Instead, lead concentrations in soil, water, and air at the site are compared with concentrations for these media that EPA has determined are unlikely to result in unacceptable blood-lead concentrations in humans.

7.1.1.4 Risk Characterization

For carcinogens, risks are estimated as the incremental probability of an individual developing cancer over a lifetime as a result of exposure to the specific carcinogen. Excess lifetime cancer risk is calculated by multiplying the SF by the quantitative estimate of exposure, the "chronic daily intake." These risks are probabilities generally expressed in scientific notation (e.g., 1x10 -6). An excess lifetime cancer of 1x10 -6 indicates that an individual has a one in one million (1:1,000,000) chance of developing cancer as a result of site-related exposure to a carcinogen under the specific exposure conditions assumed.

The potential for noncarcinogenic effects is evaluated by comparing an exposure level over a specified time period (lifetime) with an RfD derived for a similar exposure period. The ratio of exposure to toxicity is called the HQ. HQs are calculated by dividing the exposure by the specific RfD. By adding the HQs for all COCs the hazard index (HI) can be calculated.

The RME provides a conservative (protective) exposure scenario for considering remedial actions at a Superfund site. Based on the RME, when the excess lifetime cancer risk estimates are below 10 -6, or when the noncancer HI is less than 1, EPA generally considers the potential human health risks to be below levels of concern. Remedial action may be warranted when excess lifetime cancer risks exceed 10 -4 (one in ten thousand) or an HI exceeds 1. Between 10 -6 and 10 -4 remedial action may or may not be selected, depending on individual site conditions including human health and ecological concerns. (It should be noted that the State of Washington Model Toxic Control Act [MTCA] clean up levels, the criteria used by Ecology to assess the need for remedial action, are generally based on HIs of 1 and incremental cancer risk of 1xl0 -6 for individual chemicals, and HIs of 1 and total incremental cancer risk of 1x10 -5 for the site as a whole.)

Cancer Risks

Table 7-3 presents the average and upper bound (RME) estimates of cancer risks that could result from exposures to contaminants at the site that were determined during the 1993 baseline risk assessment. The highest cancer risks were associated with onsite worker exposure to indoor air (RME = 3×10^{-4}, or 3 in 10,000) and hypothetical future onsite residential use of upper and intermediate aquifer groundwater (RME = 2×10^{-2}, or 2 in 100). The chemicals primarily responsible for the indoor air cancer risk were chloromethane, carbon tetrachloride, 1,3-butadiene, 1,1-DCE, and methylene chloride. The chemical primarily responsible for the hypothetical future groundwater risk was vinyl chloride.

As discussed above, all buildings on the landfill have either been removed or are no longer occupied. Because of this, the risks due to worker inhalation of airborne indoor landfill contaminants calculated for "current" workers in the 1993 risk assessment do not presently exist.

Non-Cancer Risks

Table 7-3 presents the average and upper bound (RME) estimates of non-cancer risks that could result from exposures to contaminants at the site that were determined during the 1993 baseline risk assessment. The highest non-cancer risks were associated with onsite worker exposure to indoor air (RME = 2) and future onsite residential use of upper and intermediate aquifer groundwater (RME = 20). The chemicals primarily responsible for the indoor air non-cancer risk were Freon 12, 1,4-dichlorobenzene, and 1,1,1-TCA. The chemical primarily responsible for the future groundwater risk was vinyl chloride.

As discussed above, risks due to worker inhalation of airborne indoor landfill contaminants calculated for "current" workers in the 1993 risk assessment do not presently exist.

Because lead was not included in the risk estimates, lead concentrations in air, soil, and groundwater were compared with levels that EPA has determined are unlikely to result in unacceptable blood-lead concentrations in humans. The RME lead concentrations observed in soil, water, and air were all well below these EPA-recommended levels.

7 1.1.5 Uncertainty Analysis

The accuracy of the risk characterization depends in large part on the accuracy and representativeness of the sampling, exposure, and toxicological data. It is important to emphasize that the baseline risk assessment is primarily a decision-making tool for use in assessing the need for remedial action. The results of risk assessments are presented in terms of the potential for adverse effects based on a number of very conservative assumptions. The tendency to be conservative is an effort to err on the side of the protection of health.

Uncertainties in various aspects of site characterization and risk assessment may have led to under- or overestimation of risk. The following uncertainties were of most importance for the selection of remedial measures and for the identification of supplemental data needs:

- There was a high degree of uncertainty about whether the contaminants detected in the indoor air samples originated from the landfill or were from products present in the offices and shops themselves. This uncertainty led to a potential for overestimation of risk attributable to the landfill.

- PCBs were not arialyzed in seafood (clams). This could have caused contaminants which were present not be detected and could have led to potential underestimation of risk.

- Lead data from clams collected during two RI sampling rounds were identified as being inconsistent by the Agency for Toxic Substances and Disease Registry (ATSDR) in their 1995 Health Consultation Report. Results from these rounds were difficult to interpret because the data set included results for both depurated and non-depurated clams and included several different clam species.

7.1.2 Summary of Human Health Risks Based on 1995/1996 Supplemental Data

Human health risks due to certain exposure pathways were subsequently reevaluated using the large quantity of additional data collected during the 1995/1996 supplemental sampling program. This supplemental sampling was conducted to aid the remedial decision-making process and was targeted at the following two specific exposure pathways that the RI was judged not to have adequately evaluated:

- Risks to current and future seafood harvesters in the tide flats and Dogfish Bay. The assessments done during the RI did not identify risks exceeding EPA target levels (i.e., cancer risk > 10^{-4}, HI > 1) for seafood harvesters. However, it did identify significant uncertainty about this conclusion because of the lack of PCB analyses in clam samples and because of the inconsistency in lead data between the two RI clam sampling rounds. Therefore, it was decided that additional characterization of risks to humans from ingestion of seafood was required.

- Risks to current and future offsite residents from domestic use of intermediate aquifer groundwater. The assessments done during the RI were judged to have adequately identified the very high risk to potential future residential users of onsite upper and intermediate aquifer groundwater. However, it was concluded that additional characterization of risks to offsite residents due to groundwater use was required.

The supplemental sampling data were an improvement over those collected during the RI for the evaluation of the two human health exposure pathways listed above. For example, the supplemental sampling program included many more monitoring wells in the intermediate aquifer to assess the potential flow of contaminants to off-base areas. The supplemental sampling also included analyses of PCBs in clam tissue to help ensure that low concentrations of these contaminant types were not missed. In addition, the supplemental sampling included only non-depurated clam samples from a single, commonly-harvested species (P. staminea), to obtain more consistent data for lead and other chemicals. The supplemental sampling also included five sampling rounds to ensure that worst-case seasonal concentrations would be monitored. Results of the supplemental sampling program and the evaluation of risk based on the data collected are presented in the Summary Data Assessment Report (URS 1997a).

Because the supplemental sampling generally found the same classes of compounds and the same patterns of results as the RI, a CERCLA-type risk assessment, like that performed during the RI, was not repeated. However, the same conceptual steps, identification of COCs, exposure assessment, toxicity assessment, and risk characterization were performed for the two human health risk pathways of interest. These steps are summarized in the following sections.

7.1.2.1 Chemicals of Interest

Chemicals detected in the supplemental sampling program were evaluated by comparing their concentrations against regulatory criteria or calculated RBSCs relevant to the human health pathways under consideration. Groundwater was compared to drinking water criteria. Surface water and groundwater were compared to surface water quality criteria for the protection of human health via ingestion of seafood. Clam tissue results were compared to calculated RBSCs for human health based on recreational exposure assumptions and on cancer risk values of 1x10 -6 and non-cancer HIs of 1. Any chemical whose maximum concentration in a specific environmental medium exceeded one-third the value of the most stringent screening concentration was identified as a chemical of interest (COI). One-third the value of the screening concentration was used for comparison in order to be conservative (i.e., protective) and to account for sampling and analytical uncertainties. These chemicals were termed "COIs" to distinguish them from the "COPCs" identified during the 1993 risk assessment. Unlike the identification of COPCs during the 1993 risk assessment, the identification of COIs did not include screening chemicals against their upgradient or background concentrations.

The list of COIs for groundwater, surface water, and clam tissue is shown in Table 7-4.

The COIs were evaluated further, in terms of their spatial distribution, frequency of detection, concentration, and presence in upgradient and reference stations. Chemicals of interest for which the landfill appeared to be a significant source were identified as COCs. Two groups of chemicals were identified as COCs: CAHs and PCBs.

The CAHs identified as COCs at OU 1 are:

- 1,1-DCA
- 1,2-DCA
- 1,1-DCE
- cis-1,2-DCE
- trans-1,2-DCE
- PCE
- 1,1,1-TCA
- TCE
- vinyl chloride.

The PCBs identified as COCs at OU 1 are:

- Aroclor 1016
- Aroclor 1232
- Aroclor 1242
- Aroclor 1254
- Aroclor 1260.

7.1.2.2 Exposure Assessment

Data from the supplemental sampling rounds provided better characterization of the two human health exposure scenarios of interest: exposures of offsite residents to landfill contaminants in the intermediate aquifer and exposures to shellfish harvesters to landfill-contaminated shellfish in the tide flats and Dogfish Bay.

Average and RME exposure concentrations were not used for risk evaluations in the supplemental sampling program. Instead, sample results were used individually to represent exposure point concentrations. These were compared on a point by point basis with regulatory values and risk based concentrations to characterize risk.

Current Offsite Groundwater Use Scenario

Based on the observed groundwater flowpaths, intermediate aquifer groundwater from the landfill converges toward the tide flats and Dogfish Bay where it discharges. These observations indicate that landfill contaminants do not currently flow beneath land areas where wells tapping the intermediate aquifer exist; therefore, it was concluded that there is no current exposure of offsite residents to landfill contaminants via this pathway.

Future Offsite Groundwater Use Scenario

Groundwater modeling was conducted by the USGS in order to evaluate exposure to offsite groundwater users should future changes in groundwater withdrawals change the flow field in such a way to allow landfill contaminants to be drawn into offsite wells. This study, using conservative (protective) assumptions, concluded that the development of a future withdrawal scenario that would cause contaminants to be drawn into offsite wells would be "highly improbable." Therefore, based on these results, it was concluded that future exposures of offsite residents to landfill contaminants via this pathway would be highly unlikely.

Current Shellfish Harvester Scenario

Data from all clam sample stations in the tide flats and Dogfish Bay were used to assess exposure to contaminants for this pathway. Because contaminant concentrations in ambient surface water can be related to concentrations in seafood species living in that water, surface water data from the marsh, tide flats, and Dogfish Bay were also used to evaluate exposure of current shellfish harvesters to landfill contaminants in shellfish.

Future Shellfish Harvester Scenario

The same data used to assess exposure for the current shellfish harvester scenario was used to assess exposure for the future scenario. In addition, it was recognized that bioaccumulation of certain landfill contaminants (e.g., PCBs) could occur over time and could increase exposure point concentrations in the future.

7.1.2.3 Toxicity Assessment

As discussed in Section 7.1.1.3, chemical toxicity is represented by SFs for cancer-causing chemicals and RfDs for non-cancer effects. In evaluating the supplemental sampling data, risks due to ingestion of shellfish were evaluated by comparison to RBSCs. These concentrations were calculated using oral SFs and RfDs. Toxicity factors were obtained from IRIS or, if no IRIS values were available, from HEAST. For the few chemicals which did not have toxicity values available from either source, sources other than IRIS and HEAST were used.

Risks from groundwater and surface water were evaluated by comparing sample concentrations to regulatory values. For risk-based regulatory values (most of the ones used), toxicity factors (SFs or RfDs) were determined by the regulatory agencies during the development of the regulatory values.

7.1.2.4 Risk Characterization

Human-health risks were evaluated by comparing measured concentrations of landfill contaminants in groundwater, surface water, and clam tissue against regulatory values or RBSCs. A separate and additional evaluation of risks associated with consumption of shellfish using supplemental sampling data was also performed by ATSDR.

Offsite Drinking Water Pathway

As discussed above in Section 7.1.2.2, site data and groundwater modeling concluded that current exposure of offsite residents to landfill contaminants via intermediate aquifer groundwater was not occurring and that future exposure is highly unlikely. Given these conclusions, no exposure was assessed. Since risk is the product of exposure and toxicity, no current or future risk was calculated for this pathway.

Seafood Ingestion Pathway

As discussed above in Section 7.1.2.3, concentrations of COCs in clam samples from the tide flats and Dogfish Bay were compared with RBSCs. These RBSCs were calculated using recreational ingestion rates and risk levels of 1xl0 -6 for cancer and HI = 1 for non-cancer effects. PCBs were detected in clams at one of three tide flats stations and at one of three Dogfish Bay stations during the 1995/1996 supplemental sampling program. The concentration in the tide flats sample exceeded the cancer RBSC by approximately 8 times, corresponding to a current risk of 8x10 -6. The concentration in the Dogfish Bay sample exceeded the cancer RBSC by approximately 3 times, corresponding to a current risk of 3x10 -6.

A separate study conducted by ATSDR also addressed current risk to shellfish harvesters, including subsistence and commercial users. The ATSDR study evaluated shellfish data from the tide flats and Dogfish Bay that was collected during both the RI and supplemental sampling programs (this included the new lead and PCB data). ATSDR concluded that the shellfish did not currently contain chemical contaminants at levels of health concern to humans, including recreational, subsistence, and commercial harvesters. The ATSDR report, Health Consultation Follow-Up, Naval Undersea Warfare Center Division, Keyport, dated September 21, 1996, is included in Appendix H in the Summary Data Assessment Report.

PCBs were detected in groundwater at the landfill as well as in the seep which discharges directly to the marsh system. PCBs were also detected in a surface water sample immediately downstream from the seep and in sediment samples near the landfill. Taken together, these data indicate the probability of ongoing PCB inputs to the adjacent marine environment. Since PCBs do not rapidly break down in the environment and because they can bioaccumulate in marine organisms, future risks to shellfish harvesters could increase to unacceptable levels. This conclusion is consistent with that of the ATSDR report which also identified the possibility of future increases in PCB concentrations in shellfish due to bioaccumulation.

Shellfish samples were not analyzed for VOCs; therefore, human health risks caused by CAHs could not be directly evaluated by comparison with seafood RBSCs. Instead, risks due to shellfish ingestion were evaluated by comparing CAH concentrations in surface water samples from the tide flats and Dogfish Bay against surface water regulatory criteria that have been developed for the protection of human health from the consumption of seafood. This comparison showed that CAH concentrations in the tide flats and Dogfish Bay, where edible shellfish species live and can be harvested, did not exceed these human health criteria. These results indicate that current human health risks associated with this pathway due to CAHs is not unacceptable.

If future discharges of CAHs from the landfill led to significant increases in surface water concentrations, then equilibrium CAH concentrations in shellfish tissue might reach unacceptable levels. However, future increases in risk from CAHs in shellfish are less likely than for PCBs because CAHs do not tend to bioaccumulate.

Future Onsite Residential Pathways

Data collected as part of the supplemental sampling rounds can also be used to reexamine the future onsite residential use scenario, involving residential exposure to shallow groundwater and landfill soils. Work done during the 1993 risk assessment identified unacceptable risk (e.g., cancer risk = 2x10 -2) to hypothetical future onsite residents due to domestic use of shallow onsite groundwater. Although this scenario was not explicitly evaluated in the Summary Data Assessment Report (because it was expected that residential development would never be allowed on the landfill) it is apparent that risks from such use would greatly exceed the EPA target risk range for consideration of remedial action. The following example illustrates this:

The primary contributor to cancer risk for the drinking water pathway identified using the RI data was vinyl chloride. The maximum concentration detected during the RI was 1,762 Ig/L in well MW1-5. The maximum concentration of vinyl chloride detected during the supplemental sampling program was 12,000 Ig/L in upper aquifer well MW1-16 (a well that did not exist during the RI). The risk from exposure 12,000 Ig/L of vinyl chloride in drinking water can be estimated by comparing it to the MTCA Method B cleanup level of 0.02 Ig/L. The MTCA value is based on a cancer risk of 1 x 10 -6 and default toxicity and residential exposure assumptions. Since the maximum concentration detected during supplemental sampling was 600,000 times higher than the MTCA value, then cancer risk associated with the maximum concentration would be 600,000 times 1 x 10 -6, or 6x10 -1. Based on this calculation, it is clear that cancer risk to future onsite residents continues to greatly exceed the EPA target range of 10 -6 to 10 -4 for consideration of remedial action.

7.1.2.5 Uncertainty Analysis

The following uncertainties in the evaluation of human health risk were the most important ones that were considered in the remedial decision-making process:

- Future risk to shellfish harvesters due to bioaccumulation of PCBs in shellfish tissue in the tide flats and Dogfish Bay. Although current risks were not identified as being unacceptable, there is uncertainty regarding future risk, since PCBs bioaccumulate and it appears that the landfill is an ongoing source of these chemicals to the marine environment.

- Future risk to shellfish harvesters due to increases of CAHs in shellfish tissue in the tide flats and Dogfish Bay. Although current risks were not identified as being unacceptable, there is uncertainty regarding future risk should CAH concentrations in these water bodies increase in the future due to increased inputs from the landfill.

- Future risk to offsite groundwater users due to offsite migration of landfill contaminants via the intermediate aquifer. No current or future risks were identified for this pathway and the uncertainty associated with this conclusion is small. However, the consequences of offsite migration of contaminants to drinking water wells, should a large, unforeseen change in the overall pattern of groundwater flow occur, would be significant.

7.2 ECOLOGICAL RISKS

An ecological risk assessment was conducted in 1993 as part of the RI for OU 1. Details of the calculations and assumptions used in this risk assessment can be found in the 1993 ecological risk assessment report (URS 1993c).

Ecological risks for specific exposure pathways were also reevaluated using the large amount of additional data that was collected during the 1995/1996 supplemental sampling program. Because this later sampling generally found the same classes of contaminants and the same patterns of results as the RI, an ecological risk assessment, like that performed during the RI, was not repeated. Instead, ecological risks were evaluated using comparisons of chemical results to ecologically-relevant regulatory criteria, evaluations of sediment bioassays, and other types of evaluations.

7.2.1 Summary of the 1993 Ecological Risk Assessment

An ecological risk assessment was performed for OU 1 using data collected during the RI. The risk assessment was reviewed by EPA. The risk assessment report incorporated EPA comments and was finalized October 25, 1993. The risk assessment included the following five components:

- The identification of COPCs
- An exposure assessment that included the identification of exposure pathways
- A toxicity assessment
- A characterization of risk
- An evaluation of the effects of various uncertainties on the results of the assessment.

These five components are summarized in the following sections.

7.2.1.1 Chemicals of Potential Concern

Chemicals of potential concern (COPCs) were identified in the risk assessment using the following process:

First, chemicals in each environmental medium (e.g., soil, sediment, surface water) were compared to background concentrations. Chemicals whose RME concentrations in each medium exceeded background screening values were carried forward in the COPC evaluation process. Chemicals for which no background values existed were also carried forward. Then, the chemicals carried forward from the first step were compared to conservative ecological RBSCs. Chemicals exceeding these concentrations were identified as COPCs. The COPCs identified by the above process are listed by medium in Table 7-5.

7.2.1.2 Exposure Assessment

The exposure assessment characterized the exposure scenarios, identified potentially exposed organisms and their exposure pathways and routes of exposure, and quantified exposure. Exposures to both terrestrial and aquatic plants and animals were evaluated.

Table 7-6 shows the exposure pathways that were examined. For terrestrial plants, exposure to surface and root-zone soil was evaluated. For terrestrial mammals, like the Townsend's vole, exposure to both soil and terrestrial plants was evaluated. For herbivorous birds, such as the mallard duck, exposure to aquatic sediment, aquatic plants, and surface water via ingestion was evaluated. For benthic invertebrates, contact with and ingestion of sediment and ambient surface water was evaluated. For demersal fish, ingestion of benthic invertebrates was evaluated. For carnivorous birds, such as the pigeon guillemot, ingestion of aquatic food species (fish and invertebrates) was evaluated.

The pathways that were evaluated were considered to represent conservative "worst-case" exposures. Other pathways that were judged to result in far less exposure to landfill contaminants, such as exposure of terrestrial wildlife species to landfill gas and exposure of pelagic fish to contaminants in surface water, were not quantitatively evaluated.

7.2.1.3 Toxicity Assessment

Ecological risk was evaluated using a weight of evidence approach that included comparing environmental concentrations of chemicals to toxicological reference values (TRVs) as well as by assessing toxicity directly using toxicity tests.

TRVs were developed for the COPCs. A large number of sources of toxicological information were consulted and evaluated in the selection of TRVs. Sources of ecological toxicity information included ecological risk-based regulatory values, such as Washington State Sediment Management Standards and federal and state water quality criteria and other sources, such as EPA maximum permissible tissue concentrations and apparent effects thresholds for Puget Sound. In some cases, TRVs were developed indirectly. For example, TRVs for chlorinated pesticides in sediments were derived by calculating the concentration in sediment of these chemicals that could lead to an exceedance of a toxicological value in benthic infauna.

The toxicity of soil and sediment was also evaluated directly using soil and sediment toxicity tests (i.e., bioassays). In these tests, test organisms are exposed to samples of the environmental medium of interest (e.g., sediment) and specific toxic responses (e.g., mortality) are quantified and compared against responses occurring on uncontaminated reference material. Soil toxicity tests were conducted on surface and root-zone soil samples. Both acute tests (earthworms) and chronic tests (algae) were performed. Sediment toxicity tests were conducted on surface and subsurface sediments. Both acute tests (amphipod and echinoderm larvae) and chronic tests juvenile polychaete) were performed.

7.2.1.4 Risk Characterization

Results of the exposure assessment and toxicity assessment were combined and potential ecological risks were identified. The 1993 ecological risk assessment did not identify unacceptable ecological risks to terrestrial organisms at OU 1. It did, however, identify the following potential risks to aquatic organisms:

- Potential risk to benthic organisms exposed to marsh sediment and interstitial water. Primary contributors to this risk were bis(2-ethythexyl)phthalate and organochlorine pesticides.
- Potential risk to organisms exposed to marsh water. Primary contributors to this risk were antimony and mercury.
- Potential risk to benthic organisms, including clams, from exposure to tide flats sediments. Potential risk to demersal fish (i.e., English sole) from ingestion of benthic organisms and sediment in the tide flats. Primary contributors to these risks were bis(2-ethy1hexyl)phthalate and organochlorine pesticides.
- Potential risk to organisms exposed to tide flats water. Primary contributors to this risk were antimony and mercury.
- Potential risk to benthic organisms exposed to Dogfish Bay sediment. Primary contributor to this risk was bis(2-ethylhexyl)phthalate.

These risks are summarized in Table 7-7.

7.2.1.5 Uncertainty Analysis

There were three primary areas of uncertainty in the ecological risk assessment that were of most relevance to the remedial decision-making process and the scope of the supplemental data collection effort:

- The detection limits obtained for analyses of PCBs and some SVOCs in sediments were elevated. This could have caused contaminants which were present not have been detected and could have led to potential underestimation of risk from the landfill.
- Mortality, in excess of reference, of amphipods in the three sediment bioassay tests may have been caused by the physical nature of the sediment (i.e., grain size) and not by the presence

of landfill contaminants. This could have led to overestimation of risk from the landfill.

- The chemicals responsible for the risks identified in Section 7.2.1.4 (bis[2-ethylhexyl]phthalate, organochlorine pesticides, antimony, and mercury) may not have been clearly attributable the OU 1 landfill and may have originated elsewhere or have reflected background conditions. This could have led to overestimation of risk from the landfill.

7.2.2 Summary of Ecological Risks Based on 1995/1996 Supplemental Data

Ecological risks for aquatic pathways were reevaluated using the large quantity of additional data collected during the 1995/1996 supplemental sampling program. This supplemental sampling was conducted to aid the remedial decision-making process. The assessment was designed to address the uncertainties identified in the 1993 ecological risk assessment and summarized in Section 7.2.1.5: detection limits, bioassay failures, and the relationship of risk drivers to the landfill. Because the supplemental sampling generally found the same classes of compounds and the same patterns of results as the RI, a CERCLA-type risk assessment, like that performed during the RI, was not repeated. However, the same conceptual steps, identification of COCs, exposure assessment, toxicity assessment, and risk characterization were performed. These steps are summarized in the following sections.

7.2.2.1 Chemicals of Interest

Chemicals detected in the supplemental sampling program were evaluated by comparing their concentrations against regulatory criteria relevant to the ecological exposure pathways under consideration. For example, sediment results were compared to Washington State sediment quality standards (SQS) and surface water and groundwater were compared to surface water criteria for the protection of aquatic organisms. Any chemical whose maximum concentration in a specific environmental medium exceeded one-third the value of the most stringent screening concentration was identified as a COI. One-third the value of the screening concentration was used for comparison in order to be conservative (i.e., protective) and to account for sampling and analytical uncertainties. These chemicals were termed "COIs" to distinguish them from the "COPCs" identified during the 1993 risk assessment. Unlike the identification of COPCs during the 1993 risk assessment, the identification of COIs did not include screening chemicals against their upgradient or background concentrations.

The list of ecological COIs for groundwater, surface water, and clam tissue is shown in Table 7-8. The COIs were evaluated further in terms of their spatial distribution, frequency of detection, concentrations, ecological toxicity, behavior in the environment, and presence in upgradient and reference stations. Chemicals of interest for which the landfill appeared to be a significant source and which had the potential to pose ecological risk were identified as COCs. Members of one group of chemicals, PCBs, were identified as COCs.

7.2.2.2 Exposure Assessment

Using data from the supplemental sampling rounds, the Summary Data Assessment Report provided better characterization of the ecological exposure pathways of interest. Risks to aquatic organisms from exposure to contaminants in sediment and surface water that were transported to the aquatic environment via groundwater discharge from the landfill were evaluated.

Average and RME exposure concentrations were not used in the evaluation for the supplemental sampling program. Instead, sample results were used individually to represent exposure point concentrations. These were compared on point by point basis with regulatory values and risk based concentrations to characterize risk.

Surface water samples from the marsh, tide flats, and Dogfish Bay were used to evaluate exposure of aquatic organisms to landfill contaminants.

Sediment samples from the marsh, tide flats, and Dogfish Bay were used to evaluate exposure of benthic organisms to landfill contaminants in sediment. Sediment results were also used to evaluate potential bioaccumulation up the food chain to fish and birds. To address uncertainties arising from elevated detection limits for PCBs and SVOCs in the RI, the supplemental sampling program used analytical methods that yielded improved detection limits for these compounds.

7.2.2.3 Toxicity Assessment

The ecological toxicity of a chemical is usually expressed as a concentration below which there are expected to be no or few adverse effects to representative sensitive organisms. These concentrations form the basis of those regulatory values that are meant to be protective of ecological organisms and against which the supplemental sampling data from OU 1 were compared.

Ecological toxicity can also be measured directly by use of toxicity tests or bioassays. In these laboratory tests, organisms are exposed to samples of the environmental medium of interest and specific toxic responses are quantified and compared against responses occurring on uncontaminated reference material. Bioassays were conducted on sediment samples from the marsh, tide flats, and Dogfish Bay collected during the supplemental sampling program. Both acute tests (using amphipod and echinoderm larvae) and chronic tests (using juvenile polychaete) were performed. To address concerns that excess mortality of amphipods in the sediment, bioassays conducted during the RI might have been caused by the fine-grained nature of the sediment, an amphipod species more tolerant of these physical conditions was utilized for fine-grained samples.

7.2.2.4 Risk Characterization

Current and future risks to organisms were evaluated for the COCs (PCBs) by comparison with regulatory and other risk-based values and by analysis of the results of sediment bioassays.

Current Ecological Risk

The sediment chemical results for PCBs and the sediment bioassays predict no adverse effects to sediment benthic organisms. The Washington State Sediment Management Standards define two levels of chemical criteria. The most stringent level, the "marine SQS," corresponds to the long-term goal of "no adverse effects" on sediment biological resources; while the less stringent level, "cleanup screening level" (CSL), corresponds to "minor adverse effects" on these resources. At contaminant levels above the CSL, more significant effects are predicted, and sediment cleanup must be considered. The highest PCB sediment concentration, found at the station near the seep, was above the state marine SQS, but was below the state marine CSL. The absence of adverse effects is predicted by attainment of the more stringent chemical criteria, the SQS, while the minor adverse effects are predicted by chemical concentrations ranging from the SQS to the less stringent CSL.

Potential risk to aquatic organisms was also indicated by surface water exceedances of PCBs in the seep and in the surface water station immediately downstream from the seep (MA09).

Ecological risks from PCBs in the marsh, tide flats, and Dogfish Bay were also characterized using two other approaches: 1) Measured and estimated body burdens of PCBs in benthic aquatic organisms and clams were compared to tissue screening concentrations and published toxicity values. 2) Food chain models were used to predict risks to upper trophic level organisms (fish and birds) that forage on aquatic organisms. Based on these analyses, it was concluded that current ecological risks from PCBs were below levels of concern in the tide flats and Dogfish Bay for all receptor organisms evaluated. It was also concluded that risks to upper trophic levels in the marsh were below levels of concern. Concentrations of PCBs in benthic invertebrates in marsh station MA09, however, (where the maximum concentrations of PCBs were detected) were estimated to be about four times higher than published lowest observed adverse effect concentrations for aquatic organisms.

Future Ecological Risk

PCBs were detected in groundwater at the landfill as well as in the seep which discharges directly to the marsh system. PCBs were also detected in a surface water sample immediately downstream from the seep and in sediment samples near the landfill. Taken together, these data indicate the probability of ongoing PCB inputs to the adjacent marine environment. PCBs do not break down easily and may accumulate if there are continuing discharges into the environment. For this reason, PCBs were identified as posing potential future risk to benthic invertebrates, and possibly fish and birds, should they accumulate in sediments and tissue and increase in concentration over time. When such accumulations occur, PCBs are normally detected in sediments and the bodies of aquatic organisms such as clams, because PCBs are strongly attracted to the organic matter in sediment particles and fat in animal tissues.

7.2.2.5 Uncertainty Evaluation

The following uncertainties were the most important to the remedial decision-making process:

- Current risk to benthic organisms in the marsh. No adverse effects to benthic organisms from PCBs were predicted by the sediment bioassay tests at marsh station MA09. However, bioaccumulation modeling conducted as part of the post-RI data collection did predict potential adverse effects to benthic organisms due to PCBs at this station. This difference may be because of the uncertainty associated with the bioaccumulation model that was used to estimate the benthic invertebrate body burden.

- Future risk to organisms due to bioaccumulation of PCBs in sediment and tissue. Although current risks were not identified as being unacceptable, there is uncertainty regarding future risk, since PCBs degrade slowly, bioaccumulate, and the landfill appears to be an ongoing source of these chemicals to the marine environment.

8.0 REMEDIAL ACTION OBJECTIVES

Actual or threatened releases of hazardous substances from OU 1, if not addressed by implementing the response action selected in this ROD, may present an imminent and substantial endangerment to public health, welfare, or the environment. This section summarizes the reasons why remedial action is needed and describes the remedial action objectives that are deemed necessary for protection of human health and the environment.

8.1 NEED FOR REMEDIAL ACTION

As described in Section 3.3, 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. In addition to these pathways, the baseline risk assessment also identified the potential for unacceptable human health risks to on-site workers from air inhalation exposures to volatile organic compounds (VOCs). These risks were driven by VOCs detected in several indoor air samples collected in modular office buildings that were situated on the northern part of the landfill during the remedial investigation. The RI sampling program was not sufficient to determine with certainty whether these VOCs were present in the buildings because of activities in the buildings themselves (e.g., cleaning solutions for electronic repairs) or because of vapors migrating from the landfill. Shortly after the baseline risk assessment, the Navy removed the modular office buildings from the landfill to eliminate these potential indoor air risks. In addition, Navy personnel are no longer assigned to work full-time in the buildings that presently remain (i.e., on the southern part of the landfill). Because the existing landfill cover is not impervious, it allows landfill vapors to travel upwards rather than laterally away from the landfill. If the landfill were capped with an impervious liner, there would be increased potential for lateral migration of vapors toward buildings located adjacent to the landfill. This potential vapor migration could be minimized by including vents in any future impervious cover.

Chemicals of concern (COCs) were identified for the three main pathways by the methodology summarized in Section 7. The COCs fall into two classes of compounds: polychlorinated biphenyls (PCBs) and chlorinated aliphatic hydrocarbons (CAHs). The specific types of PCBs that were identified in the investigation include Aroclors 1016, 1232, 1242, 1254, and 1260. The specific CAHs that were identified are listed in Section 7, and include trichloroethene (TCE), trichloroethane (TCA), tetrachloroethene (also known as perchloroethene), and the natural degradation products of these compounds. The CAHs identified in Section 7 are also referred to as "TCE-family compounds" in this document. This phrase was developed for this project during the preparation of the focused feasibility study to make it easier to communicate the results to the public; it refers to TCE because it is the most prevalent parent compound detected at the site.

The sampling results show that concentrations of the COCs are above regulatory limits within the landfill and would cause unacceptable risks if the landfill were disturbed and people or the environment were exposed to these concentrations. Hence, remedial action is needed to prevent unacceptable exposures to the soil, groundwater, or vapor within the landfill.

On the other hand, the results show much lower concentrations of contaminants in the downstream environment than at the landfill. Based on the site hydrogeology and nature of the chemicals, the levels found here are judged to not require immediate active engineered measures to remediate these downgradient resources for the protection of human health or the environment, as discussed in the following paragraphs. Although current risks for the downgradient resources are limited by hydrogeology or are below levels that necessitate immediate active cleanup, remedial action is necessary to assure that conditions do not worsen over time and cause unacceptable risks in the future. Thus the Navy, Ecology, and EPA believe it is desirable to reduce the potential for PCBs to accumulate to an unacceptable level downstream of the landfill. They also believe it is desirable to reduce, as much as practicable, the high concentrations of the TCE-family compounds within the landfill. In addition, state law requires consideration of reasonable active cleanup measures when contaminant concentrations exceed state cleanup levels.

In the case of the drinking water pathway, concentrations in the groundwater at OU 1 exceed regulatory criteria. However, this has not resulted in a current risk to human health because the groundwater at the landfill is not being used for drinking water or domestic purposes, and the groundwater downgradient of the landfill is not affecting off-base drinking water wells. The hydrogeologic conditions at the site have prevented human health drinking water risks from occurring. While there is a plume of TCE-family compounds downgradient of the landfill in the intermediate aquifer, the groundwater flow patterns are directing the plume toward the middle of the tide flats and Dogfish Bay so that the plume discharges into these surface water bodies rather than migrating to on-shore areas where drinking water wells are located. The fate of the TCE-family compounds in surface water is to volatilize into the atmosphere, where they are rapidly destroyed by photo-oxidation reactions (i.e., chemical degradation caused by the action of sunlight). Migration of landfill contaminants downward to the deeper aquifers, where the public supply wells and most of the private wells are screened, is considered a remote possibility because of the presence of upward groundwater gradients in the deep aquifers and the presence of thick aquitards below the landfill, such as the Clover

Park unit, which is a thick, dense, silty clay layer of very low permeability. With these hydrogeologic conditions, it appears that drinking water risks to off-base groundwater resources are unlikely to occur, even in the future. Nonetheless, remedial action is needed for the drinking water pathway because of the high COC concentrations in the groundwater under the landfill and the importance of protecting drinking water resources, and to guard against the possibility of unforeseen changes that could lead to human health risk.

For the seafood ingestion pathway, chemicals of concern (e.g., PCBs, TCE, 1,1-DCE, and vinyl chloride) are present in the groundwater at the landfill in concentrations that exceed surface water standards developed for protection of human health. Concentrations of certain TCE-family compounds (e.g., vinyl chloride) have intermittently exceeded surface water standards for seafood ingestion[1] in the surface water samples near the landfill (i.e., the marsh water), but not in the tide flats or Dogfish Bay where the clams live. PCBs discharging from the landfill via the seep or groundwater can bioaccumulate in seafood tissues from the surface water or from the sediments. In the recent shellfish sampling program, PCBs were detected in the clams sampled closest to the landfill. PCBs were also detected in the sediments at this location, indicating bioaccumulation may be occurring from the sediments. PCB results for all clam stations were below a cancer risk level of 1 x lO -5 (based on protection of recreational harvesters, as discussed in Section 7.1.2.4, and on protection of subsistence harvesters, per the exposure assumptions given in Appendix B). These results indicate that contaminants from the landfill have not made littleneck clams in the tide flats or Dogfish Bay unsafe to eat (although the shellfish are not currently safe for humans to eat because of fecal coliform contamination that is not related to the landfill). This conclusion is consistent with the health consultation performed in 1996 by the Agency for Toxic Substances and Disease Registry (ATSDR). ATSDR evaluated the shellfish results for subsistence, recreational, and commercial consumers and concluded the chemical contaminant levels in the clam samples do not present a health hazard to any of these groups(ATSDR 1996). ATSDR recommended that the Navy conduct routine sampling of shellfish in Dogfish Bay to verify that future chemical contaminant levels in shellfish do not pose a public health hazard. Remedial action is needed for the seafood ingestion pathway to prevent concentrations from increasing over time and causing unacceptable risks in the future.

With respect to the ecological pathway, the sediment sampling results for the marsh, tide flats, and Dogfish Bay have been evaluated by comparison to the Washington State Sediment Management Standards (SMS). The SMS include sediment quality standards (SQS) and cleanup screening levels (CSLs), which are explained in Section 7. Current chemical concentrations in the sediment samples are below the SQS in all but three stations. PCBs are the only chemicals that exceed SQS that are considered chemicals of concern (see Section 7). PCBs are about two times the SQS for the marsh station nearest the seep, indicating a potential for adverse effects to biological resources at this location, but are below the CSL. PCBs are below the SQS at all the other stations. All but one of the sampling stations meet the SQS for biological effects measured by sediment bioassay tests. The exception is one of the stations in Dogfish Bay, which exceeds the SQS for the Neanthes test; however, this station meets the SQS for all the other bioassay tests. Taken together, the sediment chemical results and bioassays predict no adverse effects to the benthic organisms. Although current concentrations of landfill-related chemicals in the sediments do not pose adverse effects to the benthos, the landfill source is not controlled and therefore remedial action is needed to prevent concentrations from increasing over time and causing unacceptable risks in the future via the ecological pathway.

[1] The phrase "surface water standards for seafood ingestion" is used in this ROD to refer to the most stringent value for protection of human health from among the federal water quality criteria, the National Toxics Rule, the state water quality standards, and the MTCA Method B cleanup levels for surface water.

8.2 REMEDIAL ACTION OBJECTIVES

This section lists the remedial action objectives (RAOs) for OU 1 that are necessary for protection of human health and the environment. The discussion is organized by the environmental media associated with OU 1 that have been sampled in field investigations and will be used to evaluate future risks posed by the site.

The following RAOs apply to the soil, waste, and vapor within the landfill:

- Prevent exposures to humans due to dermal contact with or ingestion of soil or waste material within 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 soil (MTCA Level 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 Level B).

The following RAOs apply to 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 Level B).

- 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.

The following RAOs apply to 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 Level 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 following RAOs apply to 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 thence 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 bioassays.

The following RAOs apply to 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 a noncancer hazard index of 1.0, using exposure assumptions for subsistence harvesters as identified in Appendix B. These risk levels are within EPA's acceptable risk range, which refers to an incremental cancer risk 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, or MATCs) in Appendix J of the Summary Data Assessment Report.

8.3 REMEDIATION GOALS

Remediation goals are specific numeric values, derived from RAOs, that define acceptable concentrations in particular media at specific locations. For the RAOs that have unacceptable risk defined in terms of MTCA cleanup levels, the unacceptable risk level for an individual chemical is based on an incremental cancer risk of 1 x 10 -6 and a hazard quotient of 1.0 for noncancer effects. For multiple chemicals, the unacceptable cumulative risk level will be based on an incremental cancer risk of 1 x 10 -5 and a hazard index of 1.0 for noncancer effects. Remediation goals derived from the RAOs listed in the previous section are presented where appropriate in the discussion of the selected remedy in Section 11 (see Section 11.5.3.1 and Tables 11-4 through 11-7).

9.0 DESCRIPTION OF ALTERNATIVES

Alternatives were developed for OU 1 in two feasibility studies: the original FS Report published in 1993 and the Focused FS Report issued in 1997. The elements of the remedial action alternatives that were developed for the landfill in the 1993 feasibility study are described in the following list.

- Alternative 1: No Action
    - Taking no further actions to reduce contaminant concentrations, reduce potential exposures, or monitor conditions at the site.
    - Required by federal law to be included for consideration.
    - Alternative 2: Limited Action
    - Upgrading and maintaining the landfill cover.
    - Using institutional controls to preclude groundwater use at the landfill and prevent development or activity that could disturb the landfill.
    - Conducting long-term monitoring.
- Alternative 3: Intercept Groundwater from Upper Aquifer
    - Implementing all measures described in Alternative 2.
    - Using an upper aquifer cutoff wall between the landfill and marsh.
    - Pumping and treating upper aquifer groundwater prior to the marsh.
    - Installing a landfill gas cutoff wall between the landfill and nearby buildings.
    - Alternative 4: Intercept Groundwater from Upper and Intermediate Aquifers
    - Implementing all measures described in Alternative 3.
    - Installing a row of intermediate aquifer extraction wells between the landfill and tide flats.
    - Pumping and treating intermediate aquifer groundwater prior to the tide flats.
- Alternative 5: Contain and Pump Groundwater from Upper Aquifer
    - Implementing all measures described in Alternative 2.
    - Installing an upper aquifer cutoff wall around the entire landfill.
    - Pumping and treating upper aquifer groundwater to promote groundwater upflow from the intermediate aquifer into the upper aquifer within landfill.
- Alternative 6: Cover and Contain Upper Aquifer
    - Implementing all measures described in Alternative 2.
    - Installing an upper aquifer cutoff wall around the entire landfill.
    - Upgrading the landfill cover to prevent rainfall infiltration into the landfill and thus avoid or minimize groundwater pumping and treatment.
- Alternative 7: Contain Upper and Intermediate Aquifers

  - Implementing all measures described in Alternative 2.
  - Installing a cutoff wall around the entire landfill for both the upper and intermediate aquifers.
  - Pumping and treating groundwater from inside the cutoff wall as needed to keep the groundwater level from rising too high inside the contained landfill.

The following list describes the remedial actions of the alternatives developed in the supplemental 1997 feasibility study.

- Alternative 1: Source Reduction
  - Implementing all measures described in "Common Actions" below.
  - Installing a gas sparging system to remove and treat TCE-family compounds in the upper aquifer in the source area at the southern part of landfill.
  - Using phytoremediation to reduce the amount of TCE-family compounds within the landfill. This involves planting poplar trees to treat TCE-family compounds in the upper aquifer in the source area at the central part of landfill. Poplar trees remove TCE-family compounds that are dissolved in the groundwater as they take up the contaminated groundwater through their roots, and break down the contaminants by metabolic reactions within their roots and above-ground tissues. The roots also exude enzymes that can break down contaminants in the root zone.
- Alternative 2: Plume Control
  - Implementing all measures described in "Common Actions" below.
  - Using a funnel-and-gate system to reduce the amount of TCE-family compounds discharging from the landfill into the marsh via groundwater flow in the upper aquifer in the southern part of the landfill. This involves installing a subsurface barrier wall designed to direct ("funnel") groundwater through an opening in the wall ("gate") so the groundwater passes through a reaction zone. The reaction zone is a subsurface cavity filled with elemental iron (i.e., solid particles or filings of metallic iron). As the groundwater passes through the reaction zone, the iron is able to break down TCE-family compounds to less toxic (non-chlorinated) forms.
  - Using phytoremediation to reduce the amount of TCE-family compounds discharging from the landfill into the marsh via groundwater flow in the upper aquifer. This involves planting poplar trees between the landfill and the marsh in the central part of the landfill. Poplar trees remove and treat TCE-family compounds that are dissolved in the groundwater as discussed above for the source reduction alternative.
- Alternative 3: Sediment Trap
  - Implementing all measures described in "Common Actions" below.
  - Removing sediments in the northern part of the marsh in order to construct a settling basin to trap PCB-contaminated sediments before they discharge into the tide flats.
  - Periodically removing the trapped sediments for off-site disposal.
  - Upgrading the tide gate at the marsh outlet to maintain tidal action between the tide flats and the marsh while controlling the potential for flooding or eroding the landfill.
- Actions Common to All Three Alternatives:
  - Upgrading and maintaining the landfill cover.
  - Using institutional controls to preclude groundwater use at the landfill and prevent development or activity that could disturb the landfill.
  - Conducting long-term monitoring.

    - ▸ Implementing contingent actions for off-base drinking water wells if necessary.

The 1993 feasibility study emphasized a variety of containment approaches, while the 1997 study evaluated several innovative technologies for addressing the concerns posed by the site. The Navy developed a new preferred alternative by combining a number of actions taken from various alternatives in the two feasibility studies. The Navy presented the new preferred alternative for public comment in a new proposed plan issued in November 1997.

The preferred alternative presented in the 1997 proposed plan included the following remedial action elements:

- Use phytoremediation (poplar trees) to remove and break down contaminants (TCE-family compounds) from the groundwater in the high concentration source areas within the landfill.

- Remove the majority of the loose PCB-contaminated sediments from the marsh creek area near the seep and downstream from the seep to the tide gate.

- Upgrade the tide gate for improved control of the tidal action between the tide flats and the marsh.

- Upgrade and maintain the landfill cover.

- Use long-term monitoring to check the expectations that contaminants will not cause unacceptable future risks, and to evaluate the results to determine if additional action is needed in the future, and implement additional measures if warranted.

- Monitor off-base groundwater to check whether domestic wells could become contaminated in the future. If needed, use contingent actions to prevent drinking water risks.

- Use institutional controls to preclude installation of drinking water wells at the landfill and prevent development or activity that could disturb the landfill.

10.0 COMPARATIVE ANALYSIS OF ALTERNATIVES

The remedial alternatives were assessed in comparison with the nine evaluation criteria specified by CERCLA. The objective of the comparative analysis is to identify the advantages and disadvantages of the alternatives in order to facilitate the remedy selection process. It is not the intent of the analysis to present recommendations. Rather, comparative information is provided for use by appropriate risk management decision-makers in selecting a remedy for the site. The following sections summarize the comparative analysis of alternatives with respect to the CERCLA evaluation criteria.

In the 1993 FS, seven remedial alternatives were evaluated for the landfill that ranged from no-action, to limited action, to various containment alternatives. There were five containment alternatives in the 1993 FS. Some of these alternatives emphasized physical containment with groundwater cutoff walls, while others emphasized hydraulic containment using groundwater extraction systems. However, the differences among the containment alternatives with respect to the CERCLA evaluation criteria were relatively small when compared with the limited action alternative and the three alternatives developed in the 1997 FS. Therefore, for purposes of brevity and clarity, the containment alternatives have sometimes been discussed as a group rather than as individual alternatives, in cases where this is appropriate in the following sections.

The alternatives evaluated in the two feasibility studies were as follows:

- Alternative 1 from the 1993 FS: No action
- Alternative 2 from the 1993 FS: Limited action
- Containment Alternatives from the 1993 FS:
    - ▸ Alternative 3: Intercept Groundwater from Upper Aquifer
    - ▸ Alternative 4: Intercept Groundwater from Upper and Intermediate Aquifers
    - ▸ Alternative 5: Contain and Pump Groundwater from Upper Aquifer
    - ▸ Alternative 6: Cover and Contain Upper Aquifer
    - ▸ Alternative 7: Contain Upper and Intermediate Aquifers
- Alternative 1 from the 1997 FS: Source reduction (gas sparging, poplar trees)
- Alternative 2 from the 1997 FS: Plume control (funnel-and-gate system, poplar trees)
- Alternative 3 from the 1997 FS: Sediment trap.

The preferred alternative presented to the public in the 1997 proposed plan consisted of various actions selected from the alternatives in the two feasibility studies. Because the preferred alternative does not directly match any of the alternatives from the feasibility studies, the preferred alternative has been included in the following discussion.

To improve clarity and reduce potential confusion between the alternatives, references to the alternatives in the following sections are made using abbreviated names rather than the numbers of the alternatives. When the abbreviated name is used, it is meant to refer to the entire alternative, including all the actions of the alternative as listed in Section 9, even though the abbreviated name is based only on the key action distinguishing the alternative from the others. The abbreviated alternative names are as follows:

- No-Action Alternative (Alternative 1 from the 1993 FS)
- Limited Action Alternative (Alternative 2 from the 1993 FS)
- Containment Alternatives (Alternatives 3 through 7 from the 1993 FS)
- Hydraulic Containment Alternatives (Alternatives 3 and 4 from the 1993 FS)
- Physical Containment Alternatives (Alternatives 5 through 7 from the 1993 FS)
- Source Reduction Alternative (Alternative 1 from the 1997 FS)
- Plume Control Alternative (Alternative 2 from the 1997 FS)
- Sediment Trap Alternative (Alternative 3 from the 1997 FS)
- Preferred Alternative (As described in the 1997 proposed plan).

10.1 OVERALL PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The no-action alternative would not provide adequate protection of human health and the environment because it would not prevent the landfill from being disturbed and takes no actions to guard against unacceptable future risks.

The limited action alternative would protect human health and the environment by:

- Maintaining the landfill cover,

- Using institutional controls to prevent future installation of water wells at the landfill and future disturbance of the landfill that would allow unacceptable exposures to landfill contaminants, and

- Monitoring site conditions to check expectations that unacceptable risks will not occur in the future and assess whether further actions are needed to protect people, plants, or animals.

The preferred alternative would protect human health and the environment by including all the measures of the limited action alternative, and would provide additional protection by:

- Using poplar trees to reduce sources of TCE-family compounds in the landfill,
- Removing PCB-contaminated sediments from the lower part of the marsh, and
- Upgrading the tide gate to prevent erosion of the landfill slopes.

The source reduction achieved by the poplar trees within the landfill in the preferred alternative would lead to improved conditions over the long-term for all three pathways of concern.

The preferred alternative includes active measures to reduce the amounts of both of the chemical classes of concern at OU 1 (i.e., sediment removal for PCBs and phytoremediation for TCE-family compounds). Hence the preferred alternative would provide more protection than the source reduction and plume control alternatives because the latter have active measures only for TCE-family compounds (i.e., sparging, phytoremediation, funnel and gate) and have no active measures to address PCBs.

The following paragraphs discuss the overall protection provided by the preferred alternative in comparison with that provided by the various active response actions of the other alternatives. The paragraphs discuss in turn the following types of response alternatives: 1) source reduction, 2) plume control, 3) sediment trap, and 4) containment.

The response actions evaluated for source reduction were gas sparging and phytoremediation. Neither of these technologies is expected to be able to remove a high percentage of the TCE-family compounds from the source areas in the landfill within a short time frame. This is because residual DNAPL probably exists in pore spaces in the parts of the aquifer within the landfill that have high concentrations of TCE-family compounds in the groundwater. Although sparging can remove these residuals relatively rapidly from those portions of the aquifer that can be reached by the sparge gas, a large percentage of the aquifer space is not directly treated by sparging because the sparge gas tends to travel in discrete, separated channels as it travels up through the aquifer rather than moving throughout the entire aquifer volume equally. This leaves a large fraction of the aquifer volume unaffected by sparging that must be cleaned up by the slower processes of diffusion and dissolution from the pores into the bulk groundwater followed by advection to the sparge channels. As long as residual DNAPL continues to dissolve into the bulk groundwater, the sparging system will not have achieved reduction of groundwater concentrations below the remediation goals (i.e., drinking water standards). These slower processes are the same ones that must occur in order to bring dissolved TCE to the roots of poplar trees where they can be removed by phytoextraction (i.e., uptake of contaminated groundwater). Thus, the poplar trees should be able to remove TCE to the same degree as sparging over the long periods that are probably needed to reach remediation goals in the groundwater. The favorable hydrogeology and natural attenuation processes at the site are presently acting to limit contaminant migration and downgradient risks. These favorable conditions appear to allow the time needed for a slow process such as phytoremediation to work and be evaluated. In addition, the poplar trees exude enzymes into the groundwater that may assist breakdown of contaminants in addition to those removed by phytoextraction alone. The trees can also provide increased access to residual DNAPL for improved contaminant removal by extending their roots in the vadose zone soil and changing its pore structure over time. This effect will be greater if the trees are designed and operated to lower the water table so they may extend their roots farther downward below the existing vadose zone. Poplar trees are a lower cost approach than sparging for treating and reducing TCE contamination within the high concentration areas of the landfill.

For plume control, a funnel-and-gate groundwater treatment system was evaluated in the plume control alternative for the purpose of reducing the amount of TCE-family compounds migrating from the landfill into the marsh. The phytoremediation action in the preferred alternative may also serve this purpose by reversing the hydraulic gradient during summer months such that the net annual flux of groundwater into the marsh is reduced. The Funnel-and-gate system may provide better reduction of TCE-family compounds entering the marsh than the poplar trees. This is because the funnel-and-gate system can be designed to intercept all the groundwater discharging from the source area in the landfill to the marsh and degrade the TCE-family compounds with high treatment efficiency, whereas the poplar trees will likely allow some contaminant discharges to the marsh unless the degree of treatment and groundwater reversal achieved during the summer growing season is sufficient to fully eliminate discharges to the marsh during the winter dormant period. On the other hand, the plume control alternative would provide less overall protection than the preferred alternative because it includes no active measures to reduce the contaminant sources within the landfill. The poplar trees would be less intrusive on the marsh and are estimated to cost less than the funnel and gate system.

The sediment trap alternative would not provide more protection than the preferred alternative because it includes no active measures to address the TCE-family compounds, and the sediment trap may not be very effective in controlling PCBs. The purpose of the sediment trap would be to limit the migration of PCBs into the tide flats by intercepting and removing sediments in the water column of the marsh prior to entering the tide flats. The sediment trap may not be effective, however, because the sediments are small and difficult to settle, and because the high and variable flows in the marsh require a large settling area for the sediment basin. Both the sediment trap alternative and the preferred alternative would remove PCB-contaminated sediments from the part of the marsh with the highest PCB concentrations, but the sediment trap alternative would result in substantial impacts to the marsh environment, permanently changing the marsh creek area into an engineered settling basin, while the preferred alternative would remove only loose sediments with much reduced and temporary impacts.

The containment alternatives would protect the downgradient environment and human health by preventing the flow of contaminated groundwater from the landfill. The greatest degree of protection would be provided by the alternatives that include containment measures for both the upper and the intermediate aquifers (Alternatives 4 and 7 from the 1993 FS). The remaining containment alternatives would be less protective because they would initially contain only the upper aquifer, with contingent actions implemented subsequently for the intermediate aquifer when and if they are needed. The containment alternatives would all encroach on the marsh and cause short-term environmental impacts in the marsh system. The preferred alternative would be less intrusive on the marsh and much less expensive than the containment alternatives.

None of the alternatives include source control for PCBs inside the landfill, because PCB source locations in the landfill are unknown. Groundwater results for wells within the landfill and on the downgradient margin show only very low concentrations of PCBs in a sporadic pattern that do not suggest a source area. PCB hot spot soil removal was considered during the screening step of the 1997 feasibility study, but was not retained for evaluation. The reasons given were: (1) excessive sampling would be needed to attempt to locate PCB hot spots, and they still may not be found, and (2) if some hot spots were located, it would be technically difficult and expensive to handle, sort, treat, and dispose of the soil, debris, and other landfill material, and to dewater these areas to allow excavation.

10.2 COMPLIANCE WITH APPLICABLE OR RELEVANT AND APPROPRIATE REQUIREMENTS (ARARs)

The no-action alternative would not comply with requirements of environmental regulations because concentrations at the landfill are above regulatory standards (e.g., state cleanup levels) and no measures are included in this alternative to prevent potential future risks. Since the no-action alternative does not comply with regulatory requirements and would not protect human health and the environment, this alternative is not considered further nor discussed under the remaining criteria.

The remaining alternatives would comply with regulatory requirements. Although COCs would remain at the site above state cleanup levels in all alternatives, state requirements could be met through the institutional controls, long-term monitoring, and other actions proposed for each alternative.

10.3 LONG-TERM EFFECTIVENESS AND PERMANENCE

This criterion addresses how effective the alternative would be for long-term protection from risks to human health and the environment. None of the alternatives include active measures for complete removal or treatment of COCs throughout the site.

The non-containment alternatives, including the preferred alternative, would allow natural remediation processes to continue. These natural processes are expected to ultimately cleanse the site of the TCE-family compounds, although this will occur slowly and take many years to accomplish. In the meantime, the natural remediation processes are expected to continue acting to reduce the migration of contaminants from the landfill so that downstream risks remain acceptable. The physical containment alternatives could interfere with natural remediation but would prevent contaminants from leaving the landfill by encircling it with physical containment walls. The walls would have a long service life but may develop some cracks and leakage over time. The containment alternatives would require long-term operation of groundwater pumping, treatment, and disposal systems.

The preferred alternative appears to be the most effective of the alternatives in terms of permanently removing the greatest portion of the COCs from the site (through the use of poplar trees in landfill source areas and sediment removal in the marsh). The poplar trees would reduce the overall time frame for natural remediation to cleanse the site of TCE-family compounds and thus provide better long-term effectiveness than the plume control and sediment removal alternatives, which do not feature active source reduction measures. The sparging action of the source control alternative might interfere with the natural biological remediation processes occurring in the landfill and could actually result in reduced overall effectiveness in the long-term. This is because sparging with air would introduce oxygen into the source areas in the landfill which presently depend on the existing anaerobic conditions to effect reductive dechlorination of TCE by natural bacterial processes. The sparge air would create aerobic conditions, which could halt the natural degradation of TCE. This could be avoided by sparging with an anoxic gas such as nitrogen, but at much greater cost.

10.4 REDUCTION OF TOXICITY, MOBILITY, OR VOLUME THROUGH TREATMENT

State and federal cleanup laws (CERCLA and MTCA) include provisions that specify a preference for the use of treatment measures as a principal element of the site remedy. The preferred alternative and the source reduction alternative would satisfy these statutory preferences, because these alternatives include treatment measures (phytoremediation or sparging) to reduce the quantity of the TCE-family compounds at source areas within the landfill. Except for the limited action alternative, the remaining alternatives include groundwater treatment measures for containment or plume control purposes. These measures include groundwater pumping and treating for hydraulic containment of groundwater migrating from the landfill, funnel-and-gate treatment of downgradient groundwater, and groundwater pumping and treating to control the water table level in the landfill for alternatives that surround the landfill with a groundwater containment wall. However, these containment and plume treatment measures are not designed to treat the contaminants at the source and thus would not reduce the toxicity, mobility, or volume of contaminants in the high concentration areas within the landfill.

10.5 SHORT-TERM EFFECTIVENESS

None of the alternatives is expected to cause short-term human health risks during implementation, because the potential short-term risks should be manageable by appropriate control measures. Short-term impacts to the environment would occur for those alternatives that include construction next to or in the marsh; this includes the preferred alternative, all the containment alternatives, and the plume control and sediment trap alternatives. The source reduction alternative and the limited action alternative involve construction activity and remedial actions only within or on top of the landfill, and therefore would have little or no impact on the marsh. The preferred alternative would have less potential for impacts than the other alternatives because these involve trench construction along the margin of the landfill while the preferred alternative does not. Short-term impacts in the preferred alternative would be mitigated by appropriate measures developed in remedial design such as hydraulic controls, sediment removal techniques aimed at removing the loose sediments and minimizing disturbance of stable sediments and vegetation, and restorative planting or stabilization techniques.

All of the alternatives would leave residual contamination in the landfill, so none of them would achieve cleanup levels in a short time frame. All the alternatives would therefore need to use institutional controls to help protect human health, and these measures could be implemented immediately.

It is expected that natural attenuation processes at the site, with or without the aid of the active source treatment measures such as phytoremediation or sparging, will eventually be able to clean up the groundwater at the landfill over the long term. Because of the likelihood that residual DNAPLs are present in the high CAH-concentration areas of the landfill, the groundwater cleanup time frame may be very long (e.g., decades) for any of the alternatives. Estimates of cleanup times for the landfill are highly variable (e.g., years to centuries) because they depend on the quantity of DNAPL in the aquifer, which must be totally dissolved (or volatilized in the case of sparging) before groundwater remediation goals can be reached. Practicable methods do not exist for obtaining reliable field measurements of DNAPL quantity in the heterogeneous conditions of the landfill, so quantifying the cleanup time frame is not feasible. The phytoremediation and sparging source reduction alternatives may shorten the overall cleanup time frame, while the physical containment alternatives would eliminate natural cleanup processes that depend on groundwater flushing of the landfill,

10.6 IMPLEMENTABILITY

There are no major technical or construction difficulties with implementing any of the alternatives. All of them use equipment and materials that are readily available. However, for all the alternatives except the limited action alternative, close coordination would be required with regulatory agencies during the design phase. The alternatives that involve construction in the marsh would require the greatest regulatory coordination, in order to resolve issues concerning wetlands, habitat, surface water flows, and water quality during construction. The preferred alternative includes sediment removal in the marsh, so wetlands and surface water issues would need to be considered, but the degree of impacts should be much less than for the other alternatives that involve construction along the marsh (e.g., the funnel-and-gate system, the sediment trap, and containment alternatives using groundwater cutoff walls).

Phytoremediation in the preferred alternative would not be difficult to implement, although planting the trees will require removal of existing asphalt and possibly amendments to improve the top soil in the planting zones. Pilot testing for the poplar trees is not envisioned because the size of the planting zones is not much larger than plots that would typically be planted for a pilot project. The alternatives that involve physical containment for the intermediate aquifer would be more difficult to implement than those involving containment for just the upper aquifer, because of the greater depth for installing the groundwater cutoff walls. However, the depth required to contain the intermediate aquifer is within the reach of known techniques for slurry wall construction.

10.7 COST

The estimated present worth costs of the alternatives, based on a 30-year estimating period and a 5% net discount rate, are shown in Table 10-1 and summarized as follows:

- The preferred alternative has an estimated cost of $3.5 million.
- The containment alternatives would be the most expensive, with estimated cost ranging from $12 million to $14 million depending on the alternative.
- The limited action alternative would have the least cost, estimated at $2.3 million.
- The alternatives from the 1997 feasibility study would have intermediate costs, ranging from $4.1 million for the funnel-and-gate plume control alternative, to $4.2 million for the downstream sediment trap alternative, to $5.4 million for the gas sparging source reduction alternative.

10.8 STATE ACCEPTANCE

The State of Washington's statement regarding state acceptance is as follows:

> "The State of Washington Department of Ecology has participated in of the review of the conditions at the site, possible remedial measures, and the selection of the remedy. We agree the approach to use natural methods and processes for the reduction of CAHs appears appropriate for this site. It is expected that the site geological structure, and the hydrogeological and geochemical conditions present now will continue to provide the time and conditions needed for these processes to develop and be appropriately evaluated. The removal of PCB containing sediments to minimize future downgradient accumulation is appropriate. Monitoring of the site will provide verification that the site conditions remain appropriate for the continued use of the selected remedy and that the remediation is

succeeding in removing contaminants from the environment. Ecology concurs with the Selected Remedy and this Record of Decision."

10.9 COMMUNITY ACCEPTANCE

Community acceptance was not specifically addressed as part of the evaluation of the individual alternatives in the feasibility studies. Rather, this criterion was assessed in the context of the preferred alternative presented to the public in the 1997 proposed plan and the associated public meeting.

Based on comments received on the 1997 proposed plan during the public comment period, as summarized in Appendix A, the selected remedy described in Section 11 appears to be acceptable to most people in the community. Although one person stated he did not support the proposed actions, and some did not indicate a definitive position, a large majority of the commenters noted their support for the Navy's proposed plan. A responsiveness summary, which addresses the questions and comments received during the public meeting and the public comment period, is included in Appendix A.

11.0 SELECTED REMEDY

Based on consideration of CERCLA and state requirements, the assessment of alternatives, and public input, the Navy, Ecology, and EPA have decided that the most appropriate remedy for OU 1 is the preferred alternative as presented in the 1997 proposed plan. The major components of the selected remedy are as follows:

- Phytoremediation using poplar trees
- Removal of PCB-contaminated sediments
- Upgrade of the tide gate
- Upgrade and maintenance of the landfill cover
- Long-term monitoring
- Contingent actions for off-base domestic wells
- Institutional controls

The phytoremediation action is aimed at removing and treating TCE-contaminated groundwater from the main source areas within the landfill, to help reduce the long-term potential for migration of TCE-family compounds from the site. The action is not designed to directly address the residual DNAPLs that may exist in the landfill, but will instead work on the dissolved phase of the TCE-family compounds. The sediment removal action is aimed at reducing the amount of PCBs in the part of the marsh having the highest PCB concentrations, in order to reduce the potential for ecological risks in the marsh and limit the movement of PCBs to the fish and shellfish areas downstream. These actions are expected to improve conditions over the long term and to reduce the potential for the chemicals of concern (COCs) to cause unacceptable risks in the future.

The institutional controls and landfill cover actions will be used to prevent human health risks at the landfill that could otherwise occur from groundwater use or contact with soil or landfill material. Upgrading the tide gate will be done to protect the landfill from flooding and long-term erosion that could result from tidal action. Long-term monitoring will be used to check the expectations that contaminants will not cause unacceptable future risks, and the results will be evaluated to determine if more action is needed or if actions can be decreased or discontinued in the future. Contingent actions will be taken to prevent contamination of off-base domestic wells if the monitoring shows that groundwater flow directions to change such that one or more domestic wells are within the projected flow path of the groundwater plume.

The selected actions are preferred over those of the limited action alternative because they include active measures to address the chemicals of concern at the site: source reduction measures for the TCE-family compounds and sediment removal for PCBs. Source reduction and sediment removal will reduce the potential for the chemicals of concern to cause unacceptable risks in the future. The selected actions are not expected to interfere with the natural attenuation processes operating at the site and will be much less disruptive of the marsh environment than the containment, plume control, and sediment trap options. The use of poplar trees for reducing sources of the TCE-family compounds will be aesthetically pleasing and will avoid disturbing the contents of the landfill, and is an innovative measure that is less costly and more technically feasible than the other options. The source reduction achieved by the poplar trees is expected to work in concert with the natural attenuation processes and help decrease the overall time frame for cleansing the site of the TCE-family compounds.

In addition to these remedial actions, there are also natural attenuation processes working at the site to reduce the migration and the concentrations of the COCs. As discussed in Section 6.2.2, these processes include intrinsic biodegradation as well as non-biological mechanisms such as volatilization, mixing, dispersion, photo-oxidation, and adsorption to soil or sediment particles. Thus, intrinsic biodegradation is only one of several natural attenuation processes that are significant at OU 1. Accordingly, the reader should note that the text in this ROD (and this section in particular) maintains this distinction between natural attenuation and intrinsic biodegradation when these terms are used, such that "intrinsic biodegradation" or "intrinsic bioremediation" refers to naturally occurring biological degradation processes, while "natural attenuation" or "natural remediation" refers to the broader set of natural mechanisms including intrinsic bioremediation.

The following sections provide additional description and details for each component of the selected remedy for OU 1.

11.1 PHYTOREMEDIATION

This element of the selected remedy will use phytoremediation (with poplar trees) to remove and break down contaminants (i.e., TCE-family compounds) from the high concentration source areas within the landfill. The poplar trees will be planted in the source zones shown in Figure 11- 1.

11.1.1 Objective

The phytoremediation action is aimed at reducing the main sources of TCE-family contamination in the landfill in order to improve conditions over the long term and to reduce the potential for these chemicals to cause unacceptable risks in the future. It is anticipated that source reduction by the poplar trees will work in concert with natural attenuation processes and decrease the overall time frame for cleansing the site of TCE-family compounds (i.e., reducing their concentrations toward remediation goals).

The intent of this action is to use a reasonable, proactive technology to speed up the removal of TCE-family compounds at the source areas compared to that being accomplished by natural attenuation processes. The poplar tree process has been judged as a reasonable technology for this purpose at this site because of its expected cost-effectiveness in comparison with risk benefits. With present site conditions and expected future conditions in mind, other technologies evaluated in the feasibility studies--including hydraulic containment, physical containment, sparging, and funnel and gate treatment--have currently been judged as not appropriate at this site based on cost considerations.

Because the trees act like small groundwater extraction wells, some degree of water table drawdown will occur as they remove TCE-contaminated groundwater from the aquifer. As a result of this drawdown, there should be a reversal of the hydraulic gradients in the upper aquifer near the tree planting zones during the growing season, so the trees may reduce the average yearly groundwater flow rate and flux discharging from the landfill into the marsh. Hence, the poplar trees may provide plume control benefits in addition to reducing TCE quantities at the source zones. The degree of plume control is expected to depend on the extent of water table drawdown that occurs during the growing season. Accordingly, the phytoremediation design and implementation may need to be adjusted to achieve a degree of water table drawdown that strikes a balance between the desire to maximize treatment by the trees by increasing the planting density as much as possible, the desire to minimize irrigation requirements, and the desire to avoid excessive drawdown that may cause unacceptable or undesirable changes due to:

- Adverse dewatering of the wetlands adjacent to the landfill.
- Adverse changes in groundwater flow (such as drawing too much saline water from the marsh into the landfill source areas where the poplars are meant to thrive, and thus affecting the health of the trees in the planted zones).

The poplar trees should also reduce the mass flux of contaminants discharging from the landfill into the marsh. However, this may not occur during the early years of operation, and will depend on the degree of reduction in groundwater flow rates and whether groundwater concentrations increase or decrease initially. During initial operation, the groundwater concentrations might increase as a result of reduced groundwater flow because this would increase the residence time for groundwater to remain, in contact with DNAPL areas and approach equilibrium conditions. The greater residence time may allow the groundwater concentrations to approach closer to solubility concentrations, and these higher concentrations could cause an increase in contaminant flux to the marsh in spite of the trees removing TCE and reducing the groundwater flows. If the trees do cause an increase in mass contaminant flux to the marsh, the flux should eventually decrease because the removal of TCE-family compounds by the trees will ultimately bring groundwater concentrations down. If an initial increase in the contaminant flux does occur, the benefits of TCE removal and treatment provided by the trees will need to be weighed against any adverse trends and the potential for unacceptable risks to downgradient receptors along the pathways of concern, to decide whether to adjust the phytoremediation design or operation.

When implementing the phytoremediation process, its effects on intrinsic biodegradation at the landfill will also be considered. Some impact on the intrinsic biodegradation processes within the landfill source zones is expected due to groundwater drawdown caused by the poplar trees. In particular, the upper portions of the aquifer that become dewatered due to the drawdown will likely become aerobic because of oxygenation by the trees in the root zone, and the biological degradation of TCE by the action of natural anaerobic bacteria is expected to slow down considerably (or cease) in these dewatered zone. In addition, the phytoremediation system might affect intrinsic biodegradation if the trees somehow interfere with the supply of dissolved reactants in the groundwater that are needed for the intrinsic biodegradation reactions to proceed.

Currently, the Navy, Ecology, and EPA believe that the anaerobic conditions that exist below the water table in the landfill source areas, which are favorable for promoting natural biodegradation of TCE, are desirable and should be maintained, to the extent feasible, as phytoremediation is implemented. Therefore, initial implementation of the poplar trees will attempt to avoid excessive drawdown of the water table in order to retain anaerobic conditions in the lower part of the aquifer in hopes of making phytoremediation work in concert with the intrinsic bioremediation process. The effects of the trees on the intrinsic biodegradation conditions will be monitored as described in Sections 11.1.4 and 11.1.5.

However, as the phytoremediation action is implemented and evaluated, the poplar trees may prove to be highly effective, so as to reduce or eliminate the need and desire to maintain anaerobic conditions for intrinsic TCE biodegradation. In that case, the Navy may decide, with concurrence by Ecology and EPA, to use the poplar trees more aggressively (i.e., increased drawdown) to enhance the treatment by phytoremediation at the expense of intrinsic biodegradation.

11.1.2 Description

The phytoremediation action involves poplar trees planted over TCE-family source zones in the landfill. The poplar species will be selected in remedial design. The trees will be used to treat groundwater in two source zones as discussed in the proposed plan. Figure 11-1 shows the general extent of the source zones to be planted with trees. The exact extent of the planting zones will be established during remedial design. For the initial implementation of phytoremediation, the existing buildings will not be removed. However, if the Navy subsequently decides, with concurrence by Ecology and EPA, that the phytoremediation planting zone should be expanded to areas where existing buildings are located, the Navy will remove the buildings as needed for planting.

The initial planting may cover the entire areal extent of the planting zones (i.e., no pilot test is envisioned, because of the relatively small areas involved). The planting density will be selected during remedial design and adjusted during operation (by thinning, pruning, and planting) to achieve an appropriate degree of water table drawdown as discussed in Section 11.1.1.

The existing asphalt will be removed from areas where the trees will be planted. The surface soil will be amended with imported materials or fertilizer based on testing for agronomic requirements. After planting, the Navy will provide silvicultural operation and maintenance (O&M) as needed to manage growth and health of the poplars, including:

- Watering (supplement as needed to establish mature stands)
- Pruning and thinning
- Fertilizing
- Weed control
- Pest/disease assessment and control.

11.1.3 Process Monitoring and Control

The treatment provided by the poplars may need to be controlled and optimized by pruning and thinning to achieve an appropriate degree of water table drawdown as discussed in Section 11.1.1. If needed, the adjustments in planting density and degree of pruning will be made such that the water requirements of the trees are matched to the available groundwater supply and precipitation during the year, so that the need for supplemental irrigation water is avoided or minimized while achieving treatment objectives. The drawdown will be monitored and evaluated using water level measurements and water table contouring as described in Sections 11.1.4 and 11.1.5.

In addition, the Navy will perform a one-time demonstration to address each of the following concerns:

- Air quality: whether the mature stands of trees comply with action-specific regulatory requirements for air quality (i.e., acceptable source impact levels [ASILs] of the Puget Sound Air Pollution Control Agency [PSAPCA]). This evaluation will be in accordance with the PSAPCA procedures and criteria.

- Leaf management: whether the leaves retain toxic substances that require special leaf management (i.e., can the leaves be allowed to fall and degrade naturally, or do they pose unacceptable risks to human health or the environment and thus need to be collected for proper disposal?).

- Limb management: whether the tree limbs resulting from process O&M (e.g., pruning and thinning) retain toxic substances that require special management to comply with action-specific ARARs (e.g., land disposal regulations) and not pose unacceptable risk to human health or the environment.

For each of the above concerns, the demonstration may be met by the Navy presenting any of the following three approaches, with concurrence by Ecology and EPA:

(1) Pertinent data from controlled research studies in the scientific literature, if adequate to show that these ARARs or risks will be satisfied when the poplars are implemented at OU 1, or

(2) Site-specific sampling data collected at OU 1 to show that these ARARs or risks will be satisfied, or

(3) A combination of (1) and (2).

Existing information suggests that emissions from poplar trees will not likely cause unacceptable risks (Chappell, 1997; Schmiedeskamp 1997; Gordon et al., 1997a). However, if the air quality demonstration indicates that the ASILs will not be met, the Navy will work with Ecology and EPA on appropriate action.

For limb management, anticipated disposition options include:

- Disposal in a permitted landfill: in this case, the demonstration would show that the tree limbs will be in compliance with land disposal restrictions for expected toxic substances retained in the limbs.

- Offer as firewood to base personnel: in this case, the demonstration would show that expected toxic substances retained in the limbs will not pose unacceptable risks.

- Offer to commercial enterprise (e.g., pulp mill, composter): in this case, the demonstration would show that expected toxic substances retained in the limbs will not pose unacceptable risks.

Existing information suggests that TCE-family compounds will be degraded by metabolic processes within the trees (Newman et al., 1997; Gordon et al., 1997b; Schnoor, 1997). However, if the leaf or limb toxicity demonstrations show the leaves or limbs pose risks that require special management, the Navy will work with Ecology and EPA on appropriate action. The Navy has included phytoremediation in the selected remedy with the expectation that air emissions from the trees will not require treatment, tree leaves will not require special management, and tree tissues from pruning and thinning will be manageable by disposal in a non-hazardous waste landfill or by recycling to a commercial enterprise (e.g., pulp mill or composter). These expectations are based on consultation with scientists conducting research on phytoremediation using poplar trees. Because this is a new research area, some of these expectations may not be met. If any of these demonstrations results in the need for special management that substantially increases the cost of phytoremediation beyond these expectations, the Navy may decide, with concurrence by Ecology and EPA, to discontinue the use of the trees on the basis that the cost of continuing phytoremediation is disproportionate to its benefits.

If phytoremediation is discontinued, the Navy will evaluate and decide, with concurrence by Ecology and EPA, how the phytoremediation areas should be covered (e.g., with asphalt or vegetation). Consideration and implementation of other actions in the event phytoremediation is discontinued are discussed in Section 11.1.6.

11.1.4 Performance Monitoring

The long-term monitoring plan for OU 1 will include performance monitoring for phytoremediation that consists of:

- Water level measurements and contouring of the water table surface
- Sampling for VOCs and reduction/oxidation parameters at selected stations.

The stations for water level measurements will be located within or near the poplar planting zones and will include existing monitoring wells and adjacent surface water stations, supplemented with new piezometers as needed to provide adequate contouring detail for the performance evaluation described below. The sampling stations for VOCs and redox parameters will be monitoring wells located within or downgradient of the planted zones (and, in the case of the southern zone, the nearby surface water in the marsh) that can be used to assess the potential effect of phytoremediation on redox conditions and concentrations of TCE-family compounds in or near the planted zones.

The anticipated performance monitoring is detailed in Table 11-1 and Table 11-2. Station locations are shown in Figure 11-3. Table 11-1 shows the data that will be collected to assess phytoremediation itself, while Table 11-2 shows the data collection that will be used to track intrinsic bioremediation conditions and assess whether phytoremediation affects those conditions. Specific stations, parameters, and sampling frequencies are listed in the table for both initial implementation and subsequent years, in order to show the intended level of effort associated with the poplar tree performance monitoring assuming favorable results in accordance with current expectations. The sampling program may need to be modified to provide additional information or if results differ from expectations. Such modifications may be made by mutual agreement between the Navy, Ecology and EPA.

Some of the sampling stations, frequencies, and analyses in Table 11-1 are duplicated in Table 11 -2. This is because many of the same data collection parameters are appropriate for monitoring the performance of both phytoremediation and intrinsic biodegradation. Where monitoring is duplicated between Tables 11-1 and 11 -2, a single sampling event will be used to satisfy the purposes of both tables.

11.1.5 Performance Evaluation

The performance monitoring data will be used to assess the source removal and treatment performance of the poplar trees and to check for potential adverse effects the trees may have on the adjacent wetlands or the intrinsic biodegradation conditions at the landfill source zones.

The water level measurements and water table contouring data will be used to show that the poplars are accomplishing the source removal objective (i.e., removing contaminated groundwater from the areas of high TCE concentrations in the landfill). In controlled studies, the scientific literature shows that if poplar trees are living and growing and are utilizing groundwater for their water requirements, then they will remove TCE from the aquifer along with the groundwater they are taking up in their roots, and the majority of the TCE taken up by the tree will be treated and degraded by the tree's metabolic processes (Newman et al., 1997; Gordon et al., 1997b). Therefore, if the water table contouring data show that the trees are extracting and transpiring the groundwater (i.e., creating groundwater gradients that show groundwater is flowing inward toward the trees or planted zone during the growing season), this will be one indication that the trees are actively removing TCE from the aquifer. Additional evidence of phytoremediation performance will be obtained via the demonstrations discussed in Section 11.1.3 to show whether the treatment of TCE-family contaminants in the tree is adequate to meet air quality requirements and whether the tree limbs and leaves retain toxic residuals. VOC sampling will also be performed in monitoring wells within and downgradient of the planting zones to monitor for changes in concentrations of TCE-family compounds. As discussed earlier (Section 11.1.1), the trees might cause groundwater concentrations to increase in the short-term by increasing the residence time of groundwater within the planted zones where residual DNAPLs might be present. Over the long-term, however, the groundwater concentrations of TCE-family compounds are expected to eventually decrease, and this will provide additional evidence of the effectiveness of phytoremediation in concert with natural attenuation processes. Because phytoremediation and natural attenuation are expected to work in concert to remove and degrade the TCE-family compounds, the long-term performance of phytoremediation in treating the groundwater will not be separable from that of natural attenuation when evaluating the groundwater results. The Navy expects that, during the remedial design phase, the phytoremediation design team will work to further define appropriate methodology for demonstrating the performance of the phytoremediation system. If this results in feasible methods for demonstrating performance beyond those described in this ROD, the Navy will add them to the monitoring program.

The water level measurements will also be used to help determine if the poplars are drying up the southern reaches of the adjacent wetlands. The poplar trees should not be able to affect the water levels in the marsh pond or areas north of the pond, because the water levels in these areas are determined by the degree of tidal flooding into the marsh, which occurs daily and is controlled by the tide gate. The new tide gate will be designed to control the amount of tidal flooding into the marsh system.

The VOCs and redox parameter data from performance monitoring will be evaluated as a group to access whether the trees cause changes in the overall pattern of CAH concentrations or redox conditions that suggest the trees may be adversely affecting the intrinsic biodegradation processes at the landfill source zones or increasing the potential for unacceptable downgradient risks to occur in locations where the receptors of concern may exist.

If redox changes are observed, the changes will be evaluated to determine if they are undesirable or unacceptable such that the phytoremediation action should be stopped or modified. In this regard, it is possible for adverse effects to occur that might be favorably offset by the desirable treatment benefits the trees provide, as discussed earlier in Section 11.1.1. In this event, the Navy may decide, with concurrence by Ecology and EPA, to continue or to enhance the phytoremediation process in spite of the changed redox conditions. For this reason, adverse effects on intrinsic biodegradation processes will not necessarily be considered undesirable.

11.1.6 Evaluation of Natural Attenuation if Phytoremediation is Discontinued

If phytoremediation is determined to be ineffective and is discontinued, natural attenuation and intrinsic bioremediation will be evaluated to determine whether they satisfy the key objectives for which the phytoremediation action was intended to address. This section describes the rationale and methodology for this evaluation.

Based on data collected to date, natural attenuation processes and hydrogeologic conditions appear favorable for controlling the migration of contaminants downgradient from the landfill. Test results have shown downgradient concentrations that (1) do not indicate current unacceptable risk to human health via the seafood ingestion pathway at locations where seafood resources now exist, (2) do not flow toward off-base drinking water resources, and (3) do not pose sufficient ecological risk to require active remediation of downgradient resources at this time. The site characterization studies indicate that this favorable situation will most likely continue in the future. Long term monitoring results will be used to verify the site conditions and whether they remain favorable (see Section 11.5).

In addition, the natural attenuation processes are also providing source reduction. Natural attenuation processes that are acting to reduce the quantity of TCE-family compounds at the landfill include intrinsic biodegradation, dissolution, advection, and volatilization. The compounds that vaporize into the atmosphere are destroyed by photo-oxidation.

Phytoremediation is included in the selected remedy for the purpose of achieving faster and possibly greater reduction of TCE-family compounds, beyond that provided by the natural attenuation processes. Eventually, removal of dissolved TCE-family compounds from the groundwater by the poplar trees is expected to result in decreased groundwater concentrations at the landfill. Since it is likely that there are some pure-phase sources of TCE-family compounds (e.g., globules of dense phase nonaqueous phase liquid) in the landfill that must be dissolved into the groundwater before they can be removed by the trees, decreased groundwater concentrations may not be observed for a fairly long time.

The poplar trees are expected to be able to thrive on the landfill and help reduce the amount of TCE-family compounds. However, since this is a new technology, its implementation might not be successful, or the trees might not be effective in meeting the phytoremediation objectives; thus, a decision might be made to discontinue their use at the site. For example, there is a chance that healthy trees might not grow on the landfill in the desired locations, or the trees might be judged as not cost-effective as discussed at the end of Section 11.1.3. If phytoremediation is discontinued, the Navy will evaluate the effectiveness of the natural attenuation processes at the site, including intrinsic biodegradation, to replace phytoremediation. This evaluation will follow the conceptual approach described below, modified as necessary to reflect EPA guidance on evaluating monitored natural attenuation, as site conditions dictate (see Section 12.2.4).

(1) If site data indicate that intrinsic biodegradation processes are continuing to operate at the landfill and in the downgradient groundwater plume to aegrade TCE-family compounds and assist the other natural attenuation processes in reducing the quantity of TCE-family contaminants, the Navy may choose to make a demonstration to Ecology and EPA that monitored natural attenuation is a reasonable and adequate action for replacing phytoremediation (i.e., achieving source reduction and groundwater treatment). This demonstration will be as described in item #2 below and will be reviewed by Ecology and EPA. If the demonstration is satisfactory to Ecology and EPA, and downgradient risks are still being adequately controlled or prevented by natural attenuation, then the Navy will implement monitored natural attenuation. In this case, evaluation of other remedial measures will not be necessary. If the Navy elects not to perform this demonstration, it will consider other remedial measures for achieving the source reduction and groundwater treatment objectives that were served by the phytoremediation action. In this case, the approach will be the same as in item #3 below.

(2) The demonstration in item #1 will use site data to show that:

    (a) Natural attenuation is constraining the plume such that downgradient receptors are being protected from unacceptable risks and the conditions constraining the plume are expected to continue.
    (b) Natural attenuation is degrading the TCE-family compounds by intrinsic biodegradation mechanisms that are reducing the contaminant source.
    c) Intrinsic biodegradation reactants continue to be present in sufficient concentrations

to indicate that the intrinsic biodegradation processes will be sustained.

The site data to make this demonstration will include the periodic sampling of groundwater for redox parameters and for natural degradation products of TCE-family compounds listed in Table 11 -2. These results will be used to track the redox conditions and downgradient daughter products and indicate whether the intrinsic biodegradation mechanisms identified in the Navy's present studies are continuing. The Navy will supplement these monitoring data with additional sampling as appropriate to make a satisfactory demonstration to Ecology and EPA. The specific methodologies for assessing the site data to make the demonstration will be developed in post-ROD documents (e.g., during the remedial design phase, or at such time that it is decided to discontinue phytoremediation). The demonstration will include a description of any sampling and analyses that would be added to the long-term monitoring program for the purpose of implementing the monitored natural attenuation action.

(3) If site data indicate that conditions have changed such that intrinsic biodegradation processes are no longer operating to degrade TCE-family compounds within the landfill or in the downgradient groundwater plume, and if on-site and downgradient risks are still being adequately controlled or prevented in spite of the changed intrinsic biodegradation conditions, then the Navy will consider additional remedial action for source reduction. This will involve evaluating the feasibility of using another proactive remedial measure for the purpose of assisting the remaining natural attenuation processes in reducing the quantity of TCE-family compounds in the high concentration zones of the landfill. In this case, the Navy will evaluate a limited number of technologies (e,g., two or three) identified by the Navy and Ecology that are appropriate to consider for this purpose. The Navy will evaluate the technologies for reasonableness of costs and impacts compared with the expected benefits and propose a course of action ranging from no further action to implementation of one or more technologies if they are cost-effective. The evaluation and proposed action will be subject to review and concurrence by Ecology and EPA. The Navy will implement the course of action that results from this process.

4) If the long-term monitoring data show that on-site or downgradient risks are increasing (due to changes in the pathway route or increased concentrations) and are not being or will not be adequately controlled or prevented, the Navy will consider additional remedial actions to prevent or control the particular risk (or risks) of concern. In this case, the Navy will evaluate technologies that are applicable to the particular risks that the monitoring results have identified as being of concern. The Navy will conduct this evaluation regardless of whether the site data show intrinsic biodegradation remains active for degrading TCE-family compounds. The evaluation and selection of a new remedial action will be subject to review. and concurrence by Ecology and EPA. The Navy will implement any newly chosen remedial action that result from this process.

11.2 SEDIMENT REMOVAL

This element of the selected remedy involves removal of PCB-contaminated surface sediments from the part of the marsh near the seep. The sediments will be removed from the area shown in Figure 11-2.

11.2.1 Objective

The sediment removal action is aimed at decreasing the amount of PCBs associated with the marsh sediments thus reducing the potential for PCBs to cause unacceptable risks in the future. This will be accomplished by removing sediments from the area of the marsh where the highest PCB concentrations were found. The intent is to reduce the ecological risks posed by PCB-contaminated sediments in the marsh, as well as reduce the potential for them to migrate downstream where they might accumulate and cause unacceptable ecological risks or human health risks in the tide flats or Dogfish Bay. The method of sediment removal will be selected, designed, and implemented so as to minimize disruption and short-term impacts to the marsh.

Current sampling results show that the concentration of PCBs at one of the sediment sampling stations (MA09, the station nearest the seep) does not meet the sediment quality standard (SQS) of the Washington state management standards (SMS), while the SMS cleanup screening levels (CSLs) are met by all the sediment sample results. The bioassay tests for the sediment station near the seep passed the SQS, as did all the other sediment stations except for one of the test species at the station farthest from the landfill in Dogfish Bay. However, because PCBs persist in the environment, there is concern they will accumulate in sediments or marine organisms if there are ongoing discharges from the landfill. The current sampling results also show that there are low concentrations of PCBs (near detection limits) in the groundwater discharging to the surface at the seep, indicating ongoing discharges of PCBs into the marsh from the landfill via the seep. Because of the low concentrations, the mass discharge of PCBs from the seep is relatively small, and PCBs are not expected to accumulate rapidly in the marsh sediments. The removal of marsh sediments will be undertaken to reduce the potential for PCBs to bioaccumulate in shellfish above levels of concern for human consumption, reduce the amount of PCBs in the area of highest concentrations, and help prevent the occurrence of future. unacceptable risks to benthic organisms. Source control measures for PCBs in the landfill itself have not been included in the selected remedy for the reasons discussed in Section 10 - 1.

11.2.2 Description

The sediment removal action involves removal and off-site disposal of approximately the top 6 inches of surface sediments in the marsh near the seep, in the area shown in Figure 11-2, where sampling has shown the highest concentrations of PCBs. This action is not intended to remove all the surface sediments throughout this entire area, but will focus on removing those sediments that are suspendible in the water column and subject to migration via tidal action and stream flow. Sediments that are stabilized by the root structure of the wetlands plant community will be left in place to the extent feasible. The method of removal will be selected during remedial design, but the intention is to remove the suspendible sediments in a manner that minimizes short-term impacts to the wetlands and the disruption of stable sediments. For example, the use of a vacuum truck and a suction hose in a controlled manner is a possible method that could satisfy the intent.

The sediment removal action must comply with the substantive requirements of Section 404 of the Clean Water Act including those in the Section 404(b)(1) Guidelines. Under the Guidelines, no discharge of dredge or fill material is permitted if a practicable alternative exists to the proposed discharge. In this case, no practicable alternative exists because the purpose of the action is to remove PCB-contaminated sediments from the marsh environment. When there are no practicable alternatives to the discharge, compliance with the Guidelines may be achieved through the use of appropriate and practicable mitigation measures to minimize the potential impacts of the discharge on the aquatic ecosystem. At this site for this remedial action, impact avoidance is most important and will be achieved by methods including but not limited to avoiding disturbance of sediments that are stabilized by the present root structure of the wetlands plant community and ensuring that heavy equipment is kept off the wetlands as much as practicable. Impact minimization will be achieved by methods determined to be appropriate during agency review of the remedial design, such as removing only those sediments likely to be contaminated with PCBs, hydraulic controls to minimize the release of loosened sediments past the tide gate, and replanting with native vegetation any vegetated areas disturbed by the sediment removal as practicable. Compensatory mitigation is not, needed for this specific remedial work because the ecological loss will disturb only near-surface sediments, and thus, when combined with the impact avoidance and impact minimization measures listed above, will result in minimal impacts to the environment.

The sediment removal action is expected to involve a relatively small volume of sediments (e.g., less than 100 cubic yards). The method of sediment removal might create a slurry, increasing the volume and possibly causing a need for dewatering prior to disposal. The removed sediments (including filtrate if the sediments are dewatered on site) will be sampled and tested to determine requirements for proper treatment or disposal in accordance with regulations for solid and hazardous waste. Specifics of testing, treatment, and disposal will be established in remedial design.

11.2.3 Performance Monitoring

PCB concentrations within and outside the sediment removal area are currently below cleanup screening levels defined in the state sediment management standards for benthic protection. The removal action will not include sampling to establish that the boundary of the removal area meets a particular sediment concentration or action level. Instead, after the removal action, sediment sampling will be conducted to establish new baseline concentrations in the area where sediment was removed. This will include the two sampling stations identified in the long-term monitoring plan (Section 11.5) that are located in this part of the marsh. The Navy plans to conduct this sampling round in the spring of the year 2000 (see discussion in Section 11.5.3.4). Following this baseline sampling, performance monitoring related to the sediment removal action will include periodic sampling to look for trends in the sediment concentrations and compare the results to sediment remediation goals identified in Section 11.5. This will be accomplished by the sediment sampling and data evaluations of the long-term monitoring program as described in Section 11.5.

11.3 UPGRADE THE MARSH OUTLET TIDE GATE

This element of the selected remedy involves repair and improvement of the existing tide gate and marsh outlet structure. This includes the culvert under the road, the berm and concrete abutment, and the tide gate. The location of the tide gate is shown in Figure 2-3.

The existing tide gate is a hinged-type flap valve on the outlet of the culvert through which surface water from the marsh discharges into the tide flats. The tide gate allows some tide water to enter the marsh but prevents high tides from flooding the landfill. Currently, the tidal action extends up to the elevation of the marsh pond and increases the salinity of the water in and downgradient of the pond. The existing marsh outlet structure has developed leaks through the embankment around the culvert that have started to erode the embankment.

The tide gate will be upgraded to improve the control of the tidal flow between the tide flats and the marsh and to assure that the landfill is protected from extreme tidal action that could flood its surface, erode its banks, or adversely affect the groundwater levels within the landfill.

The marsh outlet will be upgraded to replace the existing tide gate and to correct the leaks and structural integrity of the culvert and embarkment. The upgrades are intended to:

- Control tidal action into the marsh sufficiently to avoid flooding the landfill surface or eroding its embankments.

- Control tidal flooding to prevent adverse changes in the groundwater levels and groundwater flow patterns at the landfill that could reverse groundwater flow directions or allow groundwater to flow from the landfill toward new areas of the base that are currently unaffected.

The remedial design will consider the feasibility of using a type of tide gate that can be adjusted to maintain and maximize the estuarine character of the marsh while sufficiently controlling the tides to meet the objectives discussed above.

11.4 LANDFILL COVER

This element of the selected remedy involves upgrading the landfill cover and maintaining it in good condition. The existing asphalt will be removed from those parts of the landfill where the poplar trees are to be planted. The landfill surface in these planted areas will be maintained as described in Section 11.1. The remainder of the existing asphalted areas will be upgraded to repair cracks and other damaged pavement. Portions of the landfill not presently covered with asphalt will be left unpaved. The Navy may elect to pave these areas of the landfill in the future, subject to the institutional controls discussed in Section 11.7. The Navy will maintain the surface of the landfill in good condition, including periodic sealing and repair of the asphalted areas, to achieve the following objectives:

- Prevent direct human contact with the waste material and contaminated soil in the landfill and limit erosion of the landfill surface that could lead to such exposures.

- Limit the amount of rainfall that infiltrates into the landfill in the paved areas that remain after the poplar planting areas are established.

- Allow the Navy to use portions of the landfill for parking and storage purposes provided that this does not interfere with remedial actions or remedial action objectives.

The above discussion describes the general approach for how the landfill surface will be managed. However, the remedy will be implemented in a manner that allows for flexibility in the types of surfaces used on various parts of the landfill, both in the remedial design and during the remediation itself, in order to balance the following tradeoffs:

- The desirability of having an asphalt cover over parts of the landfill because this limits infiltration of rainfall and slows the discharge of landfill contaminants into the downgradient environment.

- The need to remove asphalt in order to plant and grow healthy poplar trees that are expected to be able to speed the removal of TCE-family compounds from the landfill.

- The need to provide the poplar trees with water while desiring to avoid or minimize irrigation requirements.

- The potential of the poplar trees to counteract the increased infiltration that occurs due to removing the pavement, by taking up the extra infiltration in their roots during the growing season.

- The desirability of retaining the anaerobic conditions in the landfill hot spot areas, which might be compromised by removing the asphalt or planting poplars, in order to maintain the intrinsic biodegradation reactions that are breaking down TCE-family compounds in these source areas.

- The desirability of having semi-permeable or permeable surfaces on parts of the landfill that allow for slow release of vapors to the atmosphere so that vapor concentrations do not build up and cause them to migrate laterally in the soil away from the landfill boundary.

The long-term monitoring data will be used to evaluate the functioning of phytoremediation and intrinsic biodegradation; these results will be used to adjust the extent of the poplar planting zones, the asphalt pavement, and the unpaved areas of the landfill in order to strike a balance between the desire to maximize the reduction of the contaminant sources, the desire to minimize risk to downgradient receptors, and the need to avoid unacceptable risks to downgradient receptors.

As discussed above, the remediation phase will not include an impervious cover on the landfill. A landfill cover with an impermeable liner or clay layer does not appear to be necessary or desirable for this site for the following reasons:

- Some of the wastes are buried below the water table, so an impermeable cover would not eliminate leaching of contaminants into the groundwater.
- Some degree of stormwater infiltration appears to be beneficial in promoting the intrinsic biodegradation processes in removing TCE-family compounds from the more oxidized zones of the landfill.
- The current degree of infiltration results in a relatively small rate of contaminant discharge from the landfill, which the downgradient environment appears able to assimilate without causing unacceptable risks to human health or the environment.

For these reasons, it is expected that a final cover with an impermeable liner or clay layer will not be necessary. Long-term monitoring (Section 11.5) will be used to determine whether conditions change such that an impermeable cover should be considered or required.

11.5 LONG-TERM MONITORING

This element of the selected remedy involves periodic sampling of groundwater, surface water, sediments, and clams. It also involves periodic measurement of water levels to monitor groundwater flow.

11.5.1 Objective

The long-term monitoring program will be used to watch trends in chemical concentrations and evaluate whether the selected remedy meets remedial action objectives and remains protective of human health and the environment. The program will include periodic sampling, described in Section 11.5.2, designed to check expectations that contaminants will not cause unacceptable future risks and to determine if more action is needed in the future. Trends to be watched and the methods for evaluating the trends are discussed in Section 11.5.3.

11.5.2 Description

The long-term monitoring program will include periodic sampling to assess the risks posed by the site, as detailed in Table 11-3. Station locations are shown in Figure 11-3. Specific stations, parameters, and sampling frequencies are listed in Table 11-3. Sampling for performance monitoring purposes for active cleanup measures is discussed earlier (see Sections 11. 1 and 11.2, and Tables 11-1 and 11-2). Some of the sampling stations, frequencies, and analyses in Table 11-3 are duplicated in Table 11-1 or Table 11-2. This is because many of the same data collection parameters are suitable for both risk monitoring and performance monitoring purposes. Where monitoring is duplicated among Table 11-1, Table 11-2, and Table 11-3, a single sampling event will be used to satisfy the purposes of all three tables.

The sampling identified in Tables 11-1 through 11-3 is the basic monitoring effort currently envisioned for initiating the long-term monitoring program. It is meant to indicate the sampling that will be most important for evaluating the remedial actions, determining whether the RAOs are being met, and monitoring for changes in site conditions that may require additional sampling or actions. The level of effort shown in the tables is based on current information and assumes favorable results in accordance with current expectations that RAOs will continue to be met and conditions at the site will eventually improve. The sampling program may need to be modified if results differ from expectations or if other information is needed. For example, the remedial design team may identify other sampling that should be added to monitor phytoremediation or intrinsic biodegradation. The sampling program level of effort may be adjusted upwards or downwards based on the monitoring results or other information (e.g., monitoring trends or input from remedial design) by mutual agreement between the Navy and Ecology and EPA.

11.5.3 Evaluation of Results

This section describes how the monitoring results will be evaluated for the purpose of assessing the risks posed by the site and whether the remedial action objectives are being met. The methodology for evaluating performance monitoring results is discussed in Section 11.1.

Table 11-3 includes a general explanation of the intended purpose for each sampling location and how the chemical results for particular stations and pathways of concern will be evaluated. The following sections describe the specific remediation goals and data evaluation methods that will be used for each particular sampling medium. Any evaluation by the Navy regarding the need for additional action or the type of action that should be taken will be subject to review and concurrence by the agencies.

11.5.3.1 Remediation Goals and Points of Compliance

Remediation goals for the media to be sampled are shown in Tables 11-4 through 11-7. The numerical values listed in these tables are derived from the definitions of unacceptable risk in the remedial action objectives (RAOs) given for each medium in Section 8. 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, and monitoring of these media is not planned. If remediation goals become necessary for these media, they can be derived from the RAOs for soil and vapor given in Section 8.

Remediation goals for chemicals of concern in groundwater are listed in Table 11-4. The table includes two sets of remediation goals: those for the drinking water pathway and those for surface water pathways (i.e., seafood ingestion and ecological pathways). These pathways are defined in Section 3.3. The remediation goals for the drinking water pathway are based on drinking water standards (including MTCA cleanup levels). The remediation goals for the surface water pathways are based on the federal water quality criteria, state water quality standards, and MTCA surface water cleanup levels, and are thus intended for protection of human health and the environment in the water bodies downgradient of the landfill.

The points of compliance for the groundwater remediation goals depend on the pathway of concern (i.e., drinking water or surface water pathway). For the remediation goals based on the drinking water pathway, the point of compliance includes 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. Groundwater near marine shorelines might not be suitable as a drinking water resource due to high salinity from seawater; MTCA defines this as groundwater that contains totals dissolved solids at concentrations greater than 10,000 mg/L (WAC 173-340-720[1][ii]B). The monitoring program in Table 11-3 includes sampling of several monitoring wells in each of the upper and intermediate aquifers, in addition to the PUD and base supply wells. These monitoring well locations (Figure 11.3) are all within the groundwater point of compliance for drinking water.

For the groundwater remediation goals based on surface water pathways (i.e., migration of groundwater into the adjacent surface water), MTCA regulations include a provision [WAC 173-340-720(6)(d)] that allows the use of an alternative or conditional point of compliance if four conditions are met. These conditions are:

(1) That no dilution zone is allowed. This is satisfied by taking the conditional points of compliance upgradient of the actual surface water into which the groundwater is discharging.

(2) That the groundwater will be provided with all known available and reasonable methods of treatment prior to release into surface waters. This is satisfied by the treatment to be provided by phytoremediation.

(3) That the groundwater discharges will not result in violation of sediment quality values published in chapter 173-204 WAC. This is satisfied by the sediment removal action discussed in Section 11.2 and the subsequent monitoring of the sediments.

(4) That groundwater monitoring will be performed to estimate contaminant flux rates, and to address potential bioaccumulation problems resulting from surface water concentrations below method detection limits. The flux estimation requirement is satisfied by the monitoring of groundwater levels (and resulting flows) and monitoring the plume concentrations. The bioaccumulation requirement is met by monitoring the downgradient sediments and tissues for possible accumulation of landfill contaminants.

Therefore, the requirements for using a conditional point of compliance will be met by the selected remedy. WAC 173-340-720(6)(d) defines the conditional point of compliance as being "located within the surface water as close as technically possible to the point or points where groundwater flows into the surface water." The existing monitoring wells located on the downgradient side of the landfill are considered to be suitable monitoring points for the conditional point of compliance. The following wells will be monitored for this purpose: 1MW-1, MW1-2, MW1-4, MW1-5, MW1-25, and MW1-28. Because these monitoring points are located upstream of the actual point of compliance (i.e., the water at the interface between surface water and groundwater), a considerable drop in contaminant concentrations probably exists between the monitoring points and the actual point of compliance due to natural attenuation. Therefore, the Navy may elect to collect data to quantify the degree of natural attenuation along the groundwater flow path and use these results to derive adjusted remediation goals that would apply to the groundwater at the monitoring points. The adjusted remediation goals would be set higher than the remediation goals listed in Table 11-4 in proportion to the degree of natural attenuation found in the data collection effort. Any adjusted remediation goals would be subject to review and concurrence by Ecology. The Navy may also decide, with concurrence by Ecology, to replace any of the existing monitoring points with an alternate monitoring point located closer to the groundwater/surface water interface. If a monitoring point that has adjusted remediation goals is replaced with an alternate monitoring point, the remediation goals will need to be readjusted. Such readjustment will be subject to Ecology review and concurrence, and may require new data to quantify the degree of natural attenuation.

Remediation goals for chemicals of concern in surface water are listed in Table 11-5. The surface water point of compliance includes surface waters that can be affected by the landfill contaminants, such as the marsh, tide flats and Dogfish Bay. The monitoring program in Table 11-3 includes sampling of several surface water stations in these water bodies, emphasizing locations in each water body that are proximal to (rather than distal from) the landfill where contamination is most likely. The locations of these stations (Figure 11.3) are all within the point of compliance for surface water.

Remediation goals for chemicals of concern in sediments are listed in Table 11-6. The sediment point of compliance includes sediments in surface waters that can be affected by the landfill contaminants, such as the marsh, tide flats and Dogfish Bay. The monitoring program in Table 11-3 includes sampling the top ten centimeters of several sediment stations in the marsh, tide flats, and the part of Dogfish Bay closest to the landfill. The locations of these stations (Figure 11.3) are all within the point of compliance for sediments.

Remediation goals for chemicals of concern in shellfish tissues are listed in Table 11-7. The point of compliance for shellfish tissues includes shellfish habitat areas in surface waters that can be affected by the landfill contaminants, such as the tide flats and Dogfish Bay. The monitoring program in Table 11-3 includes sampling of several shellfish tissue stations in the tide flats and the part of Dogfish Bay closest to the landfill. The locations of these stations (Figure 11.3) are all within the point of compliance for shellfish tissue, and emphasize the shellfish habitat areas closest to the landfill where contamination is most likely to occur.

Compliance with the remediation goals will be determined by comparing the monitoring results to the remediation goals for the points of compliance described above. As long as contaminants remain at levels that exceed the remediation goals, institutional controls and some degree of monitoring will be needed.

As noted earlier, this site has a unique set of hydrogeological and geochemical conditions that appear to constrain the contaminant plume and reduce contaminant concentrations along downgradient pathways. With these conditions, and with the selected remedy institutional controls in place, it is believed that risks to human or environmental receptors will not likely increase. This allows the time to use the selected actions to remediate the site, and to evaluate the effectiveness of these remedial measures. These conditions are expected to continue, and monitoring will be done to confirm that they do. So long as conditions exist that constrain the plume and the institutional controls are in place, review of the selected remedy or consideration of any future actions should focus on the effectiveness of the remedy based on whether the remedial action objectives in Section 8 are met, and not on whether the specific remediation goals are met at all points of compliance identified above.

11.5.3.2 Groundwater

Compliance with groundwater remediation goals based on protection of drinking water resources will be evaluated by comparing these remediation goals to the monitoring results at points of compliance defined for the drinking water pathway in the previous subsection. Compliance with groundwater remediation goals based on protection of surface water will be evaluated by comparing these remediation goals to the monitoring results at the monitoring points defined in the previous subsection for the conditional point of compliance for groundwater discharging to surface water. Many of the current groundwater sampling results are greater than the remediation goals, as indicated in Table 11-4. This has led to the remedial actions that will be implemented under the selected remedy. The following paragraphs describe how the monitoring results will be evaluated to determine whether RAOs are being met and whether additional actions should be implemented beyond those in the selected remedy.

Natural attenuation processes, assisted by phytoremediation, are expected to eventually lead to improvements in groundwater CAH concentrations over the long term. If such improvement does not occur, the Navy will evaluate whether to take additional active measures. Key factors for this will be assessment of monitoring trends and the time frame for expecting improvement. As discussed earlier (e.g., Section 10.5), the time frame for improvement is uncertain but will likely take many years (perhaps decades) because of the likelihood that residual NAPL is present in the landfill. Because phytoremediation will reduce the amount of groundwater discharging into the marsh, it is likely that improved concentrations would be observed in surface water sooner than in the groundwater. Whether this occurs will depend on whether the poplar trees achieve a net reduction in the mass flux of CAHs into the marsh. This may not happen, because phytoremediation might actually cause groundwater concentrations to increase, especially in the initial years of operation, as discussed in Section 11.1.1. For these reasons, when evaluating improvement in site conditions, the Navy will take into account that the actions of the selected remedy are slow processes, especially in the presence of NAPLs, that are not necessarily expected to result in measurable improvement in a short time frame.

In addition to assessing monitoring trends for improvement in site conditions, the Navy will evaluate the monitoring results for adverse trends that indicate risks to receptors downgradient of the landfill will become unacceptable in the future. This will include assessment of whether RAOs are being met for the drinking water pathway, the seafood ingestion pathway, and the ecological pathway, and whether trends in the monitoring data show that additional actions should be implemented.

Drinking Water Pathway. If adverse trends are observed in the compliance point monitoring wells for chemicals that have remediation goals for protection of human health via the drinking water pathway, the Navy will evaluate what further action should be taken. The appropriate action may range from sampling to further study to active remedial measures, including the contingent actions discussed in Section 11.6. The evaluation will include the following:

- Whether the institutional control measures of the selected remedy remain adequate and effective for preventing human health drinking water risks for groundwater on Navy property.

- Whether the groundwater showing adverse trends is located along groundwater flow pathways that can affect off-base drinking water resources downgradient of the landfill The current hydrogeologic conditions and groundwater flow patterns direct contaminants in the upper and intermediate aquifers into the adjacent surface water bodies rather than toward the shorelands, and thus do not allow the landfill contaminants to affect off-base drinking water wells in these aquifers. The water level monitoring results for the upper and intermediate aquifers will be used to determine whether these groundwater flow patterns change such that off-base drinking water wells could become affected.

- Whether CAHs are detected in the monitoring results for the PUD and base supply wells, and whether these detections are related to the CAHs in groundwater at the landfill.

Seafood Ingestion Pathway. If adverse trends are observed in the compliance point monitoring wells for chemicals that have remediation goals for protection of human health via the seafood ingestion pathway, the Navy will evaluate what further action should be taken. The appropriate action may range from sampling to further study to active remedial measures. The evaluation will include the following:

- Whether the marsh continues not to be a significant harvesting area pertinent to the human health risk seafood ingestion pathway.

- Whether the adverse groundwater trends will result in concentrations in seafood that will pose unacceptable risk to human health, using littleneck clams (P. staminea) as an indicator species for seafood.

- Whether the adverse trends correspond with trends in downgradient surface water at locations populated by seafood resources, and whether the surface water concentrations at these locations exceed or will exceed the remediation goals.

- Whether the chemicals showing adverse trends can bioaccumulate in aquatic organisms.

- Whether the clam monitoring results show adverse trends corresponding to those in groundwater.

Ecological Pathway. If adverse trends are observed in the compliance point monitoring wells for chemicals that have remediation goals for the ecological risk pathway, the Navy will evaluate what further action should be taken. The appropriate action may range from additional sampling to further study to active remedial measures. The evaluation will include the following:

- Whether the adverse groundwater trends will result in unacceptable ecological risk, using the sediment monitoring results as an indicator for ecological risk.

- Whether the downgradient surface water and sediment monitoring results show adverse trends corresponding to those in groundwater.

11.5.3.3 Surface Water

Compliance with surface water remediation goals for the ecological pathway and the human health (seafood ingestion) pathway will be evaluated by comparison of the goals to the monitoring results at the points of compliance defined earlier in this section. Some of the current surface water sampling results are greater than the remediation goals, as indicated in Table 11-5. This has led to the remedial actions that will be implemented under the selected remedy. The following paragraphs describe how the monitoring results will be evaluated to determine whether RAOs are being met and whether additional actions should be implemented beyond those in the selected remedy.

Natural attenuation processes, assisted by phytoremediation, are expected to eventually lead to improvements in surface water CAH concentrations over the long term. If such improvement does not occur, the Navy will evaluate whether to take additional active measures. This evaluation and implementation of any resulting actions will be the same as discussed for groundwater in the previous subsection.

In addition to assessing monitoring trends for improvement in site conditions, the Navy will evaluate the monitoring results for adverse trends that indicate risks to receptors downgradient of the landfill will become unacceptable in the future. This will include assessment of whether surface water RAOs are being met for the seafood ingestion pathway and the ecological pathway, and whether trends in the monitoring data show that additional actions should be implemented.

Seafood Ingestion Pathway. If adverse trends are observed in surface water for chemicals that have remediation goals for protection of human health via the seafood ingestion pathway, the Navy and will evaluate what further action should be taken. The appropriate action may range from sampling to further study to active remedial measures. The evaluation will include the following:

- Whether the marsh continues not to be a significant harvesting area pertinent to the human health risk seafood ingestion pathway.
- Whether the adverse surface water trends will result in concentrations in seafood that will pose unacceptable risk to human health, using littleneck clams (P. staminea) as an indicator species for seafood.
- Whether the adverse trends occur in surface water at locations populated by seafood resources and whether the surface water concentrations at these locations exceed or will exceed the remediation goals.
- Whether the chemicals showing adverse trends can bioaccumulate in aquatic organisms.
- Whether the clam monitoring results show adverse trends corresponding to those in surface water.

Ecological Pathway. If adverse trends are observed in surface water for chemicals that have remediation goals for the ecological risk pathway, the Navy will evaluate what further action should be taken. The appropriate action may range from additional sampling to further study to active remedial measures. The evaluation will include the following:

- Whether the adverse surface water trends will result in unacceptable ecological risk, using the sediment monitoring results as an indicator for ecological risk.
- Whether the sediment monitoring results show adverse trends corresponding to those in surface water.

11.5.3.4 Sediments

Sediments will be sampled in the marsh, tide flats, and Dogfish Bay, and the monitoring results will be used to indicate the ecological risk downgradient of the landfill. Sample locations are shown in Figure 11-3. The monitoring program in Table 11-3 includes analysis for the chemicals of concern (COCs), plus additional chemicals of interest (COIs) that should continue to be monitored for possible accumulation downstream of the landfill. The basis for selecting these COIs for long-term monitoring is discussed in Section 6.2. The sediment sampling will be performed once every five years and will be scheduled to coincide with the five-year review periods.

Because the five-year review periods for OU 1 will be set to coincide with those for OU 2 and the first five-year review for OU 2 will occur in the year 2000, the Navy plans to initiate the OU 1 sediment sampling as follows:

- Sediment and clam tissue samples will be collected at the same time and locations to allow comparison of results.
- The first sediment sampling round will occur in the spring of 2000. This assumes that the sediment removal action will occur in the summer of 1999 and sampling will occur the following spring to coincide with the appropriate time of year for collecting clam tissue samples. Sampling in the spring should allow enough time for the results to be available for completing the five-year review by the end of the year 2000. This sampling round will also be used to provide the data for the post-sediment-removal baseline sampling event described in Section 11.2.3.
- The second sediment sampling round will occur in the spring of 2005, to coincide with the next five-year review date.

The remediation goals for sediments listed in Table 11-6 are based on the Washington state sediment management standards and include sediment quality standards (SQSs) and cleanup screening levels (CSLs), which will serve different purposes as discussed below.

Compliance with sediment remediation goals will be evaluated by comparison of the SQS to the monitoring results at the points of compliance defined earlier in this section (all stations shown in Figure 11-3 are within the point of compliance). Bioassay tests will be run for stations where the chemical results exceed the SQS of the state sediment management standards. The Navy will have the option to perform the chemical and bioassay tests at the same time or to defer the bioassay testing until the chemical results are evaluated against the SQS. In either case, the Navy will schedule the sampling and testing so that all results are available in timely fashion for the five-year review.

If the chemical and bioassay results exceed the SQS or if adverse spatial and temporal trends in the sediment chemical results indicate that the SQS will be exceeded in the future, the Navy will evaluate what further action should be taken. In this case, the appropriate action may range from sampling to further study to active remedial measures. Consideration of the following factors will be included in the determination of whether the data show adverse trends such that this evaluation of further action is needed: the chemical patterns and trends in other media along the migration pathway from the landfill to the sediments, the closeness of the results to the SQS or background, and the variability of the results compared to concentration changes apparent in the trend. The evaluation will also consider how soon the SQS is likely to be exceeded based on the trend.

If the chemical and bioassay results exceed the CSLs, active cleanup measures will need to be considered. In this case, the Navy may elect to conduct confirmatory sampling prior to evaluating or implementing active cleanup measures.

11.5.3.5 Clam Tissues

Clams (Protothaca. staminea) will be sampled at three stations in each of the tide flats and Dogfish Bay; the monitoring results will be used to indicate the risks downgradient of the landfill that may occur via the seafood ingestion and ecological risk pathways. Sample locations are shown in Figure 11-3. The monitoring program in Table 11-3 includes analysis of the chemicals of concern (COCs), plus additional chemicals of interest (C0Is) that should continue to be monitored for possible accumulation downstream of the landfill. The basis for selecting these COIs for long-term monitoring is discussed in Section 6.2. The clam sampling will be performed once every five years and will be scheduled to coincide with the five-year review periods. The clam sampling will coincide with the sediment sampling schedule described in Section 11.5.3.4.

Compliance with the clam tissue remediation goals will be evaluated by comparison of the goals to the monitoring results at the points of compliance defined earlier in this section (all stations shown in Figure 11-3 are within the point of compliance). The remediation goals for clam tissues listed in Table 11-7 include values for both the human health (seafood ingestion) pathway and the ecological pathway.

The values in Table 11-7 for the seafood ingestion pathway were derived for subsistence harvesters using the calculation procedures and exposure assumptions given in Appendix B. These values are for single chemicals using a cancer risk level of 1x10 -5 and a hazard quotient of 1.0 for noncancer effects. Cumulative effects will be taken into account if multiple chemicals are detected.

The ecological risk pathway values listed in Table 11-7 are ecological risk-based screening values identified in the Summary Data Assessment Report (SDAR). In particular, the values are from the list of maximum acceptable tissue concentrations (MATCs) developed in Appendix J of the SDAR.

If the clam tissue chemical results exceed the remediation goals or if adverse spatial and temporal trends in the chemical results indicate that the remediation goals will be exceeded in the future, the Navy will evaluate what further action should be taken. The appropriate action may range from confirmatory sampling to further study to active remedial measures. The determination of whether the data show adverse trends will include consideration of the following factors: the chemical patterns and trends in other media along the migration pathway from the landfill to the clams, the closeness of the results to the remediation goal or background, and the variability of the results compared to concentration changes apparent in the trend. The evaluation will also consider how soon the remediation goal is likely to be exceeded based on the trend.

11.5.3.6 Implementation of Additional Actions

In evaluating any of the monitoring results for either improving or adverse trends, consideration will be given to the variability of the results compared to the magnitude and slope of the apparent trend, and to the magnitude of the apparent change compared with current concentrations. The intent is to account for data variability so that decisions to implement additional action are based on actual trends that are discernible as such rather than apparent trends that may be due to temporal or sampling variations.

Any evaluation or proposal by the Navy regarding the need for additional action or the type of action that should be taken will be subject to review and concurrence by the agencies. The additional action would also need to meet the National Contingency Plan (NCP) criteria for selection of remedies, including benefits relative to costs. The Navy will implement appropriate additional measures concurred upon by the agencies.

11.6 CONTINGENT ACTIONS

This element of the selected remedy involves contingent actions that would be used to prevent drinking water risks if the long-term monitoring results show that off-base domestic wells could become contaminated in the future.

The site characterization results for groundwater flow and site geology show it is extremely unlikely that contaminated groundwater will migrate to off-base domestic wells. The long-term monitoring program includes tracking of groundwater concentrations and groundwater flow directions in the intermediate aquifer downgradient of the landfill. As discussed in Section 11.5, if the monitoring results show that conditions change such that domestic wells could become contaminated, the Navy will evaluate what further actions should be taken. This will include implementation of contingent actions if these are deemed necessary to protect residents from unacceptable drinking water risks. The contingent action that will be implemented in a specific instance will depend on the circumstances of the particular domestic well and residents that need to be protected, and may involve hooking up the affected property to the public water supply, installing a new drinking water well on the property to tap a deeper aquifer, or some other measure that is protective and feasible for the particular situation and concurred upon by Ecology and EPA. If contingent action is needed, the Navy will initiate the contingent action before the off-base drinking water well can become contaminated.

11.7 INSTITUTIONAL CONTROLS

This element of the selected remedy involves the use of institutional controls to prevent undue exposures to landfill contaminants on Navy property. In addition, these institutional controls will limit or prevent activities that would interfere with the remedial activity at the site. These controls will preclude installation of water wells at OU 1 and prevent development or activity that would disturb the landfill in a manner that could lead to unacceptable risks to human health and the environment. The institutional controls will include the following measures for Navy property in the areas identified in Figure 11-4:

- For the land between the tide flats and the marsh (Area A in Figure 11-4): Land use restrictions that prevent construction of water wells except for monitoring wells or wells that may be needed for future remedial actions. This area is downgradient of the landfill with respect to the intermediate aquifer.

- For the land between the tide flats and the Pass & ID Building parking lot (Area B in Figure 11-4): Land use restrictions that prevent construction of water wells except for monitoring wells or wells that may be needed for future remedial actions. This area is or may be downgradient of the landfill with respect to the upper and intermediate aquifers.

- For the tide flats and adjacent shoreline owned by the Navy (Area C in Figure 11-4): Land use restrictions that address procedures for controlling construction or maintenance activities to prevent activities that would interfere with or compromise the monitoring or other remedial actions for the site. The Navy will be able to conduct construction or maintenance activities, with concurrence by Ecology and EPA.

- For the land at the landfill (Area D in Figure 11-4): Land use restrictions and requirements that address maintenance of the landfill cover and procedures for controlling activities that involve digging or construction at the landfill that could cause exposures to contaminants in soil, groundwater, or vapor within or from the landfill. This includes restrictions that prevent construction of water wells except for monitoring wells or wells that may be needed for remedial actions. The Navy will be able to conduct digging and construction activities (e.g., street and utilities improvements or maintenance) subject to taking necessary preventive measures to protect against short-term and long-term risks from landfill contaminants, and with concurrence by Ecology and EPA.

  The institutional controls will also include restrictions on occupancy of buildings located on the landfill. These will preclude use of the buildings by humans except for occasional, temporary activities (i.e., workers will not be assigned full-time to an office or post located on the landfill). The initial plans for phytoremediation do not require the existing buildings to be removed. However, if the Navy subsequently decides, with concurrence by Ecology and EPA, that the phytoremediation planting zone should be expanded to area where existing buildings are located, the Navy will remove the buildings. The land use on the landfill will be limited to parking, storage, and facilities that involve only occasional occupancy by workers, and remedial activities. The institutional controls will limit activities at the landfill that would impair the natural attenuation processes working at the site, unless it is mutually agreed to do so (e.g., to facilitate a remedial action besides natural attenuation). If the Navy has a need to amend the land use or activity in the future, it may propose a change subject to concurrence by Ecology and EPA.

- For the marsh pond and marsh system (Area E in Figure 11-4): Land use restrictions that address procedures for controlling construction or maintenance activities that (1) would disturb the wetlands adjacent to the landfill and could cause exposures to contaminants from the landfill that may be present in the sediments or surface water or (2) would interfere with or compromise the monitoring or other remedial actions for the site. The Navy will be able to conduct necessary construction or maintenance activities subject to (1) taking measures to protect workers and prevent short-term and long-term risks from landfill contaminants, (2) complying with requirements of pertinent wetlands regulations (e.g., Section 404 of the Clean Water Act, State of Washington Hydraulic Code), and (3) with concurrence by Ecology and EPA.

- For all of the institutional control land areas shown in Figure 11-4: NUWC Keyport will remain a secure facility limiting access to individuals with bona fide business with the Navy or invitees. Should the United States decide to cease using the property for military operations, the need for and appropriate degree of fencing and security measures will be reviewed and re-established at such time by the Navy, with concurrence by Ecology and EPA.

The institutional controls will include land use restrictions that prevent installation of water wells on Navy property within 1000 ft of the landfill (except for monitoring wells or wells that may be needed for remedial actions).

To document and maintain institutional controls identified in this ROD, the Navy will prepare an Institutional Control Plan (ICP). A schedule for the development of the ICP will be submitted by the Navy to EPA and Ecology in accordance with the terms of the Federal Facility Agreement between the parties. The ICP will identify with geographic specificity all areas subject to the institutional controls selected in the ROD; identify the objectives of the institutional controls; provide for the frequency and type (e.g., field inspection, process review, record review) of monitoring of the institutional controls; require a monitoring report; and identify current land users and uses. The ICP will be included in the five-year CERCLA review.

In furtherance of the ICP, the Navy will develop appropriate management directives (i.e., ISO directives or base instructions) that may be referred to as standard operating procedures (SOPs) that will identify the process(es) to maintain institutional controls. The SOP will apply to all personnel at NUWC Keyport, including contractors and tenants, and all activities that will affect the institutional controls or the remedial actions selected for the site. The SOP will include the following:

- A point of contact for implementing, maintaining and monitoring institutional controls.

- A requirement that Navy notify EPA and Ecology at least 60 days prior to implementation of any major change in land usage at a site subject to institutional controls. By way of illustration, not limitation, "major change in land usage" is intended to include such activities as a change in land use from industrial or recreational to residential that would be inconsistent with those specific exposure assumptions in the human health and/or ecological risk assessments that served as the basis for the institutional controls that were implemented at the site. The purpose of the notification is to obtain regulatory concurrence with Navy's determination as to whether a contemplated major change in land use will necessitate the need for re-evaluation of the selected remedy.

- A commitment by the Navy to use its best efforts to obtain the appropriate funding to maintain institutional controls.
- A requirement that the Navy notify EPA and Ecology as soon as possible but no later than 60 days prior to any transfer, sale or lease of any property subject to institutional controls. The notification process is intended so that the parties can ensure that appropriate provisions are included in conveyance documents to maintain institutional controls.
- A requirement that the Navy coordinate with EPA and Ecology any proposed deletion or termination of an institutional control. In the event of a disagreement between the parties, EPA shall decide whether an institutional control should be deleted or terminated.
- A requirement that the Navy promptly notify EPA and Ecology if it is discovered that an institutional control has not met its objective. The notification process is intended to allow the parties to identify any specific deficiencies in the IC process and for the Navy to implement corrections in order to prevent similar deficiencies in the future.

The management directives may be incorporated into the ICP however, the management directives do not create legal rights in any person or entity.

11.8 COST

The estimated life cycle cost of the selected remedial actions for OU 1 is shown in Table 11-8, based on a life cycle of 30 years and a net discount factor of 5 percent. Table 11-8 provides a breakdown of the main capital, operating, and maintenance items that contribute to the overall life cycle cost.

12.0 STATUTORY DETERMINATIONS

Under CERCLA Section 121, selected remedies must be protective of human health and the environment, comply with ARARs, be cost-effective, and use permanent solutions and alternative treatment technologies to the maximum extent practical. In addition, CERCLA includes a preference for remedies that use treatment that significantly reduces volume, toxicity, or mobility of hazardous wastes as a principal element. How the selected remedy for OU 1 meets these statutory provisions is discussed in the following sections. MTCA regulations also require these statutory provisions to be met by the selected remedy.

12.1 PROTECTION OF HUMAN HEALTH AND THE ENVIRONMENT

The selected remedy for OU 1 will protect human health and the environment by treating TCE hot spots within the landfill, removing PCB-contaminated sediments from the adjacent marsh, maintaining a cover on the landfill and using institutional controls to prevent exposures to contaminants within the landfill, and monitoring groundwater and downgradient media to verify expectations that unacceptable risks will not occur in the future. These actions will prevent exposures above the risk levels specified by CERCLA and will address state cleanup regulations (MTCA) and other ARARs; specified in Section 12.2.

The landfill cover will be maintained to prevent direct exposure to contaminated soil and wastes within the landfill. The institutional controls will preclude installation of water wells and control land use activities at the landfill that could cause unacceptable exposures to contaminants in the vapor, soil, and groundwater within the landfill. These potential exposures will be reduced by using phytoremediation (with poplar trees) to treat hot spots of TCE-family compounds within the landfill, which are the highest known concentrations of chemicals of concern (COCs). The phytoremediation action is not intended to address PCBs. The poplar trees are expected to work in concert with natural attenuation processes to gradually reduce the amount of TCE-family compounds in these source areas and to achieve faster overall reduction than would occur by natural attenuation processes alone. Reducing the TCE-family compounds at the landfill will decrease the potential for downgradient concentrations of these chemicals to increase to unacceptable risk levels in the future.

The sediment removal action will address the sediments having the highest concentrations of chemicals of concern (i.e., PCBs). This will also reduce the potential for PCBs to accumulate and cause unacceptable human health risks (e.g., from ingestion of seafood) and ecological risks downstream of the landfill in the future. The long-term monitoring of groundwater, surface water, sediments and shellfish tissues will check expectations that downgradient risk levels remain acceptable in the future. Long-term monitoring of groundwater levels will verify expectations that hydrogeologic conditions continue to direct contaminated groundwater from the landfill into the adjacent surface water bodies and away from the shorelines where off-base drinking water wells currently exist or could exist in the future. Long-term monitoring of the PUD and base supply wells will check expectations that the aquitards and upward gradients below the landfill will prevent the landfill from contaminating these water supplies. The monitoring results will initiate consideration of additional actions if data trends show any of these expectations will not be met. The Navy will implement appropriate remedial measures, with concurrence by Ecology and EPA.

The selected remedial actions are not expected to pose unacceptable short-term risks or cross-media impacts. Cross-media risks or impacts might arise due to transpiration of TCE-family compounds through the poplar trees into the atmosphere or incorporation of landfill contaminants into the poplar leaves or limbs. However, based on current research for this innovative technology, poplar trees are known to treat and degrade a high percentage of the TCE-family compounds taken up in their roots, and unacceptable risks or impacts from the leaves, limbs, and air emissions are not expected. The poplar tree performance demonstration will check these expectations. If unacceptable cross-media risks and impacts are found, the cost-effectiveness of the phytoremediation action will be reconsidered.

12.2 COMPLIANCE WITH ARARs

The selected remedy for OU 1 will comply with federal and state ARARs. No waiver of any ARAR is being sought or invoked for any component of the selected remedies. The ARARs identified for OU 1 are discussed in the following sections.

12.2.1 Chemical-Specific ARARs

- The State of Washington Model Toxics Control Act regulations set forth in WAC 173-340 Part VII, which establish cleanup standards for groundwater, surface water, and air quality for cleanup sites, are applicable to the selected remedy at OU 1.

- Federal Safe Drinking Water Act (regulations set forth in 40 CFR ºº141, 142, and 143), which establishes maximum contaminant levels for public water supplies, are relevant and appropriate for groundwater that may be a drinking water source downgradient of the landfill.

- State of Washington Drinking Water Regulations (WAC 246-290-310), which establish maximum contaminant levels for public water supplies, are relevant and appropriate for groundwater that may be a drinking water source downgradient of the landfill.

- Water Quality Standards for Surface Waters of the State of Washington (WAC 173-201A) are applicable to the surface waters downstream of the landfill. Standards for the protection of aquatic life for specific chemicals are listed in WAC 173-201A-040[3]. For chemicals not listed in this section, WAC 173-201A-040[5] specifies that standards for protection of aquatic life shall be derived from the federal water quality criteria (USEPA Criteria for Water, 1986, as revised). WAC 173-201A-040[5] also states that human health-based water quality criteria used by the state are contained in 40 CFR º131.36(known as the National Toxics Rule).

- State of Washington Sediment Management Standards (WAC 173-204), which establish state sediment quality standards and cleanup screening levels for marine sediments, are applicable to sediments downstream of the landfill.

12.2.2 Location-Specific ARARs

- Federal Executive Order 11990, 40 CFR Part6, Appendix A is applicable to the actions that may affect the wetlands at OU 1.

- Section 404 of the Clean Water Act (Federal Water Pollution Control Act, 33 U.S.C. ºº1344 promulgated by 33 CFR ºº320-330 and 40 CFR º230), which requires the minimization and mitigation of impacts due to unavoidable dredging or filling activities in navigable waters including wetlands, is applicable to the sediment removal and tide gate improvement actions of the selected remedy at OU 1.

- State of Washington Hydraulic Code (WAC 220-110), which requires review by the Washington Department of Fish and Wildlife for projects affecting the natural flow of state waters, is applicable to the sediment removal and tide gate improvement actions of the selected remedy at OU 1.

- The Endangered Species Act (16 U.S.C. º1531 promulgated by 33 CFR ºº320-330) is relevant and appropriate to NUWC Keyport in general because several birds listed as threatened or endangered species are known to inhabit the base. However, the actions of the selected remedy at OU 1 will not affect critical habitat of these species.

12.2.3 Action-Specific ARARs

- Federal Resource Conservation and Recovery Act (regulations set forth in 40 CFR ºº261, 262, 263, and 268), which specifies waste identification requirements for solid waste that may contain hazardous substances, is applicable to poplar tree tissues and sediments that are managed during remediation of OU 1. The waste storage, manifest, transport, treatment, and disposal requirements of these regulations will be applicable to the tissues or sediments if they are designated as a hazardous waste by these identification requirements.

- State of Washington Dangerous Waste Regulations (WAC 173-303), which specify waste identification requirements for solid waste that may contain hazardous substances, are applicable to poplar tree tissues and sediments that are managed during remediation of OU 1. The waste storage, manifest, transport, treatment, and disposal requirements of these regulations will be applicable to the tissues or sediments if they are designated as a dangerous waste by these identification requirements.

- Federal Clean Air Act General Provisions (40 CFR º52) and Puget Sound Air Pollution Control Agency Regulation 1, Section 9.15 for the control of fugitive dust during construction activities, are applicable to the phytoremediation and tide gate replacement actions of the selected remedy at OU 1.

- Puget Sound Air Pollution Control Agency Regulation III, which requires compliance with acceptable source impact levels (ASILs) for new air contaminant sources, is applicable to the phytoremediation action of the selected remedy at OU 1.

- Federal Resource Conservation and Recovery Act (RCRA) regulations set forth in 40 CFR ºº264.116 and 117, which require survey requirements and institutional controls for facilities where hazardous wastes remain after closure, are relevant and appropriate to the selected remedy at OU 1.

- State of Washington Model Toxics Control Act regulations set forth in WAC 173-340-440, which require institutional controls for cleanup sites where hazardous substances will remain above cleanup levels following remedial actions, are applicable to the selected remedy at OU 1.

- State of Washington water well regulations (WAC 173-160), which specify standards for construction and maintenance of wells, are applicable to the monitoring wells at OU 1.

- State of Washington Minimum Functional Standards for Landfills set forth in WAC 173-304 ºº407(3) and 460(3)(e), which specify standards for closure performance and closure design for landfills, are relevant and appropriate to the maintenance of the landfill cover in the selected remedy at OU 1. For the reasons discussed in Section 11.4, those aspects of the design requirements in º460(3)(e) that pertain to a low-permeability layer or liner are not applicable nor relevant and appropriate to the selected remedy at OU 1, but would be relevant and appropriate if a future decision is made to implement a low permeability landfill cover at OU 1.

- State of Washington Model Toxics Control Act regulations set forth in WAC 173-340-360(7), which specify the methods to be employed for groundwater remediation if groundwater cleanup levels are not met at or beyond the point of compliance, is applicable to future decisions regarding the need for possible additional remedial actions at OU 1. Currently, the hydrogeologic conditions and natural attenuation conditions at OU 1 satisfy the requirement for containment/control called for in subsection (b)(ii), and the actions of the selected remedy described in this ROD satisfy the remaining requirements under subsection (b).

12.2.4 Other Criteria, Advisories, or Guidance

This section discusses other criteria, advisories, or guidances that are considered to be appropriate for the remedial actions of the selected remedy for OU 1.

- If any of the sediments or other waste removed during remediation of OU 1 will be disposed, treated, or stored in any off-site facility, the National Contingency Plan (NCP) off-site disposal rule (40 CFR º300.440) must be followed. This will require that the Navy obtain prior approval from EPA that any off-site facility to be used for this purpose is in compliance with requirements of the off-site rule.
- The following EPA directive describes the content that will be addressed in the five-year reviews to be conducted for OU 1: Memorandum: Structure and Components of Five- Year Reviews. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER Directive 9355.7-02. May 23, 1991.

- The following EPA directive describes protocols and guidance that will be addressed by the Navy when conducting the demonstration of monitored natural attenuation discussed in Section 11.1.6 of this ROD: Use of Monitored Natural Attenuation at Superfund, RCRA Corrective Action, and Underground Storage Tank Sites. U.S. Environmental Protection Agency, Office of Solid Waste and Emergency Response. OSWER Directive 9200.4-17. November, 1997. Because this directive is written broadly and generically to provide guidance for any and all sites, it is expected that some of its protocols may not be pertinent to the particular site conditions at OU 1.0 therefore, any demonstrations in the natural attenuation protocol may be adjusted for site conditions or eliminated by mutual agreement between the Navy and the agencies.

12.3 COST-EFFECTIVENESS

The selected remedy for OU 1 is cost-effective because it affords overall effectiveness proportional to its cost, with an estimated present worth cost of $3.5 million. Its cost-effectiveness is illustrated by comparison with the costs and benefits of the other alternatives in the following paragraphs.

Although the estimated cost for the selected remedy is about 50% greater than the limited action alternative, it would provide a solution with better long-term effectiveness, because the COCs would be permanently reduced in quantity by removing PCB-contaminated sediments from the marsh and by using poplar trees to treat the TCE-family hot spot areas within the landfill. Reducing the amount of contaminants in these areas will reduce the potential for the COCs to cause unacceptable risks in the future.

The containment alternatives would be more effective than the selected remedy in preventing the migration of contaminated groundwater away from the landfill, particularly in the cases where the groundwater cutoff wall is extended to contain the intermediate aquifer as well as the upper aquifer. However, the containment alternatives are estimated to cost three to four times more than the selected remedy. This additional cost does not appear to be warranted, based on the site investigation results showing that the landfill has not caused unacceptable downgradient risks that require immediate action and that there is a good likelihood for natural attenuation to maintain acceptable downgradient risks in the future. Given the current and expected future risks, the source reduction benefits emphasized in the selected remedy appear more worthwhile than the plume control benefits afforded by the containment alternatives.

The downstream sediment trap alternative would cost more than the selected remedy ($4.5 million) but would provide less overall benefit because it does not include treatment or control measures for the TCE-family compounds. In addition, the sediment trap system would cause significant short-term and ongoing physical impacts to the marsh environment, and it may not be very effective in controlling the migration of PCB-contaminated sediments. The sparging alternative would cost even more ($5.4 million), but would also provide less overall benefit than the selected remedy because the sparging process is not able to remove a large percentage of the TCE-family compounds in a reasonable time frame (e.g., 5 years), especially those compounds present in non-aqueous liquid phase, and it is cost-prohibitive to operate the process for an extended time frame (for detailed explanation, see Section 10.1). In contrast, the poplar trees can provide treatment for an extended period with little attention and operating cost, and may likely achieve better TCE-family reductions than sparging in the long run. The poplar trees are a less intrusive, lower cost approach than sparging for treating and reducing TCE-family compounds in the high concentration areas of the landfill.

The funnel-and-gate treatment system in the plume control alternative would be effective in reducing the discharge of TCE-family compounds from the landfill into the marsh via the upper aquifer. However, this alternative would cost more than the selected remedy ($4.2 million) and would provide benefits for plume control rather than emphasizing source reduction. Therefore, the funnel-and-gate alternative appears less worthwhile and less cost-effective than the selected remedy for the same reasons discussed above for the containment alternatives.

12.4 UTILIZATION OF PERMANENT SOLUTIONS AND TREATMENT TECHNOLOGIES TO THE MAXIMUM EXTENT PRACTICAL

The selected remedy represents the maximum extent to which permanent solutions and treatment technologies can be utilized in a cost-effective manner for OU 1. It is protective of human health and the environment, complies with ARARs, and provides the best balance of tradeoffs in terms of long-term effectiveness, permanence, short-term effectiveness, implementability, cost, and reductions in toxicity, mobility, or volume achieved through treatment. In considering these tradeoffs, the most decisive factors for selecting the preferred remedy from the other alternatives are summarized as follows:

- The proposed actions are preferred because they include source reduction measures for the TCE-family compounds and sediment removal for PCBs.

- The source reduction and sediment removal actions will address the locations of highest concentrations and will reduce the potential for the COCs to cause unacceptable risks in the future.

- The selected actions are not expected to interfere with the natural attenuation processes at the site, which would happen with the physical containment alternatives and might occur with the gas sparging alternative.

- The selected actions will cause much less physical impact to the marsh environment than the containment, funnel-and-gate, and sediment trap options.

- The use of poplar trees for reducing sources of the TCE-family compounds will be aesthetically pleasing, will avoid disturbing the contents of the landfill, and is an innovative measure for removing and treating these compounds that is less costly and more technically feasible than the gas sparging option, and may be more effective in the long run.

- The source reduction achieved by the poplar trees is expected to work in concert with the natural attenuation processes and decrease the overall time frame for cleansing the site of the TCE-family compounds compared with the time frame for natural attenuation alone.

The selected actions correspond to those in the preferred alternative in the Navy's 1997 proposed plan. In general, the response of the community and the public comments on the proposed actions, in particular the use of poplar trees to treat the TCE-family hot spots, have been favorable. While some have expressed concerns, many citizens, including RAB members, have voiced their preference to utilize natural processes to remediate the site, and have indicated their support for phytoremediation and the proposed plan.

12.5 PREFERENCE FOR TREATMENT AS A PRINCIPAL ELEMENT

The selected remedy meets the statutory preference for selecting remedial actions that employ treatment technologies to permanently and significantly reduce the toxicity, mobility, or volume of the hazardous substances as a principal element. The poplar trees will remove and treat TCE-family compounds from hot spot areas within the landfill. These source areas contain the highest concentrations of COCs at OU 1 and constitute a principal threat posed by the site.

13.0 DOCUMENTATION OF SIGNIFICANT CHANGES

The original proposed plan for the NUWC Keyport site was released for public comment in January 1994. For OU 1 (Area 1), the 1994 proposed plan identified the preferred alternative for the site as a combination of actions selected from the alternatives developed in the 1993 FS report, including institutional controls, monitoring, vacating buildings where indoor air risks were identified, and installing a final landfill cover.

As a result of public concerns about this preferred alternative for Area 1, the NUWC Keyport site was split into two operable units: Operable Unit 1 (OU 1) consisting of Area 1, and Operable Unit 2(OU 2) consisting of Areas 2, 3, 5, 8, and 9. Splitting the site into two operable units was done to allow more time to consider alternatives for Area 1 while proceeding to a decision for the remaining Areas. Creation of two operable units represents a significant change compared with the proposed plan. The Navy, Ecology, and EPA reviewed all written and verbal comments submitted during the public comment period for the Areas that constitute OU 2. Upon review of these comments, it was determined that no significant changes to the remedy for OU 2, as it was originally identified in the proposed plan, were necessary to satisfy public concerns.

For OU 1, the Navy, Ecology, and EPA decided to collect additional site characterization data and evaluate several additional alternatives in a supplemental focused feasibility study. These efforts resulted in a Summary Data Assessment Report, a Focused Feasibility Study Report, and a new proposed plan for OU 1, all issued in November 1997. The 1997 proposed plan presented a preferred alternative that included phytoremediation, sediment removal, tide gate improvement, maintaining the landfill cover, long-term monitoring, and institutional controls. Some of the components of this preferred alternative differ from the elements of the original preferred alternative of the 1994 proposed plan and represent a change in the original preferred alternative.

A public meeting was held on December 3, 1997 for the new proposed plan, and a 30-day public comment period occurred from November 16 to December 15, 1997. The Navy, Ecology, and EPA reviewed all written and verbal comments submitted during the 1997 public comment period. Upon review of these comments, the Navy, Ecology and EPA determined that no significant changes to the remedy for OU 1, as it was identified in the 1997 proposed plan, were necessary to satisfy public concerns.

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FIGURES

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Table 6-4
Summary of Hydrogeologic Conditions at the Landfill

Parameter	Units	Wet Season (Round 3)	Intermediate Season (Round 4)	Dry Season (Round 5)
Groundwater Discharge Along Downgradient margin of Landfill - Upper Aquifer				
Average	gpm	2.6	2.3	1.8
Range a	gpm	0.8 - 9	0.7 - 8	0.5 - 6
Groundwater Discharge Along Downgradient Margin of Landfill - Intermediate Aquifer				
Average	gpm	1.7	1.7	1.4
Range b	gpm	0.4 - 7	0.4 - 7	0.3 - 6
Groundwater Velocity Across Landfill - Upper Aquifer				
Average	ft/day	0.16	0.14	0.13
Range a	ft/day	0.05 - 0.5	0.04 - 0.5	0.04 - 0.4
Groundwater Velocity Across Landfill - Intermediate Aquifer				
Average	ft/day	0.096	0.091	0.083
Range b	ft/day	0.02 - 0.4	0.02 - 0.4	0.02 - 0.3
Groundwater Velocity Across Tide Flats - Intermediate Aquifer				
Average	ft/day	-	0.027	0.020
Range b	ft/day	-	0.007 - 0.1	0.005 - 0.08
Estimated Groundwater Travel Times c				
Upper aquifer - Bradley Road to marsh	yr		5 - 8	
Intermediate aquifer - south end of landfill to Keys Road	yr		31	
Intermediate aquifer - Bradley Road to Keys Road	yr		15	
Intermediate aquifer - Keys Road to bridge	yr		50	

a Based on one standard deviation about the geometric mean of the hydraulic conductivity measurements for Unit H1.

b Based on one standard deviation about the geometric mean of the hydraulic conductivity measurements for Units Jo and H4.

c Based on averaged conditions. Note that there is considerable uncertainty associated with them estimated groundwater travel times, as evidenced by the magnitude of the ranges shown above for estimated groundwater velocities. The estimated velocity and travel time across the tide flats is particularly uncertain.

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Table 7-1
Summary of Human Health COPCs Identified During the 1993 Human Health Risk Assessment

Chemical	Soil	Groundwater a	Air (indoor & outdoor)	Surface Water (marsh, tide flats & Dogfish Bay)	Sediment (marsh, tide flats & Dogfish Bay)	Seafood (tide flats & Dogfish Bay)
Inorganics						
Arsenic					*	*
Beryllium	*					
Chromium				*	*	*
Cobalt						*
Copper				*	*	*
Lead	*			*	*	*
Manganese		*			*	
Mercury	*				*	
Volatile Organic Compounds						
Acetone			*			
Benzene		*	*			
Bromodichloromethane		*				
1,3-Butadiene			*			
2-Butanone		*				
Carbon tetrachloride			*			
Chlorobenzene		*				
Chloroform		*	*			
Chloromethane			*			
Cyclohexane			*			
1,4-Dichlorobenzene			*			
1,1-Dichloroethene		*	*			
1,2-Dichloroethenes		*				
1,3-Dichloropropene			*			

Table 7-1
Summary of Human Health COPCs Identified During the 1993 Human Health Risk Assessment

Chemical	Soil	Groundwater a	Air (indoor & outdoor)	Surface Water (marsh, tide flats & Dogfish Bay)	Sediment (marsh, tide flats & Dogfish Bay)	Seafood (tide flats & Dogfish Bay)
Freon 11			*			
Freon 12			*			
Freon 114			*			
Methylene chloride			*			
Octane			*			
Propylene			*			
Styrene			*			
Tetrachloroethene			*			
Toluene			*			
1,2,4-Trichlorobenzene			*			
1,1,1-Trichloroethane			*			
Trichloroethene		*	*	*		
1,2,4-Trimethylbenzene			*			
1,3,5-Trimethylbenzene			*			
Vinyl chloride		*	*	*		
Xylenes			*			
Semivolatile Organic Compounds						
Benzo(a)anthracene						
Benzo(a)anthracene					*	
Benzo(a)pyrene					*	
Chrysene	*				*	
bis(2-ethylhexyl)phthalate					*	*
Phenanthrene	*				*	
Propyleneglycol dinitrate	*	*		*		
Chlorinated Herbicides						
Endosulfan sulfate					*	
Pesticides/PCBs						
Aroclor-1254		*				

a Pathways involving future domestic use of upper and intermediate aquifer groundwater at OU 1 were not presented in the 1993 baseline human health risk assessment report; however, they were evaluated during its development, and are presented here.

Table 7-2
Summary of Human Health Exposure Pathways Evaluated During the 1993 Human Health Risk Assessment

Receptors	Exposure Medium	Exposure Pathway
Onsite Workers (current and future)	Soil	Ingestion
	Air [a]	Inhalation of VOCs (outdoor) Inhalation of VOCs (indoor) Inhalation of particulates (outdoor)
Site visitors & nearby residents-including subsistence seafood users (current and future)	Surface water	Ingestion
	Sediment	Ingestion
	Seafood	Ingestion (including subsistence users)
Onsite residents [b] (future)	Groundwater (upper & intermediate aquifer)	Ingestion Inhalation of VOCs

[a] Risks to then current and hypothetical future onsite workers to airborne landfill contaminants via inhalation of indoor air were evaluated in the 1993 risk assessment. However, since 1993, all buildings on the landfill have either been removed or are no longer occupied. Because of this, risks calculated for "current" workers in the 1993 risk assessment do not presently exist.

[b] Pathways involving future domestic use of upper and intermediate aquifer groundwater at OU 1 were not presented in the 1993 baseline human health risk assessment report; however, they were evaluated during its development and are presented here.

Table 7-3
Summary of Human Health Cancer Risks and Hazard Indices Calculated During the 1993 Human Health Risk Assessment

		Cancer Risk		Non-Cancer Risk	
Exposure Scenario	Medium	Average	RME	Average	RME
Onsite Workers (current and future)	Soil	3x10 -7	7x10 -7	<0.001	<0.001
	Indoor Air [a]	7x10 -5	3x10 -4	1	2
	Outdoor Air	1x1 -6	3x10 -6	<0.001	<0.001
Site visitors & nearby residents-including subsistence seafood users (current and future)	Surface water	9x10 -8	5x10 -7	<0.001	<0.001
	Sediment	8x10 -9	1x10 -7	<0.001	<0.001
	Seafood (subsistence users)	1x10 -6	1x10 -5	0.03	0.1
Onsite residents [b] (future)	Groundwater (upper & intermediate aquifers)	2x10 -3	2x10 -2	7	20

[a] Risks to then current and hypothetical future onsite workers to airborne landfill contaminants via inhalation of indoor air were evaluated in the 1993 risk assessment. However, since 1993, all buildings on the landfill have either been removed or are no longer occupied. Because of this, risks calculated for "current" workers in the 1993 risk assessment do not presently exist.

[b] Pathways involving future domestic use of upper and intermediate aquifer groundwater at OU 1 were not presented in the 1993 baseline human health risk assessment report; however, they were evaluated during its development and are presented here.

Table 7-4
Summary of Human Health COIs Identified During the 1995/1996 Supplemental Data Collection Rounds

Chemical	Groundwater	Surface Water	Seafood
Inorganics			
Antimony	*		
Arsenic	*	*	*
Beryllium	*	*	*
Cadmium			*
Lead			*
Manganese	*		
Mercury	*		
Silver			*
Thallium	*		
Volatile Organic Compounds			
Benzene	*		
Chloroform	*		
1,4-Dichlorobenzene	*		
1,1-Dichloroethane	*		
1,2-Dichloroethane	*		
1,1-Dichloroethene	*	*	
1,2-Dichloroethencs	*		
Tetrachloroethene	*		
1,1,1-Trichloroethane	*		
Trichloroethene	*	*	
Vinyl chloride	*	*	
Semivolatile Organic Compounds			
bis(2-ethylhexyl)phthalate	*		
Organochlorine Pesticides/PCBs			
Aldrin	*		
Chlordane	*	*	
Dieldrin	*		
Heptachlor	*		
Heptachlor epoxide	*		
Aroclors	*	*	*

Table 7-5
Summary of Ecological COPCs Identified During the 1993 Ecological Risk Assessment

Chemical	Soil	Surface Water	Sediment	Shellfish
Inorganics				
Aluminum		*		
Antimony		*		
Arsenic				*
Cadmium	*			
Chromium				*
Copper	*	*		
Iron		*		
Lead	*			*
Manganese		*		
Mercury	*	*		
Selenium				*
Silver	*			*
Zinc	*			*
Cyanide	*			
Volatile Organic Compounds				
1,4-Dichlorobenzene			*	
1,1-Dichloroethane		*		
Vinyl chloride		*		
Xylenes	*			
Semivolatile Organic Compounds				
Anthracene	*			
Benzoic acid			*	*
Butylbenzyl-phthalate	*			
Chrysene	*			
bis(2-ethylhexyl)phthalate	*	*	*	
Diethylphthalate				*
Di-n-butylphthalete	*			
Fluoranthrene	*			
4-Nitrophenol			*	
Phenanthrene	*			
Phenol			*	
Propyleneglycol dinitrate	*	*		*
Pyrene	*			
Organochlorine Pesticides				
Chlordanes			*	
2,4-D		*		
4,4'-DDD			*	
4,4'-DDE			*	
4,4'-DDT			*	
Dicamba		*		
Endosulfans			*	
Endrin			*	
Methoxychlor			*	
Methyl parathion			*	*

Table 7-6
Summary of Ecological Exposure Pathways Evaluated During the 1993 Ecological Risk Assessment

Receptors	Exposure Medium	Exposure Pathway
Terrestrial plants	Soil	Root uptake
	Soil	Ingestion
Terrestrial mammals	Plants	Ingestion
	Sediment	Ingestion
Herbivorous birds	Plants	Ingestion
	Surface water	Ingestion
		Ingestion
Benthic invertebrates	Sediment	Contact
		Ingestion
	Surface water	Contact
Demersal fish	Benthic invertebrates	Ingestion
Carnivorous birds	Aquatic food species	Ingestion

Table 7-7
Summary of Potential Unacceptable Ecological Risks Identified During the 1993 Ecological Risk Assessment

Receptor	Pathway	Primary Risk Contributors
Marsh		
Benthic organisms	Exposure to sediment & interstitial water	bis(2-ethylhexyl)phthalate, organochlorine pesticides
	Exposure to surface water	Antimony, mercury
Tide Flats		
Benthic organisms	Exposure to sediment	bis(2-ethylhexyl)phthalate, organochlorine pesticides
Demersal fish (e.g., English sole)	Exposure to sediment	bis(2-ethylhexyl)phthalate, organochlorine pesticides
	Ingestion of benthic organisms	bis(2-ethylhexyl)phthalate, organochlorine pesticides
Benthic organisms	Exposure to surface water	Antimony, mercury
Dogfish Bay		
Benthic organisms	Exposure to sediment	bis(2-ethylhexyl)phthalate

Table 7-8
Summary of Ecological COIs Identified During the 1995/1996 Supplemental Data Collection Rounds

Chemical	Groundwater	Surface Water	Sediment
Inorganics			
Arsenic			*
Cadmium		*	
Chromium			*
Copper	*	*	
Lead		*	
Mercury	*		
Nickel	*		
Silver	*		
Zinc	*	*	
Semivolatile Organic Compounds			
Acenaphthene			*
Phenol			*
Organochlorine Pesticides & PCBs			
Aldrin	*		
Dieldrin	*		
Endosulfans	*		
Endrin	*	*	
Heptachlor	*		
Heptachlor epoxide	*		
Aroclors	*	*	*

Table 10-1
Estimated Costs of Remedial Action Alternatives

Alternative	Initial Capital Investment $ million	Present Value of O&M Costs a $ million	Total Present Worth b $ million
Source Reduction	2.8	2.6	5.4
Plume Control	1.5	2.6	4.1
Sediment Trap	1.7	2.5	4.2
Limited Action	0.7	1.6	2.3
Containment	4 to 7 c	5 to 8 c	12 to 14 c
Preferred Alternative	0.9	2.6	3.5

a Present value of operating and maintenance (O&M) costs assuming 5 percent net discount factor and a life-cycle period of 30 years.

b Present worth is the sum of initial capital investment and the present value of the O&M costs. The estimates of probable cost shown here are based on the assumptions listed in the feasibility studies, which used cost estimating techniques that typically have an estimating uncertainty within +50% to -30% for the quantities assumed. If actual quantities differ from the assumed quantities, the actual costs may exceed this range.

c These costs show the range for several different containment alternatives from the original FS. Because the containment alternatives with the lowest capital cost had higher O&M cost, and because the alternatives with the highest capital cost had lower O&M cost, the range of total present worth costs for the containment alternatives is relatively narrow.

Table 11-1
Long-Term Monitoring for Phytoremediation

Stations	Explanation	Parameters	Frequency
Upper aquifer wells MW1-4, MW1-5 & MW1-16	To assess contaminant reduction in southern contaminant zone.	VOCs	Once every yr, yrs 1-5 * Once every 2 yrs, yrs 5-10 Once every 5 yrs, yrs 10+
Upper aquifer wells 1MW-1 & MW1-2	To assess contaminant reduction in the central contaminant zone.	VOCS	Once every yr, yrs 1-5* Once every 2 yrs, yrs 5-10 Once every 5 yrs, yrs 10+
Surface water station MA12	To assess concentration reduction in surface water due to contaminant reduction in southern contaminant zone.	VOCs	Once every yr, yrs 1-5 Once every 2 yrs, yrs 5-10 Once every 5 yrs, yrs 10+
Existing upper aquifer wells near phytoremediation zones, plus additional piezos as needed	To contour water table in treatment zone to demonstrate that contaminated water is being taken up by trees.	Water levels	Four times per yr, yrs 1-5 Once per year, yrs 5+ Once per 5 yrs, yrs 10+

NOTE: The sampling locations, frequencies, and analytes listed in this table may be adjusted, by mutual agreement between the Navy and the agencies, during the development of sampling and monitoring plans in the remedial design and subsequent phases of this project, and may be modified as needed at any time by mutual agreement.

* After trees are established, but before the first 5-year review, these wells will be sampled twice in the same year--once at the end of the growing season and once at the end of the dormant season--to assess seasonal changes in contaminant concentrations.

Table 11-2
Long-Term Monitoring for Intrinsic Bioremediation

Stations	Explanation	Parameters	Frequency
Upper aquifer wells MW 1-4, MW1-5 & MW1-16	To track conditions in southern contaminant zone.	Vocs Redox parameters*	Once every yr, yrs 1-5 Once every 5 yrs, yrs 5+
Upper aquifer wells 1MW-1 & MW1-2	To track conditions in central contaminant zone.	VOCS Redox parameters*	Once every yr, yrs 1-5 Once every 5 yrs, yrs 5+
Intermediate aquifer wells MW1-25 & MW1-28	To track conditions within intermediate aquifer plume.	Vocs Redox parameters*	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Intermediate aquifer well MW1-39	To track conditions at leading edge of off-base plume margin.	Vocs Redox parameters*	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+

NOTE: The sampling locations, frequencies, and analytes listed in this table may be adjusted, by mutual agreement between the Navy and the agencies, during the development of sampling and monitoring plans in the remedial design and subsequent phases of this project, and may be modified as needed at any time by mutual agreement.

* Redox parameters = total organic carbon, dissolved inorganic carbon, alkalinity, pH, Eh, dissolved oxygen, conductivity, temperature, hydrogen, methane, iron(II), manganese(II), hydrogen sulfide, nitrate, and sulfate.

Table 11-3
Long-Term Monitoring For Assessing Risk and Compliance

Stations	Explanation	Parameters	Frequency
	Drinking Water Pathway		
Deep aquifer supply wells (PUD well & Base well)	To provide direct indication of drinking water risk from deep aquifer system.	VOCs	Once every yr
Intermediate aquifer well at Highway 308 bridge (MW1-39)	To confirm that concentrations at the leading edge of the off-base intermediate aquifer plume remain low. This would provide additional evidence (in conjunction with groundwater gradients) that landfill does not pose drinking water threat in off-site intermediate aquifer.	VOCs	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Upper and intermediate aquifer wells & piezometers	To monitor groundwater gradients and flow directions to demonstrate continued absence of off-site drinking water risks in upper and intermediate aquifers.	Water levels	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
	Ecological Pathway		
Upper aquifer groundwater (MW1-4, MW1-5, 1MW-1, & MW1-2)	Representative stations downgradient from the southern and central CAH contaminant zones to monitor for possible adverse trends for inputs to surface water (marsh).	VOCs	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Seep	To monitor input of PCBs to surface water.	PCBs/Pesticides	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+

Table 11-3 (Continued)
Long-Term Monitoring For Assessing Risk and Compliance

Stations	Explanation	Parameters	Frequency
Ecological Pathway (Continued)			
Intermediate aquifer wells MW1-25 & MW1-28	Highest concentration stations within intermediate aquifer plume to monitor for possible adverse trends for inputs to surface water (tide flats).	VOCS	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Surface water (MA09 & MA12)	Representative stations downgradient of southern and central CAH groundwater zones to monitor ecological risk in marsh system.	VOCS	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Surface water (TF19 & DB14)	To monitor inputs to off-base environment.	VOCS	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Sediment: Pond station (MA11) Stations in sediment removal area (MA09 and one other) Tide flats stations (TF18, TF20, TF21) Dogfish Bay stations(DB05, DB07, DB08)	To monitor ecological risks (by comparison to SMS) in marsh, tide flats, and Dogfish Bay.	PCBs/Pesticides SVOCs Metals (arsenic, beryllium, chromium, lead, mercury, nickel, and zinc)	Once every 5 yrs (Timed to coincide with the 5-yr review periods, as explained in Section 11.5.3.4)

Table 11-3 (Continued)
Long-Term Monitoring For Assessing Risk and Compliance

Stations	Explanation	Parameters	Frequency
		Seafood Ingestion Pathway	
Upper aquifer groundwater (MW1-4, MW1-5, 1MW-1, & MW1-2)	Representative stations downgradient from the southern and central contaminant zones to monitor for possible adverse trends for inputs to surface water (marsh).	VOCs	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Seep	To monitor input of PCBs to surface water.	PCBs/Pesticides	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Intermediate aquifer wells MW1-25 & MW1-28	Highest concentration stations within intermediate aquifer plume to monitor for possible adverse trends for inputs to surface water (tide flats).	VOCs	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Surface water (TF19 & DB14)	To monitor inputs to off-base environment.	VOCs	Once every 2 yrs, yrs 1-5 Once every 5 yrs, yrs 5+
Clams (TF18, TF20, TF21, DB05, DB07, DB08)	To monitor human health ingestion risks in tide flats and Dogfish Bay where potential harvesting could occur. Also, to demonstrate that VOCs in surface water do not partition or accumulate significantly in clams.	PCBs/Pesticides SVOCs Metals (arsenic, beryllium, chromium, lead, mercury, nickel, and zinc) VOCs*	Once every 5 yrs (Timed to coincide with the 5-yr review periods, as explained in Section 11.5.3.4)

NOTE: The sampling locations, frequencies, and analytes listed in this table may be adjusted, by mutual agreement between the Navy and the agencies, during the development of sampling and monitoring plans in the remedial design and subsequent phases of this project, and may be modified as needed at any time by mutual agreement.

* VOCs would only be tested during the first sampling round.

Table 11-4
Remediation Goals for Groundwater

		Regulatory Criteria and Remediation Goals, Ig/L						
		Drinking Water Pathway				Surface Water Protection Pathways		
Chemical of Concern	Range of Detected Concentrations, Ig/L	Federal MCL	State MCL	MTCA Method B [d]	Remediation Goal	Seafood Ingestion [a]	Ecological Risk [a]	Remediation Goal
1,1-Dichloroethane	0.2 - 30,000			800	800			
1,2-Dichloroethane	0.2 - 35	5	5	5 [b]	5	59		59
1,1,-Dichloroethene	0.24 - 680	7	7	0.073	0.5 [c]	1.9		1.9
cis-1,2-Dichloroethene	0.32 - 14,000	70		80	70			
trans-1,2-Dichloroethene	0.24 - 520	100		160	100	33,000		33,000
Tetrachloroethene	0.4 - 4	5		5 [b]	5	4.2		4.2
1,1,1-Trichloroethane	430 - 5,600	200	200	7,200	200	41,700		41,700
Trichloroethene	0.3 - 22,000	5	5	5 [b]	5	56		56
Vinyl chloride	0.47 - 12,000	2	2	0.023	0.5 [c]	2.9		2.9
Polychlorinated biphenyls	0.06 - 1.4	0.5		0.011	0.04 [c]	0.000027	0.03	0.04 [c]

NOTE: A blank cell in this table means there is no criterion for the chemical for that particular category.

[a] Federal water quality criteria (WQC) are the same as state water quality standards (WQSs) for this pathway.

[b] WAC 173-340-700(6) states that in cases where cleanup levels are below the practical quantitation limit (PQL), compliance with cleanup standards will be based on the PQL. For this chemical, the PQL is higher than the cleanup level. In accordance with WAC 173-340-700(6) and Ecology's Implementation Memorandum No. 3 (PQLs as Cleanup Standards, dated November 24, 1993), the PQL has been listed as the remediation goal for this chemical.

[c] The values listed are MTCA Method B cleanup levels for individual chemicals; they require downward adjustment to account for multiple chemicals or pathways as needed to meet a cumulative excess cancer risk of < 10^{-5} and a cumulative noncancer risk hazard index of < 1.0, per WAC 173-340-708(5)&(6) and WAC 173-340-700(3)(6).

Table 11-5
Remediation Goals for Surface Water

		Regulatory Criteria and Remediation Goals, Ig/L					
		Seafood Ingestion Pathway			Ecological Risk Pathway		
Chemical of Concern	Range of Detected Concentrations, Ig/L	State WQS [a]	MTCA Method B [c]	Remediation Goal	Federal WQC	State WQS	Remediation Goal
1,1-Dichloroethane	0.23 - 11						
1,2-Dichloroethane	not detected	99	59	59			
1,1-Dichloroethene	0.5 - 1.0	3.2	1.9	1.9			
cis-1,2-Dichloroethene	0.24 - 480						
trans-1,2-Dichloroethene	0.26 - 3.5		33,000	33,000			
Tetrachloroethene	not detected	8.9	4.2	4.2			
1,1,1-Trichloroethane	not detected		41,700	41,700			
Trichloroethene	0.49 - 64	81	56	56			
Vinyl chloride	0.25 - 56	525	2.9	2.9			
Polychlorinated biphenyls	0.13	0.000045	0.000027	0.04 [b]	0.03	0.03	0.04 [b]

NOTE: A blank cell in this table means there is no criterion for the chemical for that particular category.

[a] These criteria are equal to the surface water RGs for the corresponding pathway (from Table 11-5). The point of compliance for these criteria is as discussed in the text.

[b] The MTCA cleanup level equals the drinking water MCL in this case, because it is "sufficiently protective" in accordance with WAC 173-340-720(3)(a).

[c] WAC 173-340-700(6) states that in cases where cleanup levels are below the practical quantitation limit (PQL), compliance with cleanup standards will be based on the PQL. For this chemical, the PQL is higher than the cleanup level. In accordance with WAC 173-340-700(6) and Ecology's Implementation Memorandum No. 3 (PQLs as Cleanup Standards, dated November 24, 1993), the PQL has been listed as the remediation goal for this chemical.

[d] The values listed are MTCA Method B cleanup levels for individual chemicals; they require downward adjustment to account for multiple chemicals or pathways as needed to meet a cumulative excess cancer risk of < 10^{-5} and a cumulative noncancer risk hazard index of < 1.0, per WAC 173-340-708(5)&(6) and WAC 173-340-700(3)(6).

Table 11-6
Remediation Goals for Sediments

Chemical of Concern	Range of Detected Concentrations mg/kg	State Sediment Management Standards, mg/kg		Remediation Goal, mg/kg
		Sediment Quality Standard	Cleanup Screening Level	
1,1-Dichloroethane	not analyzed	bioassay	bioassay	bioassay SQS
1,2-Dichloroethane	not analyzed	bioassay	bioassay	bioassay SQS
1,1-Dichloroethene	not analyzed	bioassay	bioassay	bioassay SQS
cis-1,2-Dichloroethene	not analyzed	bioassay	bioassay	bioassay SQS
trans-1,2-Dichloroethene	not analyzed	bioassay	bioassay	bioassay SQS
Tetrachloroethene	not analyzed	bioassay	bioassay	bioassay SQS
1,1,1-Trichloroethane	not analyzed	bioassay	bioassay	bioassay SQS
Trichloroethene	not analyzed	bioassay	bioassay	bioassay SQS
Vinyl chloride	not analyzed	bioassay	bioassay	bioassay SQS
Polychlorinated biphenyls	1.08 - 29 a	12 a	65 a	12 a
Polychlorinated biphenyls	passed bioassay SQS b	bioassay	bioassay	bioassay SQS

NOTE: Bioassays will be performed if chemical results fail SQS.

a These concentrations are carbon-normalized values (i.e., mg per kg organic carbon).

b At stations where PCBs were detected.

Table 11-7
Remediation Goals for Clam Tissues

		Regulatory Criteria and Remediation Goals, mg/kg				
		Seafood Ingestion Pathway [a]			Ecological Risk Pathway	
Chemical of Concern	Range of Detected Concentrations, mg/kg	Noncancer Risk (HQ = 1.0)	Cancer Risk (10^{-5} Level)	Remediation Goal	MATC [b]	Remediation Goal
1,1-Dichloroethane	not analyzed	304		304		
1,2-Dichloroethane	not analyzed	91	0.33	0.33		
1,1-Dichloroethene	not analyzed	27	0.051	0.051		
cis-1,2-Dichloroethene	not analyzed	30		30		
trans-1,2-Dichloroethene	not analyzed	61		61		
Tetrachloroethene	not analyzed	30	0.59	0.59		
1,1,1-Trichloroethane	not analyzed	61		61		
Trichloroethene	not analyzed	18	2.8	2.8		
Vinyl chloride	not analyzed		0.016	0.01 6		
Polychlorinated biphenyls	0.005 - 0.013	0.061	0.015	0.015	2.6	2.6

NOTE: A blank cell in this table means there in no criterion for the chemical for that particular category.

[a] The remediation goals for the seafood ingestion pathway are derived from the assumptions given in Appendix B. For compliance purposes, remediation goals calculated in accordance with the assumptions in Appendix B will be compared with RME concentrations calculated from the results of all samples collected from Dogfish Bay and the tide flats, including any stations added in future monitoring rounds.

[b] MATC = maximum acceptable tissue concentration from Appendix J of the Summary Data Assessment Report (URSG 1997).

Table 11-8
Estimated Costs of Selected Remedial Actions

Remedial Action	Capital Cost $ million	Present Value of O&M Cost $ million	Total Present Worth Cost $ million
Phytoremediation	0.35	1.11	1.46
Sediment Removal	0.08	0	0.08
Upgrade Marsh Outlet	0.09	0.02	0.11
Landfill Cover	0.39	0.38	0.77
Monitoring	0	1.07	1.07
Total Costs	0.91	2.58	3.49

NOTES: The costs shown above were based on feasibility study assumptions.

Present value and present worth costs are based on a 30-year life cycle and a 5% net discount rate.

The estimates of probable cost shown here are derived from the 1997 feasibility study, which used cost estimating techniques that typically have an estimating uncertainty within +50% to -30% for the quantities assumed. If actual quantities differ from the assumed quantities, the actual costs may exceed this range.

APPENDIX A
RESPONSIVENESS SUMMARY

The responsiveness summary addresses public comments on the proposed plan for remedial action at the Naval Undersea Warfare Center (NUWC), Keyport, Operable Unit 1 (OU 1). The proposed plan was issued November 13, 1997. The public comment period was held from November 16 through December 15, 1997. A public meeting was held on December 3, 1997 to present the proposed plan and to accept oral and written public comments.

Most comments were received on pre-printed comment forms that had been distributed along with the proposed plan. In addition to providing space for written comments, the pre-printed comment forms included two statements that could be checked; one statement indicated that the commenter supported the preferred alternative presented in the proposed plan and the other indicated that the commenter did not support the preferred alternative. Of the 21 forms received, 17 of them (81 percent) had the statement checked indicating support for the preferred alternative. One form (5 percent) had the statement checked indicating that the commenter did not support the preferred alternative. Three forms (14 percent) had neither statement checked. Many of the forms contained no separate written comments; others contained one or more comments on the proposed plan. In addition to comments provided on the comment forms, four people gave oral comments at the public meeting and one agency provided comments in a letter.

In all, 26 comments were received. The comments fall into several categories, as follows:

- Comments expressing general approval of the preferred plan
- Comments concerning phytoremediation, natural attenuation, and the landfill cover
- Comments concerning long-term monitoring
- Comments concerning indoor air quality in the former modular offices
- Comments concerning future community involvement activities
- Miscellaneous comments

The following sections list the comments received under each category. Responses are provided for each comment, except those in the first group that express approval of the proposed plan. Some of the comments that were received orally are paraphrased and several of the written comments were edited slightly for clarity.

The following comments indicate general approval of the proposed plan and preferred alternative:

1. I am very pleased with the proposed plan and think that it is cost effective and that it addresses all of the concerns of the RAB [Restoration Advisory Board] and the community.

2. The plan is well conceived and should adequately protect public health under current and future land use scenarios.

3. I support the preferred alternative because it reduces the source of the chemicals of concern, it is cost effective, and it addresses the three main exposure pathways.

4. I am confident that the proposed plan meets the requirements of federal law for cleanup of contaminated landfill. It also responds to the public concerns for the long time effect of the contaminants from the landfill.

5. I hope and expect that such comprehensive plans for cleanup will be applied to all Superfund sites in our nation.

6. I am very pleased with the proposed plan and the work that has gone into reviewing options.

7. As a member of the RAB, it has been an interesting process. The proposed plan is a compromise among the stakeholders. It was a long-time-coming process in which all parties are satisfied. I am happy to see that source-reduction became important.

8. Good job.

The following comments concern phytoremediation, natural attenuation, and the landfill cover:

9. The use of trees simply moves the problem from one part of the environment to the other. What do you do with the contaminated trees? Do you burn them?

Response: Research conducted to date at other hazardous waste sites by the University of Washington and others indicates that most of the chlorinated solvents that enter the trees are broken down within the trees into harmless compounds. Because the contaminants are largely destroyed, phytoremediation does not simply transfer contaminants from one part of the environment to the other at these sites. The small amount of contaminants that are not broken down are released through the leaves to the atmosphere where they are destroyed by chemical reactions caused by sunlight. Assuming that the same processes described above will occur at OU 1, it is not expected that the trees at the landfill (ie., the leaves, limbs, and trunks) would become contaminated. Under these conditions, waste wood (such as that from pruning and thinning) could be disposed of in a normal manner or sold as firewood.

However, because phytoremediation is a relatively new technology, and because of the importance of the issues raised in the comment, the ability of poplar trees to break down the types of contaminants found in the landfill (both chlorinated solvents as well as other landfill contaminants) and not to release them into the air in unacceptable concentration or accumulate them within the trees will be verified by conducting studies at Keyport and or by evaluating the results of comparable studies conducted at other similar contaminated sites.

10. I like the idea of using poplars, but I question how effective they will be for drawing those contaminants that are beyond the working depth for this tree species.

Response: Although the tree roots extend only to the top of the water table, they are capable of drawing contaminants from deeper in the aquifer. This is because, during the growing season, each tree acts like a miniature pumping well, depressing the water table and forming a "cone of depression." The cone of depression causes contaminants to flow both radially inward, as well as upward, toward the tree roots. In this way, phytoremediation is capable of reducing the amount of contaminants from deeper in the aquifer.

11. It looks as if there are pathways for groundwater flow that will bypass the poplars. Why?

Response: The objective of the phytoremediation is not necessarily to intercept all groundwater flow from the landfill, but to reduce the amount of TCE-family contaminants within the landfill over the long term. For this reason, the proposed plan shows the poplars planted above groundwater contaminant "hot spots." Planting the trees over hot spots will provide the most contaminant reduction using the fewest trees because every gallon of water taken up will contain more contaminants than if the trees were planted over less contaminated areas. In any case, although it is not their primary objective, the pumping action of the trees planted over hot spots will intercept a significant amount of the most contaminated groundwater and prevent it from reaching the marsh system. The actual placement of the trees, and the balance between contaminant reduction and groundwater interception, will be determined during the remedial design phase of the project, and confirmed by monitoring and assessment during the operational phase.

12. The proposed plan states that, "If using poplar trees to reduce contaminants proves to be a problem in the areas with high contamination levels, then the planting areas could be modified so the trees would control the groundwater plume in areas where concentrations are lower." How will this be measured? What monitoring will be done?

Response: This statement from the proposed plan means that if the contaminant concentrations in the hot spots are too high for the poplar trees to grow, then trees could instead be planted downstream of the hot spots to intercept contaminated groundwater before it reaches the marsh. However, based on research studies it is expected that the trees should be able to thrive in the contaminant levels found at the landfill hot spots. Long-term monitoring associated with the performance of phytoremediation will include sampling groundwater for chlorinated aliphatic hydrocarbons (CAHs) (to track their reduction over time) and periodically measuring water table elevations to assess the amount of drawdown being induced by the trees.

13. The protective asphalt cover may limit rainfall accumulation in the landfill site, but it also seals the site and prevents the natural cleanup by light, air, and vegetation to occur. The proposed phytoremediation is an excellent start, but a plan should be adopted for the eventual removal of the top seal over the complete site and a phased-in vegetation (phytoremediation) planting of the complete area.

Response: This comment points out the careful balance that must be struck between a number of potentially conflicting remediation processes. For example, the asphalt cover limits rain infiltration. This is desirable because it reduces the mobilization of landfill contaminants and their ultimate discharge to the downgradient environment. On the other hand, poplar trees will reduce the source of landfill contaminants. This is also desirable; however, the trees cannot be planted without first removing the asphalt cover. Also, planting too many trees could use excessive water and require extensive irrigation. Finally, intrinsic biodegradation of CAHs is occurring in groundwater within the landfill. This, too, is desirable because it reduces the contaminant source; however, removing the asphalt cover and planting trees (or paving areas that are currently unpaved) could interfere with the microorganisms that are currently degrading TCE-family contaminants. The Navy and the Department of Ecology believe that the approach outlined in the proposed plan provides a good starting point and a balance between the various processes described above. In addition, results of the long-term monitoring will be used to assess the functioning of phytoremediation and intrinsic biodegradation; these results will be used to fine tune the extent of the poplar trees and pavement that is needed to minimize risk to downgradient receptors and maximize reduction of the contaminant source.

14. Has there been any suggestion to eliminate or prevent motor vehicle traffic over the landfill cover area as a control method to prevent pavement cracking?

Response: It is the Navy's intention to continue to use the paved areas of the landfill for vehicle parking and equipment storage. Vehicle traffic and equipment storage on the asphalt pavement has some effect on cracking; however, the primary cause for cracking is that the material in the landfill settles unevenly as it decomposes. The Navy will continue to maintain the pavement in order to maintain its function and integrity as a barrier to infiltration. This maintenance is not a major cost item.

15. If these [natural biological breakdown] processes are occurring, and the cis- isomer of 1,2-DCE [dichloroethene] is broken down by biological processes rather than the trans- isomer, then why the heck is there so much cis- isomer in the groundwater? Shouldn't the proportion of the trans- to cis- be higher? Maybe the natural process is stopping at DCE? Since DCE is more toxic than TCE [trichloroethene], why is this "natural biological process" a good thing?

Response: Intrinsic biodegradation (i.e., reductive dechlorination) breaks down TCE into both cis- and trans-1,2-DCE. Similarly, both DCE isomers undergo further degradation via reductive dechlorination, direct oxidation, and cometabolism (not just the cis- isomer, as suggested by the comment). The higher concentrations of cis-1,2-DCE observed at OU 1 are consistent with other studies, both field and laboratory, that indicate that the reductive dechlorination of TCE typically results in concentrations of cis-1,2-DCE than are greater than those of trans-1,2-DCE.

Second, the implication that DCE is more toxic than TCE is not correct. Based on human health risk based regulatory levels, such as the Washington State Model Toxics Control Act (MTCA), the DCEs are about ten to a thousand times less toxic than TCE, depending upon the route of exposure. The ranges of reported toxicity values of these compounds to aquatic organisms are overlapping, so it is not possible to say that one is clearly more toxic than the other to aquatic organisms.

Finally, the natural processes that biodegrade the CAHs are desirable because they reduce the concentration of contaminants entering the environment and they reduce the amount of contaminants within the landfill.

<u>The following comments concern long-term monitoring:</u>

16. How will the Navy ensure that [natural remediationg processes continue? That is, what parameters will be measured?

Response: The Navy will make two basic types of measurements on a long-term, ongoing basis to assess the functioning of the intrinsic bioremediation processes. One type of measurement will monitor the redox conditions in groundwater at a number of locations. These measurements are important because they can tell whether the geochemical conditions are remaining favorable for the breakdown of the CAHs. The other type of measurement will monitor the concentrations of the various CAHs themselves. These measurements are important because they can tell whether the more-chlorinated "parent compounds" are continuing to be broken down into less-chlorinated "daughter compounds" by biological processes.

17. [The Navy should] ensure that [long-term monitoring of groundwater, sediments, and shellfish] continues [to receive] strong emphasis. [The Navy should] especially watch [conditions that ensure the safety of drinking water].

Response: The long-term monitoring program for OU 1 will periodically test groundwater, surface water, sediments, and shellfish tissue. This testing will be used to track and document conditions relative to human health (including risks to drinking water) and ecological risks. The results of the long-term monitoring will be reviewed with the Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (EPA) to determine whether additional monitoring, investigation, or engineered action should be considered. Both the superfund law and state cleanup law require that these reviews take place at least every five years.

18. What will the time interval be for the long-term periodic monitoring?

Response: In general, groundwater and surface water stations will be monitored every one to two years. Media in which any changes are expected to occur very slowly, such as sediment and shellfish tissue, will be tested less frequently (e.g., every four or five years).

19. The Agency for Toxic Substances and Disease Registry (ATSDR) health consultation follow-up report

recommended that shellfish from Dogfish Bay be monitored for chemical contaminants every four years. It also recommended control measures for any future intrusive remedial activities to ensure that additional contaminants will not be released from the landfill into the Tide Flats and Dogfish Bay. Although Dogfish Bay is currently closed to shellfish harvesting due to biological contamination, we [Washington State Department of Health] support these recommendations as necessary to ensure that future consumption of shellfish from Dogfish Bay will not pose a public health hazard. We recognize that the proposed plan includes a provision for long-term monitoring and suggest that the recommendations made by ATSDR be considered in developing an implementation strategy.

Response: The long-term monitoring program for OU 1 will include the sampling of shellfish in Dogfish Bay and the tide flats. The first sampling will occur prior to the first required five-year agency review of the long-term monitoring data. Subsequent sampling events are planned at five-year intervals in order to coincide with the subsequent five-year reviews. This sampling interval is slightly longer than the four-year interval mentioned in the ATSDR health consultation report; however, ATSDR has informed the Navy that a five-year interval is acceptable to them. This is because the five-year interval is still less than the age at which native littleneck clams reach edible size (six years, according to the ATSDR report) and will, therefore, still be protective of human health. Any occurrence of adverse contaminant trendy in the shellfish or other environmental media would lead to the consideration of more frequent monitoring of clams.

<u>The following comments concern risk due to the air pathway:</u>

20. Is worker exposure to VOCs [volatile organic compounds] in buildings still an issue at OU 1?

Response: No, all buildings at OU 1 have either been removed or are no longer occupied.

21. The responsiveness summary should include a statement addressing the risk incurred by the employees who worked in the trailers on the landfill for varying periods of time. For example: Employee A, 5 days, 10 hours a day for 5 years; Employee B, 5 days, 9 hours a day for 1 year; etc.

Response: The following examples, based on data in the human health risk assessment, give an idea of the range of cancer-risks that were calculated: A worker exposed to the maximum detected contaminant concentrations for 25 years (5 days per week, 50 weeks per year) would experience an additional one-in-3,000 chance of cancer. This is above the maximum EPA target risk range value of one-in-10,000. However, a worker exposed to the average contaminant concentrations for 10 years would only experience an additional one-in-14,000 chance of cancer. This is below the maximum EPA target risk range value. Since the modular offices were in use for less than ten years, actual risk would likely have been even lower than one-in-14,000. There is no longer any ongoing risk to workers from inhalation of landfill contaminants because the Navy removed the modular offices from the north end of the landfill.

<u>The following comments concern future community involvement activities:</u>

22. Thanks for all the cooperative efforts to keep the community informed. I hope that we can continue with "Community Update" style newsletters and open meetings (informal RAB-style) to keep us appraised of design, installation, and results of the remedial actions. How will this happen as the RAB's responsibilities end?

Response: The Community Update newsletters will continue to be issued on a quarterly basis (i.e., four times per year) through the time of planting the poplar trees, expected to be Spring of 1999. After that, the frequency of the newsletters will be evaluated and possibly changed to semi-annually (i.e., two times per year). The RAB will continue to meet and plans to monitor the progress of remediation at, the landfill, the long-term monitoring results, and the OU 2 areas. These issues will continue to be discussed in RAB meetings, which are open to the public. Finally, the Superfund law requires that the Navy inform the public of the status of the site at least every 5 years until the contaminants at the site fall below cleanup levels.

23. How, when, and how often will the (long-term monitoring] results be made available to the public? Will meetings be held, and if so how often, to discuss the monitoring results? Will a mailing list of interested parties be maintained?

Response: The long-term monitoring reports for each round will be placed in the repositories for public review. Their availability will be announced in the Community Updates. The Community Update newsletters will continue to be issued on a quarterly basis (ie., four times per year) through the time of planting the poplar trees, expected to be Spring of 1999. After that, the frequency of the newsletters will be evaluated and possibly changed to semi-annually (i.e., two times per year). The results will also be a topic of discussion in the RAB meetings, which are open to the public. The RAB will continue to meet and plans to monitor the progress of remediation at the landfill, the long-term monitoring results, and the OU 2 areas. A mailing list is currently maintained for the Keyport sites and will continue to be maintained. People on the mailing list receive the Community Update and notices of RAB meetings. In addition, the Superfund law requires that the Navy inform the public of the status of the site at least every 5 years until the contaminants at the site fall below cleanup levels.

The following miscellaneous comments on the proposed plan were also received:

24. The Navy should consider making OU 1 into a public park that would be operated jointly with the county. Please include me on future considerations of this.

Response: This idea has been considered and it has been determined that the areas surrounding and encompassed by Operable Unit 1 remain operationally important to the base. While the poplar trees will be planted over portions of the landfill, other areas will continue to be used for parking and storage. Due to this need, and issues of federal real estate use and liabilities, the Navy will maintain this area in its current state.

25. Manchester fuel depot had a similar problem. They have removed the soil and had it processed. We are still studying the problem. Maybe we should find out how they resolved their problem and take similar action. We have spent enormous amounts of money studying the problem!

Response: The study phase of the OU 1 cleanup was finished in November 1997 when the Summary Data Assessment Report and the Focused Feasibility Study were finalized. Following that, federal and state laws require that a number of steps be completed,, including the publication of the proposed cleanup plan, a public hearing, a public comment period, and the preparation of this document, the Record of Decision (ROD). Now that these requirements have been met, the implementation of remedial activities can begin.

The action at the Manchester fuel depot that the comment refers to involved soil contaminated with polychlorinated biphenyls (PCBs). Approximately 5,000 cubic yards of contaminated soil were excavated and transported to facilities in Texas and Utah where it was incinerated. The Manchester cleanup involved a relatively small area in which the extent of contamination could be well defined. The contaminants of concern at Manchester, PCBs, are very resistant to natural degradation and, therefore, often require the use of expensive, "non-green" remedial measures, such as incineration. The situation at OU 1, however, is very different and does not lend itself to a similar remedial action. The contaminants at OU 1 are dispersed throughout large portions of the multi-acre former landfill. Because of this, the amount of material that would have to be excavated, transported, and processed would be enormous if the type of cleanup done at Manchester were attempted. Because much of the contamination at OU 1 is below the water table, excavation would be very difficult and would require extensive dewatering measures and the disposal of large amounts of contaminated groundwater generated by the dewatering. Finally, unlike Manchester, the main contaminants at OU 1 are chlorinated solvent-type chemicals (i.e., CAHs). These types of chemicals are readily susceptible to biological and chemical breakdown under the right conditions. Because of this, the remediation of OU 1 does not have to rely on technology-intensive actions like incineration and can take advantage of "green" remedial measures, such as phytoremediation and intrinsic bioremediation to reduce the amount of contaminants in the landfill.

26. The plan looks OK except I have a strong feeling you're only trying to cover up the problem instead of solving it.

Response: The phytoremediation and sediment removal actions, in concert with natural attenuation, are expected to reduce the amount of contamination at the landfill in order to improve conditions over the long term. Although these processes will take time, unlike more intrusive cleanup measures, they will occur in an environmentally friendly manner that will not significantly harm the marsh environment.

APPENDIX B
EXPOSURE ASSUMPTIONS FOR SHELLFISH REMEDIATION GOALS FOR PROTECTION OF HUMAN HEALTH

The remediation goals for clam tissues shown in Table 11-7 for the seafood ingestion pathway are risk-based concentrations for the protection of human health derived from the following equations:

RG n = (HQ)(RâD)/(IF n)
RG c = (CRL)/(SF)/(IF e)
IF n = (IR)(FI)(EF)(ED)/(BW)(AT c)
IF c = (IR)(FI)(EF)(ED)/(BW)(AT c)

where:

RG n = remediation goal for noncancer risk, mg/kg
HQ = hazard quotient
RâD = reference dose, mg/kg-d
IF n = intake factor for noncancer risk, kg/kg-d
RG c = remediation goal for cancer risk, mg/kg
CRL = cancer risk level
SF = cancer slope factor, (mg/kg-d) -1
IF c = intake factor for cancer risk, kg/kg-d
IR = ingestion rate, kg/d
FI = fraction ingested from contaminated source
EF = exposure frequency = 365 d/y
ED = exposure duration, y
BW = body weight, kg
AT n = averaging time for noncancer risk, d
AT c = averaging time for cancer risk, d

The shellfish remediation goals (RGs) for the seafood ingestion pathway shown in Table 11-7 are based on protection of human health for subsistence consumers, using a cancer risk level of 10 -5 and a hazard quotient of 1.0 for noncancer effects for reasonable maximum exposure (RME) within the Dogfish Bay resource area (including the tide flats). The exposure assumptions used to derive shellfish RGs for the seafood ingestion pathway are listed in Table B-1. The toxicity factors for calculating the PGs in Table 11-7 are listed in Table B-2. For compliance purposes, RG values calculated in accordance with the assumptions in this Appendix will be compared with RME concentrations for this resource area calculated from the results of all samples collected from Dogfish Bay and its tide flats, including any stations that might be added in future rounds.

As shown in Table B-1, the RGs are based on a value of 0.25 for the fraction ingested (FI). This value matches that used for estimating RME risks for the subsistence scenario in the baseline risk assessment. The 0.25 value was used in the baseline risk assessment as a conservative estimate of the fraction of shellfish in the diet of subsistence consumers that could come from the potentially contaminated resource area (Dogfish Bay) in estimating RME risks. It is planned to use a targeted sampling approach rather than a random sampling approach to initiate the long-term monitoring program for OU 1 (i.e., sample stations will be located near the landfill rather than located randomly throughout the entire resource area). Because concentrations in shellfish most likely decrease markedly with distance from the landfill for a chemical of concern migrating from the landfill, these targeted sampling results will likely provide a more conservative estimate of RME concentrations for this pathway than the RME estimates in the baseline risk assessment. Because the targeted sampling locations are not representative of the entire resource area (Dogfish Bay and its tide flats), the inclusion in the RME calculation of results from any possible future additional sampling locations from within this resource area will not cause a reduction in the intended level of protectiveness provided by the shellfish RAO and RGs for this pathway.

Table B-1
Exposure Assumptions for Shellfish Remediation Goals-Seafood Ingestion Pathway

Parameter	Unit	Value	Source/Reference
Ingestion Rate (IR)	kg/d	0.092	Subsistence consumption using 95th percentile shellfish ingestion rate for adult tribal members (1.308 g/kg-d), adjusted for a 70-kg body weight (from Toy et al. 1996) a
Fraction Ingested from Contaminated Source (FI)	unitless	0.25	This value matches that used for estimating RME risk for the subsistence scenario in the baseline risk assessment. The 0.25 value was used in the baseline risk assessment as a conservative estimate of the fraction of shellfish in the diet of subsistence consumers that could come from the potentially contaminated resource area (Dogfish Bay) in estimating RME risks.
Exposure Frequency (EF)	d/y	365	This value corresponds to the ingestion rate (IR) value given above, which has been expressed as a daily rate for every day of the year.
Exposure Duration (ED)	y	70	Taken as the lifetime (i.e., 70 years) because subsistence consumers (e.g., tribal members) are likely to live in one location their entire lives.
Body Weight (BW)	kg	70	EPA's default value for adult body weight (from EPA 1991) b
Averaging Time - Noncancer (AT a)	d	25,550	For noncancer health effects, the averaging time is equal to the exposure duration (ED).
Averaging Time - Cancer (AT c)	d	25,550	For cancer, the averaging time is the taken lifetime (i.e., 70 years).

a Toy, K.A., Polissar, N.L., Liao, S., and Mittelstaedt, G.D. 1996. A fish consumption survey of the Tulalip and Squaxin Island tribes of the Puget Sound region. Tulalip Tribes, Department of the Environment, 7615 Totem Beach Road, Marysville, WA 98271.

b EPA 1991. Human Health Evaluation Manual, Supplemental Guidance: Standard Default Exposure Factors. OSWER Directive 9285.6-03. Office of Solid Waste and Emergency Response, U.S. Environmental Protection Agency. March 1991.

Table B-2

Toxicity Factors Used for Shellfish Remediation Goals-Seafood Ingestion Pathway

Chemical	Oral Rfd mg/kg-d	Reference	Oral SF (mg/kg-d) -1	Reference
1,1-Dichloroethane	0.1	H	NA	
1,2-Dichloroethane	3.00E-02	N	9.10E-02	I
1,1-Dichloroethene	9.00E-03	I	6.00E-01	I
cis-1,2-Dichloroethene	1.00E-02	H	NA	
trans-1,2-Dichloroethene	2.00E-02	I	NA	
Tetrachloroethene	1.00E-02	I	5.20E-02	N
1,1,1-Trichloroethane	2.00E-02	N	NA	
Trichloroethene	6.00E-03	N	1.10E-02	W
Vinyl chloride	NA		1.9	H
Polychlorinated biphenyls	2.00E-05	I;a	2	I

a Oral RfD for PCBs is based on the oral RfD for Aroclor 1254

I = EPA Integrated Risk Information System (IRIS)

H = Health Effects Assessment Summary Tables (HEAST)

N = EPA-NCEA Regional Support provisional value