# Groundwater Conceptual Site Model Update Report for the Former Process Area

## Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units

Prepared for

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# List of Acronyms and Abbreviations

| | |
|---|---|
| bgs | below ground surface |
| BNA | base/neutral and acid extractable |
| CERCLA | Comprehensive Environmental Response, Compensation, and Liability Act |
| CFR | Code of Federal Regulations |
| COC | contaminant of concern |
| CSM | Conceptual Site Model |
| CUL | cleanup level |
| DNAPL | dense nonaqueous-phase liquid |
| DOH | Washington Department of Health |
| FPA | Former Process Area |
| FS | Feasibility Study |
| ft bgs | foot/feet below ground surface |
| ft/day | feet per day |
| gpm | gallons per minute |
| LNAPL | light nonaqueous-phase liquid |
| MCL | maximum contaminant level |
| mg/L | milligrams per liter |
| MSL | mean sea level |
| MTCA | Model Toxics Control Act |
| NAPL | nonaqueous-phase liquid |
| OU | Operable Unit |
| PAH | polynuclear aromatic hydrocarbon |
| PCB | polychlorinated biphenyl |
| PCP | pentachlorophenol |
| RI | Remedial Investigation |
| ROD | Record of Decision |
| SLA | Sea Level Aquifer |

| | |
|---|---|
| SPA | Semi-Perched Aquifer |
| SVOC | semivolatile organic compound |
| TDS | total dissolved solids |
| TPH | total petroleum hydrocarbons |
| USACE | U.S. Army Corps of Engineers |
| USEPA | U.S. Environmental Protection Agency |
| VOC | volatile organic compound |
| µg/L | micrograms per liter |

# 1.0 Introduction

This Groundwater Conceptual Site Model (CSM) Update Report for the Former Process Area (FPA) has been prepared for reference by Wyckoff Site stakeholders, based on their requests for a summary of existing groundwater and subsurface information collected since the mid-1980s at the Wyckoff/Eagle Harbor Superfund Site.

Critical figures and tables from existing sources that are needed to support the updated CSM are duplicated here (with minor edits for clarity and renumbered for this document), but the vast majority of the existing information is incorporated by reference only. New figures and tables have only been prepared in cases where these will enhance the reader's comprehension of the subject matter. Soil quality and nonaqueous-phase liquid (NAPL) data are included to the extent needed to clarify the conceptual model of the groundwater pathway. Most source documents and references are compiled in electronic format for easier reference, and are included as a CD insert in the hardcopies of this Groundwater CSM Update Report. Exceptions are identified in Section 7.0.

## 1.1 Objectives

The objectives of this Groundwater CSM Update Report are as follows:

- Provide an updated Groundwater CSM of the Wyckoff Site based on current data (Sections 2.0 through 4.0).
- Summarize the Contingency Remedy specified in the 2000 Record of Decision (ROD) for the Wyckoff Soil and Groundwater Operable Units (OUs) in the FPA (Section 5.0).
- Summarize the Contingency Remedy groundwater design data requirements and monitoring system in the FPA (Section 6.0).

## 1.2 Site Location and Description

The Wyckoff/Eagle Harbor Superfund Site is located on the east side of Bainbridge Island in central Puget Sound, Washington (see Figure 1-1). The site includes the former Wyckoff Company wood treatment facility and subtidal/intertidal sediments in Eagle Harbor. Different environmental media, sources of contamination, enforcement strategies, and environmental risks in different areas of the site led to the division of the site into four OUs:

- OU-1, the East Harbor OU (subtidal and intertidal sediments in Eagle Harbor contaminated by polynuclear aromatic hydrocarbons [PAHs])
- OU-2, the Wyckoff Soil OU (unsaturated soil contaminated with PAHs and pentachlorophenol [PCP])
- OU-3, the West Harbor OU (subtidal and intertidal sediments in Eagle Harbor contaminated by metals, primarily mercury, and upland sources)

- OU-4, the Wyckoff Groundwater OU (the saturated soil and groundwater beneath OU-2)

Overall, the Wyckoff property occupied approximately 57 acres; of this, about 18 acres are in OU-2. OU-2 consists of three areas: the FPA, the Former Log Storage/Peeler Area, and the Well CW01 area. This Groundwater CSM Update Report primarily addresses OU-4 beneath the approximate 8-acre FPA, where the vast majority of known remaining NAPLs are found (see Figure 1-2). The volume of creosote product remaining in the site's soil and groundwater has been estimated to be as great as one million gallons.

## 1.3 2000 ROD Groundwater Components

The U.S. Environmental Protection Agency (USEPA) issued a final ROD for OU-2 and OU-4 in February 2000. The ROD conditionally selected thermal remediation as the cleanup remedy and included containment as a contingent remedy if thermal remediation was found not to meet the performance criteria stated in the ROD. This section briefly summarizes the groundwater remedial action objectives (RAOs) and cleanup levels (CULs) presented in the ROD, which sets the overall framework for the site remediation. It also identifies the ROD's Contingency Remedy component.

Primary Reference: *Record of Decision, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units, Bainbridge Island, Washington* (USEPA, February 2000)

### 1.3.1 Remedial Action Objectives

The 2000 ROD identified (in Section 8.2) the following RAOs for groundwater beneath the FPA (defined as the area within the outer sheet pile wall):

- Reduce the NAPL source and the quantity of NAPL leaving the upper aquifer beneath the FPA sufficiently to protect marine water quality, surface water, and sediments (i.e., ensure that the quantity of NAPL leaving the FPA will not adversely affect aquatic life and sediments). Site-specific groundwater contaminant concentration limits will be met at the mudline.
- Ensure that contaminant concentrations in the upper-aquifer groundwater leaving the FPA will not adversely affect marine water quality and aquatic life in surface water and sediments.
- Protect humans from exposure to groundwater containing contaminant concentrations above maximum contaminant levels (MCLs).
- Protect the groundwater outside the FPA and in deeper aquifers which are drinking water sources.

### 1.3.2 Cleanup Levels

CULs included in the 2000 ROD are summarized below.

The Groundwater OU addressed in the 2000 ROD is the upper-aquifer groundwater beneath the FPA. Table 1-1 presents the groundwater CULs at the mudline, and Table 1-2 presents the maximum allowable pore-water concentrations protective of sediments that are presented in the ROD.

### 1.3.3 Contingency Remedy

The Selected Remedy for the Soil and Groundwater OUs presented in the 2000 ROD (Section 12.1) was Alternative 3, Thermal Remediation. In addition to the alternatives presented in the document, the ROD identified a Contingency Remedy as follows:

*"If the pilot test [for thermal remediation] does not reasonably achieve performance expectations, then Alternative 2b, Containment with a Sheet Pile Wall Remedy, will be implemented."*

This Contingency Remedy was determined by USEPA to be protective of human health and the environment. The Wyckoff Site groundwater containment remedy as described in this Groundwater CSM Update Report is the Contingency Remedy as defined in the 2000 ROD.

# 2.0 Groundwater Investigation History

Numerous groundwater and soil investigations have been conducted at the Wyckoff Site since the 1970s. This section provides a chronological summary of groundwater investigations conducted at the Wyckoff Site to date.

Primary References: *Remedial Investigation Report for the Wyckoff Soil and Groundwater Operable Units* (CH2M HILL, June 1997); *Comprehensive Report, Wyckoff NAPL Field Exploration* (U.S. Army Corps of Engineers [USACE], May 2000*); Record of Decision, Wyckoff/Eagle Harbor Superfund Site, Soil and Groundwater Operable Units* (USEPA, February 2000); *Thermal Remediation Pilot Study Summary Report* (USACE, 2006); *January 2006 Groundwater Sampling Results for Wyckoff/Eagle Harbor Superfund Site Report* (CH2M HILL, March 2006); *September 2006 Groundwater Sampling Results for Wyckoff/Eagle Harbor Superfund Site Report* (CH2M HILL, February 2007); *Evaluation of Groundwater Level Data* (CH2M HILL, various Technical Memoranda from September 2004b through December 2006).

## 2.1 Pre-Remedial Investigation Studies

Investigation of groundwater conditions at the Wyckoff Site began in the early 1970s, with drilling of shallow soil borings and installation of slotted casings in the borings. Data from these "wells" were used to determine general hydrogeologic conditions at the site in order to evaluate possible strategies for eliminating oil seepage from the site to Puget Sound.

In 1986, nine shallow monitoring wells (EW03 through EW08 and EW10 through EW12, 10.8 to 29 feet below ground surface [ft bgs]) and three deeper wells (EWC1 through EWC3, 59.7 to 64.5 ft bgs) were installed within the FPA. Water-level measurements and analytical data obtained from samples collected from the wells were used to evaluate hydrogeologic conditions and contaminant concentrations in groundwater at the FPA.

In 1988, 12 additional monitoring wells (MW13 through MW23, and MWC20) were installed at the Wyckoff Site. Well depths were between 20 and 60 ft bgs. Water-level measurements and analytical data collected from these wells and those installed in 1986 were used to evaluate hydrogeologic conditions and contaminant concentrations in groundwater, to assess potential risk, and to develop possible remedial actions. An aquifer pumping test was also conducted in 1988. Four pumping wells (PW1 through PW4) and 10 observation wells (OB1 through OB10) were installed for the test.

Additional exploratory drilling and installation of wells were conducted in 1989. Seventeen shallow observation wells (PO1 through PO17, 19 to 20 ft bgs) and one deeper observation well (PO18, 47 ft bgs) were installed to gauge NAPL thickness in the FPA. Water-level data, NAPL thickness measurements, and analytical results obtained from samples collected at these wells were used to evaluate the extent of light NAPL (LNAPL) and characterize contaminant concentrations in the upper aquifer. Three extraction wells (PW5, PW6, and PW7) were also installed to depths of 39 to 40 ft bgs.

## 2.2 Remedial Investigation/Feasibility Study

A focused Remedial Investigation/Feasibility Study (RI/FS) for groundwater at the Wyckoff Site was conducted in 1994. The purpose of the focused RI/FS was to provide information for interim actions while the full RI/FS for the Soil and Groundwater OUs was being conducted. The focused RI/FS assessed the risks posed by contaminants present in the groundwater to human health and the environment, the integrity of water supply wells located within the FPA, and the condition of the existing groundwater extraction and treatment systems.

Five additional monitoring wells were installed in the FPA in 1994, two in the upper aquifer (CW03 and CW04) and three in the lower aquifer (CW01, CW02, and CW05). Water-level measurements and groundwater samples were collected from these wells and from 29 previously installed monitoring, observation, and extraction wells. The samples were analyzed for volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, and polychlorinated biphenyls (PCBs). In addition, a sample of dense NAPL (DNAPL) was collected from one well (CW05) and analyzed for physical properties.

The information and data obtained from the focused RI/FS and the Supplemental RI (see below) were incorporated into the *Remedial Investigation Report for the Wyckoff Soil and Groundwater Operable Units* (CH2M HILL, June 1997).

## 2.3 Supplemental Remedial Investigation

Additional well installation and groundwater sampling were conducted as part of the 1995 Supplemental RI. Nine new monitoring wells were installed. Six wells were completed in the upper aquifer: three to monitor LNAPL (CW07, CW08, and CW13) and three to monitor DNAPL (CW06, CW10, and CW14). Three wells were completed in the lower aquifer (CW09, CW12, and CW15) to evaluate the interconnection between the lower and upper aquifers and to monitor water quality in the lower aquifer. The new wells, as well as 10 existing wells, were sampled as part of the investigation. The groundwater samples were analyzed for PAHs, polychlorinated phenols, VOCs, base/neutral and acid extractables (BNAs), pesticides, and PCBs.

## 2.4 NAPL Field Exploration

In 1999, USACE conducted an intensive field investigation in the FPA to more clearly define the extent of NAPL in the subsurface and to characterize the continuity and topography of the upper aquitard. The investigation focused primarily on soil conditions above and below the water table. As part of the investigation, however, two monitoring wells (99CD-MW02 and 99CD-MW04) were installed in the lower portion of the aquitard where sand lenses and DNAPL had been observed.

## 2.5 Pilot Study Baseline Investigation

In 2002, USACE conducted a baseline investigation of groundwater conditions in the vicinity of the thermal treatment pilot study area in the central portion of the FPA.

Groundwater samples were obtained from seven extraction wells (E-01 through E-07, five lower-aquifer monitoring wells (99CD-MW02, 99CD-MW04, CW05, CW09, and CW15), and three upper-aquifer monitoring wells (MW17, MW18, and MW19). The samples were analyzed for PAHs and PCP.

## 2.6 Groundwater Monitoring

Groundwater monitoring to demonstrate hydraulic containment and monitor changes in contaminant levels in the upper and lower aquifers was initiated in 2004. The current hydraulic containment monitoring program involves continuous water-level monitoring using data loggers installed in 17 upper-aquifer wells and eight lower-aquifer wells. Contaminant concentrations in the upper and lower aquifers are monitored on a semi-annual basis, and the most recent sampling events were conducted in January and September 2006. The current sampling program includes the following wells and piezometers: CW01, CW02, CW05, CW09, CW12, CW15, PZ-03, PZ-07, PZ-08, PZ-09, PZ-10, PZ-11, PZ-12, MW19, MW21, 02CD-MW01, 99CD-MW02, and 99CD-MW04. The groundwater samples are analyzed for BNAs, PAHs, PCP, and total petroleum hydrocarbons (TPH).

# 3.0 Hydrogeology

The hydrogeology of the Bainbridge Island area and the Wyckoff Site has been well documented. This section describes the regional hydrogeology and the site hydrogeology in detail.

## 3.1 Regional Hydrogeology

The regional hydrostratigraphic units, groundwater flow directions, and existing water supply wells in the vicinity of the Wyckoff Site are described in this section.

<u>Primary References:</u> *City of Bainbridge Island Level II Assessment--An Element of the Water Resource Study* (Kato & Warren and Robinson & Nobel [Kato & Warren], December 2000); *Preliminary Evaluation of Hydrogeologic Conditions Beneath Eagle Harbor* (CH2M HILL, November 2006).

### 3.1.1 Hydrostratigraphic Units

The subsurface beneath Eagle Harbor is divided by Kato & Warren into six major hydrostratigraphic units based principally on their hydrologic characteristics. The six major hydrostratigraphic units are:

1. Vashon Till Confining Unit (Qvt)
2. Upper Confining Unit (C1)
3. Lower Confining Unit (C2)
4. Semi-Perched Aquifer System (SPA)
5. Sea Level Aquifer System (SLA)
6. Confining Unit C3

The Kato & Warren descriptions of these six units (lightly edited and augmented for clarity) are presented below from youngest to oldest. Because the upper aquifer beneath the Wyckoff Site, the primary target aquifer for remediation at the site, is not a regional feature and is limited to the area immediately around the site it is not described by Kato & Warren. The aquitard underlying the upper aquifer at the Wyckoff Site correlates with the Qvt, C1, and C2 Confining Units described below. The lower aquifer beneath the FPA correlates with the SLA.

Figure 3-1 is a schematic geologic cross-section from Blakely Harbor to the south to Murden Cove to the north, showing the relationships among the six hydrostratigraphic units.

Note: The Kato & Warren descriptions of the geologic units do not exactly match those previously developed and currently used specifically for the Wyckoff Site; however, they present a consistent regional conceptual model that is useful for this evaluation.

### Vashon Till Confining Unit (Qvt)

Vashon Till is the predominant surficial deposit on the island and forms an aquitard below the Vashon recessional outwash. Typically it is a gray, dense layer, composed of clay through boulder-sized detritus. It is usually unsaturated but may contain small perched zones within isolated pockets of more permeable material.

This unit covers approximately 21 square miles, or 75 percent of Bainbridge Island's land surface. The unit's thickness varies from approximately 10 to 150 feet across the island in no discernible pattern, with an average thickness of approximately 50 feet. Despite its relatively low permeability, leakage through the unit to the lower aquifer does occur. Principal recharge to the lower-aquifer systems is likely accommodated in areas where the till is thin or absent. Based on the characteristics of the till, the hydraulic conductivity (permeability) is highly variable and is estimated to range from $10^{-6}$ to 10 ft/day.

### Upper Confining Unit (C1) and Lower Confining Unit (C2)

Underlying the Vashon Till in the vicinity of the Wyckoff Site is a sequence of less permeable strata that are collectively defined as the Upper and Lower Confining Units (C1 and C2). The C1 unit is usually found as a till or silt-rich sand deposits in the area. Isolated peat zones are also occasionally present within this unit. The Upper Confining Unit is continuous across most Bainbridge Island and ranges in thickness from 10 to 150 feet, with an average thickness of approximately 50 feet similar to the Vashon Till. The materials present within this unit have low hydraulic conductivity, with estimated values ranging from $10^{-1}$ to $10^{-7}$ ft/day.

Below the C1 unit, material with relatively low permeability is designated as the Lower Confining Unit (C2). This unit is composed of alternating layers of silts, clays, and clay-rich sands. This unit also contains discontinuous sections of till, which usually occur in the upper portion of the unit, and interspersed layers containing wood and pumice. In areas where the SPA does not occur, the Upper and Lower Confining Units are unconformably in contact with one another. The Lower Confining Unit is laterally continuous across the island with thicknesses ranging from 30 to 300 feet. Typically the thickness of this unit is approximately 100 feet. The materials present within this unit typically have a low hydraulic conductivity, with estimated values ranging from $10^{-1}$ to $10^{-7}$ ft/day.

Figure 3-1 shows that the Upper and Lower Confining Units are continuous beneath Eagle Harbor.

### Semi-Perched Aquifer System (SPA)

To the north of Eagle Harbor, the SPA, which is located between the Upper and Lower Confining Units, occurs above sea level. The thickness of the aquifer ranges from 10 to 65 feet, with an average thickness of approximately 30 feet. The SPA does not influence the hydraulic connection across Eagle Harbor, but is included here for completeness.

### Sea Level Aquifer System (SLA)

Lithologically the SLA unit is composed largely of sands and gravels, with lesser amounts of silt, clay, and clay-rich sands. The thickness of the aquifer reaches 210 feet beneath the south-central portion of the island; it has an average thickness of approximately 110 feet.

This aquifer underlies approximately 23.5 square miles, or 85 percent of island's total area. Figure 3-2 shows the lateral extent of the SLA in the vicinity of the Wyckoff Site.

#### Confining Unit C3

The first sequence of low-permeability material occurring below the SLA has been designated as Confining Unit C3. This unit is largely composed of silt and clay, with lesser amounts of sandy silt and clay. Thin, discontinuous layers of water-bearing sand and gravel also occur. Geophysical logging of wells drilled through the unit show occasional resistivity signatures, indicating some zones of moderate permeability. The lithologic sequence, together with the occasional presence of organic material, suggests that this unit is primarily of non-glacial origin. The thickness of this unit ranges from approximately 150 to 600 feet, with an average thickness of approximately 350 feet. The materials present within this unit typically have low hydraulic conductivity, with estimated values ranging from $10^{-2}$ to $10^{-7}$ ft/day.

### 3.1.2 Groundwater Flow Directions

The SLA is a confined system occurring, for the most part, below sea level. Generally, higher groundwater levels or heads occur below the inland portion of the island and decrease toward the shoreline (Figure 3-3). Correspondingly, groundwater in the SLA slowly flows from the central portion of the island outward toward the shore at a rate of just a few feet per day. Groundwater-level elevations within the SLA range from a high of 114 feet above mean sea level (MSL) near Murden Cove to approximately sea level near the shoreline.

The SLA discharges naturally through underwater springs, through upward leakage to Eagle Harbor, upward and lateral leakage to Puget Sound, and through leakage to the deeper aquifer systems. Inferred groundwater flow directions in the Eagle Harbor area are shown in Figures 3-1 and 3-3.

### 3.1.3 Existing Water Supply Wells

Figure 3-3 shows the locations of wells that have been completed in the SLA in the vicinity of the Wyckoff Site. Figure 3-4 shows the locations of Group A (15 or more connections) and Group B (14 or fewer connections) wells of record with the Washington Department of Health (DOH), regardless of the aquifer in which the wells are completed. Only two Group A wells are shown east of Madison Avenue North. The closest Group A well to the north shore of Eagle Harbor is listed by DOH as belonging to the City of Bainbridge Island. Eighteen Group B wells are shown east of Madison Avenue North; the nearest is listed by DOH as belonging to the Madrona Water District. The Group A well shown at the Wyckoff Site probably represents the abandoned supply well that has been replaced by the Taylor Avenue well located west of the site. Because the aquifer is relatively shallow and laterally continuous, approximately 53 percent of the island's domestic and purveyor wells (524 wells) have been completed in this zone. Yields from these wells range from 1 to 260 gallons per minute (gpm), with an average of 20 gpm and a median of 14 gpm. The hydraulic conductivity of the SLA in the vicinity of the Wyckoff Site is less than 10 ft/day. This indicates that the well yields would most likely be moderate.

The groundwater contours in Figure 3-3 do not show any significant pumping influence (drawdown pumping centers), thus confirming the overall moderate SLA well yields in the area and the lack of domestic water supply pumping influence extending beneath Eagle Harbor.

North of Eagle Harbor, groundwater in the SLA flows south to southeast, and south of Eagle Harbor it flows north to northeast in the direction of decreasing groundwater-level elevations. Therefore, any dissolved contaminants migrating from the Wyckoff Site cannot affect current groundwater users on the north side of Eagle Harbor, because the groundwater flowing beneath the Wyckoff Site in the SLA cannot flow in an upgradient direction and thus reach the north side of the harbor.

The majority the contaminants at the Wyckoff Site are in the upper aquifer overlying the aquitard (the Qvt, C1, and C2 units) and the SLA, and are contained within the FPA by the sheet pile wall and groundwater extraction system. Therefore, site contaminants would have to migrate from the upper aquifer through the relatively impermeable aquitard to the SLA (the lower aquifer) before migrating horizontally.

If a high-capacity water supply well was in the future installed in the SLA near the Eagle Harbor shoreline, it is possible that the groundwater flow pattern could be altered to induce groundwater from beneath the Wyckoff Site to flow to the well. However, this well would most likely significantly lower the water levels and yields of other local SLA wells, and would also most likely induce saltwater intrusion before any contamination from the Wyckoff Site could be drawn to the well.

The potential for adverse impacts to other wells and saltwater intrusion are the primary reasons that the high-capacity water supply wells in the vicinity of Eagle Harbor are completed in deep aquifers below the Confining Unit C3, not in the SLA. These wells include the water supply well located at the Wyckoff Site, the City of Bainbridge Island well located at the end of Taylor Avenue, and the well at the Wing Point Golf & Country Club. The very thick Confining Unit C3 above the aquifers tapped by these wells greatly reduces the possibility of induced saltwater intrusion or pumping effects from influencing the groundwater flow patterns in the SLA, and thus inducing contaminants to migrate from the Wyckoff Site.

## 3.2 Site Hydrogeology

This section describes the hydrogeologic units, groundwater flow directions, hydraulic interconnection between aquifers, and groundwater salinity at the Wyckoff Site. As summarized in Section 2.0, numerous subsurface investigations and studies have been conducted at the site including the installation of many borings, monitoring wells, extraction wells, piezometers, and push probes/cone penetrometers. Currently there are approximately 70 wells at the site that can be used for monitoring; these are shown in Figure 3-5 and listed with their installation details in Table 3-1.

Three hydrogeologic units underlie the Wyckoff Site: the upper (unconfined) aquifer, a silt/clay aquitard, and the lower (confined to semi-confined) aquifer. These units are described in Section 3.2.1. Schematic cross-sections showing the relationships among the units and groundwater flow are shown in Figures 3-6 through 3-10. Figure 3-6 shows a site plan including the locations of the schematic cross-sections. Figures 3-7 and 3-8 show the original groundwater conditions at the site, and Figures 3-9 and 3-10 show the current conditions.

Primary References: *Groundwater Extraction System Assessment, Report 1* (CH2M HILL, August 1996); *Remedial Investigation Report for the Wyckoff Soil and Groundwater Operable Units* (CH2M HILL, June 1997); *Comprehensive Report, Wyckoff NAPL Field Exploration* (USACE, May 2000); *Geotechnical Data Report, Borings and Piezometer Installation--Upgradient Cut-off Wall, Wyckoff/Eagle Harbor Superfund Site* (CH2M HILL, September 2004a); *Evaluation of Groundwater Level Data* (various Technical Memoranda, CH2M HILL, September 2004b through December 2006); *Engineering Evaluation of Groundwater and Soil Remediation Scenarios, Wyckoff Soil and Groundwater Operable Units* (CH2M HILL, November 2005); *Thermal Remediation Pilot Study Summary Report* (USACE, October 2006).

## 3.2.1 Hydrogeologic Units

The USACE (May 2000) and CH2M HILL (September 2004a) reports present detailed cross-sections showing the relationships among and within the three hydrogeologic units at the Wyckoff Site. To supplement the following discussion, cross-section plates and figures from these two reports are presented here as Figures 3-11 through 3-19 (USACE, May 2000) and Figures 3-20 and 3-21 (CH2M HILL, September 2004a). Figures 3-22 and 3-23 (USACE, May 2000) show the thickness of the marine silt and the topography of the top of the glacial portion of the aquitard, respectively. Figures 3-24 through 3-26 are new cross-sections developed for this Groundwater CSM Update Report that tie the USACE and CH2M HILL cross-sections together.

### Upper Aquifer

The upper aquifer consists of fill and a marine sand and gravel unit. It is essentially an isolated sand and gravel “spit” at the southern entrance to Eagle Harbor. The upper aquifer is unconfined, with groundwater levels of approximately 5 to 10 feet bgs. Tidal influence within the upper aquifer has historically ranged in magnitude from 1 to 10 feet, with the highest tidally induced changes near the shoreline. Since the installation of the perimeter sheet-pile wall in 2001, tidal influence has been diminished, and most upper-aquifer wells now show a tidal influence ranging from 0.1 to 4 feet.

### Aquitard

A relatively impermeable aquitard separates the upper aquifer from the lower (confined to semi-confined) aquifer. The aquitard is composed of marine silt, glacial deposits, and non-marine clay. The top of the aquitard extends from near ground surface in the south-central portion of the Wyckoff Site to approximately 75 feet bgs along the northern portion of the site. Based on numerous field explorations conducted during the RI for the Wyckoff Soil and Groundwater OUs (CH2M HILL, June 1997) and various USACE exploratory drilling events (USACE, January 1998, April 1998, May 2000, and October 2006), the aquitard appears continuous throughout most of the site. Its thickness ranges from 10 to 40 feet, with the thinnest area localized near the northeast corner of the site (at well EWC04) and in the central portion of the site (at well CW12). CH2M HILL borings installed along the south hillside in 2004 to characterize the area for a possible upgradient cutoff wall (CH2M HILL, 2004a) identified gaps in the aquitard in the southwest and southeast corners of the site upgradient of the FPA. Moreover, the last 200-foot segment of the sheet pile wall in the southeast corner of the site may not be seated in aquitard material. No aquitard material was observed in boring PZ-03, which is located about 20 feet east of the end of the sheet pile wall and completed about 10 feet below the base of the wall.

Although none of the many onsite subsurface explorations before 2004 directly identified "holes" in the aquitard, existing data indirectly support hydraulic connection between the aquifers. Some of the evidence of interconnection includes the following findings:

- Pumping one aquifer affected levels in the other (CH2M HILL, August 1996 and June 1997).
- Tidal influence was noted in upper aquifer monitoring wells after construction of the perimeter sheet pile wall (CH2M HILL, various Technical Memoranda, September 2004b through December 2006).
- Unexpected cooling occurred in a thermal treatment pilot study extraction well after the steam was turned off (USACE, October 2006).

This inferred hydraulic interconnection is discussed in more detail in Section 3.2.3.

#### Lower Aquifer

The lower aquifer is continuous across the Wyckoff Site and is strongly influenced by tides. The lower aquifer consists primarily of sand, with small amounts of silt, clay, and gravel. The lower boundary of this aquifer has not been characterized at the site. However, it is believed that this aquifer extends to approximately 200 ft bgs, based on the regional work of Kato & Warren (December 2000) and the logs recorded for two deep onsite water supply wells that were decommissioned in 1997 and for a new water supply well that was completed in January 2002.

### 3.2.2 Groundwater Flow Directions

Groundwater flow in both aquifers prior to installation of the sheet pile wall was from south to north, toward Eagle Harbor and Puget Sound. The flow was also upward from the lower aquifer to the upper aquifer as expected in a sea-level groundwater discharge zone.

Groundwater in the upper aquifer flowed from the southern portion of the Wyckoff Site north toward Eagle Harbor and Puget Sound, where it formerly discharged into the intertidal and subtidal zones. The perimeter sheet pile wall now blocks groundwater flow into Eagle Harbor, and a pump-and-treat system now extracts the excess groundwater to maintain a net hydraulic gradient into the upper aquifer.

Before construction of the perimeter sheet pile wall, NAPL discharge from the site to Eagle Harbor/Puget Sound was evident at low tide in the form of intertidal seeps. The seeps have been monitored before and since the installation of the sheet pile wall, and have decreased since the wall's installation.

Historically, subtidal discharges have been observed in Eagle Harbor, west of the FPA. This was the focus of the NAPL removal and harbor capping effort that was conducted at OU-1, the East Harbor OU.

### 3.2.3 Hydraulic Interconnection between the Upper and Lower Aquifers

To better understand the potential/inferred interconnection between the upper and lower aquifers, transducers were installed in 2004 in 17 upper-aquifer wells and seven lower-aquifer wells. The ongoing results have been presented in a series of *Evaluation of Groundwater Level Data* Technical Memoranda (CH2M HILL, September 2004b through December 2006).

The key findings of the intensive transducer water-level measurements are as follows:

- The upper aquifer is not as hydraulically isolated as presented in the original conceptual site model. Hydraulic connection is demonstrated by tidal fluctuations in the upper aquifer, similar upper- and lower-aquifer tidal lag times, and the rapid and widespread upper-aquifer water-level response to shutting down the extraction/treatment system. The water-table fluctuations indicate mass movement of water, rather than a pressure phenomenon as seen in the lower confined aquifer. Because most of the wells are located more than 50 feet from the sheet pile wall, it is unlikely that gaps in the wall (e.g., construction joints) explain the fluctuations.
- Hydraulic containment at the site has been monitored and maintained since May 2004. Hydraulic containment is defined at the Wyckoff Site as when the average vertical groundwater gradient is upward over a calendar quarter as measured in all upper/lower aquifer well pairs. (Current well pairs include MW14/CW05, MW18/02CD-MW01, PO03/99CD-MW02, and CW03/CW02.) This means that on average, the water levels in the lower aquifer are greater than those in the upper aquifer, demonstrating a net inward and upward groundwater flow potential into the upper aquifer.

### 3.2.4 Groundwater Salinity

Class II and Class III groundwater are present at the Wyckoff Site. Class III groundwater occurs where saltwater intrusion raises TDS concentrations above 10,000 milligrams per liter (mg/L). Class II groundwater occurs where TDS concentrations are below 10,000 mg/L. Class III groundwater occurs in the upper aquifer within the FPA. Groundwater in the lower aquifer generally meets the requirements for Class II groundwater.

Field specific conductivity and salinity measurements were collected during water quality sampling by SCS in September 2004 and by CH2M HILL in January 2006 and September 2006. The data for the lower-aquifer wells are summarized in Table 3-2. TDS concentrations were estimated by multiplying specific conductivity by a rule-of-thumb factor. This factor can vary from 500 to 900 depending on the ionic components in the water sample. A factor of 600 is commonly used and was therefore used for this evaluation.

Wells CW02, CW05, CW09, CW15, and PZ-03 (in January 2006 only) all likely exceeded the state and federal secondary drinking standard for TDS of 500 mg/L. Well CW05 exceeded the Class III criterion of >10,000 mg/L during the September 2006 sampling.

# 4.0 Nature and Extent of Contamination

As described in Section 2.0 and 3.0, the Wyckoff Site has been extensively investigated over time. This section describes the nature and extent of NAPL and associated soil and groundwater contamination in the FPA at the Wyckoff Site.

Primary References: *Comprehensive Report, Wyckoff NAPL Field Exploration* (USACE, May 2000); *Record of Decision for the Wyckoff Soil and Groundwater Operable Units* (USEPA, February 2000). The historical groundwater data presented in these documents is augmented by data from the *Thermal Remediation Pilot Study Summary Report* (USACE, October 2006) and the *September 2006 Groundwater Sampling Results for Wyckoff/Eagle Harbor Superfund Site Report* (CH2M HILL, February 2007).

The distribution of contaminants in soil and groundwater at the Wyckoff Site is related to the types of chemicals released at the site (i.e., creosote, PCP, and aromatic carrier oils as NAPL) and to the geology and hydrogeology underlying the site. The primary sources of contamination were the daily operation of the wood treatment facility, including leaks, spills, and other releases of wood-treating chemicals into the ground, and the storage of wood treatment products. The conceptual model for contaminant migration at the site is summarized below:

- As the spills and leaks occurred, the contaminants moved as mobile NAPL into the vadose zone, adsorbing onto soil, volatilizing into soil gas, and dissolving into pore water.
- The mobile NAPL migrated downward through the vadose zone until it reached the water table and separated into light and dense phases:
  - The LNAPL spread out along the water table surface and migrated laterally with the groundwater.
  - Downward migration of DNAPL was slowed or halted as it encountered higher-density brackish groundwater and lower-permeability zones within the upper aquifer. Some DNAPL continued migrating downward until it reached the aquitard.
  - Lateral movement of DNAPL has occurred through high-permeability gravel and cobble zones, or through spreading when the DNAPL reached low-permeability zones within the upper aquifer or at the top of the aquitard.
  - NAPL underwent dissolution as it encountered groundwater in the upper aquifer, resulting in dissolved contamination. The aqueous-phase contaminants were then transported with the groundwater flow, laterally toward Eagle Harbor.

Potential mechanisms for transport of contaminants into the lower aquifer include:

- Leakage of DNAPL or dissolved contaminants through "holes" and sand zones in the aquitard. Downward advective transport of dissolved contaminants through the aquitard is considered unlikely under natural conditions or containment pumping, because the hydraulic head is higher in the lower aquifer than in the upper aquifer creating a net upward flow potential.

- Transport of DNAPL across the aquitard by water displacement/"wicking" mechanisms.
- Leakage of DNAPL or dissolved contamination as a result of early drilling activities on the site, which may have provided conduits through the aquitard. In 1995, USEPA decommissioned 12 old wells. These were industrial water supply wells, monitoring wells, groundwater/contaminant extraction wells, and two deep drinking water supply wells.
- Transport of dissolved contaminants by molecular diffusion across the aquitard from DNAPL on top of the aquitard.

Any dissolved contaminants reaching the lower aquifer would be carried by regional groundwater flow toward discharge areas deep in Eagle Harbor and Puget Sound. However, due to the long transport distances involved, it is likely that any contaminants reaching the lower aquifer would likely be removed by sorption and decay before discharge to the surface waters.

## 4.1 NAPL Characterization and Distribution

The NAPL present in the FPA consists of a mixture of creosote, PCP, and/or aromatic carrier oils. Creosote was used by itself in the early years of facility operations. Later, it was mixed with aromatic carrier oils to obtain deeper penetration of the preservative in the wood. Depending on the mixture of creosote, PCP, and carrier oils, the NAPL can behave as either an LNAPL or a DNAPL. Data from the RI (CH2M HILL, June 1997) and subsequent investigations by USACE (May 2000) indicate that there are approximately 1 million gallons of NAPL in the upper aquifer of the FPA.

Chemicals detected in NAPL at the Wyckoff Site are consistent with the products historically used onsite. Samples of LNAPL and DNAPL collected at the site generally contain varying concentrations of PAHs, PCP, and other VOCs and SVOCs, as listed in Tables 4-1 and 4-2.

### 4.1.1 LNAPL Distribution

Based on the USACE NAPL field exploration (USACE, May 2000), LNAPL is distributed in the upper aquifer over the center and most of the eastern portion of the site (Figure 4-1). The thickest accumulation of LNAPL is in the vicinity of the former tram loading area, on the south side of the transfer pit, where up to 10 feet of LNAPL was reported during the USACE NAPL field exploration. The LNAPL layer generally thins to the north and the east.

The accumulation of LNAPL is likely the result of dripping logs that were removed from the retorts at the Wyckoff Site as well as discharge from the retorts. Significant thicknesses of LNAPL occur at other locations across the eastern portion of the site and may be associated with historical contaminant release episodes.

The LNAPL extends to the current sheet pile wall and historically discharged onto the east and north shorelines. In 1999 and 2000, the sheet pile wall was installed between the FPA and the shoreline to prevent further migration and discharge of LNAPL from the Wyckoff Site. By design, the sheet pile wall did not encompass all of the contaminated upper-aquifer/intertidal sediments. Residual contamination outside the sheet pile wall was expected to naturally attenuate. Residual contaminant seepage outside the sheet pile wall along the shoreline is limited to a small portion of the East Beach.

### 4.1.2 DNAPL Distribution

DNAPL is present in the upper aquifer beneath most of the FPA (Figure 4-2). As with LNAPL, the thickest accumulation of DNAPL (14 feet total within the full thickness of the upper aquifer) occurs in the vicinity of the former tram loading area, and the accumulation of DNAPL is likely the result of dripping logs that were removed from the retorts as well as discharge from the retorts. Significant occurrences of DNAPL are also found along the northwest shoreline and along the eastern edge of the facility, and may be related to localized sources and/or the migration of DNAPL along the more permeable gravel zones within the marine sand and gravel unit.

Some of the DNAPL is in the upper aquifer at various depths and some has migrated downward through the upper aquifer until it encounters the relatively low-permeability aquitard. The aquitard dips (slopes) toward the north and east. The DNAPL builds up above the aquitard, forming accumulations in depressions in the aquitard surface, and generally migrating down-dip along the aquitard surface toward Eagle Harbor. Further lateral migration of DNAPL toward Eagle Harbor was mitigated by the installation of the sheet pile wall in 1999 and 2000.

DNAPL has been observed within the aquitard in several borings located in the central portion of the site (near well CW12). It is not apparent how the DNAPL may have entered and migrated into the aquitard. However, borings show that the aquitard in this area contains very thin sand lenses (less than ¼-inch thick) and sand-filled fractures, which may have acted as conduits for DNAPL migration. Based on data collected to date, NAPL has not been identified in the lower aquifer.

## 4.2 Soil Contamination

During the RI, site soils were differentiated into near-surface soil (0 to 4 ft bgs) and subsurface vadose zone soil (soil between 4 ft bgs and the maximum elevation of the water table, typically 5 to 10 ft bgs). These conventions are used in the following discussion, which has been excerpted from the RI Report (CH2M HILL, June 1997); however, it is important to note that the original ground surface over large portions of the FPA is now covered by several feet of recent fill. Consequently, the contaminant levels reported for near-surface soil in the following discussion do not reflect current near-surface conditions.

The chemicals detected in near-surface soil included PAHs, PCP, and dioxins and furans, as listed in Table 4-3. The highest concentrations of contaminants of concern (COCs) in soil were found in the FPA, where average concentrations of several PAHs exceeded 20 milligrams per kilogram (mg/kg). Near-surface soil contamination extended throughout the FPA.

The chemicals detected in subsurface soil included PAHs, PCP, dioxins and furans, and carbozole, as listed in Table 4-4. As with near-surface soil, the average concentrations of several PAHs in the subsurface soils exceeded 20mg/kg. The samples with the highest PAH concentrations tended to coincide with areas where NAPL had been observed.

## 4.3 Groundwater Contamination

High concentrations of dissolved-phase groundwater contaminants at the Wyckoff Site occur in the upper (unconfined) aquifer, and low to trace concentrations occur in the lower (confined to semi-confined) aquifer. The chemicals detected in groundwater samples obtained from wells screened in the upper aquifer during the RI and Supplemental RI field investigations included PAHs, PCP, VOCs, and BNAs, as listed in Table 4-5. Naphthalene was the primary groundwater contaminant, followed by fluoranthene, fluorene, PCP, and bis(2-ethylhexyl)phthalate. The chemicals detected in groundwater samples obtained from wells screened in the lower aquifer during the RI and Supplemental RI field investigations included PAHs, PCP, carbon tetrachloride, and several BNAs, as listed in Table 4-6. However, the concentrations reported in the lower-aquifer wells were approximately two to three orders of magnitude lower than the concentrations in the upper aquifer wells.

USACE conducted a baseline investigation of upper- and lower-aquifer groundwater conditions in the vicinity of the thermal treatment pilot study area in the central portion of the FPA immediately after the pilot test was initiated in early November 2002. Because the thermal treatment pilot study had begun (i.e., steam was being added to the upper aquifer), the results from this baseline investigation may not have been representative of site conditions. As noted in Section 2.5, groundwater samples were obtained from seven extraction wells (E-01 through E-07), five lower-aquifer monitoring wells (99CD-MW02, 99CD-MW04, CW05, CW09, and CW15), and three upper-aquifer monitoring wells (MW17, MW18, and MW19). Elevated concentrations of PAHs, PCP, and other constituents were detected in the extraction well samples (Table 4-7). Among PAHs, naphthalene was present at the highest concentration. PAHs were also detected at high concentrations in the upper-aquifer wells (Table 4-8) and at low to trace concentrations in the lower-aquifer wells (Table 4-9).

Groundwater samples have been collected periodically from wells located within the FPA. The primary objective of these sampling events has been to monitor groundwater conditions in the lower aquifer. The most recent groundwater sampling event occurred in September 2006, when samples from four upper-aquifer wells and 16 lower-aquifer wells were analyzed for PAHs, PCP, TPH, and SVOCs. The analytical data for these samples, as well as for samples collected previously at the Wyckoff Site, were compiled in a report (CH2M HILL, February 2007). The report included a comparison of the 2006 analytical data to data collected previously at the site and concluded that, for the most part, the upper- and lower-aquifer results for 2006 did not differ significantly from the 2004 results (Tables 4-10 and 4-11). However, concentrations of PAHs in three lower-aquifer wells (CW15, CW09, and PZ-09) changed between 2004 and 2006:

- PAH concentrations in well CW15 increased between January and September 2006.
- Concentrations of PAHs in well CW09 declined between January and September 2006.

- PAH concentrations in piezometer PZ-09 increased between January and September 2006.

These trends in PAH levels will be monitored over future events, and the installation of additional lower-aquifer wells is planned to further evaluate conditions in the lower aquifer (see Section 6.0).

# 5.0 Summary of 2000 ROD Contingency Remedy

The Contingency Remedy identified in the 2000 ROD is Alternative 2b (containment with a sheet pile wall and a new pump and treat system).

The groundwater containment remedy currently anticipated for the FPA consists of the following elements: (1) facilities for extracting groundwater from the FPA and treating the removed water; (2) reducing the volume of groundwater and surface water flow into the FPA, thereby reducing the potential movement of LNAPL, DNAPL, and dissolved contaminants; (3) improving shoreline stabilization; and (4) long-term monitoring of upper- and lower-aquifer groundwater.

Long-term monitoring of the groundwater would include the ongoing measurement of upper- and lower-aquifer water levels to verify the net hydraulic gradient into the containment area; lower-aquifer water quality sampling and analysis to monitor potential contaminant movement into the lower aquifer; and upper-aquifer sampling and analysis at the boundary of the FPA with the surface water.

Primary Reference: *Engineering Evaluation of Groundwater and Soil Remediation Scenarios, Wyckoff Solid and Groundwater Operable Units* (CH2M HILL, November 2005)

## 5.1 Groundwater Contaminant Exposure Pathways

The groundwater containment remedy at the Wyckoff Site would address the four primary groundwater contaminant exposure pathways shown in Figure 5-1:

- From the upper aquifer through the sheet pile wall above the mudline directly into surface water
- From the upper aquifer through the sheet pile wall below the mudline into the upper aquifer and into surface water
- From the upper aquifer under the sheet pile wall into the aquitard/upper aquifer and into surface water
- From the upper aquifer through the aquitard into the lower aquifer and into surface water

## 5.2 Groundwater Containment Remedy Components

As discussed in the *Engineering Evaluation* (CH2M HILL, November 2005), the groundwater containment remedy would consist of the following components:

- **Site Cap.** This cap would reduce the amount of precipitation recharge entering the FPA that needs to be treated and to prevent direct contact with contaminated soil.

- **Shoreline Stabilization System**. This system would protect the existing sheet pile wall that is exposed above the mudline and would mitigate lateral contaminant movement from the FPA.
- **Optimized Upper-Aquifer Groundwater Extraction Well System**. The numbers, locations, and extraction rates of this system would be based on the results of the ongoing groundwater monitoring work to enhance the groundwater containment criteria of net average upward and inward gradients, and thus maintain a net inward groundwater flow potential.
- **Monitoring Enhanced Containment System Effectiveness**. Additional monitoring wells would be installed in the upper and lower aquifers to complete and enhance the water-level coverage inside the sheet pile wall and to determine compliance with RAOs (see Section 6.0).
- **Upgradient Groundwater Cutoff Wall (optional)**. This hydraulic cutoff wall may be needed to reduce the amount of groundwater entering the FPA. The upgradient cutoff wall would tie into the existing perimeter sheet pile wall, thus completing the lateral flow containment structure.

## 5.3 Protection of Human Health

Any final remedy implemented at the Wyckoff Site will need to be protective of human health and the environment. The groundwater containment remedy would be protective of human health because there are no human groundwater receptors downgradient of the FPA in either the upper or the lower aquifer. As discussed in Section 3.1, the upper aquifer:

- Is limited in areal extent.
- Is not used as a drinking water source.
- If the portion of the upper aquifer outside the FPA were used in the future, it would likely be or quickly become saline because of the direct connection with Eagle Harbor/Puget Sound.

In addition, as discussed in previous sections of this report, it has been demonstrated that:

- Groundwater on the south side of Eagle Harbor at the Wyckoff Site generally flows northward and discharges to Eagle Harbor/Puget Sound.
- Groundwater on the north side of Eagle Harbor generally flows southward and discharges to Eagle Harbor/Puget Sound.
- No wells exist downgradient of the Wyckoff Site (i.e., in Eagle Harbor/Puget Sound).
- Cross- or upgradient wells installed in the future and pumping sufficient groundwater to reverse the hydraulic gradient would likely become saline.
- Low-yield wells located cross- or upgradient would obtain groundwater from upgradient sources to the Wyckoff Site.

## 5.4 Protection of the Environment

The groundwater containment remedy would be protective of the environment. Monitoring would be a key component of the remedy to confirm continued protectiveness (CH2M HILL, November 2005):

- Lower-aquifer monitoring at the sheet pile wall would offer “early warning” for contaminants that potentially might migrate through the aquitard into the lower aquifer many years or decades before potentially reaching a receptor in Eagle Harbor or Puget Sound sediment.
- Surface water monitoring at the surface of the proposed sheet pile wall protection and attenuation layer would provide data to evaluate potential impacts to the marine environment.
- Vertical hydraulic gradient containment monitoring would provide data to evaluate the potential for dissolved contaminants to enter the lower aquifer and to some degree the potential for DNAPL to migrate through the aquitard.

# 6.0 Contingency Remedy Design Data and Monitoring System

To implement the groundwater containment remedy at the Wyckoff Site, additional subsurface data would need to be obtained.

Additional onsite drilling work would be required as described in the *Engineering Evaluation of Groundwater and Soil Remediation Scenarios, Wyckoff Soil and Groundwater Operable Units* (CH2M HILL, November 2005). The work can be broken into two components: (1) collection of additional groundwater containment remedy design data, and (2) installation and sampling of additional wells to complete the configuration of a long-term groundwater monitoring system for the Wyckoff Site.

The additional groundwater containment remedy design data would focus on further characterization of the area south and east of the treatment plant at the Wyckoff Site to evaluate the effectiveness of the existing sheet pile wall in hydraulically isolating the site, given that the aquitard has been shown to be missing in the southeast corner of the site (CH2M HILL, September 2004a).

Additional groundwater monitoring wells to complete the monitoring network for the containment remedy at the Wyckoff Site would consist of:

- Lower-aquifer wells to monitor the potential offsite migration of lower-aquifer groundwater at the sheet pile wall.
- Additional vertical hydraulic containment well pairs to supplement and enhance the areal coverage of the current four well pairs. The lower-aquifer well of each well pair would also serve as an additional "early warning" water quality monitoring location.

## 6.1 Proposed Locations and Priorities

Figure 6-1 shows the proposed boring and well locations for the Contingency Remedy and the proposed installation priority/rank for each individual boring and well. The proposed priorities and rationale are as follows:

- The highest priority would be assigned to the southeast borings (to be converted to monitoring wells if warranted), which would be used to:
  - Reduce the uncertainty of the location and depth of the aquitard affecting the containment effectiveness of the sheet pile wall and the hydraulic containment pumping system.
  - Evaluate groundwater quality and flow paths in the area.
  - Evaluate the presence of NAPL in the area.
  - Assess the need for extending/realigning the sheet pile wall in the area.

- The lower-aquifer perimeter wells would have the next highest priorities. These wells would be used to:
  - Determine whether there is contamination in the lower aquifer at the sheet pile wall.
  - Start the collection of baseline water quality data.
- The next highest priorities would be assigned to the lower-aquifer wells associated with the vertical gradient well pairs, followed by the upper-aquifer wells associated with the well pairs. Lower-aquifer wells 7 and 8 would complete well pairs and thus be assigned higher priority. These wells would be used to:
  - Complete the vertical hydraulic containment component of the monitoring network.
  - Better define the hydraulic interconnection between the upper and lower aquifers.
- The lowest installation priorities are assigned to two perimeter lower-aquifer wells that are optional.

# 7.0 Source Documents and References


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