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A Report Prepared for:

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FINAL
FOCUSED REMEDIAL INVESTIGATION SUMMARY/FEASIBILITY STUDY REPORT

BSB PROPERTY
KENT, WASHINGTON

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1.0 INTRODUCTION

1.1 Purpose

B.S.B. Diversified Company, Inc. (BSB) has prepared this Focused Remedial Investigation Summary/ Feasibility Study Report (FRI/FS) to document the development and evaluation of cleanup action alternatives (CAA) to address contamination present on BSB's property in Kent, Washington (the site) in compliance with BSB's Agreed Order No. DE-2551XXXX (*complete number yet to be assigned by Ecology)* (BSB AO). The FRI/FS was prepared consistent with the FRI/FS scope of work (PES, 2004) contained in Exhibit B of the BSB AO and the Model Toxics Control Act (MTCA, WAC 173-340) and is designed to provide the necessary documentation so that the Washington State Department of Ecology (Ecology) can select the most appropriate CAA. This FRI/FS is being conducted in parallel with Hexcel Corporation's RI/FS for contamination present on their property in accordance with Hexcel's Enforcement Order No. DE-2552YYYY (*complete number yet to be assigned by Ecology)* (Hexcel EO). Potential migration of contamination downgradient of the Hexcel property is being addressed under Agreed Order No. DE-2553ZZZZ (*complete number yet to be assigned by Ecology)* entered into by Hexcel and BSB (Offsite AO).

As described in more detail in the following sections, a metal finishing and electroplating plant operated at the location of the current BSB and Hexcel Corporation (Hexcel) facilities from the mid-1950s until 1985. Beginning in the early 1980s, waste management activities and associated releases of hazardous substances were investigated and cleanup actions initiated under the Resource Conservation and Recovery Act (RCRA). These initial RCRA cleanup actions included the excavation and/or stabilization of the metal plating sludges and soils associated with the waste management lagoons, as well as excavation of soils in a former drum handling area that were contaminated with volatile organic compounds (VOCs). These initial cleanup actions addressed the metal-related waste and contamination, as well as the primary VOC source area in unsaturated soil.

The remaining primary environmental concern at the site, which has been the focus of cleanup actions since the early 1990s, is VOCs in groundwater. Therefore, while the RI portion of this document includes detailed descriptions of all of the previous investigations and historical cleanup actions, the primary objective of the focused FS (FFS) portion of this document is development of CAAs for VOCs in groundwater.

1.2 Report Organization

Section 1 – Introduction: Describes the background, purpose, and organization of this report.

Section 2 – Site Background: Provides a summary of the site location and history.

Section 3 – Environmental Setting: Summarizes the environmental background of the site, including climate, hydrology, geology, and area water wells.

Section 4 – Site Investigations: Describes the subsurface explorations, hydraulic and chemical testing, groundwater monitoring, and surveying conducted at the site.

Section 5 – Previous and Ongoing Cleanup Actions: Summarizes the RCRA closure and post-closure activities and groundwater remediation.

Section 6 – Investigation Results: Describes the site geology, groundwater flow, and nature and extent of contamination.

Section 7 – Conceptual Site Model: Provides a summary of the indicator hazardous substances, contaminant sources, chemical fate and transport, exposure pathways and receptors, and cleanup standards for the site.

Section 8 – Feasibility Study Scoping: Summarizes the regulatory requirements and develops cleanup action objectives.

Section 9 – Identification and Screening of Remedial Technologies: Identifies potential cleanup technologies and screens the technologies to determine those most likely to be effective at the site.

Section 10 – Development of Cleanup Action Alternatives: Assembles the retained technologies into a range of preliminary CAAs.

Section 11 – Evaluation of Cleanup Action Alternatives: Evaluates the CAAs against the criteria defined in WAC 173-340-360.

Section 12 – Comparative Evaluation and Recommended Cleanup Action: Compares the alternatives to each other and recommends a CAA, provides the rationale for the recommendation, and discusses the implementation of the preferred CAA.

Section 13 – References: Lists the sources of information referenced in the document.

2.0 SITE BACKGROUND

2.1 Site Location and Description

The BSB property (also referred to as the site or Parcel G) is located at 8202 South 200th Street in Kent, Washington (Figure 1). The site is located in Township 22 North, Range 4 East, Section 1H at a latitude of 47 degrees 25’ 22” North and a longitude of 122 degrees 13’ 51” West. The 4.2-acre site is currently a fenced, vacant lot that slopes gently to the north. The area surrounding the site is topographically flat and is zoned “Limited Industrial.” The site is bounded on the north by South 200th Street and the Hexcel industrial facility. Commercial and industrial park properties are located to the west and south of the site, and the Carr industrial facility is immediately to the east of the site.

2.2 Site History and Development

2.2.1 Site History

The Hytek Finishes Company (Hytek), a division of Criton Technologies, operated a metal finishing and electroplating plant at 8202 South 200th Street (now part of the Hexcel Facility). Criton Technologies also had an adjacent composite products manufacturing division named Heath Tecna Aerospace Company at 19819 84th Avenue South. The Hytek division ceased treatment, storage, and disposal (TSD) operations regulated under RCRA in 1985. In 1987, BSB obtained both the Hytek and Heath Tecna Aerospace divisions, including real property described as Parcels A through G (Figure 2). In 1988, BSB sold the Heath Tecna Aerospace division and Parcels A through F to the Phoenix Washington Corporation, a wholly owned subsidiary of Ciba-Geigy. The Phoenix Washington Corporation subsequently changed its name to Heath Tecna Aerospace Company. BSB relocated Hytek's operations off-site and sold the division in 1989, retaining ownership of Parcel G. By mid 1996, Hexcel had acquired Heath Tecna Aerospace Company, including Parcels A through F, and had assumed all obligations of Heath Tecna regarding Parcels A through F. Parcel F, located adjacent to Parcel G to the east, was sold by Hexcel in August 2003 to Carr Prop II, LLC.

2.2.2 Parcel G Waste Treatment Operations

A variety of industrial and hazardous wastes that were generated on Parcels A through E were formerly treated and stored in a waste treatment area located on Parcel G (Figure 3). The wastewater treated contained metals and inorganics. The waste treatment area was located in the northeast and southern portions of Parcel G; a parking lot was located in the northwest portion of the parcel. The waste treatment area was equipped to treat large volumes of dilute wastewater as well as highly concentrated plating baths. The processes that were available included reduction/oxidation of chromium, cyanide, and nickel; neutralization of acids; precipitation of heavy metals; and dewatering of metal hydroxide sludges. Waste handling reportedly occurred on Parcel G between the mid 1950s, when electroplating operations were begun on the property north of South 200th Street, and 1985, when Hytek TSD activities ceased. Following is a brief discussion of the former waste handling and treatment components and practices that occurred on Parcel G:

- Wastewater generated on Parcels A through E was transferred to Parcel G through pipes under South 200th Street (Hytek, 1985a). The pipe run entered the northeast corner of Parcel G. According to former Hytek employees, the pipes were buried approximately 3 to 4 feet below grade and were constructed of steel and polyvinyl chloride (PVC); some of the pipes have been abandoned. Based on employee interviews (Ecology and Environment [E&E], 1981), approximately 40,000 gallons of wastewater were generated daily in 1981.

- The waste pipes from Parcel E discharged into a 160-foot-long by 40-foot-wide by 6-foot-deep unlined equalizing lagoon (also called an equalizing basin, a holding basin, or a holding lagoon) located in the northeast portion of Parcel G. Wastewater was held in this lagoon until a treatment batch (22,000 gallons) had accumulated (E&E, 1981).

- Batches of water from the equalizing lagoon were pumped into one of four 22,000-gallon treatment tanks located to the immediate west of the equalizing lagoon. Metals were precipitated, cyanide was removed, and wastewater was neutralized in the treatment process.

- The treated solution in the tanks was pumped into a 75-foot-long by 25-foot-wide unlined sludge settling lagoon (also referred to as a sedimentation pond, settling pond, or settling basin) located approximately 40 feet west of the equalizing lagoon. After settling of the solids in this lagoon, the water was pumped into the sanitary sewer, and the wet sludge was pumped into drying beds. According to Hytek (1985a), the sludge settling lagoon was used until approximately 1965 when it was filled and paved over.

- The first sludge drying beds (also referred to as surface impoundments) used on Parcel G were located in the southeast portion of the parcel. The area of the drying beds was approximately 190 feet long by 175 feet wide. These beds received metal hydroxide sludge from the late 1960s until the summer of 1979 (Hytek, 1985a).

- The four most recently used sludge drying beds were located in the southwest portion of Parcel G. They were used between 1979 and 1985. The area of these drying beds was approximately 190 feet long by 160 feet wide. According to E&E (1981), approximately 200,000 to 260,000 gallons of sludge were generated yearly.

- A drum storage area was formerly located in the central portion of Parcel G. The area was used to store raw materials, store hazardous wastes awaiting shipment to disposal facilities or recyclers, and transfer chemicals. This area was used between the early 1960s and 1979. According to Hytek (1985a), the hazardous materials stored in this area primarily consisted of degreasing and paint stripping chemicals, including methyl ethyl ketone, trichloroethene (TCE), methylene chloride, phenol (in paint strips), hydrofluoric acid, nitric acid, and chromium and lead compounds. Any spills or container leakage that may have taken place in this area would have flowed to an unlined ditch running in an east-west direction near the southern boundary of this area; Hytek (1985a) states that the ditch was located near the southern fenceline.

3.0 ENVIRONMENTAL SETTING

3.1 Physical Setting

The BSB site is located in the southeastern portion of the Puget Sound Lowland, a topographic low between the Cascade Range and the Olympic Mountains. Alluvial valleys and plains, and glacially formed or modified hills and ridges dominate the lowland. The site lies in the Duwamish Valley between the Covington Plain on the east and the Des Moines Plain on the west. The elevation of the valley ranges from about 25 to 100 feet above sea level, with the site at an elevation of approximately 35 feet.

3.2 Climate

Air masses originating over the Pacific Ocean strongly affect the climate of the Puget Sound Lowland, with generally overcast, cool, damp, and mild weather during the autumn, winter, and spring, and warm and dry weather during the summer. The annual precipitation ranges from about 30 to over 60 inches in the lowland. The average annual precipitation in the Kent area is about 38 inches, with 76 percent of it falling between October and March.

3.3 Surface Water Hydrology

The Duwamish Valley lies in the Duwamish-Green River Watershed, a northwest-southeast trending basin extending from the Cascade foothills to Puget Sound. Major surface water bodies in the Duwamish Valley include the Green River, the Black River, the Duwamish River, Mill Creek, and Springbrook Creek. The closest surface water body to the site is a ditch located about 2,000 feet northeast of the site (Figure 1). The ditch, referred to as the 196th East Valley Highway Drainage, receives water from Garrison Creek (located on the plateau southeast of the site) and an unnamed creek southeast of the site; the ditch discharges to Springbrook Creek about 2,800 feet northeast of the site. Although data are unavailable for the ditch, the monthly mean streamflow in Springbrook Creek ranges from about 4 cubic feet per second (cfs) in July, August, and September to about 20 cfs in December.

3.4 Regional Geology

The Duwamish Valley is thought to have been formed during the last glacial advance between 14,000 and 18,000 years ago (Mullineaux, 1970; Jones, 1999). The valley is filled with over 300 feet of Quaternary alluvium interbedded with marine sand deposited after the last glaciation. Beneath that lies approximately 500 feet of older unconsolidated, undifferentiated deposits (Woodward and others, 1995), and beneath that Tertiary bedrock consisting of sandstone, shale, and coal (Mullineaux, 1970).

According to the U.S. Geological Survey (Mullineaux, 1970), most of the upper 100 feet of deposits in the Duwamish Valley consist of sand, gravel, silt, clay, and peat deposited by the White River. In a series of borings drilled in the valley, the U.S. Geological Survey found finer-grained deposits (fine sand, silt, clay, and peat) up to 35 feet thick at the surface with underlying sand and gravel deposited by the White River. Environmental investigations and water well logs near Kent report that the finer-grained surficial deposits (interbedded sand, silty sand, sandy silt, and silt) extend to depths greater than 50 feet. The shallowest layers of sandy silt or silt are generally found within 30 feet bgs and are generally continuous across a given site.

3.5 Regional Hydrogeology

The Duwamish Valley lies in the South King County Groundwater Management Area. Groundwater is found at shallow depths throughout the Duwamish Valley. Groundwater elevations in shallow valley wells near Kent are about 25 feet above mean sea level (Woodward and others, 1995). In general, groundwater elevations in deeper wells in the Duwamish Valley are higher than in shallower wells, indicating upward groundwater flow. Hydraulic conductivities measured in water wells in the valley vary from 10^{-4} to 3 cm/sec, with average or geometric mean values ranging from 3×10^{-3} to 1×10^{-1} cm/sec (Jones, 1999).

Groundwater flows regionally from topographic highs to topographic lows, with recharge in unpaved areas and discharge to streams, lakes, or saltwater bodies (Vaccaro and others, 1998). Shallow groundwater flow in the Kent area is generally toward the Green River, Mill Creek, or Springbrook Creek.

3.6 Water Supply Wells

To determine the number of beneficial users of groundwater and surface water within a 1-mile radius of the site, Ecology's well log database and the Washington State Department of Health's (DOH's) public water system databases were accessed, and water rights information was obtained from Ecology's water rights tracking system. The latter was only used to provide additional information for well locations found in Ecology's well log database, due to the admitted inaccuracies in the water rights tracking system to account for unused or abandoned water rights. Although public water system information was also requested from the drinking water program of Public Health – Seattle & King County (who track public water systems with less than nine connections), this information was not available due to the lack of an easily searchable database.

Figure 4 and Table 1 present the results of the beneficial use survey. Thirty-six potential water supply wells were identified within a 1-mile radius of the site: 12 (map numbers 1 through 5 and 16 through 22) in Ecology's well log database and 24 (map numbers 6 through 15 and 23 through 36) in the DOH databases. Well logs for the 12 wells found in Ecology's database are provided in Appendix A.

Fifteen of the potential 36 water supply wells identified within a 1-mile radius of the site (map numbers 1 though 15) likely no longer exist; all were installed west of Highway 167 prior to industrialization of the area (those with records were installed prior to 1960) and were installed for irrigation, stock watering, and domestic purposes that no longer exist in the area. The presence of numerous abandonment logs in Ecology's database, which could not be precisely matched to the well installation logs, also indicates that it is likely that these wells no longer exist. Two of these wells that likely no longer exist (map numbers 6 and 7) are the only wells reported to be downgradient and between the site and the 196th East Valley Highway Drainage Ditch. Based on the Washington State Plane coordinates provided in the DOH database, the two wells (which were reported to be 200 and 300 feet deep, respectively) plot beneath a commercial building and in a grassy field. A field check of the area and inquiries of tenants in the adjacent commercial buildings did not locate the wells, indicating that the wells no longer serve as water supply wells and were very likely abandoned when the area was developed as a business park.

Twenty-one of the potential 36 water supply wells identified within a 1-mile radius of the site (map numbers 16 through 36) are known to or likely exist; those with records were installed after 1960, most are in the DOH database, and most are domestic wells. None of the likely or known water supply wells are located closer than 1,000 feet of the site, and none are reported to be downgradient and between the site and the 196th East Valley Highway Drainage Ditch. One represents a test well installed by the City of Kent, 4 represent City of Kent municipal water supply wells, 13 represent domestic water supply wells, 1 represents an irrigation well, 1 represents an industrial supply well, and the use of 1 well is unknown.

Two of the water supply wells that are known to or likely exist are located in the valley west of Highway 167. One is a test well (map number 21) installed in 1998 approximately 3,500 feet southwest of the site. According to City of Kent personnel, the well was installed for an environmental restoration project; the well is not in use but has not been abandoned. The other well is an industrial water supply well (map number 36) with conflicting location data; the Washington State Plane coordinates locate the well almost a mile east of the BSB property (beneath the Covington Plain), while the reported township, range, and section locate the well approximately 1,200 feet northwest of the BSB property. To be conservative, the well is shown on Figure 4 in the latter location; even in this location, the well is not downgradient of the BSB property.

Nineteen of the water supply wells that are known to or likely exist (map numbers 16 through 20 and 22 through 35) are located east of Highway 167 under the western edge of the Covington Plain. Given that regional groundwater flows to the west (from the plain to the valley), these wells are not located downgradient of the site. The four City of Kent water supply wells (map numbers 17, 18, 19, and 22) are completed at significantly greater depths than the deepest impacts at Parcel G, and the domestic and irrigation water supply wells are known to or likely are completed at significantly higher elevations (beneath the Covington Plain) than the Parcel G impacts.

In summary, 20 likely existing water supply wells were found within a 1-mile radius of the site. None are downgradient of the site, all but one are located east of Highway 167, the location of one is questionable, and none are likely completed in the same hydrogeologic unit as the units investigated and monitored at the site.

4.0 SITE INVESTIGATIONS

Site investigations were performed on Parcel G between 1980 and 2000, with routine groundwater monitoring still being performed. This section discusses the investigations conducted at Parcel G and, for the sake of completeness, the other parcels previously operated by Hytek. Drawing 1 and Figure 5 provide a site map of Parcel G showing the exploration locations, and Figure 6 shows the exploration locations on all of the former Criton Technologies property (the current BSB, Hexcel, and Carr properties), as well as off-site locations.

4.1 1980-1981 USEPA Site Investigation

The United States Environmental Protection Agency (USEPA) initiated investigation of Parcel G in 1980 under the Field Investigation Team program. The investigation was performed to evaluate the hazard potential of the Hytek waste treatment facility and the potential for subsurface contamination. A USEPA contractor reviewed agency files for the site and interviewed company personnel. In December 1980, the same USEPA contractor drilled three borings around the former equalizing lagoon (HTP-1, HTP-2, and HTP-3) and three borings around the former sludge drying beds located in the southwestern portion of Parcel G (HTP-4, HTP-5, and HTP-6). The boring locations are shown on Figure 5. The equalizing lagoon and sludge drying beds were in use at the time of the investigation. Each boring was advanced to a depth of 6 feet with an auger, a polyvinyl chloride (PVC) casing was installed to hold open the boring, soil samples were collected for lithologic identification from the bottom of the PVC casing to the bottom of the hole, and a well was installed through the casing to a depth of approximately 3 feet below the water table. Groundwater samples were collected from HTP-1 through HTP-6 in January 1981 and submitted for laboratory analysis of VOCs, semivolatile organic compounds (SVOCs), pesticides, cyanide, and metals (arsenic, barium, beryllium, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, selenium, silver, and zinc). The locations of the wells were surveyed, and groundwater levels were measured in February 1981.

The investigation found organic and inorganic compounds in the subsurface and recommended additional groundwater monitoring to determine groundwater flow direction and the nature and extent of groundwater contamination. The work and results were summarized in Ecology and Environment (1981).

4.2 1982 Hytek Phase 1 Investigation

Based on the results of the USEPA Parcel G investigation and the recommendation for additional groundwater monitoring, Hytek installed shallow monitoring wells HY-1s, HY-2, HY-3, and HY-4 in June 1982. HY-1s was installed on Parcel G, HY-3 was installed to the south of Parcel G, and HY-2 and HY-4 were installed north of South 200th Street on the south side of the current Hexcel Plant 1 building (Figure 6). The wells were completed with nominal 2-inch-diameter PVC with 5-foot-long screens located at depths below grade between 9 and 19 feet. The wells were surveyed and developed, and slug tests were subsequently performed in each well. Groundwater levels were measured and groundwater samples were collected in each well in June and October 1982. The samples were submitted for laboratory analysis of pH, specific conductance, metals (cadmium, chromium, copper, nickel, and zinc), hardness, total organic carbon (TOC), and total organic halides (TOX).

The Phase 1 investigation identified a northeasterly shallow groundwater flow direction and detected VOCs in wells HY-2 and HY-4. The results were presented in tabular fashion in Sweet, Edwards & Associates (1984a).

4.3 1983-1984 Hytek Phase 2 Investigation

Based on the groundwater quality data and estimated groundwater flow direction developed during the Phase 1 investigation, Hytek and the USEPA agreed that additional investigation was required. A Phase 2 groundwater investigation plan was developed and negotiated with the USEPA and Ecology. Per the final plan, the following activities were conducted:

- **Sampling and analysis of soil in the equalizing basin.** One soil sample was collected and submitted for laboratory analysis of metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), total cyanide, total phenol, and VOCs.

- Sampling and analysis of equalizing basin water (plant effluent). One water sample was collected and submitted for laboratory analysis of metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), total cyanide, total phenol, VOCs, dibutyl phthalate, and bis(2-ethylhexyl)phthalate.

- Sampling and analysis of drying bed sludge. One sludge sample from the drying beds located on the southwestern portion of Parcel G was collected and submitted for laboratory analysis of metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), total cyanide, total phenol, VOCs, dibutyl phthalate, and bis(2-ethylhexyl)phthalate.

- Installation of shallow monitoring wells. HY-5, HY-6, and HY-7s were installed in October 1983. HY-5 was installed north of the current Hexcel Plant 1 building, and HY-6 and HY-7 were installed east of the current Hexcel Plant 1 building (Figure 6). The wells were completed with nominal 2-inch-diameter PVC with 10-foot-long screens located at depths below grade between 12.5 and 26 feet. The wells were surveyed and developed.

- Installation of intermediate and deep monitoring wells. Monitoring well HY-8i and deep monitoring well HY-8d were installed in January 1984. Both wells were installed east of the current Hexcel Plant 1 building (Figure 6) to determine the extent of downward migration of VOCs detected in the adjacent shallow monitoring wells. Prior to the installation of HY-8i and HY-8d, groundwater was extracted from temporary monitoring points placed in six test holes (TH-1 through TH-6) on the north side of the current Hexcel Plant 1 building between HY-5 and HY-6. The electrical conductance (specific conductance) of water extracted from each test hole and from HY-5 and HY-6 was measured. Since the highest specific conductance was measured in HY-6 (1,550 microsiemens/cm [μS/cm]), monitoring wells HY-8i and HY-8d were located adjacent to HY-6. HY-8i and HY-8d were completed with 10-foot-long PVC screens located between 35 and 45 feet and 50 and 60 feet below grade, respectively. HY-8i was completed with a nominal 2-inch-diameter monitoring well, and HY-8d was completed with a nominal 4-inch-diameter monitoring well. The wells were surveyed and developed.

- Groundwater level measurement. Groundwater levels were measured during six events during the Phase 2 investigation. Water levels were measured in HY-1s through HY-4 on January 10, 1983; in HY-1s through HY-4 and HTP-1 through HTP-6 on April 8, 1983; in HY-1s through HY-7s on November 2, 1983; in HY-1s through HY-7s and HTP-1 through HTP-6 on November 22, 1983, and January 23, 1984; in HY-1s through HY-7s, HY-8i, HY-8d, and HTP-1 through HTP-6 on February 22, 1984.

- Hydraulic conductivity testing. Constant rate, single-well pumping tests were conducted in HY-5, HY-6, HY-7, and HY-8d in April 1984.

- Groundwater sampling. Four rounds of groundwater samples were collected during the Phase 2 investigation. Groundwater samples were collected from HY-1s through HY-4 in January and April 1983. The samples were submitted for laboratory analysis of pH, specific conductance, metals (cadmium, chromium, copper, nickel, and zinc), hardness, TOC, TOX, VOCs, dibutyl phthalate, and bis(2-ethylhexyl)phthalate. Groundwater samples were collected from HY-1s through HY-7s in November 1983 and from HY-1s through HY-7s, HY-8i, and HY-8d in February 1984. The samples were submitted for laboratory analysis of pH, specific conductance, metals (antimony, arsenic, beryllium, cadmium, chromium, copper, lead, mercury, nickel, selenium, silver, and zinc), total cyanide, TOC, TOX, total phenol, VOCs, dibutyl phthalate, and bis(2-ethylhexyl) phthalate.

The Phase 2 investigation verified that groundwater flow is toward the northeast, and found inorganic constituent concentrations below USEPA primary drinking water maximum contaminant levels (MCLs) in wells downgradient of Parcel G and VOC detections downgradient of Parcel G only in shallow monitoring wells. The Phase 2 investigation results were presented in Sweet, Edwards & Associates (1984a); the report recommended additional groundwater monitoring and the installation of two additional wells downgradient of the HY-5, HY-6, and HY-7 area.

4.4 1984 Hytek Phase 3 Investigation

Based on the Phase 2 investigation results and with concurrence from USEPA and Ecology, Hytek conducted a Phase 3 investigation to provide additional Parcel G data, additional monitoring in the area downgradient of areas previously investigated, and continued groundwater monitoring. The following activities were conducted:

- **Drilling and sampling of 14 soil borings.** Soil borings HYSS-1 through HYSS-14 were drilled in August 1984. Borings HYSS-3 and HYSS-5 were drilled south of the current Hexcel Plant 1 building, HYSS-13 was drilled north of the former Hytek building, and HYSS-1 and HYSS-2 were drilled southwest of Parcel G (Figure 6). The remaining nine borings were drilled on Parcel G (Figure 5). Due to limited drilling rig access, borings HYSS-1, HYSS-2, HYSS-9 through HYSS-12, and HYSS-14 were hand augered to depths ranging from 6.5 to 10.5 feet bgs. Borings HYSS-3 through HYSS-8 and HYSS-13 were drilled to depths between 11.5 and 18 feet bgs with a drilling rig equipped with hollow-stem augers. Continuous soil samples were collected during drilling; the samples were screened for VOCs with a photoionization detector (PID), with selected samples submitted for laboratory analysis. HYSS-1 and HYSS-2 were first hand augered southwest of Parcel G to test the effect of background VOCs on the PID; three soil samples were collected from each boring and screened with a PID. HYSS-3 through HYSS-14 were then drilled and sampled. Eighty-four soil samples were collected from HYSS-3 through HYSS-14, with 28 of the samples being submitted for laboratory analysis of VOCs.

- Installation of shallow monitoring wells HY-9, HY-10, and HY-11. In September 1984, HY-9 and HY-10 were installed to the northeast of the current Hexcel Plant 1 building, east of 84th Avenue South, and HY-11 was installed off site, south of the southwestern corner of Parcel G (Figure 6). The wells were completed with nominal 2-inch-diameter PVC with 10-foot-long screens located at depths below grade between 12 and 24 feet (HY-9 and HY-10) and 8 and 18 feet (HY-11). The wells were surveyed and developed.

- Installation and groundwater level measurement of temporary groundwater monitoring points. In September 1984, three groundwater level monitoring points, HYHT-1, HYHT-2, and HYHT-3, were installed off site to the southwest of the southwestern quarter of Parcel G to evaluate the extent of seasonal groundwater mounding beneath the sludge drying beds (Figure 6). The groundwater monitoring points were surveyed. Although the depths and installation methods of the points were not reported, it is likely that the groundwater level monitoring points were installed at shallow depths, similar to HYHT-4 and HYHT-5 (see Section 4.5).

- Groundwater level measurement. Groundwater levels were measured during three events during the Phase 3 investigation. Water levels were measured in HY-1s through HY-7s, HY-8i, HY-8d, and HTP-1 through HTP-6 on February 22, 1984; and in HY-1s through HY-7s, HY-8i, HY-8d, HY-9, HY-10, HY-11, HTP-1 through HTP-6, and HYHT-1 through HYHT-3 on September 12 and September 22, 1984.

- Hydraulic conductivity testing. Constant rate, single-well pumping tests were conducted in HY-8d, HY-9, HY-10, and HY-11 in October 1984.

- Groundwater sampling. One round of groundwater samples was collected during the Phase 3 investigation. Groundwater samples were collected from HY-1s, HY-3, HY-5 through HY-7s, HY-8i, HY-8d, and HY-9 through HY-11 in September 1984. The samples were submitted for laboratory analysis of pH, specific conductance, metals (arsenic, chromium, copper, nickel, silver, and zinc), total cyanide, TOC, TOX, total phenol, VOCs, dibutyl phthalate, and bis(2-ethylhexyl) phthalate. HY-2 was sampled in October 1984; the sample was submitted for laboratory analysis of the Appendix VIII parameters, VOCs, semivolatile organic compounds (SVOCs), pesticides, and metals.

- Surface water monitoring and evaluation. Two surface water locations in the 196th East Valley Highway Drainage Ditch (Figure 6) were screened for VOCs on September 12, 1984. Samples collected at locations designated SW-1 and SW-2 were screened with a PID. Neither sample had VOC concentrations above background; thus, no additional sampling was conducted. Surface water metals data collected by Metro in the 196th East Valley Highway Drainage Ditch at South 208th Street were reviewed and compared to site groundwater data.

- Sewer monitoring. The specific conductance of liquids in two sanitary sewer manholes located on South 200th Street was measured in September 1984.

The Phase 3 investigation confirmed the Phase 2 investigation results. The Phase 3 investigation also concluded that the highest Parcel G soil and groundwater VOC concentrations were in and immediately downgradient of the former drum storage area and that the low specific conductance values in the sanitary sewer indicated that the sewer pipe on South 200th Street was not a significant interceptor of groundwater VOCs. The Phase 3 investigation results were presented in Sweet, Edwards & Associates (1984b). The Phase 3 investigation report recommended additional groundwater monitoring and the installation of the HYCP-1 through HYCP-4 wells in and downgradient of the former drum storage area and drainage ditch.

4.5 1984 and 1985 Hytek Monitoring Well Installation

Based on the Phase 3 investigation results and with concurrence from USEPA and Ecology, Hytek implemented recommendations of the Phase 3 report, including the following:

- **Drilling and sampling of five soil borings.** Soil borings HYSS-15 through HYSS-19 were drilled in December 1984 immediately north of the unlined ditch on the south side of the former Parcel G drum storage area (Figure 5). The borings were drilled with a hollow-stem auger drilling rig to depths ranging from 20.5 to 41 feet bgs. Soil samples were collected on a continuous basis from ground surface to at least 10 feet bgs and at 5-foot intervals thereafter. The samples were screened for VOCs with a PID, with selected samples submitted for laboratory analysis of VOCs.

- Installation and development of monitoring wells. Shallow wells HYCP-1s, HYCP-2, HYCP-3s, HYCP-4, HYO-2, and HYO-4, intermediate wells HYCP-1i and HYCP-3i, and deep wells HYCP-1d, HYCP-3d, HYO-1, and HYO-3 were installed in November and December 1984. All wells were installed on or immediately north of Parcel G (Figure 5). The shallow wells were completed with nominal 2-inch-diameter PVC with 5-to 20-foot-long screens located at depths below grade between 8 and 33 feet. The intermediate wells were completed with nominal 2-inch-diameter Schedule 80 PVC with 10-foot-long (HYCP-3i) or 20-foot-long (HYCP-1i) screens located at depths below grade between 16 and 36 feet. The deep wells were completed with nominal 2-inch or 3-inch-diameter Schedule 80 PVC with 20-to 30-foot-long screens located at depths below grade between 53.5 and 83.5 feet. Each well was surveyed and developed.

- Hydraulic conductivity testing. Constant rate, single-well pumping tests were conducted in HY-8d, HY-9, HY-10, and HY-11 in October 1984. Constant rate, multiple-well pumping tests were conducted using HYO-2, HYO-4, HYCP-1s, HYCP-1i, HYCP-2, HYCP-3s, and HYCP-4 in January 1985; all but HYO-2 were used as pumping wells in these tests. All of the field hydraulic conductivity tests conducted through January 1985 were tabulated and presented in Hytek (1985b).

- Installation and groundwater level measurement of temporary groundwater monitoring points. Two groundwater level monitoring points, HYHT-4 and HYHT-5, were installed in December 1985 to evaluate groundwater levels around the former sludge drying beds. HYHT-4 was installed to the east of the southeastern Parcel G sludge drying beds, and HYHT-5 was installed to the south of the southwestern Parcel G sludge drying beds (Figure 6). The groundwater monitoring points were surveyed. Based on field notes, both monitoring points were drilled to 15 feet bgs, with well screens installed between 13 and 15 feet bgs.

- Installation and development of additional monitoring wells. Monitoring wells HY-1i, HY-1d, HY-7i, HY-7d, HY-11i, and HY-11d were installed in December 1985 to determine the lateral extent of VOCs in groundwater. Additionally in December 1985, HY-7ss was installed to investigate the affect of well material on water quality, and HY-11, which was installed in September 1984, was abandoned and replaced with HY-11s to comply with state well construction standards. All wells were installed adjacent to their shallow counterparts (Figures 5 and 6). The shallow wells were completed with nominal 2-inch-diameter PVC with 10-foot-long screens located at depths below grade between 8 and 22.5 feet. The intermediate wells were completed with nominal 2-inch-diameter Schedule 80 PVC with 10-foot-long screens located at depths below grade between 26 and 50.5 feet. The deep wells were completed with nominal 2-inch or 3-inch-diameter PVC with 10-foot-long screens located at depths below grade between 69 and 94 feet. Each well was surveyed and developed.

- Groundwater level measurement. Groundwater levels were measured in all available monitoring wells and points in December 1984, and in October, November, and December 1985. Additionally, surface water levels were measured in the Equalizing Basin in October 1985; in the 196th East Valley Highway Drainage Ditch in October, November, and December 1985; and in the Sludge Lagoon and Equalizing Lagoon in December 1985. Water levels were provided in Sweet-Edwards & Associates (1986).

4.6 1986 Hytek Soil Gas Survey

Two soil gas surveys were conducted on the Parcel G and current Hexcel and Carr properties to evaluate the extent of the VOC plume, check the assumptions used in an analytical transport model, and evaluate on-site and off-site sources of VOCs. Twenty-five locations were tested in February 1986. Due to complications with high water levels in February 1986, 43 locations were tested in August 1986. To collect the samples, iron pipe was driven into the ground to a depth generally less than 5 feet bgs, the end cap was knocked off, the pipe was retracted a few inches, the vapor in the pipe was allowed to equilibrate, and a vacuum was applied to the pipe to fill sample bottles. The February 1986 samples were analyzed for TCE, and the August 1986 samples were analyzed for tetrachloroethene (perchloroethene or PCE), TCE, and DCE. An on-site laboratory was used for all analyses.

Soil gas sampling locations, techniques, and results were presented in Sweet-Edwards & Associates (1986). The report concluded that the soil gas survey was not successful in delineating the extent of VOCs in groundwater but did confirm VOC hot spot locations.

4.7 1987 Hytek Groundwater Investigation

In March 1987, the USEPA issued a RCRA Section 3013 order to develop and implement a proposal for additional monitoring, analysis, and testing. An investigation plan was developed and negotiated with the USEPA. Per the final plan, the following activities were conducted:

- **Sludge sampling in the abandoned sludge drying beds.** In June 1987, six core samples (RS6/103, RS19/108, RS72/119, RS76/111, RS77/70, and RS103/34) were collected in random locations with the former sludge drying beds located in the southeastern portion of Parcel G (Figure 5). Samples were collected between 1.7 and 3.7 feet bgs using a 1-foot-long split spoon sampler. Samples were tested in an on-site laboratory for VOCs and an off-site laboratory for arsenic and cyanide.

- Drilling and sampling of 35 soil borings. Hand-auger borings HA-1 through HA-4, HA-4N, HA-4S, HA-4E, HA-5, HA-6, HA-6S, HA-6E, HA-6W, HA-7 through HA-27, HA-BN, and HA-BS were drilled in June and July 1987. Borings HA-1 through HA-4, HA-4N, HA-4S, HA-4E, HA-5, HA-6, HA-6S, HA-6E, HA-6W, and HA-7 through HA-12 were drilled around the current Hexcel Plant 1 building (Figure 6). Borings HA-13 through HA-27 were drilled near and downgradient of the former Parcel G drum storage area (Figure 5). Borings HA-BN and HA-BS (Figure 6) were drilled off-site to the southwest of Parcel G (on the east shoulder of 80th Avenue South) to provide information on background soil quality. All borings were advanced with a 3-inch-diameter hand auger, and soil samples were collected with a 1-foot-long split spoon sampler. One unsaturated and one saturated soil sample were collected from each boring at depths ranging from 3 to 6 feet bgs. Samples were analyzed in an on-site laboratory for VOCs and an off-site laboratory for arsenic and cyanide.

- Installation and development of 6 piezometers and 15 monitoring wells. Piezometers were installed at six locations (A, D, E, F, I, and J), and monitoring wells were installed at six locations (B, C, G, H, K, and L) between June and August 1987. Locations I and L were on Parcel G, and the remaining locations were off site (Figures 5 and 6). A hollow-stem auger drilling rig was used to first drill a test boring at each location, soil samples were collected from each test boring approximately every 5 feet during drilling, representative soil samples were submitted for grain-size analysis, random soil samples (one each from B, D, and F, and two from C) were tested in an on-site laboratory for VOCs, and one to three groundwater samples were collected from each test boring and analyzed for VOCs in an on-site laboratory. If the test boring VOC results were below action levels (generally 10 parts per billion), deep piezometers were installed to allow water level monitoring. If the test boring VOC results were above action levels, monitoring wells were installed at multiple depths to allow both groundwater level monitoring and sampling. Deep piezometers were installed at test boring locations A, D, E, F, I, and J. The piezometers were completed with nominal 2-inch-diameter, Schedule 80 PVC with 10-foot-long screens located at depths below grade between 43 and 99 feet. Shallow and deep monitoring wells were installed at locations B, C, and L. Shallow, intermediate, and deep monitoring wells were completed at locations G, H, and K. All monitoring wells were completed with nominal 2-inch-diameter stainless steel with 10-foot-long. Shallow well screens were located at depths below grade between 4 and 15 feet, intermediate well screens were located at depths below grade between 23 and 38 feet, and deep well screens were located at depths below grade between 47 and 79 feet. Each well was surveyed and developed. Development techniques included surging, bailing, pumping, and air lifting.

- Drilling and sampling of 4 test borings. In addition to the test borings at locations A through L, four additional test borings were drilled and sampled to provide additional groundwater data near locations B and C. The soil borings were designated B’, M, M’, and N. Soil samples were not collected from these borings. Each boring was drilled with a hollow-stem auger drilling rig to a total depth of 32 feet bgs, and groundwater samples were collected at shallow and intermediate depths. Groundwater samples were collected from 2-foot-long temporary well screens. The shallow screens were set between 9 and

16 feet bgs, and the intermediate screens were set between 30 and 32 feet bgs. The groundwater samples were analyzed in an on-site laboratory for VOCs.

- Hydraulic conductivity testing. One soil sample collected in a Shelby tube from the silt at the base of test boring A was submitted for analysis of vertical hydraulic conductivity. In-situ hydraulic conductivity testing of the silt at the base of test borings G and K was also conducted; the rising head slug test method was used for these tests.

- Groundwater level measurement. Groundwater levels were measured in all available monitoring wells and piezometers in August, September, October, and November 1987.

- Groundwater sampling. Groundwater samples were collected from 42 monitoring wells in August, September, October, and December 1987. Groundwater samples were collected from Bs, Bd, Cs, Cd, Gs, Gi, Gd, Hs, Hi, Hd, Ks, Ki, Kd, Ls, Ld, HY-1s, HY-1i, HY-1d, HY-2 through HY-7s, HY-7ss, HY-7i, HY-7d, HY-8i, HY-8d, HY-9 through HY-11s, HY-11i, HY-11d, HYCP-1s, HYCP-1i, HYCP-1d, HYCP-2, HYCP-3s, HYCP-3d, HYCP-4, and HYO-4. The samples were submitted for laboratory analysis of VOCs by USEPA Method 624, arsenic, and cyanide.

The investigation identified six hydrogeologic units at the site, two aquifers, horizontal groundwater flow to the northeast, upward flow between the two aquifers, VOC plume boundaries similar to previous investigations, and significantly lower VOC concentrations in the lower aquifer than the upper aquifer. Results were presented in Sweet-Edwards/EMCON (1988a).

4.8 1988 Hytek Parcel G Investigation of Unsaturated Soil Contamination

To further evaluate the extent of VOCs in unsaturated soil on Parcel G, 25 shallow test borings (designated TH-1 through TH-25; see Figure 5) were drilled in the area of the former unlined ditch near the southern boundary of former drum storage area. All borings were completed in April 1988 using a post-hole digger, hand auger, or portable hollow-stem auger drilling rig. Boring depths ranged from 1.7 to 6.5 feet deep. Soil samples collected from each boring were analyzed for halogenated VOCs (HVOCs) using Modified USEPA Method 601 in an on-site analytical laboratory.

The soil VOC results indicated two areas with total VOCs in unsaturated soil above 5 mg/kg, both located in the former drum storage area. The volume of soil with VOCs above 5 mg/kg was estimated to be 1,730 cubic yards. Results were presented in Sweet-Edwards/EMCON (1988b).

4.9 1989 BSB Pilot Recovery Program Investigation

A pilot recovery program investigation was conducted in 1989 in accordance with the final Post-closure Permit Condition IV.C.4.b (USEPA, 1989). The objective of the investigation was to develop the hydrogeological and operational data necessary to design a groundwater extraction and treatment system. The investigation included the following:

- **Monitoring well installation and development.** Parcel G monitoring wells HYCP-5 and HYCP-6 were installed, and HYCP-3s and HYCP-3i were replaced in March 1989 (Figure 5). HYCP-5 and HYCP-6 were installed per Post-closure Permit Condition V.F.1.a to monitor groundwater on the northeast side of Parcel G. HYCP-3s and HYCP-3i were installed to replace the original wells that were abandoned during October 1988 remediation activities (see below). Each well boring was drilled with a hollow-stem auger drilling rig. Soil samples collected at 5-foot intervals from HYCP-5 were submitted for laboratory analysis of grain size; the results were used to design the well screen of HYR-1. HYCP-5 and HYCP-6 were completed with nominal 2-inch-diameter stainless steel with 20-foot-long screens located at depths below grade between 10 and 30 feet. HYCP-3s and HYCP-3i were completed as the original wells, with nominal 2-inch-diameter Schedule 80 PVC, HYCP-3s screened between 8 and 13 feet bgs and HYCP-3i screened between 22 and 32 feet bgs. Each well was surveyed and developed.

- Observation well installation and development. Observation wells OW-2a, OW-2b, OW-2c, OW-3, and OW-4 were installed on the east side of the current Hexcel Building 1 in March 1989 (Figure 6). Each well boring was drilled with a hollow-stem auger drilling rig. Soil samples collected at 5-foot intervals from OW-2a, OW-3, and OW-4 were submitted for laboratory analysis of grain size; the results were used to design the well screens of CG-2, CG-3, and CG-4, respectively. OW-2a, OW-2b, and OW-2c were placed 6, 28, and 57 feet, respectively, south of the subsequent location of recovery well CG-2. OW-3 was placed 10 feet north of the location of subsequent recovery well CG-3, and OW-4 was placed 13 feet south of the subsequent location of recovery well CG-4. Each observation well was completed with nominal 2-inch-diameter Schedule 40 PVC, screened between 10 and 30 feet bgs. Each observation well was surveyed and developed.

- Recovery well installation and development. Recovery wells HYR-1, CG-1, CG-2, CG-3, and CG-4 were installed in March and April 1989. HYR-1 was installed on the north side of Parcel G, and CG-1 through CG-4 were installed on the east side of the current Hexcel Building 1 (Figures 5 and 6). A cable tool drilling rig was used to install each well. Soil samples collected at 5-foot intervals from CG-1 were submitted for laboratory analysis of grain size, and the results were used to design the well screen. All wells were completed with nominal 6-inch-diameter stainless steel screens and risers in 35- to 36-foot-deep borings. CG-1 through CG-4 were screened between 15 and 30 feet bgs, with screen slot sizes ranging from 0.010 to 0.020 inches. HYR-1 was screened between 10 and 30 feet, with a screen slot size of 0.010 inches. Recovery well HYR-2 was installed after the conclusion of the pilot recovery program investigation. The well boring was drilled, sampled, and completed similar to the other recovery wells; the well was screened between 9 and 29 feet bgs, with slot sizes of 0.010 and 0.015 inches. The wells were surveyed and developed using surging and pumping techniques.

- Recovery well step tests. Step tests were performed in HYR-1, CG-1, CG-2, CG-3, and CG-4 in April and May 1989. The tests were performed to determine preliminary estimates of aquifer parameters and to determine optimum pumping rates for each well. HYR-1 was pumped at increasing rates of 5, 10, and 20 gallons per minute (gpm) for a period of one hour per step. Water levels were allowed to recover for 1 hour between each pumping step. CG-1 through CG-4 were each pumped at three different rates ranging from 6 to 20 gpm with varying recovery periods between pumping steps.

- Short-term aquifer tests. Short-term, constant-rate aquifer tests were performed in HYR-1 in April and CG-2 in October 1989. The tests were performed to refine estimates of aquifer parameters. HYR-1 was pumped at a rate of 20 gpm for 10 hours. HYR-1, HYCP-1s, HYCP-1d, HYCP-2, HYCP-5, and HYCP-6 were monitored with pressure transducers during pumping and for a period of 12 hours after pumping ceased. Periodic water levels in Gs, Gi, Gd, HY-2, and HY-4 were also collected with an electric well probe. CG-2 was pumped at a rate of 10.3 gpm for 24 hours. CG-2, HY-6, OW-2a, OW-2b, and OW-2c were monitored with pressure transducers during pumping and for a period of 24 hours after pumping ceased.

- Pilot recovery well system test. An extended pumping test of the entire pilot system was conducted in October 1989. The test was conducted to evaluate the aquifer response to long-term pumping stress, the reliability of estimated aquifer parameters, and vertical and horizontal hydraulic head responses. The test also provided additional data for numerical modeling of groundwater conditions. HYR-1, CG-1, CG-2, CG-3, and CG-4 were pumped for a two-week period at 18, 6, 10, 10, and 14 gpm, respectively. Water levels were monitored in the recovery wells and adjacent observation and monitoring wells using a combination of pressure transducers and an electric well probe. Following the cessation of pumping, water level recovery was monitored for a period of one week.

- Recovery well water sampling. Groundwater samples were collected from each recovery well before and after step testing. Samples were submitted for laboratory analysis of VOCs; total and dissolved arsenic, iron, and manganese; major cations and anions; cyanide; total dissolved solids (TDS); total suspended solids (TSS); and settleable solids. Groundwater samples were collected from HYR-1 at the beginning and end of the short-term aquifer test; these samples were submitted for laboratory analysis of VOCs, major cations and anions, cyanide, TDS, TSS, and settleable solids. During the pilot recovery well system test, groundwater samples were collected four times from the recovery wells, twice from HYCP-1i, HYO-2, Gs, Gi, HY-4, Cs, HY-7s, Ks, and HY-9, and once from HYCP-2 and HYCP-5. Samples were submitted for laboratory analysis of VOCs; total and dissolved arsenic, iron, and manganese; major cations and anions; cyanide; TDS; TSS; and settleable solids.

The results of the pilot recovery program field activities were used to estimate and evaluate aquifer parameters, evaluate the shallow aquifer response to long-term pumping stress, assess recovered groundwater quality, and provide additional data for numerical modeling of groundwater conditions. Results were presented in Sweet-Edwards/EMCON (1990).

4.10 1988 through 2004 Groundwater Monitoring

Groundwater samples were collected on a regular basis from most available wells on the present BSB, Hexcel, and Carr properties between 1988 and 2004. These samples were collected to provide baseline data prior to remediation system startup and to provide data used to assess groundwater conditions during remediation. Three sampling events were conducted each year in 1988, 1989, and 1990; quarterly sampling events were conducted between 1991 and 1997; three events were conducted in 1998; and biannual events have been conducted from 1999 through the present.

Groundwater samples collected between October 1992 and September 1998 were collected in accordance with the Evaluation Monitoring Plan (EMP; Sweet-Edwards/EMCON, 1991), which was prepared per the final Post-closure Permit Conditions IV.C.4.c and V.F.2 (USEPA, 1989). Groundwater samples were collected from Bs, Bd, Cs, Cd, Gs, Gi, Gd, Hs, Hi, Hd, Ks, Ki, Kd, Ls, Ld, HY-1s, HY-1i, HY-1d, HY-2 through HY-7s, HY-7ss, HY-7i, HY-7d, HY-8i, HY-8d, HY-9 through HY-11s, HY-11i, HY-11d, HYCP-1i, HYCP-1d, HYCP-2, HYCP-3s, HYCP-3i, HYCP-4, HYCP-5, HYCP-6, and HYO-2. Between 1992 and 1998, groundwater levels were measured approximately monthly from all available wells on the present BSB, Hexcel, and Carr properties.

Groundwater samples collected between the fourth quarter of 1998 and the present have been collected per an approved Evaluation Monitoring Plan Amendment (EMPA; EMCON, 1998a). Per the EMPA, groundwater samples were collected from Cs, Hi, Hd, Ks, Ki, Kd, Ls, HY-1s, HY-1i, HY-1d, HY-7ss, HY-7i, HY-9, HY-11s, HY-11i, HY-11d, HYCP-1i, HYCP-1d, HYCP-2, HYCP-3s, HYCP-3i, HYCP-5, and HYCP-6. Groundwater levels were measured approximately monthly from all available wells on the present BSB, Hexcel, and Carr properties between 1999 and 2004.

Groundwater samples were submitted for laboratory analysis of VOCs, dissolved arsenic, and total cyanide by USEPA Methods 8010/8020, 7060, and 335.3, respectively. Annually, groundwater samples from monitoring wells Cs, HY-6, HYCP-2, and HYCP-5 were also analyzed for VOCs, SVOCs, PCBs, and metals (barium, cadmium, chromium, copper, nickel, and zinc) by USEPA Methods 8240, 8270, 8080, and 6010, respectively.

Groundwater monitoring results were presented and discussed in annual progress reports (EMCON, 1993, 1994, 1996, 1997, 1998b, 1999; IT Corporation, 2000 and 2002; and PES Environmental, 2002 and 2003).

4.11 1999 and 2000 BSB Parcel G Source Area Investigations

Additional investigations of Parcel G soil and groundwater was conducted in 1999 and 2000 to evaluate the nature and extent of VOC contamination of the parcel. The 1999 investigation involved the following activities:

- **Drilling and sampling of 15 borings.** Borings were advanced at 15 locations downgradient and cross-gradient of the former drum storage area (Figure 5) in April 1999. Borings GP-1 through GP-15 were drilled with a direct-push drilling rig to depths ranging from 36 to 58 feet bgs to provide additional soil lithology. Soil samples were collected on a nearly continuous basis during drilling for lithologic logging and screening for VOCs with a PID.

- Grain size vertical hydraulic conductivity analysis. Soil samples from GP-1, GP-2, GP-3, GP-4, GP-5, GP-6, GP-8, GP-9, GP-11, GP-12, GP-13, and GP-14 were submitted for laboratory grain size testing. Soil cores from GP-10 and separate borings next to GP-5 and GP-7 were submitted for laboratory testing of vertical hydraulic conductivity.

- Groundwater sampling of five borings. After identification of the lithology at GP-1 through GP-15, separate borings were advanced next to GP-1, GP-2, GP-12, GP-13, and GP-14 to allow collection of groundwater samples; two to three groundwater samples were collected from each boring at depths ranging from 10 to 39 feet bgs. Thirteen groundwater samples were submitted for laboratory analysis of HVOCs by USEPA Method 8010 or 8260; five samples were also submitted for laboratory analysis of chloride, nitrate, sulfate, TDS, TOC, and dissolved metals (calcium, iron, magnesium, manganese, and sodium).

- In-situ hydraulic conductivity testing. Two separate borings next to GP-1 and one boring next to GP-2 were drilled to allow constant rate aquifer testing of the shallow aquifer. GP-1c was tested between 9 and 14 feet bgs, GP-1d was tested between 22 and 27 feet bgs, and GP-2b was tested between 27 and 32 feet bgs. A peristaltic pump and an electric well probe were used to perform the tests.

The 2000 investigation was conducted to investigate the VOC source area on Parcel G, to investigate the potential for contaminant migration onto Parcel G from an unknown source upgradient of the property, and to confirm the absence of significant contamination in the area of the former sludge drying beds, and the area west of the former drum storage area. Additionally, during investigation of the area in and around the former drum storage area, efforts were made to identify the presence of dense nonaqueous phase liquid (DNAPL) in soil samples. Techniques employed included direct-push drilling, continuous coring, visual examination of soil samples, PID screening of soil cores, and laboratory VOC analysis of soil samples.

The 2000 investigation was performed in two phases and involved the use of a mobile laboratory. The following activities were conducted:

- **Drilling and sampling of 43 borings.** Forty-three borings were advanced in November and December 2000 at the locations shown on Figure 5. Borings SP-1 through SP-39, SP-12b, SP-13b, SP-30b, and SP-38b were drilled with a direct-push drilling rig to depths ranging from 27 to 47 feet bgs. Soil and groundwater samples were collected out of separate borings. Soil samples were collected on a nearly continuous basis during drilling for lithologic logging and screening for VOCs with a PID.

- Laboratory soil testing. Soil samples were analyzed for VOCs in an on-site mobile laboratory. Two to nine samples were submitted from each boring from which soil was tested. Samples were selected for laboratory analysis based on boring location, field screening results, lithology, mobile laboratory capacity, and analytical results from other borings. One-hundred, thirty-one soil samples were submitted for analysis of HVOCs using USEPA Method 8021B. Seven soil samples were submitted to an analytical laboratory for analysis of treatability parameters, chromium, iron, and manganese by USEPA Method 6010B and chemical oxygen demand (COD) by USEPA Method 410.4.

Four soil sample cores collected from the aquitard at the base of the shallow aquifer were submitted for laboratory testing of vertical hydraulic conductivity by American Society for Testing and Materials (ASTM) Method D5084.

- Laboratory groundwater testing. Thirty-nine groundwater samples were submitted for laboratory analysis of HVOCs using USEPA Method 8021B. Two to three samples were submitted from each boring from which groundwater was tested.

The investigations refined the understanding of the upper three hydrogeologic units at the site, identified a widespread intermediate silt layer in the middle of the shallow aquifer, and refined the understanding of the nature and extent of HVOCs in Parcel G soil and groundwater. Results were presented in IT Corporation (2001).

4.12 Summary

To summarize, the following activities have been conducted in the course of investigations at Parcel G over a period of 24 years:

- Drilling of 112 temporary borings;
- Installation of 28 wells or piezometers, with subsequent abandonment of 10 of them;
- VOC analysis of 23 soil gas samples;
- Chemical analysis of 8 sludge samples, 1 effluent sample, 218 soil samples, and over 700 groundwater samples;
- Physical parameter analysis of 19 soil samples;
- Measurement of over 2,000 groundwater levels; and
- Field hydraulic conductivity testing at 14 locations.

The following activities have been conducted by BSB in the course of investigations off site (upgradient and downgradient of Parcel G) over a period of 22 years:

- Drilling of 35 temporary borings;
- Installation of 47 wells or piezometers, with subsequent abandonment of 6 of them;
- VOC analysis of 45 soil gas samples;
- Chemical analysis of 10 soil samples and over 1,200 groundwater samples;
- Physical parameter analysis of 1 soil sample;
- Measurement of over 5,000 groundwater levels; and

- Field hydraulic conductivity testing at 24 locations.

5.0 PREVIOUS AND ONGOING CLEANUP ACTIONS

RCRA closure of all regulated units occurred in 1987 and 1988. In November 1988, USEPA and Ecology jointly issued a Post-closure Permit (WAD 07 665 5182) covering Parcels A through G. The permit identified the permitted facility as Parcels G and E, with recognition that Parcel E was subject to a pending transfer to Heath Tecna (later Hexcel). The permit did not name Heath Tecna and did not define the permitted facility to include Parcels A, B, C, D and F based upon the agencies' acceptance of a private agreement between BSB and Heath Tecna (later Hexcel). Under this private agreement, BSB agreed to be named as the sole permittee and Heath Tecna (later Hexcel) agreed to reimburse BSB for the costs of conducting the remedial action on the Hexcel Parcels. In accordance with the permit, a groundwater recovery program was implemented to meet the post-closure permit groundwater corrective action requirements for solid waste management units on the BSB Parcel G and on the Hexcel Parcel E.

5.1 RCRA Closure Activities

5.1.1 Former Equalizing and Sludge Settling Lagoons

The former equalizing lagoon and former sludge settling lagoon were closed between September and December 1987 consistent with the EPA-approved closure plan. During closure, lagoon sludges were removed and disposed off-site, at least 12 inches of underlying native soil were removed and disposed off-site, geotextile was installed to stabilize several areas of the settling basin, the excavations were filled with clean, granular soil, and an asphalt concrete cover system was constructed over each area.

Five confirmation soil samples were collected below the bottom of the former equalizing lagoon excavation, the samples were composited into one sample, and the sample was analyzed for water-soluble cyanide and EP Toxicity metals (arsenic, cadmium, chromium, lead, copper, nickel, and zinc). Twenty-five confirmation soil samples were collected below the bottom of the former settling lagoon excavation, the samples were composited into five samples, and the samples were analyzed for water-soluble cyanide and EP Toxicity metals.

Although the water table was encountered only at the base of the excavations, the moisture content of the excavated native soil was higher than that allowed for disposal. Therefore, kiln dust was mixed with soil to adjust the moisture content of the soil prior to transportation and disposal. A total of 614 tons of sludge, soil, and kiln dust were transported to Chemical Waste Management's TSD facility in Arlington, Oregon, for disposal. The closure procedures and laboratory analyses were documented in Landau (1988a).

5.1.2 Former Sludge Drying Beds

The former sludge drying beds located on the southwest portion of Parcel G were closed between July and October 1988 consistent with the EPA-approved closure plan. Closure activities consisted of excavation of sludge, excavation of 6 inches of underlying native soil (including the entire berms between the former sludge drying beds), lining the base of the excavations with woven geotextile for stabilization, installing an impermeable liner over the geotextile, filling the center of the excavations with mixed stabilized sludge and soil, filling the perimeter of the excavations with clean granular soil, and installation of an asphalt concrete cover system that was sloped to the north. The cover system includes two geotextile layers, a PVC liner, a granular backfill layer, a crushed rock base layer, and asphalt concrete pavement.

Confirmation soil samples were collected below the bottom of the former southwestern sludge drying beds. Sixty grab samples and one composite sample were collected. The sixty grab samples were composited into 12 samples, and all 13 composite samples were analyzed for pH, EP Toxicity metals (arsenic, cadmium, chromium, lead, copper, nickel, and zinc), and EP Toxicity cyanide. Fifty-four stabilized test cylinders were collected from the stabilized sludge; from 2 to 18 samples were collected from each of the 7 lifts of stabilized sludge. All of the test cylinders were analyzed for unconfined compressive strength, and 12 of the test cylinders were submitted for laboratory analysis of pH, EP Toxicity metals, and EP Toxicity cyanide. All of the test cylinders analyzed for chemical parameters were tested before they had fully cured. Approximately 2,105 cubic yards (cy) of sludge and 2,415 cy of excavated soil were stabilized. The closure procedures and laboratory analyses were documented in Landau (1988b).

Per Post-closure Permit Condition V.E.3.b.ii.B, the first sludge drying beds used on Parcel G (located in the southeast portion of the parcel) were filled with clean soil and capped in the same timeframe as the former southwestern sludge drying beds. The former southeastern sludge beds were filled and capped to prevent the accumulation of stormwater in the area.

5.1.3 Former Drum Storage Area

Unsaturated, contaminated soil from the former drum storage area was excavated and removed from the site in October and November 1988. Per Post-closure Permit Condition V.E.3.b.ii.A, soil with total VOC concentrations greater than 5 mg/kg was removed from ground surface to the water table (at seasonal low water levels). The approximate dimensions of the excavation footprint are shown on Figure 5. Based on the reported excavation footprint and depths, approximately 2,000 cy of soil were removed. Confirmation soil samples were collected from a backhoe bucket along the excavation sidewalls (Figure 5). At each sampled location, samples were collected at the top, middle, and bottom of the excavation, at approximate depths below grade of 2.5, 5, and 7 feet, respectively. Samples were submitted for laboratory analysis of VOCs. Monitoring wells HYCP-3s, HYCP-3i, and HYCP-3d, which were located in the excavation footprint, were abandoned prior to remediation; HYCP-3s and HYCP-3i were replaced as described in Section 4.9. The boundaries of the excavation and the confirmation soil sampling results were provided in a letter report (Sweet-Edwards/EMCON, 1988d).

5.1.4 Former Off-site Underground Septic Tank

In October 1988, an underground septic tank on the south side of the former Hytek building (south of the current Hexcel Building 1 near HY-2) was removed. Per Post-closure Permit Condition V.E.3.b.ii.D, soil with total VOC concentrations greater than 5 mg/kg was removed from ground surface to the water table and disposed of off site. Approximately 17 tons of soil were removed (Sweet-Edwards/EMCON, 1988c).

5.2 Post-Closure Groundwater Remediation

In 1989, EMCON designed and implemented a pilot groundwater remediation program for both the BSB and Hexcel parcels, in accordance with the post-closure permit and private cost-sharing agreement between BSB and Heath Tecna (later Hexcel). S.S. Papadopulos and Associates Inc. (SSPA), as Heath Tecna Aerospace Company's consultant, developed the groundwater flow model for the site. The model defines target pumping rates for each recovery well and evaluates the performance of the remediation program with respect to the capture of groundwater contaminants. In August 1991, USEPA provided final approval for implementation of the recovery and treatment program.

In August 1992, EMCON activated the groundwater extraction and treatment program required by the post-closure permit. The groundwater extraction program, which is currently still in operation, consists of six groundwater recovery wells that recover VOCs from the shallow aquifer zone consistent with the post-closure permit conditions. Recovery wells HYR-1 and HYR-2 are located on the BSB parcel and recovery wells CG-1, CG-2, CG-3, and CG-4 are located on the Hexcel parcels. An automated control system controls pumping rates, signals system alarms, records pumping volumes and rates, and collects water level data.

The groundwater program initially included a groundwater treatment system. However, following approval to discharge effluent water directly to the publicly-owned treatment works (POTW) in 1995, the on-site treatment system has been idle. Currently, groundwater enters a bypass line that transfers the water from the treatment area directly to the King County (formerly Metro) sewer treatment system.

BSB submitted a request for a Class 2 permit modification in 1998. The modification sought to streamline the groundwater monitoring program, documented in the Evaluation Monitoring Plan (Sweet-Edwards/ EMCON, 1991), by reducing the number of groundwater sampling wells and the frequency of sampling required. Ecology approved the modification in 1998, and an Evaluation Monitoring Plan Amendment (EMCON, 1998a) was prepared to reflect the approved groundwater monitoring program changes. A Post-Closure Care Permit Renewal Application (BSB, 1999) was submitted to Ecology in 1999.

Under the BSB AO and Hexcel EO the remediation responsibilities are divided by parcel with BSB responsible for remediation of Parcel G and Hexcel responsible for remediation of Parcels A through F. The groundwater treatment system will be separated with each party having a separate discharge to the sewer treatment system as described in the orders.

6.0 INVESTIGATION RESULTS

This section presents a summary of the Parcel G (the site) investigation results. Off-site results are discussed when necessary to provide clarity to the Parcel G results. Detailed results of investigations performed on Parcel G and off site are in the documents referenced in Section 4.

6.1 Geology

Appendix B presents boring logs and well completion figures for monitoring and recovery wells completed on and immediately adjacent to Parcel G; off-site, upgradient wells HY-11s, HY-11i, and HY-11d logs are also included. Tables 2 and 3 provide summaries of the Parcel G and off-site well completions, respectively. The maximum depth penetrated by the borings drilled on or adjacent to Parcel G was 96 feet bgs. Figure 5 presents the location of eight geologic cross sections (provided as Figures 7 through 14) across Parcel G. The geologic cross sections are based on boring logs from groundwater monitoring wells and the GP and SP borings drilled in 1999 and 2000. The geologic materials encountered in these borings consisted of sand, silty sand, silt, and organic silt. Previous investigation reports have categorized the materials encountered at the site into six zones, designated Layers A, B, C, D, E, and F (Sweet-Edwards/EMCON, 1988a). These layers are generally present beneath Parcel G and off-site to the northeast, although larger sampling intervals in some borings prevented the identification of some of the thinner layers in some off-site borings. Following are brief descriptions of the soil types encountered in each layer. Table 4 provides laboratory-derived soil physical properties for samples collected from direct-push borings (GP-11, SP-3, SP-4, SP-21, and SP-35) and piezometer borings (I and L). The geologic materials encountered at the site were consistent with those encountered by the U.S. Geological Survey and by other environmental investigations in the valley.

Layer A. In general, the uppermost material encountered in this layer consisted of a sand and silty sand with a thickness ranging from approximately 0 to 11 feet. This material was generally fine to medium and ranged from well to poorly graded. Beneath the sand and silty sand lay a silt unit, which varied in thickness from approximately 1 to 13 feet and extended to a maximum depth of 15 feet bgs. The silt was brown to gray, nonplastic to medium plasticity, with trace fine sand and lenses varying from sand to silty sand.

Layer B. Layer B consisted of an upper sand, intermediate silt, and a lower sand. The upper sand varied in thickness from 1 to 12 feet and the top of the unit was typically encountered between approximately 10 and 15 feet bgs. The fine sand was typically dark gray with reddish grains and contained occasional lenses varying from sand with silt to silty sand.

An intermediate silt layer was encountered at most boring locations throughout the site between depths of approximately 15 and 23 feet bgs. In general, the intermediate silt layer was represented as a series of thin discontinuous pockets in the southwest that increased in thickness, becoming a continuous layer in the northern and eastern portions of the site. Figure 9, along C-C’, represents the continuous silt layer along the northern portion of the site. In the southwestern half of the site, along B-B’ and E-E’ (Figures 8 and 11, respectively), the silt encountered in each of the borings was either a thin discontinuous lens or completely absent. In some of the borings, where the silt layer was absent, a corresponding peat layer at the approximate depth intervals was present. The silt, where found, varied in thickness from approximately 0.5 to 8 feet and was typically dark gray and nonplastic to low plasticity, and contained varying amounts of fine sand.

The lower sand of Layer B was found beneath the intermediate silt unit, with the top at approximately 18 to 23 feet bgs. It varied in thickness from approximately 8 to 23 feet. The sand was typically dark gray with reddish grains, fine to medium with coarse sand locally, and contained occasional lenses varying from sand with silt to silt. Additionally, lenses of peat and scattered organic debris were encountered at various depths and locations within Layer B.

Layer C. A third silt unit was encountered throughout the site, with the top of it at approximately 27 to 44 feet bgs (Table 5). The gray silt ranged from nonplastic to medium plasticity and contained scattered shell fragments. Layer C was encountered in all but one of the boring locations on or immediately north (south side of South 200th Street) of Parcel G. The one location in which Layer C was not encountered (HYO-1) was likely not sampled sufficiently to identify Layer C, given that nearby locations sampled more frequently did identify Layer C. The entire thickness of Layer C was only penetrated in 16 boring locations, varying from approximately 0.8 (SP-25) to 15 feet thick (Ld; see Table 5).

Layer D. Sand corresponding to Layer D was encountered in the 16 Parcel G explorations that fully penetrated Layer C. The top of the unit was encountered at approximately 35.5 to 48 feet bgs. Layer D ranged in thickness from 30 to 36 feet at the five exploration locations that fully penetrated the unit (HY-1d, HYO-1, HYO-3, I, and Ld). Layer D was composed primarily of fine to medium sand, with occasional thin interbeds of silty sand and silt. Shell fragments and occasional accumulations of wood fragments were also found in Layer D.

Layer E. Layer E was identified during the 1987 groundwater investigation as a transitional unit between the Layer D sand and the underlying fine-grained Layer F. The unit was reported (Sweet-Edwards/EMCON, 1988a) to consist of silty sand with increasing interbeds of silt with depth, typically less than 8 feet thick. Based on the deep boring logs HY-1d, HYO-1, HYO-3, I, and Ld, it appears that beneath Parcel G the unit consists of sand with increasing interbeds of silt and clay with depth. The bottom 16.5 feet of the HYO-3 boring log notes interbedded sand, clayey silt, and clay, which may represent Layer E or the top of Layer F.

Layer F. Layer F, the deepest unit encountered during on- or off-site investigations, consisted of laminated to massive, greenish gray to dark gray, moderately plastic clay and silt, with scattered wood fragments. The unit was encountered in three deep Parcel G borings (HYO-1, I, and Ld) and potentially in HYO-3, as discussed above. The top of the unit was encountered at approximately 74 to 83 feet bgs. None of the borings were advanced deep enough to penetrate the base of Layer F, but the unit is potentially 100 feet thick based on well logs for deep wells in the vicinity of the site.

6.2 <u>Groundwater Flow</u>

6.2.1 Groundwater Elevations

Appendix C provides Parcel G water levels (Tables C-1, C-2, and C-3), historical monthly precipitation (Table C-4), and hydrographs for Parcel G wells. Table 6 summarizes the maximum and minimum depths to groundwater and groundwater elevations for Parcel G wells; data from the HY-11 well cluster are also included since they are located adjacent to an unpaved recharge area. Between 1992 and December 2004, depth to groundwater at Parcel G varied from approximately 2.3 to 12.2 feet. Parcel G groundwater elevations during this same time period ranged from 11.31 to 20.82 feet (relative to the National Geodetic Vertical Datum of 1929

[NGVD 29]) in wells screened in Layers A and B and ranged from 13.60 to 21.03 feet in wells screened in Layers D and E. As seen in the hydrographs (Appendix C), groundwater elevations vary up to approximately 6.5 feet seasonally in wells completed in Layers A and B and up to approximately 5 feet seasonally in wells completed in Layers D and E. Groundwater elevations were highest winter to spring and lowest in the fall, lagging approximately 2 to 4 months behind precipitation.

Tables C-5 through C-10 in Appendix C provide Layer B and Layer D groundwater elevations at Parcel G well clusters HY-1, L, and HYCP-1 and off-site well clusters HY-11, G, and H. For comparison, Tables C-11 through C-15 in Appendix C provide Layer B and Layer D groundwater elevations at off-site well clusters B, C, HY-7, HY-8, and K, which are located at or downgradient of the Carr and Hexcel properties. Hydrographs comparing groundwater elevations in shallow, intermediate, and deep monitoring zones are also provided in Appendix C. The Layer D potentiometric heads were higher than the Layer B potentiometric heads more than 90 percent of the time at the HY-1, HYCP-1, G, and H well clusters for the period of record (July 1992 through December 2004). During the period of record, the Layer D heads were higher than the Layer B heads 82 percent of the time at the L well pair and 54 percent of the time at the HY-11 well cluster (which is located adjacent to an unpaved shallow groundwater recharge area). The comparison of Layer B and Layer D potentiometric heads at the L well pair location is hampered by the lack of an intermediate well; since heads in shallow wells were typically higher than heads in intermediate wells, the upward gradient was likely stronger than that indicated by a comparison of the Ld and Ls data.

The mean Layer D heads were higher than the mean Layer B heads by 0.89, 0.74, 2.07, 0.05, 1.94, and 0.95 feet at the HY-1, L, HYCP-1, HY-11, G, and H well clusters, respectively. The mean upward gradients at the HY-1, L, HYCP-1, HY-11, G, and H well clusters were 0.017, 0.012, 0.056, 0.001, 0.069, and 0.033 feet/foot, respectively. Downward vertical gradients across Layer C occurred periodically during winter and spring recharge. The vertical heads at well clusters HY-1, L, HYCP-1, G, and H were likely influenced to some degree by the Layer B groundwater extraction at HYR-1 and HYR-2. However, similar vertical gradients occurred at off-site piezometer cluster B, located over 500 feet away from the nearest extraction well.

6.2.2 Aquifer Test Results

Horizontal hydraulic conductivities determined from a slug test, single-well pumping tests, and constant rate, multiple-well pumping tests are summarized in Table 7. The horizontal hydraulic conductivities determined in wells screened across portions of Layers A and B ranged from 1.5 to 1,020 feet/day (5.3×10^{-4} to 3.6×10^{-1} cm/sec), and the horizontal hydraulic conductivities determined in wells screened solely in Layer B varied from 0.3 to 56 feet/day (1.0×10^{-4} to 2.0×10^{-2} cm/sec). The variability in the data is likely due to variation in aquifer testing methods, aquifer test lengths, and screened units. The most reliable aquifer test data, from the short-term pumping test in HYR-1, generated Layer B horizontal hydraulic conductivities varying from 43 to 56 feet/day (1.51×10^{-2} to 1.96×10^{-2} cm/sec). These results are consistent with those generated in off-site monitoring wells. No aquifer tests were conducted in Layer D at Parcel G, but one conducted in off-site well HY-8d east of the current Hexcel building yielded horizontal hydraulic conductivity results of 57 to 85 feet/day (2×10^{-2} to 3×10^{-2} cm/sec).

The vertical hydraulic conductivities of the GP-7b and GP-10 Layer B intermediate silt samples submitted for laboratory analysis were 6.9 x 10^{-7} and 3.5 x 10^{-6} cm/sec, respectively. The GP-5b, GP-7b, SP-3, SP-4, SP-21, and SP-35 Layer C silt samples submitted for laboratory analysis yielded vertical hydraulic conductivities varying from 1.3 x 10^{-7} to 2.6 x 10^{-7} cm/sec. No Layer F soil samples from Parcel G were analyzed for vertical hydraulic conductivity. However, the basal silt sample (Layer F) from off-site test boring A was submitted for laboratory analysis of vertical hydraulic conductivity, yielding a result of 3.6 x 10^{-7} cm/sec. These results are consistent with published hydraulic conductivity values for silt (Wolff, 1982).

6.2.3 Hydrostratigraphy

Five hydrostratigraphic units have been identified at the site: two aquifers (Layers B and D) and three low-permeability zones (Layers A, C, and E/F). Layers A, C, E, and F are fine-grained and exhibit low permeability. Layers B and D are composed of relatively high permeability sand.

Layer A. The uppermost portion of this unit is unsaturated or only seasonally saturated. The unit is laterally continuous and likely serves as a barrier to downward groundwater movement. Four wells, HYCP-2, HYCP-3s, HYO-2, and Ls, are completed partially in this layer.

Layer B. The entire thickness of Layer B is saturated, and the Layer B sand forms the shallow aquifer at the site. The intermediate silt found in most boring locations between 15 and 23 feet bgs largely divides Layer B into two subunits. For the purpose of assessing groundwater flow and the nature and extent of contamination, Layer B has historically been divided into two aquifer zones. The shallow aquifer zone is defined as the upper portion of Layer B, above the intermediate silt, and the intermediate aquifer zone is defined as the lower portion of Layer B, below the intermediate silt. Eight Parcel G wells or piezometers completed in the lower portion of Layer A and upper portion of Layer B (HYCP-2, HYCP-3s, HYO-2, and Ls) or in the upper portion of Layer B (HY-1s, HYCP-4, HYCP-5, HYCP-6) monitor the shallow aquifer zone. Due to their long wells screens, four of these wells (HYCP-2, HYCP-4, HYCP-5, and HYCP-6) also monitor the upper portion of the intermediate aquifer zone; historically, the data generated from these wells have been analyzed with the shallow aquifer zone wells. Three Parcel G monitoring wells, HY-1i, HYCP-1i, and HYCP-3i, monitor the intermediate aquifer zone. Both Parcel G extraction wells intercept the shallow aquifer zone and upper portion of the intermediate aquifer zone.

Layer C. The silt of Layer C was encountered throughout Parcel G. This unit serves as a barrier to groundwater flow and a restriction to the vertical transport of contaminants at the site. No Parcel G wells or piezometers are screened in Layer C.

Layers D and E. The saturated sand of Layers D and E form the deeper aquifer at the site, historically referred to as the deep aquifer zone. Although no aquifer tests have been conducted in the Layer D and E sand, it is likely that the horizontal hydraulic conductivity of the Layer D and E sand is similar to Layer B. Five Parcel G monitoring wells or piezometers monitor the deep aquifer zone: HYCP-1d, HYO-1, I, HY-1d, and Ld.

Layers E and F. Similar to the Layer C silt, the silt and clay of Layers E and F serve as a barrier to groundwater flow and a restriction to the vertical transport of contaminants at the site.

6.2.4 Groundwater Flow Direction

Figures 15 through 20 present groundwater potentiometric surface contour maps in the shallow, intermediate, and deep aquifer zones during April and October 2003. Off-site wells and piezometers are included in these maps to provide areal context. These groundwater contour maps are typical of those generated using data collected during periods of groundwater extraction. Groundwater flow in the shallow, intermediate, and deep aquifer zones is generally toward the northeast, with the contours showing groundwater capture by the extraction wells. Groundwater recharge likely occurs by precipitation and surface water (drainage ditches) infiltration in significant unpaved areas to the southwest of Parcel G. Groundwater discharge likely occurs to the 196th East Valley Highway Drainage Ditch, located about 2,000 feet northeast of the site.

A north-northeast to northeast flow direction was indicated by historical data collected before the groundwater extraction system was installed (Sweet-Edwards/EMCON, 1988a), with seasonal variations within a 20- to 30-degree range (S.S. Papadopulos, 1990). This is seen in groundwater potentiometric surface contour maps (Figures 21, 22, and 23) prepared using data collected on January 6, 1997, when the groundwater extraction system was down for maintenance. In 1997, groundwater flow during non-pumping conditions was to the northeast.

6.2.5 Groundwater Flow Velocity

Groundwater flow velocity is determined using the following equation:

$$v = \frac{ki}{n},$$

where v = groundwater flow velocity (cm/sec),
k = hydraulic conductivity (cm/sec),
i = hydraulic gradient (feet/foot), and
n = effective porosity.

The average horizontal hydraulic gradients in the shallow, intermediate, and deep aquifer zones on January 6, 1987, were about 0.0034, 0.0029, and 0.0021 feet/foot, respectively. The typical effective porosity of unconsolidated alluvium similar to that at the site is about 40 percent (Wolff, 1982). Using horizontal hydraulic conductivity ranges of 1.51 x 10^{-2} to 1.96 x 10^{-2} cm/sec for the shallow and intermediate zones and 2 x 10^{-2} to 3 x 10^{-2} cm/sec for the deep zone (see Section 6.2.2), the horizontal groundwater flow rate (average linear velocity) in the shallow, intermediate, and deep aquifer zones varied from 135 to 175, 115 to150, and 110 to 165 feet per year, respectively.

As discussed in Section 6.2.1, the mean upward gradients at the HY-1, L, HYCP-1, HY-11, G, and H well clusters were 0.017, 0.012, 0.056, 0.001, 0.069, and 0.033 feet/foot, respectively. Using a conservative estimate of effective porosity of 40 percent (Wolff, 1982) and vertical hydraulic conductivities between 1.3 x 10^{-7} and 6.9 x 10^{-7} cm/sec, the estimated ranges in the upward groundwater flow rate across Layer C were 0.03 to 0.2 feet per 100 years upgradient of Parcel G (at HY-11), 0.4 to 3 feet per 100 years near the middle of Parcel G (at the HY-1 and L locations), and 1 to 12 feet per 100 years at and near the downgradient edge of Parcel G (at the HYCP-1, G, and H locations).

6.3 Nature and Extent of Contamination

Soil and groundwater chemistry data tables are provided in Appendix D, and groundwater VOC time-trend plots are presented in Appendix E.

6.3.1 Effluent Water Chemistry

Tables D-1 and D-2 provide the analytical results of the effluent water sample collected from the equalizing basin in 1983. Ten of the 12 metals analyzed for were detected, with results ranging from 2.2 µg/L mercury to 300 mg/L total chromium. Total cyanide was detected at 88 µg/L. Five of the 13 VOCs analyzed for were detected, with results varying from 8.5 µg/L 2-nitrophenol to 213 µg/L methylene chloride. Of the three SVOCs analyzed for, total phenol was not detected, and dibutyl phthalate and bis(2-ethylhexyl)phthalate were detected at 5.2 and 25.5 µg/L, respectively.

6.3.2 Equalizing Basin and Drying Bed Sludge Chemistry

Analytical results for the soil (sludge) sample collected from the equalizing basin and the sludge sample collected from the southwestern drying beds are provided in Tables D-1 and D-2. Analytical results for the sludge samples collected in random locations in the southeastern drying beds are provided in Table D-3. Table D-4 presents EP Toxicity metals and cyanide results for sludge cores collected after stabilization of the sludge in the southwestern drying beds.

6.3.2.1 Inorganic Constituents

Eleven of the 12 metals analyzed in the equalizing basin soil (sludge) sample were detected, with detected concentrations varying from 60 µg/kg mercury to 300 mg/kg total chromium. Similarly, 11 of the 12 metals analyzed in the southwestern drying beds sludge sample were detected, with detected concentrations ranging from 300 µg/kg beryllium to 80,000 mg/kg total chromium. The detected concentrations of cadmium, copper, lead, and nickel were also above 1,000 mg/kg. Total cyanide was detected at 14 and 1,000 mg/kg in the equalizing basin and southwestern drying bed samples, respectively. Arsenic, the only metal analyzed for in the southeastern drying bed sludge samples, was detected in five of the six samples, with all results below 10 mg/kg. Cyanide concentrations in the southeastern drying bed sludge samples varied from 100 to 390 mg/kg; cyanide was not detected in one of the samples.

6.3.2.2 Organic Constituents

Seven of the 13 VOCs were detected in the equalizing basin sludge sample; detected concentrations ranged from 10 µg/kg 1,1-dichloroethene (1,1-DCE) to 3,900 µg/kg trans-1,2-dichloroethene (trans-1,2-DCE). TCE was detected at 3,900 µg/kg in the equalizing basin sludge sample. Only 2 of 13 VOCs were detected in the southwestern drying beds sludge sample, methylene chloride (95 µg/kg) and acetone (45 µg/kg); only one of three SVOCs were detected, bis(2-ethylhexyl)phthalate at 2,256 µg/kg. In the six southeastern drying bed sludge samples, none of the 12 VOCs were detected in two of the samples. Six of the 12 VOCs were detected in at least one of the other four southeastern drying bed sludge samples, 1,1-DCE (20 and 24 µg/kg), 1,1-dichloroethane (1,1-DCA; 17 µg/kg), TCE (3 µg/kg), toluene (13 µg/kg), PCE (30 µg/kg), and total xylenes (13, 38, and 74 µg/kg).

6.3.2.3 Stabilized Sludge

Eight of the 12 test cylinders of stabilized sludge from the southwestern drying beds were analyzed for EP Toxicity metals and cyanide before the test cylinders were fully stabilized. Four of the test cylinders were tested when more fully stabilized (see Table D-4). EP Toxicity arsenic and lead were not detected in any of the 12 sludge test cylinders. EP Toxicity cadmium was detected in five of the partially stabilized test cylinders, at concentrations ranging from 0.03 to 3.3 mg/L; EP Toxicity cadmium was not detected in any of the four more stabilized cylinders. EP Toxicity copper was detected four of the eight partially stabilized test cylinders and in three of the four more stabilized test cylinders; detected concentrations ranged from 0.1 to 0.4 mg/L. EP Toxicity nickel was detected in five of the partially stabilized test cylinders, at concentrations ranging from 0.3 to 3.3 mg/L; EP Toxicity nickel was not detected in any of the four more stabilized cylinders. EP Toxicity zinc was detected in two of the partially stabilized test cylinders, at concentrations of 0.2 and 0.5 mg/L, and in none of the four more stabilized cylinders. EP Toxicity chromium was detected in all of the test cylinders, ranging from 0.6 to 1.8 mg/L. EP Toxicity cyanide was detected in all but one of the partially stabilized test cylinders, at concentrations varying from 0.008 to 0.98 mg/L, and in none of the more stabilized test cylinders.

6.3.3 Soil Gas Chemistry

Soil gas analytical results are provided in Table D-5. PCE was not detected in any of the samples in which it was analyzed. TCE was detected at low concentrations (5 and 15 parts per billion [ppb]) in two of the six background samples and in most of the Parcel G samples. Detected TCE concentrations ranged from 5 (SG-107) to 250,000 ppb (SG-5), with the highest concentrations in samples collected near the former drum storage area (at SG-5, SG-6, SG-24, and SG-106). DCE (cis- + trans-1,2-dichloroethene) was detected at low concentrations (trace to 5 ppb) in two of the three background samples and in most of the Parcel G samples in which it was analyzed. Detected concentrations varied from 5 to 90 ppb but did not correlate well with the detected TCE concentrations.

6.3.4 Soil Chemistry

6.3.4.1 Inorganic Constituents

Confirmation soil samples collected during closure of the equalizing and settling lagoons, and the southwestern drying beds are presented in Tables D-6 and D-7, respectively. Soil inorganics data generated during the Parcel G source area investigation are presented in Table D-8. Arsenic, chromium, and lead were not detected in the EP Toxicity analyses of confirmation samples from the lagoons and drying beds. Copper, nickel, and zinc were not detected in the EP Toxicity analyses of confirmation samples from the southwestern drying beds. EP Toxicity cadmium was only detected (0.53 mg/L) in one drying bed confirmation sample, and EP Toxicity copper was only detected in two (0.2 and 1.0 mg/L) lagoon samples. EP Toxicity cadmium, nickel, and zinc were detected in most lagoon confirmation samples, ranging from 0.01 to 2.5 mg/L, 0.2 to 0.8 mg/L, and 0.1 to 0.2 mg/L, respectively. Chromium, iron, manganese, and COD results from the source area investigation ranged from 6 to 17, 5,560 to 12,800, 47 to 129, and 1,648 to 17,193 mg/kg, respectively.

6.3.4.2 Organic Constituents

Soil VOC results are provided in Tables D-9 through D-12. Total chlorinated VOCs (CVOCs) detected in soil samples collected above the water table in the former drum storage area (Table D-9) ranged from less than the laboratory method reporting limit (MRL) to 111.6 mg/kg. Twelve VOCs were detected in at least one of the confirmation soil samples collected above the water table in the former drum storage area after excavation and off-site disposal of soil (Table D-10); TCE (0.1 to 130 mg/kg), cis-1,2-DCE (0.1 to 36 mg/kg), vinyl chloride (0.1 to 2 mg/kg), and methylene chloride (0.1 to 0.4 mg/kg) were the compounds detected the most frequently.

Tables D-11 and D-12 present soil VOC results from samples collected above and below the water table in the 1987 hand-augered borings and the 1984 hand-augered and drilled borings. The highest VOC concentrations and most frequent VOC detections were in borings located in the former drum storage area and along the former ditch. TCE (0.002 to 2,000 mg/kg), TCA (0.002 to 61 mg/kg), trans-1,2-DCE (0.011 to 21 mg/kg), vinyl chloride (0.012 to 3.7 mg/kg), methylene chloride (0.012 to 0.084 mg/kg), toluene (0.010 to 60 mg/kg), and total xylenes (0.10 to 40 kg/kg) were detected the most often. Locations with few and relatively low-concentration VOC detections included the small drying bed north of the southwestern drying bed, the southwestern and southeastern drying beds, the east end of the former ditch, and the area north of the former waste handling facility.

Table D-13 provides the soil VOC results from the 2000 Parcel G source area investigation (IT Corporation, 2001), and Figure 24 presents total VOC isoconcentration contours in soil in both the upper and lower portions of Layer B that were generated during the 2000 source area investigation. The primary VOCs found during the source area investigation were TCE, cis-1,2-DCE, and vinyl chloride. Consistent with the previous soil sampling, the extent of contamination appears to be centered around the location of the former drum storage area. Total VOC concentrations above 10 mg/kg were found between depths of 17 and 34 feet below grade, with maximum VOC concentrations typically located within or directly above the confining layers (i.e., intermediate silt layer in Layer B and the top of Layer C). The maximum total VOC concentration in the depth range of the intermediate silt was 329 mg/kg at a depth of 20 feet in SP-9, and the maximum total VOC concentration at the base of Layer B was 600 mg/kg at a depth of 34 feet in SP-11. Although these soil sampling investigations included monitoring for DNAPL, none was observed. While the PID readings (see boring logs in Appendix B) measured during drilling were helpful in identifying soil samples for laboratory analysis, their inconsistent correlation with laboratory VOC results made them far less useful in identifying potential DNAPL zones. The highest soil laboratory VOC results indicate the potential presence of DNAPL. As discussed in Section 6.3.5, the concentrations of TCE in groundwater are consistent with the likely presence of DNAPL.

6.3.5 Groundwater Quality

This section provides a discussion of groundwater quality in monitoring wells installed within the boundaries of Parcel G and immediately north of Parcel G (between the site and South 200th Street). Off-site results are discussed when necessary to provide clarity to the Parcel G results.

6.3.5.1 Metals

Metals results for groundwater samples collected from HY-1s in the early 1980's, HY-1d in the mid 1980's, and HYCP-2 and HYCP-5 since 1995 are presented in Table D-14. Arsenic results for groundwater samples collected during routine sampling are presented in the Appendix E tables. In general, Parcel G groundwater metals concentrations were either infrequently detected or detected at low concentrations.

Dissolved arsenic was infrequently detected in groundwater samples from shallow wells HYCP-3s, HYCP-5, and HYCP-6, but dissolved arsenic was frequently detected in groundwater samples from shallow wells HY-1s, HYCP-2, HYCP-4, and HYO-2. Detections ranged from the MRL of 5 µg/L to 34 µg/L, with the higher detections in HYCP-2 and HYCP-4. These detected concentrations were similar to those in upgradient shallow well HY-11s, where dissolved arsenic was frequently detected at concentrations ranging from 5 to 37 µg/L. Dissolved arsenic was not detected in intermediate wells HY-1i, HYCP-1i, and upgradient intermediate well HY-11i, but dissolved arsenic was frequently detected in intermediate well HYCP-3i at concentrations ranging from 6 to 19 µg/L. In the deep aquifer zone, dissolved arsenic was infrequently detected in HYCP-1d and frequently detected in HY-11d and upgradient well HY-11d. Detections ranged from 5 to 10 µg/L. The relatively uniform spread of arsenic results from upgradient to downgradient across Parcel G and the generally decreasing arsenic concentrations with depth indicate that the source of arsenic is shallow and either area-wide or upgradient of Parcel G. It should be noted that the site is located in an area likely affected by the former Tacoma metals smelter that processed high-arsenic ore (Area-Wide Soil Contamination Task Force, 2003).

Dissolved barium was detected in all but one HYCP-2, HYCP-5, and HY-1d samples, ranging from 7 to 32 µg/L. Dissolved cadmium was only detected in one HY-1s sample just above the MRL. Dissolved trivalent chromium was detected in one HY-1s sample near the MRL, and dissolved trivalent and hexavalent chromium, not detected in HYCP-2 and only detected once in HY-1s, was detected in all HYCP-5 and HY-1d samples, varying from 7.8 to 18 µg/L. Dissolved copper, largely undetected in HYCP-2 and HYCP-5, was detected in both of the HY-1d samples and some of the HY-1s samples; copper detections ranged from 2 to 26 µg/L. Dissolved nickel was not detected in HY-1s, HYCP-2, or HY-1d. HYCP-5 dissolved nickel concentrations varied from 48 to 114 µg/L. Dissolved zinc, infrequently detected in HYCP-2 and HYCP-5 but detected in all analyzed HY-1s and HY-1d samples, ranged from 2 to 120 µg/L. Dissolved antimony, beryllium, hexavalent chromium, lead, mercury, selenium, and silver were not detected in the HY-1s samples analyzed for those constituents.

6.3.5.2 General Chemistry

General chemistry results for groundwater samples collected from HY-1s in the early 1980's are provided in Table D-15. General chemistry results and field parameter measurements for groundwater samples collected from direct-push borings advanced in 1999 are presented in Tables D-16 and D-17. Total cyanide results for groundwater samples collected during routine sampling are presented in the Appendix E tables. The results varied as follows:

- Specific conductance: 250 to 1,528 µmhos/cm;
- pH: 5.9 to 6.9;
- Hardness: 140 to 210 mg/L;
- TOC: 1 to 37.8 mg/L;
- TOX: <5 to 22,000 µg/L;
- Chloride: 5 to 197 mg/L;
- Sulfate: 0.3 to 501 mg/L;
- TDS: 280 to 1,010 mg/L;
- Total cyanide: 2 to 140 µg/L;
- Nitrate as nitrogen: < 0.2 to 0.5 mg/L;
- Dissolved calcium: 15.8 to 54.8 mg/L;
- Dissolved iron: 4.7 to 52.6 mg/L;
- Dissolved magnesium: 7.3 to 19.1 mg/L;
- Dissolved manganese: 0.36 to 5.4 mg/L;
- Dissolved sodium: 27 to 223 mg/L;
- Alkalinity: 220 to 420 mg/L;
- Oxidation reduction potential: -69 to –464 millivolts; and
- Dissolved oxygen: 0.1 to 3.9 mg/L.

6.3.5.3 Organic Constituents

VOC results for groundwater samples collected from the 1999 and 2000 Parcel G direct-push-boring investigation are presented in Tables D-18 and D-19. VOC results for groundwater samples collected during routine Parcel G sampling are presented in the Appendix E tables. Results of additional annual VOC analyses are presented in Table D-20. Parcel G groundwater SVOC, PCB, and pesticide results are provided in Tables D-21, D-22, and D-23, respectively.

No PCBs or pesticides were detected in any of the groundwater samples analyzed from HYCP-2, HYCP-5, and HY-1d. Only two SVOCs were detected in the analyzed HY-1s, HYCP-2, HYCP-5, and HY-1d groundwater samples: phenol was detected at 8 µg/L in HY-1s in November 1984, and bis(2-ethylhexyl) phthalate was detected at 17 µg/L in HY-1d in January 1985. Neither constituent was detected in any other analyzed sample.

VOCs in Direct-Push Borings. Fifteen VOCs were detected in groundwater samples collected from the Parcel G direct-push borings (sampled in the shallow and intermediate aquifer zones) in 1999 and 2000. The results from the 52 samples varied as follows:

- TCE: 9 detections, from 1.4 to 21,000 µg/L;
- cis-1,2-DCE: 33 detections, from 1.7 to 92,000 µg/L;
- Vinyl chloride: 24 detections, from 5.2 to 4,100 µg/L;
- 1,1-DCA: 23 detections, from 0.6 to 95 µg/L;
- 1,1-DCE: 13 detections, from 0.7 to 160 µg/L;
- trans-1,2-DCE: 15 detections, from 2.6 to 95 µg/L;
- 1,2-DCA: 2 detections, 1.1 and 1.3 µg/L;
- 1,2-dichloropropane: 1 detection at 79 µg/L;
- Chlorobenzene: 2 detections, 1.0 and 140 µg/L;
- 1,2-dichlorobenzene: 1 detection at 91 µg/L;
- 1,3-dichlorobenzene: 1 detection at 7 µg/L;
- 1,4-dichlorobenzene: 1 detection at 67 µg/L;
- Toluene: 3 detections, from 1.8 to 52 µg/L;
- Ethylbenzene: 2 detections, 2.1 and 4.2 µg/L; and
- Total xylenes: 2 detections, 13 and 15 µg/L.

The highest concentrations of VOCs were in borings located near and downgradient of the former drum storage area (GP-1b, GP-2b, GP-13b, and SP-12B), two borings at the north end of the former southeastern drying bed (SP-13 and SP-24), and four borings located near the western (upgradient) boundary of Parcel G (SP-15, SP-17, SP-18, and SP-21).

VOCs in Monitoring Wells. Tabulated primary VOC detections in wells located on or adjacent to Parcel G are presented in Appendix E and Table D-20. Since sampling of the wells began in the mid-1980s, fourteen VOCs have been detected routinely during at least part of the sampling history. As discussed below, Parcel G groundwater VOC concentrations have decreased since implementation of the groundwater extraction system in August 1992. Following are the 14 primary VOCs that have been detected with the ranges of detected concentrations between 1999 and 2003:

- TCE: from <0.12 to 710 µg/L in shallow wells, from <0.5 to 6,900 µg/L in shallow/intermediate recovery wells, from <0.12 to 76,000 µg/L in intermediate wells, and not detected (reporting limits from 0.12 to 0.5 µg/L) in deep wells;

- cis-1,2-DCE: from <0.12 to 26,000 µg/L in shallow wells, from <5 to 8,400 µg/L in shallow/intermediate recovery wells, from 22 to 42,000 µg/L in intermediate wells, and <0.12 to 11 µg/L in deep wells;

- Vinyl chloride: from <1.2 to 4,900 µg/L in shallow wells, from 19 to 1,100 µg/L in shallow/intermediate recovery wells, from 6.1 to 8,200 µg/L in intermediate wells, and <0.22 to 80 µg/L in deep wells;

- 1,1-DCA: from 0.15 to 270 µg/L in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from 0.42 to 32 µg/L in intermediate wells, and not detected (reporting limits from 0.09 to 0.5 µg/L) in deep wells;

- 1,1-DCE: from 0.18 to 80 µg/L in shallow wells, from <0.5 to 27 µg/L in shallow/intermediate recovery wells, from <0.12 to 52 µg/L in intermediate wells, and not detected (reporting limits from 0.12 to 0.5 µg/L) in deep wells;

- trans-1,2-DCE: from <0.14 to 72 µg/L in shallow wells, from <0.5 to 51 µg/L in shallow/intermediate recovery wells, from <0.5 to 190 µg/L in intermediate wells, and not detected (reporting limits from 0.14 to 0.5 µg/L) in deep wells;

- 1,2-DCA: from <0.12 to 0.8 µg/L in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from <0.12 to 1.1 µg/L in intermediate wells, and not detected (reporting limits from 0.12 to 0.5 µg/L) in deep wells;

- 1,1,1-trichloroethane: from <0.11 to 78 µg/L in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, not detected (reporting limits from 0.12 to 500 µg/L) in intermediate wells, and not detected (reporting limits from 0.12 to 0.5 µg/L) in deep wells;

- PCE: not detected (reporting limits from 0.12 to 50 µg/L) in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from <0.11 to 3.8 µg/L in intermediate wells, and not detected (reporting limits from 0.11 to 0.5 µg/L) in deep wells;

- Methylene chloride: from <0.2 to 26 µg/L in shallow wells, not detected (reporting limits from 15 to 1,000 µg/L) in shallow/intermediate recovery wells, from <0.12 to 120 µg/L in intermediate wells, and not detected (reporting limits from 0.2 to 5 µg/L) in deep wells;

- Benzene: not detected (reporting limits from 0.11 to 50 µg/L) in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from <0.11 to 1.6 µg/L in intermediate wells, and not detected (reporting limits from 0.11 to 0.5 µg/L) in deep wells;

- Toluene: from 0.1 to 19 µg/L in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from 0.13 to 180 µg/L in intermediate wells, and from 0.14 to 1 µg/L in deep wells;

- Ethylbenzene: from <0.13 to 74 µg/L in shallow wells, not detected (reporting limits from 0.5 to 100 µg/L) in shallow/intermediate recovery wells, from 0.13 to 68 µg/L in intermediate wells, and not detected (reporting limits from 0.13 to 0.5 µg/L) in deep wells; and

- Total xylenes: from <0.3 to 97 µg/L in shallow wells, not detected (reporting limits from 1 to 200 µg/L) in shallow/intermediate recovery wells, from 0.3 to 130 µg/L in intermediate wells, and not detected (reporting limits from 0.3 to 1 µg/L) in deep wells.

In addition to being detected at the highest concentrations, TCE, cis-1,2-DCE, and vinyl chloride were also the most frequently detected compounds.

Between 1999 and 2003, 1,1-DCA and PCE were detected at least once in upgradient shallow well HY-11s, toluene was detected twice in upgradient intermediate well HY-11i, and vinyl chloride, 1,1-DCA, and toluene were detected at least once in upgradient deep well HY-11d. Except for one toluene detection in HY-11d (11 µg/L), the upgradient VOC detections were below 1 µg/L. Other VOCs that have been detected infrequently and at low concentrations in Parcel G monitoring wells have included acetone, chloroethane, carbon disulfide, chlorobenzene, 1,2-dichlorobenzene, 1,3-dichlorobenzene, and 1,4-dichlorobenzene. Two of these (acetone and carbon disulfide) are chemicals used in analytical laboratories and may represent laboratory contamination of the samples.

6.3.5.4 VOC Time Trends

Appendix F provides time-trend plots for the primary VOCs routinely detected in Parcel G wells (TCE, cis- and trans-1,2-DCE, and vinyl chloride, see above). Plots were prepared for all Parcel G wells sampled for at least 5 years and, for reference, upgradient monitoring wells HY-11s, HY-11i, and HY-11d. All data available for each well were plotted; solid symbols represent concentrations detected above the MRL, and open symbols represent non-detections (plotted at the MRL). For wells with significant variation in VOC concentrations over time, multiple time-trend plots are presented to allow for different concentration scales.

TCE, cis- and trans-1,2-DCE, and vinyl chloride concentrations have varied in each well over time, with much of the shorter-term variation likely due to seasonal changes. Except for monitoring wells HY-1s and HY-1i, VOC concentrations in Layer B (shallow and intermediate aquifer zone) monitoring wells have decreased significantly since activation of the groundwater recovery system in August 1992. VOC concentrations in wells located near the former drum storage area (HYCP-3s, HYCP-3i, and HYCP-4) have fluctuated the most with less significant longer-term VOC concentration declines than those apparent in Layer B monitoring wells installed further from the former drum storage area (HYCP-1i, HYCP-2, HYCP-5, HYCP-6, HYO-2, and Ls). After the initial significant decrease in VOC concentrations, the wells installed further from the former drum storage area (HYCP-1i, HYCP-2, HYCP-5, HYCP-6, HYO-2, and Ls) experienced a shorter-term, less significant increase in VOC concentrations with a subsequent VOC concentration decrease; these concentration spikes occurred in different years in the wells. TCE, cis- and trans-1,2-DCE, and vinyl chloride concentrations in monitoring wells HY-1s and HY-1i increased after activation of the groundwater recovery system in August 1992, peaking in HY-1s between 1995 and 1996 and peaking in HY-1i between 1994 and 1998. VOC concentrations in both HY-1s and HY-1i have decreased since then.

No TCE, cis- and trans-1,2-DCE, and vinyl chloride concentration time trends are apparent in HY-1d due to the infrequent detections. Though low in concentration, TCE, cis- and trans-1,2-DCE, and vinyl chloride concentrations in Ld have trended downward since activation of the groundwater recovery system. HYCP-1d vinyl chloride concentrations and, to a lesser degree cis- and trans-1,2-DCE concentrations, have trended upward since 1996. These VOC detections are relatively low, but with the presence of the Layer C aquitard and the presence of higher hydraulic heads in Layer D than in Layer B, the increasing VOC trends in HYCP-1d are unexpected. HYCP-1d is installed in the same boring as HYCP-1i, and it is possible that the increasing VOC concentrations in HYCP-1d are due to downward groundwater flow through a leaking well seal induced during groundwater purging and sampling of HYCP-1d.

6.3.5.5 Spatial Distribution of VOCs

The vertical distribution of groundwater VOCs at Parcel G is depicted in Geologic Cross Sections A-A’ through H-H’ (Figures 7 through 14). The data were generated from samples collected in 1999 and 2000 in direct-push borings and monitoring wells. As seen in the cross sections, VOC concentrations were typically higher in the groundwater samples collected from the upper portion of Layer B (i.e., above the intermediate silt layer) compared to groundwater samples collected from the lower portion of Layer B. The intermediate silt layer appears to have been effective in mitigating VOC migration into the lower portion of Layer B. At four locations (GP-1, GP-13, GP-14, and the HYCP-3 groundwater monitoring well pair), however, groundwater VOC concentrations were higher in the lower portion of Layer B.

The horizontal distributions of TCE, cis-1,2-DCE, and vinyl chloride beneath Parcel G, the Hexcel Corporation property, and the Carr property are depicted in a series of isoconcentration contour maps prepared using 1992, 1995, 2000, and 2003 data (Figures 25 through 36). The 1992 maps were prepared using data collected before activation of the groundwater recovery system. The remaining maps were prepared with data collected during groundwater recovery.

Parcel G groundwater impacted with VOCs originates primarily near the former drum storage area and adjacent ditch. Although groundwater analytical results from some borings (e.g., SP-18, SP-21, SP-30) installed upgradient of the former drum storage area and downgradient of the former sludge drying beds indicated elevated levels of cis-1,2-DCE, minimal levels of TCE were detected. Because much higher levels of TCE and cis-1,2-DCE have been detected within and near the former drum storage area (e.g., HYCP-3i, SP-12b) than have been detected at the downgradient edge of the former sludge lagoons (SP-19, SP-20, and SP-22), the investigation results indicate that the predominant source on Parcel G is located in the former drum storage area, not in the former sludge drying beds.

Another source of comparatively low-level Parcel G VOCs appears to be from a location off site to the southwest of Parcel G. Monitoring wells HY-1s and HY-1i, located cross-gradient of the former drum storage area, have had consistent detections of VOCs since installation with significant increases in VOC concentrations after activation of the groundwater recovery system. Groundwater samples collected from direct-push borings SP-15, SP-16, SP-17, SP-18, SP-19, and SP-21, located upgradient or cross-gradient of the former drum storage area, also contained elevated concentrations of cis-1,2-DCE or vinyl chloride (Figures 31, 32, and 33).

The VOC plume extends from the former drum storage area to the northeast, in the direction of local groundwater flow. The maximum extent of the VOC plume is depicted in the vinyl chloride plots (Figures 27, 30, 33, and 36). The plume currently covers the northern half of Parcel G, the northwest corner of the Carr Property, and the southeastern portion of the Hexcel property. Contour lines on the Hexcel Property between the South 200th Street monitoring wells and the 84th Avenue South monitoring wells are estimated due to the lack of monitoring wells west of and beneath the Hexcel buildings (including the former Hytek building). Groundwater data collected in wells installed and sampled by Hexcel in 2003 and included in the 2003 isoconcentration contour maps (Figures 34, 35, and 36) were used to assist in positioning the estimated contours in the earlier maps. The 1995, 2000, and 2003 isoconcentration contour maps show the progressive influence of groundwater recovery at HYR-1, HYR-2, CG-1, CG-2, CG-3, and CG-4, resulting in a slightly smaller VOC plume with considerably lower VOC concentrations in the plume. The continued presence of cis-1,2-DCE and vinyl chloride beyond the northern boundary of Parcel G (where groundwater is captured by recovery wells HYR-1 and HYR-2) is currently unexplained, but is likely due to (1) dissolution or desorption into groundwater of secondary source material north of Parcel G, (2) undiscovered sources near the former Hytek building, and/or (3) the off-site VOC source southwest of Parcel G.

6.3.5.6 DNAPL

Direct-push drilling, continuous coring, visual examination of soil samples, PID screening of soil cores, and laboratory VOC analysis of soil and groundwater samples were used at Parcel G to try to identify the presence of DNAPL. As stated in Section 6.3.4, DNAPL was not observed during Parcel G drilling, but the highest soil laboratory VOC results indicate the potential presence of DNAPL. Similarly, DNAPL has not been observed in any Parcel G monitoring well; however, two lines of indirect evidence indicate that DNAPL is likely present in or near the former drum storage area:

- **Groundwater VOC concentrations.** A common indicator for the potential presence of DNAPL upgradient of the area monitored is VOC concentrations greater than 1 percent of the water solubility of the DNAPL component of interest (Kueper et al, 2003). Concentrations of TCE detected in groundwater were initially as high as 380,000 µg/L (in HYCP-3i, April 1992), which is 35 percent of the solubility limit of TCE in water (1,100 mg/L). The highest concentration in the 1999 through 2003 data set was 76,000 µg/L (HYCP-3i, April 2002), which is still 7 percent of the solubility limit of TCE in water; and

- Persistence of contamination. Contamination persistent at a location may be indicative of DNAPL upgradient of the location. TCE concentrations in recovery well HYR-1 (Appendix F) have been fairly consistent for the last 9 years, indicating the likelihood of an upgradient DNAPL source.

7.0 CONCEPTUAL SITE MODEL

7.1 Contaminant Sources

Based on historical Parcel G waste treatment operations and the distribution of contaminants at Parcel G, it appears that the VOCs in the subsurface were sourced primarily by releases in the former drum storage area. Possible release mechanisms in the former drum storage area included spillage during product transfer, leaks from product drums, and surface spillage of raw products washed into the former ditch at the southern edge of the former drum storage area.

7.2 Chemical Fate and Transport

This section describes the physical, chemical, and biological processes that influence Parcel G-related contaminant migration through the subsurface.

7.2.1 Contaminant Fate Processes

Several physical, chemical, and biological processes affect the mobility and behavior of liquid- (or pure-) phase and vapor-phase contaminants in the unsaturated zone and dissolved- or pure-phase contaminants in the saturated zone. These processes can generally be classified into two categories: nondestructive and destructive. Nondestructive processes primarily affect contaminant mobility and behavior, but do not alter the chemical composition of the contaminant. Destructive processes either destroy the contaminant or change the chemical behavior. Both processes result in effective decreases in contaminant concentration.

7.2.1.1 Non-destructive Processes

The nondestructive processes controlling the contaminant migration rate at Parcel G are sorption, dispersion, volatilization, dissolution, and dilution. These are defined as follows:

- **Sorption** is the chemical bonding of contaminants to soil particles, which slows the rate of soil vapor and pure-phase contaminant migration in the unsaturated zone and the rate of dissolved- and pure-phase contaminant migration in the saturated zone. Sorption effects are directly related to soil organic carbon content. Based on the amount of silt and organic matter in an aquifer, sorption may slow the rate of contaminant transport;

- Dispersion is the longitudinal and transverse spreading of contaminants as they move through a porous media. Dispersion spreads out the contaminant plume, which slows the migration rate and decreases the contaminant concentration of the plume boundary. Dispersion occurs when variations in soil pore size, pore "roughness," and particle flow path length result in different advective transport rates for different solute molecules. Dispersion is most significant in stratified soil zones. Its effects increase with flow path length. A narrow, high concentration plume near the source area will become a broad, low concentration plume several hundred feet from the source area. Dispersion may be more significant in siltier portions of an aquifer;

- Volatilization occurs when pure-phase contaminants in the unsaturated soil or dissolved-phase contaminants in groundwater transfer into the vapor-phase in unsaturated soil. Volatilization from groundwater occurs only at the water table. Volatilization rates depend on the relative volatility of the contaminant (TCE is moderately volatile, while vinyl chloride is highly volatile);

- Dissolution occurs when pure-phase contaminants transfer into the dissolved-phase in soil pore water above the water table or into groundwater below the water table, and when vapor-phase contaminants transfer into groundwater at the water table. This process depends on the relative solubility of the contaminant (TCE is moderately soluble, while vinyl chloride is highly soluble); and

- Dilution occurs when relatively cleaner water from natural or artificial sources infiltrates through the unsaturated soil and mixes with contaminated groundwater resulting in lower contaminant concentrations. Because Parcel G is largely paved, significant natural dilution is likely limited.

Except for dilution, the nondestructive processes described above are generally active at Parcel G. However, given the relatively high concentrations at the source, and the short distance from the source to the Parcel G boundary, attenuation by these processes has not significantly reduced concentrations as they approach the Parcel G boundary. Desorption of VOCs from soil and, probably, dissolution of DNAPL in the saturated zone likely generate most of the dissolved VOCs in groundwater at Parcel G.

7.2.1.2 Destructive Processes

Destructive processes are either biotic (biodegradation) or abiotic. Biodegradation includes all microbial activity occurring in the subsurface that permanently destroys contaminants. Abiotic processes include various chemical reactions, primarily hydrolysis, that destroys contaminants. Biodegradation processes are generally much more significant than abiotic processes; thus, only the biodegradation processes are discussed.

Microbial metabolic degradation of TCE occurs under both aerobic and anaerobic conditions. Aerobic metabolism includes direct oxidation of CVOCs as an energy source, and fortuitous degradation of CVOCs (co-metabolism) during metabolism of other organic compounds. Under anaerobic conditions, CVOCs are degraded by reductive dechlorination (the sequential removal of chlorine atoms from a CVOC molecule). Figure 37 shows the sequential dechlorination steps from primary CVOCs to secondary CVOCs to organic gases (e.g., ethene) and other breakdown products.

Anaerobic reductive dechlorination is defined as the degradation of a compound in the absence of oxygen; thus, only in the presence of other organic material that serves as the primary energy source (McCarty, 1987). Bacterial metabolism under anaerobic conditions requires both electron acceptor and electron donor compounds. Electron donors (primary energy sources or substrates) include organic compounds such as readily degradable sugars, volatile fatty acids (e.g., acetate, lactate), naturally occurring organic matter, and alcohols, or longer chain aliphatic and aromatic hydrocarbons (petroleum fuels). Under anaerobic conditions, electron acceptors include (in order of decreasing metabolic energy yield) nitrate, manganese (V), iron (III), sulfate, and carbon dioxide. During anaerobic reductive dechlorination, CVOCs (i.e., PCE, TCE, DCE, and vinyl chloride) may increasingly serve as an electron acceptor, particularly as the naturally occurring electron acceptors are consumed by microbial metabolism. Degradation of both petroleum hydrocarbons and CVOCs may occur simultaneously during reductive dechlorination. Anaerobic reductive dechlorination is most favorable under methanogenic conditions. Anaerobic reductive dechlorination efficiency decreases as chlorine atoms are removed, PCE is most readily degraded, and vinyl chloride is the most recalcitrant. Vinyl chloride, however, may be degraded aerobically with oxygen as an electron acceptor, or co-metabolically under aerobic conditions in the presence of methane and the Fe^{3+} ion.

Although a detailed evaluation of biodegradation has not been performed at Parcel G, the high groundwater iron content, the low groundwater dissolved oxygen content, the presence of the expected degradation products, and the results of biodegradation evaluations conducted in other environmental investigations conducted in the Kent valley suggest that anaerobic reductive dechlorination is occurring at Parcel G. Biodegradation has evidently contributed to substantial destruction of contaminants in the subsurface at Parcel G, but, because of the relatively high concentrations at the source and the short distance to the Parcel G boundary, has not been sufficient to attenuate contaminants to acceptable levels before they approach the downgradient Parcel G boundary.

7.2.2 Migration Mechanisms and Pathways

Residual contaminants residing in saturated and unsaturated soil may be further mobilized by flow of water or air in the subsurface. Several migration processes are likely to occur, and are described below.

7.2.2.1 Unsaturated Soil

VOCs were originally released into the subsurface during spills that occurred during waste handling in the former drum storage area. The contamination in the unsaturated soils was removed by excavating the drum storage area and ditch in 1988. This area has since been paved.

The processes that caused migration of VOCs in the unsaturated zone before it was excavated are discussed below. As noted, these processes are of much less significance since the removal action and installation of surface pavement.

- **Pure Phase Flow.** Pure-phase chemical product spilled at the surface would have migrated downward due to gravity through unsaturated soil. This pathway was probably the primary contaminant migration route in the former drum storage area. Because waste handling activities ceased at Parcel G 20 years ago, it is likely that all pure-phase VOCs originally released into the unsaturated zone have migrated into the saturated zone, adsorbed onto unsaturated soil, or volatilized. Therefore, pure-phase migration in the unsaturated soil is not considered an active migration pathway.

- **Leaching to Groundwater.** This process includes infiltration of natural precipitation through unsaturated soil, dissolution of pure-phase contaminants or flushing of soil pore water contaminants into the water, and transport of the contaminants to the saturated zone. While likely an active contaminant migration pathway when the drum storage area was active, this process is not considered a significant migration pathway at Parcel G since all unsaturated soil in the former drum storage and ditch areas is located beneath pavement.

- Diffusion. Diffusion is driven by chemical concentration gradients, and is the primary mechanism for vapor transport in unsaturated soil where soil vapor is usually stagnant. Diffusion may be an active migration pathway, though it is likely limited due to the relatively thin unsaturated zone.

7.2.2.2 Saturated Soil and Groundwater

When a release of a VOC product occurs in the subsurface, the product moves downward through the unsaturated soil as a non-aqueous phase liquid (NAPL) under the force of gravity. If the release is large enough, the NAPL eventually reaches the water table and the saturated zone. If the NAPL is denser than water, DNAPL will continue to move downward, in a typically tortuous fashion along multiple flowpaths, with downward movement controlled by the pore size distribution and bedding of the geologic unit. As DNAPL moves through the subsurface, disconnected blobs and ganglia are left behind the trailing edge of the DNAPL, effectively diminishing the migrating mass. The blobs and ganglia are small (less than 10 grain diameters in length) and occupy between approximately 5 to 20 percent of the invaded pore space behind the DNAPL body (Kueper et al., 2003). Downward DNAPL movement will continue until the mass of DNAPL is exhausted or a soil layer fine enough to stop the DNAPL is encountered. In the latter case, the DNAPL will pool and spread laterally. DNAPL in a pool is connected between adjacent pores; pore space in DNAPL pools can be up to 70 percent saturated with DNAPL (Kueper et al., 2003). Portions of a site containing DNAPL pools and/or residual DNAPL (blobs and ganglia) are termed the DNAPL source zone.

As groundwater moves through the DNAPL source zone, a plume of dissolved contaminants is generated; soluble constituents partition into groundwater dictated by the effective solubility of the solvent mixture. Dissolved contaminants then migrate by advection with groundwater. Volatile constituents from groundwater partition into the unsaturated zone vapor phase and migrate in soil gas. Over time, the DNAPL remaining in the subsurface weathers as volatile and soluble components are depleted from NAPL interfaces, with residual NAPL continuing to be a source of contaminants to both groundwater and soil gas. According to Kueper et al. (2003), the lifespan of residual DNAPL in the unsaturated zone is considerably shorter than residual DNAPL in the saturated zone due to high unsaturated zone volatilization rates.

As discussed in Section 6.3.5.6, elevated groundwater VOC concentrations and the persistence of VOC contamination in Layer B at Parcel G indicate that DNAPL is likely present in Layer B in or near the former Parcel G drum storage area with the migration mechanisms described above active at Parcel G. The probable presence of DNAPL coupled with the difficulty of finding it with wells and borings suggests that it occurs at Parcel G primarily as disseminated residuals, blobs, and ganglia in Layer B rather than extensive pooled accumulations.

7.3 Exposure Pathways and Receptors

This section evaluates the potential exposure pathways and receptors that may be impacted by contaminants present at Parcel G. Figure 38 presents the conceptual site model (CSM), which is based on the current and future industrial land use, the results of the water supply well search (Section 3.6), the soil and groundwater sampling results described in Section 6.3, and the active and potentially active fate and transport mechanisms described previously.

7.3.1 Soil

Currently, the vast majority of Parcel G is covered by asphalt pavement, an asphalt concrete cap, or concrete foundations. Parcel G characterization data and confirmation soil sampling data indicate that VOCs are present in unsaturated and saturated soil in and around the former drum storage area. The potential future exposure pathways and receptors for contaminants in soil are the following:

- Exposure to site workers through direct contact with, ingestion of, or inhalation of vapors emanating from contaminated soil during site maintenance or construction activities that disturb the existing structures or pavement (i.e., soil excavation); and

- Exposure to indoor workers in a future Parcel G occupational setting through inhalation of vapors originating from contaminated soil and migrating up through a future building floor. This is not a current pathway because there are no structures on Parcel G. However, there is a potential that future Parcel G development could include commercial or industrial buildings.

There is the potential for exposure to site workers or off-site residents/workers through consumption of contaminants that may leach from soil to groundwater. This is currently an incomplete pathway because (1) leaching is limited by the presence of the asphalt cap, (2) migration of contaminated Parcel G groundwater is controlled by the Parcel G groundwater recovery system, and (3) there are currently no groundwater supply wells located within the extent of the plume or within 1-mile downgradient of Parcel G. Furthermore, future cleanup actions will all include maintenance of (or improvements to) the existing cap. As a result, this is not considered a significant future exposure pathway and will not be evaluated as part of the FFS.

Because the residual contaminated soil is located entirely beneath pavement, there is no potential for exposure to terrestrial ecological receptors. Furthermore, Parcel G qualifies for an exclusion from a terrestrial ecological evaluation in accordance with the requirements of WAC 173-340-7491(c). Specifically, there is no area of contiguous undeveloped land on Parcel G or within 500 feet of the contaminated soil (requirement is less than 1.5 acres) and Parcel G does not contain any of the hazardous substances of concern listed in WAC 173-340-7491(1)(c)(ii). As a result, this is not considered a significant future exposure pathway and will not be evaluated as part of the FFS.

7.3.2 Groundwater

As described in Section 5.2, Parcel G groundwater is currently captured and extracted by two groundwater recovery wells (HYR-1 and HYR-2). Local groundwater flow outside of the Parcel G capture zone flows to the northeast. Some of this groundwater is currently captured by the CG extraction wells located along 84th Avenue South on the Hexcel parcels. The remainder of the groundwater not captured by the CG extraction wells continues flowing northeast, eventually discharging into the 196th East Valley Highway Drainage Ditch, approximately 2,000 feet northeast of Parcel G.

Groundwater contamination in areas immediately downgradient of Parcel G (i.e., the Hexcel property) is being addressed through site investigation and cleanup activities conducted by Hexcel under the Hexcel EO and are, therefore, not considered as part of this evaluation.

7.3.2.1 Potential Groundwater Ingestion Exposure Pathways

As described in the beneficial use evaluation (Section 3.6), 20 water supply wells may be located within a 1-mile radius of Parcel G. However, none of the potential water supply wells are located closer than 2,000 feet of Parcel G; none are reported to be between Parcel G and the 196th East Valley Highway Drainage Ditch, the local point of discharge for downgradient groundwater; and all are completed either at significantly greater depths than the deepest impacts at Parcel G or at significantly higher elevations (beneath the Covington Plain) than the Parcel G impacts. Residences and businesses in the Kent valley adjacent to Parcel G are serviced by public water districts, so there is an extremely low probability that groundwater in an aquifer hydraulically connected to the shallow aquifer at Parcel G will be used for water supply in the future.

King County's Groundwater Protection Program 2002 Annual Report (King County, 2003) indicates that arsenic is present at naturally elevated concentrations in the glacial and bedrock aquifers that feed the alluvial aquifer in the vicinity of Parcel G. Furthermore, background monitoring well HY-11s, which represents background for Parcel G, contains dissolved arsenic at concentrations of up to 37 µg/L. Background arsenic levels are therefore above the drinking water standard of 10 µg/L MCL that will become enforceable in January 2006 and orders of magnitude higher than the MTCA Method B groundwater cleanup level of 0.0583 µg/L.

For all of the reasons described above, and consistent with the requirements of WAC 173-340-720(2) related to the definition of potable groundwater, the groundwater beneath Parcel G and between Parcel G and the 196th East Valley Highway Drainage Ditch is determined to be nonpotable. Therefore, ingestion of groundwater is not a potential future exposure pathway.

7.3.2.2 Potential Groundwater to Indoor Air Exposure Pathway.

Indoor workers in a future Parcel G occupational setting could potentially be exposed through inhalation of vapors originating from contaminated groundwater and migrating up through the soil and a building floor. This is not a current pathway because there are no structures on Parcel G. However, there is a potential that future Parcel G development could include commercial or industrial buildings. Therefore, this is a potential future pathway.

7.3.2.3 Potential Groundwater to Surface Water Exposure Pathway

Groundwater downgradient of the Hexcel property (across 84th Avenue South) is currently the subject of an ongoing groundwater investigation being conducted jointly by BSB and Hexcel in accordance with the Offsite AO. Based on the available information, the low VOC concentrations in the wells located east of 84th Avenue South, the presence of active containment systems at the Hexcel and BSB properties, and the distance to the drainage ditch indicate that the ditch is not likely a current receptor. In the absence of ongoing containment at Parcel G and at the Hexcel parcels, however, VOCs would have the potential to migrate to the ditch and enter surface water. Therefore, this potential future exposure pathway will be retained for evaluation.

Possible receptors associated with the potential future surface water exposure pathway include humans through consumption of aquatic organisms and through consumption of surface water (i.e., drinking water scenario). As noted above, residences and businesses in the Kent valley adjacent to Parcel G are serviced by public water districts, so there is an extremely low probability that surface water from the drainage ditch would be used as a drinking water source. Because significant stormwater runoff from the industrialized areas surrounding the ditch discharge into the ditch, the water quality in the ditch is likely not suitable for human consumption. There is the small potential, however, that persons may attempt to catch fish from the ditch and consume these fish. Therefore, human consumption of aquatic organisms is the only human exposure pathway associated with the groundwater-to-surface water pathway that will be evaluated as part of this FFS.

In addition to the potential human exposures considered above, aquatic organisms that may use the 196th East Valley Highway Drainage Ditch as habitat also have the potential to be exposed to VOCs in the future. Therefore, this receptor to the potential future groundwater-to-surface water exposure pathway will also be evaluated.

7.3.2.4 Summary of Groundwater Exposure Pathways

Summarizing the above discussion, the potential future exposure pathways and receptors for contaminants in groundwater associated with Parcel G are the following:

- Exposure to recreational (fishing) users of the surface water (i.e., the 196th East Valley Highway Drainage Ditch) through consumption of aquatic organisms;
- Exposure of aquatic organisms in surface water (i.e., the 196th East Valley Highway Drainage Ditch) via direct contact; and
- Exposure to indoor workers in a Parcel G occupational setting through inhalation of vapors originating from contaminated shallow groundwater that may migrate up through a future building floor.

7.4 Groundwater Cleanup Standards

MTCA-defined cleanup standards (WAC 173-340-700(2)) are composed of three separate components: cleanup levels; points of compliance; and additional regulatory requirements. Groundwater cleanup levels and points of compliance are the two primary components and are described in the following sections. The additional regulatory requirements that may apply to specific cleanup actions are addressed in Section 11. As previously discussed, soil cleanup standards are not discussed since soil remediation (excavation, on-site soil stabilization, and/or capping) has already been completed.

Cleanup levels will not be developed for the groundwater-to-indoor air and soil-to-indoor air pathways as part of the FFS. These potential pathways are only a concern if future Parcel G development includes construction of habitable structures on Parcel G. Any future development of Parcel G will have to consider this pathway and incorporate engineering controls (e.g., vapor barriers) as appropriate to control potential exposures. These engineering controls are well established. The requirement to conduct an evaluation of this pathway prior to future site development and/or to implement engineering controls will be placed in a notice on the property deed.

7.4.1 Development of Cleanup Levels

The approach to developing cleanup levels consists of the following steps:

- Selection of indicator hazardous substances (IHSs);
- Development of cleanup levels; and
- Selection of the point(s) of compliance.

The selection of IHSs and development of cleanup levels is described in this section, and the selection of the point(s) of compliance is described in Section 7.4.2.

7.4.1.1 Selection of Indicator Hazardous Substances

The investigation results indicate that 14 individual VOCs, dissolved arsenic, and total cyanide have been detected during routine groundwater sampling at Parcel G. Table 8 summarizes the Parcel G VOC, dissolved arsenic, and total cyanide detections between 1999 and 2003. The frequency of detection, maximum detected concentration, and minimum detected concentrations are summarized for each parameter at the bottom of the table.

To determine which of these 16 compounds will be selected as IHSs, and used in the development of cleanup action alternatives, they were evaluated consistent with the approach presented in WAC 173-340-703. This approach is used to reduce the number of hazardous substances being considered during development of cleanup actions by eliminating those substances that contribute a small percentage of the overall threat to human health and the environment. The remaining hazardous substances are designated as IHSs for purposes of defining site cleanup requirements.

The parameters listed in Table 8 were first evaluated based on their frequency of detection, with parameters detected less than 5 percent of the time dropped from consideration. Benzene, methylene chloride, PCE, and 1,1,1-TCA were dropped as IHSs based on frequencies of detection less than 5 percent.

The remaining parameters were then evaluated to determine if any were detected at concentrations below naturally occurring background concentrations. Based on this evaluation, arsenic was dropped as an IHS based on the similarity of the frequency and range of arsenic detections in the Parcel G wells and upgradient well HY-11s. As noted above, arsenic has been detected at concentrations up to 37 µg/L in HY-11s, while the maximum concentration detected in the remaining Parcel G monitoring wells was 27 µg/L in well HYCP-2.

The remaining 11 parameters include 10 VOCs and total cyanide and are considered potential IHSs. Further screening of these potential IHSs was conducted by comparing the detected concentrations of these parameters against the range of published cleanup levels and standards. The range of published groundwater cleanup levels was identified using Ecology's online *Cleanup Levels and Risk Calculation (CLARC)* tool (https://fortress.wa.gov/ecy/clarc/CLARCHome.aspx) and other published standards including water quality criteria established under USEPA's National Toxic Rule (40 CFR 131). Both MTCA Method A and Method B cleanup levels were identified. Table 9 summarizes these published cleanup levels and standards for the 10 VOCs and cyanide as well as the frequency of detection and maximum detected concentration for each parameter.

As can be seen in Table 9, the maximum concentrations of 1,1-DCA, ethylbenzene, toluene, and total xylenes were less than any of the published cleanup levels or standards; these four VOCs are dropped from consideration as IHSs. Of the remaining six VOCs, TCE, vinyl chloride, and cis-1,2-DCE were frequently detected and detected at concentrations well above their published cleanup levels and standards; these three VOCs are retained as IHSs for the FFS. The three remaining VOCs (trans-1,2-DCE, 1,1-DCE, and 1,2-DCA) are co-located with, and present in much lower concentrations than, the detections of TCE, cis-1,2-DCE, and vinyl chloride. The maximum concentrations for all three of these VOCs were much lower than the published surface water standard that would apply to the groundwater-to-surface water pathway. Based on this analysis, trans-1,2-DCE, 1,1-DCE, and 1,2-DCA do not contribute a significant percentage of the overall risk to human health and are dropped from consideration as IHSs.

Cyanide was detected in 18 percent of samples and at a maximum concentration of 40 µg/L. This maximum concentration is well below the lowest of the published cleanup level or standard based on the protection of human health (140 µg/L), but above both the chronic and acute surface water quality standards based on protection of aquatic organisms (5.2 µg/L and 22 µg/L, respectively). It should be noted that the cyanide results reported in Table 8 are for total cyanide, while the published water quality standards are for free or dissociable cyanide. Free cyanide values would be lower than the total cyanide values. A careful review of the data in Table 8 shows that of the 20 detections, eight are at the MRL of 10 µg/L. Nine of the 12 remaining detections, including the maximum detected value, are from monitoring well HYCP-3i located in the center of the source area.

Monitoring results downgradient of Parcel G on the Hexcel property also show sporadic, low-level detections of cyanide at or slightly above the MRL. Downgradient of the Hexcel property, the cyanide detections are even more sporadic than immediately downgradient of Parcel G. No cyanide data are available near the potential receiving surface water body located 1,000 ft downgradient of 84th Avenue South. Because the intermittent presence of low-level cyanide on and downgradient of Parcel G does not represent a risk to human health, and the potential impacts on the receiving water are minimal given the distance between the detections that are marginally above the standards and the receiving water, cyanide is not considered an IHS for purposes of this FFS.

To summarize, the following hazardous substances have been selected as IHSs:

- TCE;
- cis-1,2-DCE; and
- Vinyl chloride.

7.4.1.2 Determination of Cleanup Levels

The next step in establishing cleanup standards is to determine the appropriate cleanup levels for the IHSs identified above. MTCA provides several methods for determining cleanup levels including Method A (tables and applicable state and federal laws), Method B (universal method), and Method C (conditional method). Method C is typically used where Method A or B cleanup levels are impossible to achieve or for certain industrial properties; Method C will not be used for the Parcel G FFS. The applicability of Method A is described in WAC 173-340-704(1). Method A may be used to establish cleanup levels at sites that have few hazardous substances and meet one of the following criteria:

- Sites undergoing a routine cleanup action as defined by WAC 173-340-200; or
- Sites where numerical standards are available either in the MTCA regulations or applicable state and federal laws for all IHSs.

The three IHSs for this site have numerical standards. Furthermore, the cleanup actions being contemplated for Parcel G are consistent with the criteria listed in WAC 173-340-200 under the definition of "routine cleanup action," and as described later in this FFS, there is a limited range of cleanup actions under consideration. Therefore, cleanup levels for the Parcel G FFS will be determined using Method A.

Based on the potential future pathways identified in Section 7.3 and in the conceptual site model (Figure 38), groundwater cleanup levels were identified for the IHSs for the groundwater-to-surface water pathway for the following receptor: protection of humans through consumption of aquatic organisms (TCE, cis-1,2-DCE, and vinyl chloride). No cleanup levels have been developed for the potential aquatic ecological receptors for these substances because there are no promulgated standards available and the human health standards are assumed to be protective.

Method A cleanup levels based on protection of surface water receptors are described in WAC 173-340-730(2). Consistent with this chapter, the numerical standards for each of the IHSs are (Table 10):

- TCE – 30 µg/L;
- cis-1,2-DCE – 70 µg/L; and
- Vinyl Chloride – 2.4 µg/L.

With the exception of cis-1,2-DCE, these standards are from USEPA's water quality criteria established under the National Toxics Rule (40 CFR Part 131). There is no surface water standard for cis-1,2-DCE, so the lowest available human health based standard of 70 µg/L was used (state MCL).

7.4.2 Groundwater Point of Compliance

The point of compliance refers to the point or points where cleanup levels will be attained. Under the RCRA Post-closure Permit (WAD 07 665 5182) the Parcel G point of compliance is the downgradient property boundary. Because all of the cleanup levels are based on the groundwater-to-surface water pathway, and consistent with WAC 173-340-720(8)(d)(ii), a conditional point of compliance at or near the point where groundwater discharges into the surface water may be appropriate, but the property boundary will be used as the POC for the purposes of this FFS.

7.5 Areas Exceeding Groundwater Cleanup Levels

The current distributions of TCE, cis-1,2-DCE, and vinyl chloride in Layer B groundwater are presented in Figures 34 through 36. Layer B groundwater beneath the northern half of Parcel G exceeds the cis-1,2-DCE and vinyl chloride cleanup levels. A wedge-shaped section of Layer B groundwater from the former drum storage area northeast to the property boundary exceeds the TCE cleanup level.

In addition, Layer D groundwater at HYCP-1d exceeds the vinyl chloride cleanup level. The likely source of VOCs detected in HYCP-1d is a faulty well seal. BSB proposes to properly abandon the HYCP-1i/HYCP-1d well pair (WAC 173-160); the details of this abandonment will be described in the Deep Aquifer Investigation Work Plan that will be prepared by BSB as required by Exhibit B of BSB's Agreed Order.

8.0 FEASIBILITY STUDY SCOPING

The process of developing cleanup action alternatives (CAAs) and selecting a final cleanup action includes the following major steps:

- Determine cleanup goals and levels;
- Identify applicable regulations and standards;
- Define cleanup action objectives (CAOs);
- Identify general response actions;
- Identify and screen cleanup action technologies;
- Develop and evaluate CAAs; and
- Select the preferred alternative.

The CULs for Parcel G were developed in Section 7. This section describes the next three steps, including defining the CAOs and general response actions. CAOs are media-specific goals that provide the framework for developing and evaluating CAAs. Section 9 identifies the potentially applicable cleanup action technologies and screens the technologies on the basis of the CAOs and site-specific information. Section 10 describes the development of a range of potentially applicable CAAs, while Section 11 describes the detailed evaluation of these alternatives. The preferred alternative is described in Section 12.

8.1 Scope of Focused Feasibility Study

As described in Sections 2 through 6 of this report, extensive site characterization, monitoring, and remedial actions have been implemented at Parcel G over the last 25 years. Particularly relevant to the performance of this FFS are the remedial actions conducted at Parcel G that are described in Section 5 and include:

- Removal and closure of solid and hazardous waste management units;
- Removal of contaminated solids from the former settling lagoon and settling basin;
- Excavation of approximately 2,000 cy of contaminated soil from the primary source area on Parcel G;
- Consolidation, stabilization, and isolation of dangerous waste solids in the former sludge drying beds;

- Capping of potentially impacted portions of Parcel G; and
- Installation and operation of a groundwater extraction and treatment corrective measures system (CMS).

As a result of these cleanup actions, conditions at Parcel G have stabilized, contaminated soil and waste has been treated and/or removed from Parcel G, over 10,000 pounds of VOCs have been removed and treated by operation of the existing CMS, and the potential risks to human health and the environment have been reduced and controlled. The existing CMS is effectively protecting human health and the environment by controlling off-site migration of VOCs, and potential on-site exposures are being controlled through a combination of engineering and institutional controls. However, residual VOC concentrations in groundwater remain in the primary source area of Parcel G, and VOC concentrations within the groundwater capture zone at the downgradient property boundary remain above potentially applicable cleanup levels.

Notwithstanding these historical and ongoing remedial actions, BSB has entered into the Agreed Order with Ecology and, consistent with Exhibit B of the Agreed Order, prepared this FRI/FS. The FRI/FS will evaluate whether the existing remedy, which has been in place for 13 years, can be updated by developing and evaluating CAAs for Parcel G. BSB has also agreed that until a final CAA is implemented as recommended by the FFS, that the existing groundwater CMS will be operated as described in the Interim Corrective Action and Post Closure Monitoring and Implementation Plan (Interim CAPMIP; PES, 2005). The Interim CAPMIP describes in detail, the implementation, operation and maintenance, evaluation, and reporting activities associated with the existing groundwater CMS.

8.2 Regulatory Requirements

The following regulations may be applicable to specific technologies or CAAs. The evaluation of specific regulations will be conducted as necessary during the CAA development and detailed analysis in Sections 10 and 11, respectively.

8.2.1 Model Toxics Control Act

Ecology's MTCA regulations were the primary regulations used to guide the performance of the FFS. Specifically, the FFS was conducted following the procedures outlined in WAC 173-340-350.

8.2.2 Applicable State and Federal Laws

As noted above, MTCA's threshold requirements listed in WAC 173-340-360(2) include the requirement to "comply with applicable state and federal laws" which are defined at WAC 173-340-710. The following Washington State laws and their associated regulations may be applicable to the CAAs developed for Parcel G:

- Washington Water Well Construction Regulations (WAC 173-160) establish state standards for installing, maintaining, and decommissioning groundwater monitoring and recovery wells.

- Washington Ground Water Quality Standards (WAC 173-201) establish standards to protect groundwater quality (e.g., MCLs) and beneficial uses.

- Washington Surface Water Quality Standards (WAC 173-201A) are applicable to surface waters of the state, are protective of aquatic life and other beneficial uses, and can be applicable if an alternative includes discharge of treated water is needed.

- Washington State NPDES Program Regulations (WAC 173-220) would be applicable for discharge to surface waters under an NPDES permit.

- Washington Dangerous Waste Regulations (WAC 173-303) establish procedures and standards related to the definition, management, and disposal of dangerous wastes.

- Washington Clean Air Act Regulations (WAC 173-400) provide standards and procedures for managing the discharge of contaminants to the atmosphere.

- Washington Industrial Safety and Health Act Regulations (WAC 296-62) contain health and safety training requirements for on-site workers. They also contain permissible exposure limits for conducting work at Parcel G.

8.3 Cleanup Action Objectives (COAs)

CAOs form the basis for evaluating potential cleanup technologies and actions for Parcel G. CAOs are based on an evaluation of the data collected during previous investigations (summarized in Sections 4 through 6 above) and on the cleanup levels established in Section 7. The focus of the CAOs is protection of human health. As described in Section 7.3.1, Parcel G qualifies for an exclusion from a terrestrial ecological evaluation in accordance with the requirements of WAC 173-340-7491(c). Therefore, no terrestrial ecological-based CAOs are developed. Although the site conceptual model (Figure 38) identifies the groundwater-to-surface water pathway as a potentially complete future pathway for aquatic organisms, there are no IHSs for this pathway because there are no promulgated standards for these substances and the human health standards are assumed to be protective as described in Section 7.4.1. Therefore, there are no aquatic ecological-based CAOs for this FFS.

The following human health-based CAOs are proposed for use at Parcel G.

8.3.1 Soil Cleanup Action Objectives

The CAO for soil at Parcel G is as follows: Control incidental ingestion of and dermal contact with soil, and inhalation of particulates and vapors from soil, by future subsurface construction workers on-site.

8.3.2 Groundwater Cleanup Action Objectives

The CAOs for groundwater at Parcel G are as follows:

- Control migration of groundwater containing IHSs at concentrations exceeding the applicable CULs to surface water from Parcel G; and
- Control inhalation of VOC--containing vapors from groundwater by subsurface construction workers on site.

8.4 General Response Actions

General response actions are the general approaches that can be used, either alone or in combination with other response actions, to meet the CAOs. Like the CAOs, general response actions are medium specific.

8.4.1 Presumed Response Actions

For both soil and groundwater, CAOs address potential exposure of subsurface construction workers on site. In order to address this potential future exposure pathway, BSB will incorporate a presumed response action into all cleanup action alternatives (CAAs) developed in Section 10. This presumed response action would establish specific procedures to ensure that the potential risks to site workers are adequately assessed prior to and during invasive site work and that adequate protective measures (e.g., personal protective clothing, respiratory protection) are used. The requirement for establishing these procedures will be documented in the implementation plan for the selected cleanup action alternative and placed in a notice on the deed.

In addition, all CAAs developed in Section 10 will include a surface cap either through maintenance of the existing cap, replacement or repair of the cap should it be damaged during implementation of other CAA technologies, and/or incorporation of buildings and other impervious features when the property is redeveloped.

The general response actions that address the remaining CAOs are described below.

8.4.2 Soil General Response Actions

The presumed response actions described above address all of the CAOs for unsaturated soil at Parcel G and no additional general response actions are required.

8.4.3 Groundwater General Response Actions

The general response actions for groundwater at Parcel G are as follows:

- Institutional controls (e.g., monitoring, deed restrictions);
- Engineering Controls (e.g., surface cap, vapor barriers);
- Groundwater Containment (e.g., hydraulic controls, vertical barriers);
- Ex situ groundwater treatment/discharge; and
- In situ groundwater source treatment (e.g., in situ oxidation, enhanced bioremediation).

The first four of these groundwater general response actions are currently being utilized at Parcel G.

9.0 IDENTIFICATION AND SCREENING OF CLEANUP ACTION TECHNOLOGIES

Cleanup action technologies are actions that could be implemented to address, whether alone or in combination with other technologies, one or more of the CAOs listed in Section 8.3. The list of potentially applicable technologies was based on the general response actions discussed in Section 8.4. This section describes the process and the results of identifying and screening potentially applicable technologies for achieving the CAOs at Parcel G.

Once identified, the potentially applicable technologies are screened based on the estimated effectiveness, implementability, and overall applicability to Parcel G. In general, technologies with a low overall applicability were screened out, and technologies with a medium or high applicability were retained.

9.1 Preliminary Technology Identification

The potentially applicable technologies considered for Parcel G, organized by general response action, are listed in Table 11. This list of technologies was compiled based on the nature of the contaminants at Parcel G (VOCs), the environmental media impacted (soil and/or groundwater), and the types of exposures that need to be addressed (as defined by the CAOs). The technologies associated with the presumed response actions defined in Section 8.4.1 are included in Table 11. In general, the technologies considered have been proven effective at full-scale for similar contaminants, although some technologies in earlier stages of development were considered.

Due to the amount of site investigation, monitoring, and remediation activities that has been conducted at Parcel G, the range of technologies considered has been focused for certain types of actions, including:

- Soil Treatment – As summarized in Section 5, significant cleanup actions have been implemented at Parcel G, including a number of soil excavation, treatment, and stabilization efforts. The scope of these cleanup actions and the available sampling information (Section 6) indicate that the major areas of historical vadose zone soil contamination have been effectively addressed. As discussed in Section 8.4.1, to the extent that residual contamination exists in the vadose zone, the FFS presumes that potential exposures to these contaminants will addressed through implementation of institutional controls (e.g., requirement to evaluate indoor air pathway for future Parcel G development), engineering measures (e.g., cap, vapor control systems for possible future buildings, if required), and worker protection measures; and

- Treatment and Disposal of Extracted Groundwater – The existing CMS at Parcel G discharges extracted groundwater directly to the King County sanitary sewer system for treatment at King County's treatment plant. It is anticipated that the range of cleanup actions evaluated in this FFS will continue to use this method of groundwater treatment and disposal if required in an alternative. It is possible that in some instances, it may be necessary to pretreat the groundwater to meet King County discharge standards. In this case where supplemental ex situ groundwater treatment is determined to be necessary, treatment would be accomplished using air stripping to lower VOC concentrations in groundwater, and activated carbon adsorption would be used to treat the vapor emissions from the air stripper.

9.2 Technology Screening

The potentially applicable technologies listed in Table 11 were screened on the basis of the following criteria:

- Effectiveness - technology's ability to meet one or more of the CAOs;

- Implementability - accounts for constraints or difficulties in implementing the technology and ability to assess and verify the technology's continued effectiveness; and

- Relative Cost - overall cost of the technology relative to other technologies that address the same CAOs and with similar effectiveness and implementability.

The screening process for the potentially applicable technologies is detailed in Table 12. The retained technologies are summarized in Table 13. Technologies that were considered applicable were retained and are assembled into remedial alternatives in Section 10. Technologies that were not considered to be applicable were not retained for further consideration. A summary of the screening process is described below.

9.2.1 Groundwater Containment Technologies

Groundwater containment will be a critical component of the final cleanup action selected for Parcel G given the following combination of site-specific factors:

- The likely presence of DNAPL on Parcel G;
- The short distance between the primary source area and the point of compliance at the downgradient property boundary (i.e., South 200th Street);
- Very low cleanup levels for certain IHSs, especially vinyl chloride; and
- The inability to effectively utilize natural attenuation as a component of a cleanup action due to the ongoing cleanup actions by the downgradient property owner.

Three technologies are considered in Table 12 for groundwater containment at Parcel G: groundwater extraction, vertical barriers, and permeable reactive barriers (PRBs). All three are established technologies that have been shown to be implementable and effective in providing containment of contaminated groundwater at numerous sites. In addition to providing containment, groundwater extraction and PRB technologies also provide for some contaminant mass removal and treatment. With respect to cost, the three technologies vary significantly in their relative capital (i.e., implementation) versus operations and maintenance (O&M) costs. Specifically, groundwater extraction has relatively low to moderate capital costs but higher long-term O&M costs whereas the vertical barrier and PRB technologies have much higher capital costs and lower O&M costs. PRB technology in particular can be extremely expensive depending on how it is implemented. If a continuous PRB were deployed at Parcel G to intercept the VOC plume, it would need to be approximately 650 feet long, an average of approximately 3 feet thick, and contain in excess of 5,000 tons of zero valent iron (ZVI). An alternative based around such a PRB would cost at least $10,000,000 at the current price of ZVI, a cost that is greatly disproportionate with the other containment technologies being evaluated. Therefore, the continuous PRB application of this technology will not be considered for use in alternative development. There are other applications of the PRB technology, such as a funnel-and-gate approach, that may be cost-effective.

In order to fully evaluate these technologies, groundwater extraction, vertical barriers, and the limited application of PRB technologies will be retained for use in development of CAAs in Section 10.

9.2.2 Ex situ Groundwater Treatment/Discharge Technologies

As noted above, the existing CMS discharges extracted groundwater directly to the King County sanitary sewer system for treatment at King County’s treatment plant and this method of managing extracted groundwater, possibly with the addition of supplemental on-site pretreatment, would be used if required for an alternative.

9.2.3 In Situ Groundwater Source Treatment Technologies

As shown in Table 12, there are numerous in situ treatment technologies that are potentially applicable to the Parcel G contaminants including biological, chemical, and physical treatment technologies. The effectiveness and implementability of these technologies, and whether one or more of these technologies should be retained for use in development of CAAs, must be determined in the context of the CAOs for Parcel G as well as site-specific considerations.

One of the two CAOs for the groundwater (prevent inhalation of vapors by subsurface construction workers) will be addressed through institutional and engineering controls. The remaining groundwater CAO is controlling off site migration of groundwater containing VOCs above cleanup levels. This CAO can be addressed by containment technologies and, at least potentially, through in situ treatment. In theory, if the source area can be adequately treated, then concentrations of VOCs will decline and presumably meet cleanup levels at the point of compliance after some period of time. The critical question is: can source treatment be implemented to achieve cleanup levels at the point of compliance (POC) in a reasonable timeframe, thereby eliminating the need for long-term containment? At Parcel G, the answer to this question is no for the reasons described below.

The factors that limit the effectiveness of source treatment technologies to meet groundwater cleanup levels at the point of compliance On Parcel G include:

- Presence of DNAPL. As described in Section 6.3.5.6, the elevated groundwater VOC concentrations and the persistence of VOC contamination at Parcel G indicate that DNAPL is likely present in or near the former Parcel G drum storage area in the form of disseminated residuals, blobs, and ganglia. The difficulties associated with achieving low cleanup levels in heterogeneous aquifers contaminated with DNAPL are well documented. USEPA (2003) concluded that although partial source zone depletion is possible, there is “no documented, peer-reviewed case study of DNAPL source-zone depletion beneath the water table where U.S. drinking water standards or MCLs have been achieved and sustained throughout the affected subsurface volume, regardless of the in-situ technology applied.” A survey of the environmental community conducted for the Naval Facilities Engineering Services Center (Geosyntec, 2004) similarly concluded, “none of the remediation attempts presented in this survey/review achieved MCLs or regulatory site closure;”

- Very low cleanup levels. As shown in Table 10, there are very low proposed groundwater cleanup levels for several of the VOCs at Parcel G. This is especially important for TCE and vinyl chloride that have proposed cleanup levels 30 µg/L and 2.4 µg/L, respectively. These two IHSs have been detected at concentrations of up to 76,000 µg/L and 8,200 µg/L, respectively. Most, if not all, of the available groundwater treatment technologies are not capable of achieving these extremely low cleanup levels where residual DNAPL is present;

- Proximity of point of compliance to source area. The point of compliance is the downgradient Parcel G property boundary along South 200th Street, approximately 100 to 150 ft downgradient of the source area. Given the proximity of the POC to the source, available treatment technologies cannot reduce contaminant concentrations on-site to the levels required such that natural attenuation could further reduce contaminant concentrations in groundwater to below cleanup levels prior to moving off-site;

- Heterogeneous aquifer. The shallow aquifer at Parcel G is present mainly within Layer B that consists of an upper sand, intermediate silt, and a lower sand unit. As described in Section 6.1, the upper and lower sand units are comprised of fine to medium sands with lenses of lower permeability soil including silt, silty sand, and peat. VOCs have been detected in both the upper and lower sand as well as the intermediate silt (Section 6.3.5.3). The distribution of VOCs throughout the heterogeneous soils of the source area would make it extremely difficult for treatment technologies to effectively and uniformly achieve treatment (e.g., deliver treatment chemicals) throughout the source area; and

- Source delineation. In order to effectively implement an in situ treatment approach it is imperative that the contaminant source be accurately and completely defined. This is especially true where treatment chemicals must come in direct contact with the contaminants (e.g., DNAPL). As noted above, it is likely that DNAPL is present at Parcel G in the form of disseminated residuals, blobs, and ganglia. Although the general area where this residual DNAPL is present has been defined (i.e., former Parcel G drum storage area), it is extremely difficult to find each and every location within the source area where residual DNAPL has come to be located. This problem of identifying small discontinuous areas of DNAPL is exacerbated by the heterogeneous nature of the aquifer.

The combined and compounding effects of these five factors result in a situation where it is extremely unlikely that currently available in situ source treatment technologies could be implemented at Parcel G in a manner that would result in achievement of cleanup levels at the POC within a reasonable timeframe, or for that matter anytime in the foreseeable future. In order for in situ groundwater source treatment to achieve cleanup levels by the POC, all of the following would have to occur:

- All of the disparate areas containing residual DNAPL and high concentrations of sorbed VOCs would have to be nearly perfectly delineated;

- In situ treatment technologies would have to be effectively delivered to all of these areas, many of which are in low permeability lenses within Layer B; and

- The very low cleanup levels would have to be achieved at, or within tens of feet of, the source areas.

None of these three steps have been demonstrated to be feasible at sites similar to BSB. Looked at another way, the current concentrations of TCE and vinyl chloride on Parcel G are up to four or five orders of magnitude above their respective cleanup levels. Even if in situ treatment resulted in a 99 percent reduction in vinyl chloride concentrations, a level of treatment that has not been achieved in full-scale applications at sites similar to BSB (Geosyntec, 2004), residual concentrations would still be three orders of magnitude above cleanup levels. Furthermore, assuming that some residual DNAPL zones would remain untreated (either because they were not identified and/or incompletely treated), they would continue to result in dissolved VOC concentrations well in excess of cleanup levels (Kueper et al, 2003).

At other sites where source treatment is effective, the remedial approach that has been utilized is to implement source treatment technologies to reduce source concentrations and then control the residual concentrations using natural attenuation processes. For this approach to be feasible, however, sufficient space is required between the source area and the POC, and the prerequisite geochemical conditions present, so that natural attenuation processes can reduce contaminant concentrations to cleanup levels. At Parcel G, there is at most 100 ft between the source area and the POC at South 200th Street, greatly limiting the viability of this approach.

At some sites where insufficient space is available on site, there is the option of using off-site and downgradient portions of the aquifer to facilitate the use of natural attenuation in managing residual contaminant concentrations. However, given the site investigation and future cleanup actions being evaluated by the downgradient property owner (Hexcel), this option does not appear to be available.

As a result of all these factors, in situ groundwater source treatment cannot be used to achieve the CAOs, and groundwater containment at Parcel G will be required for the foreseeable future. Therefore, none of the source treatment technologies described in Table 12 are retained for use in developing CAAs.

9.2.4 Engineering Control Technologies

Surface capping (e.g., asphalt paving, buildings, or other structures) will be retained for use in development of CAAs, both as a means of controlling direct contact with potentially contaminated soil and for minimizing infiltration of precipitation.

9.2.5 Institutional Controls

As shown in Table 12, all three institutional controls evaluated for use at Parcel G will be retained for use in CAA development, including:

- Water- and land-use restriction;
- Worker protection measures; and
- Access restrictions.

9.3 Retained Technologies

The technologies retained for use in development of CAAs are listed in Table 13.

10.0 DEVELOPMENT OF CLEANUP ACTION ALTERNATIVES

CAAs are combinations of technologies designed to meet the CAOs. The retained technologies from the screening process were assembled into three CAAs that address the CAOs and meet MTCA's minimum requirements to the extent practicable. This section presents a detailed description of the three CAAs with respect to conceptual design, implementation, and estimated cost. The conceptual design is developed in sufficient detail to evaluate the effectiveness, performance, and estimated restoration timeframe in the detailed evaluation of CAAs presented in Section 11 and to conduct the detailed comparative evaluation of the alternatives presented in Section 12.

The costs of the CAAs discussed below were developed by accounting for capital costs as well as recurring and future costs. Capital costs include work plans, design reports, other Ecology-required documents, and construction to implement the remedy. Recurring and future costs include groundwater monitoring, operation and maintenance, and reporting for 30 years. Consideration of a longer period for recurring and future costs will not materially impact the CAAs cost evaluation.

A construction contingency cost of 20 percent was added to each alternative to reflect a level of uncertainty in the estimated costs given the conceptual design of the CAAs. The contingency on capital cost reflects uncertainty in design, permitting, and construction costs. A 10 percent contingency on recurring and future costs generally reflects uncertainty of the operation and maintenance costs and the duration of the remedy. Consistent with industry standards, these cost estimates should be considered to represent the actual CAA implementation cost within a range of minus 30 percent to plus 50 percent of the estimated cost. The cost estimates are rounded to the nearest $10,000.

Cost details are provided in Tables 14 through 16. These cost estimates do not include the significant investigation- or remediation-related project costs incurred to date including previous site assessments, routine monitoring, reporting, and costs for the existing CMS system operation and maintenance. The net present value (NPV) for future and recurring costs is based on a discount rate of 5 percent, which is the rate BSB uses for their financial planning. All costs are presented in 2006 dollars.

10.1 Ongoing Cleanup Actions

BSB is currently operating the existing CMS to control migration of VOC-containing groundwater from Parcel G. A brief description of the existing CMS system is provided below.

Since August 1992, two extraction wells, HYR-1 and HYR-2 (Figure 5), have been operated on the north side of BSB's Parcel G, and extraction wells CG-1 through CG-4 have been operated on the eastern sides of Hexcel's Parcels C, D, and E. Each extraction well is 6-inches in diameter, 30- to 35-feet-deep, and screened between 10 and 30 feet below grade. The top of each well is completed below grade in a vault. Groundwater is extracted from each well with a submersible pump and is pumped through an individual, underground conveyance line to an aboveground manifold. The individual conveyance lines (two from Parcel G and the others from the Hexcel parcels) are currently joined together at the manifold into a common header that leads to the sanitary sewer. Extracted groundwater is discharged to the sanitary sewer under King County Waste Discharge Permit No. 7575. Access ports in the system allow sampling of individual wells and the combined discharge.

Consistent with the requirements of their respective Orders, BSB and Hexcel will initiate activities that will result in the independent operation of the HYR and CG extraction wells. This separation process is scheduled to be completed by March 24, 2006, or 14 days after King County grants Hexcel a discharge permit for the CG wells, whichever is later. Following separation of the HYR and CG wells, BSB will continue operation and maintenance of the HYR extraction system consistent with the Interim CAPMIP (PES, 2005) and Hexcel will operate and maintain the CG wells consistent with their Enforcement Order.

10.2 Alternative 1 – Enhanced Groundwater Extraction System

The enhanced groundwater extraction system alternative builds on the existing extraction system described above and consists of a total of seven extraction wells located along the downgradient boundary of Parcel G, discharge of extracted groundwater to the King County sanitary sewer system for treatment, and maintenance of the existing capping at Parcel G. A detailed description of the installation, operations and maintenance, monitoring, performance evaluation, and reporting for the enhanced groundwater extraction system is provided in PES' report[1] dated June 1, 2004 (PES, 2004b). Figure 39 provides the proposed locations of the existing and new extraction wells.

10.2.1 Cleanup Action Description

10.2.1.1 Groundwater Extraction System

Under this alternative, BSB would enhance the existing Parcel G extraction system with the addition of five new extraction wells to assure and significantly augment future performance. The existing site groundwater model (MODFLOW and Path3D) was updated with the 1999 and 2000 Parcel G data, recalibrated, and used to simulate a worst-case scenario to develop an enhanced extraction system (Patterson Planning & Services, 2003). The enhanced groundwater extraction system of Alternative 1 is designed to increase the margin of safety provided by the existing system. The enhanced system includes the two existing extraction wells (HYR-1 and HYR-2) and five new extraction wells (HYR-3 through HYR-7). The new wells, like the existing extraction wells, would be installed along the north side of Parcel G (Figure 39) as follows:

- HYR-3 would be installed approximately 100 feet west of HYR-2 to provide supplemental coverage on the west end of Parcel G;

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[1] This report, entitled *Corrective Action and Postclosure Monitoring and Implementation Plan,* was developed to describe how the enhanced groundwater extraction system approach would be implemented. To avoid confusion with the current Interim CAPMIP included in Exhibit D of BSB's Agreed Order, it will be referred to as PES 2004b.

- HYR-4 and HYR-5 would be installed in the upper and lower sands of Unit B, respectively, approximately 50 feet east of HYR-1; and

- HYR-6 and HYR-7 would be installed in the upper and lower sands of Unit B, respectively, approximately 100 feet west of HYR-1.

Well installation procedures are described in the PES 2004b report.

10.2.1.2 Groundwater Extraction and Conveyance

Groundwater will be extracted from each well with a submersible pump and transferred through individual, underground conveyance lines to an aboveground manifold. At the manifold, the individual conveyance lines from HYR-1 through HYR-7 will be joined together into a common header from which extracted groundwater will be discharged to the sanitary sewer under the existing waste discharge permit. Access ports will be placed in the system to allow sampling of individual wells and the combined discharge.

As described in Section 4.1 of the PES 2004b report, an initial target pumping rate of 26 gallons per minute (gpm) has been established based on the existing site flow model updated with the latest geologic data (Patterson Planning & Services, 2003). The existing site groundwater flow model uses the U.S. Geological Survey MODFLOW code (McDonald and Harbaugh, 1988) to simulate three-dimensional groundwater flow and the PATH3D code (Zheng, 1989) to determine the extraction system capture zone. The PES 2004b report also defines increased target pumping rates based on measured hydraulic gradients at Parcel G.

Following system startup and an initial operational period, the performance of the enhanced extraction system will be evaluated as described Section 5 of the PES 2004b report. Based on this evaluation, the extraction well target pumping rates may be changed. Section 5.3.2 of the PES 2004b report requires the development of a contingency plan within three months of start-up to ensure that a well failure or a system shutdown will not allow contaminants to escape capture by the groundwater recovery system. The plan will specify responses to well failures or a full system shutdown.

O&M requirements of the enhanced extraction system will be detailed in an O&M manual consistent with Section 4.2 of the PES 2004b report. Specific O&M activities will include inspections (both remote groundwater extraction system operation checks and field inspections) and routine maintenance of extraction system components (e.g., conveyance line and pump cleaning, periodic extraction well redevelopment). Over the longer term, individual extraction system components will be replaced as needed including pumps, piping, and the extraction wells themselves if redevelopment fails to maintain well production rates.

10.2.1.3 Extraction System Control

The enhanced extraction system will be automatically operated using a PLC define to control the individual extraction pump flow rates, similar to the existing extraction system. Each extraction well will include a submersible well pump, flow rate transmitter, flow rate controller, and water level pressure transducer. A PLC interface will be installed to allow both remote and local operator control and monitoring, similar to the existing extraction system.

10.2.1.4 Monitoring Wells and Piezometers

Twenty-seven monitoring wells are currently located on Parcel G and immediately adjacent to the north, east, and southwest sides of Parcel G (Figures 5 and 6). Thirteen of these wells are shallow, six are intermediate, and eight are deep. To supplement existing monitoring points, one new monitoring well (G4) and 13 piezometers (P-1 through P-13) will be installed in Unit B in conjunction with extraction well installation. Section 2.2.3 of the PES 2004b report provides a detailed description of the new wells and piezometers and Section 4.3 of the PES 2004b report details the groundwater monitoring approach.

10.2.1.5 Asphalt Cap

The former settling basin, the former equalization lagoon, and the former sludge drying beds were capped during closure activities in the 1980s. The capped areas encompass an approximate total area of 75,000 square feet. Each cap consists of two geotextile layers, a PVC liner, a granular backfill layer, a crushed rock base layer, and asphalt concrete pavement. BSB will maintain the integrity and effectiveness of each cap by making repairs as necessary to correct the effects of settling, subsidence, erosion, or other damage. BSB will prevent run-on and run-off from damaging each cap. BSB will routinely inspect each cap. If the site is redeveloped, buildings and other impervious features may replace portions of the asphalt cap.

10.2.1.6 Security and Signage

BSB will maintain the existing security and signage system by routinely inspecting the fence, gates, and signs for deterioration or damage and repairing all defects that could cause a breach in security. The system includes a 7-foot-high chain-link fence with a barbwire top that completely surrounds the former treatment and storage areas. The perimeter of the former treatment and storage areas are placarded with highly visible signs that bear the legend “DANGER – UNAUTHORIZED PERSONNEL KEEP OUT.”

10.2.1.7 Institutional Controls

Institutional controls, which include property use restrictions including a prohibition on the consumptive use of groundwater, maintenance requirements for engineered controls (e.g., inspections), educational programs (e.g., signs), and financial assurances, have been in place since RCRA closure of the site to limit or prohibit activities that may interfere with the integrity of the cleanup action. These controls will be maintained during implementation and operations of the enhanced groundwater extraction system at Parcel G. Fencing and signage, as discussed above, will be maintained. BSB will perform the inspection and maintenance requirements of the engineered controls. The existing deed restriction will be modified to include the requirement to evaluate the potential indoor air pathway and/or implement vapor migration controls in the event of future site development activities as well as provisions requiring protection measures for future subsurface site workers.

10.2.2 Cost

For costing purposes, it is assumed that Alternative 1 will be designed, installed, and started up in 2008, and will operate for 29 years (2009 through 2037).

The capital costs would include the cost of designing and constructing the enhanced groundwater extraction system. It is assumed that capital costs for Alternative 1 will be incurred in 2008 and include the following:

- Preparation of design plans and specifications;
- Installing groundwater extraction wells and pumps;
- Installing monitoring wells and piezometers;
- Conducting aquifer testing and model recalibration;
- Installing conveyance piping and controls; and
- System startup and reporting.

It is assumed that future and recurring costs include the following costs starting in late 2008:

- Routine operations and maintenance costs associated with the enhanced groundwater extraction;
- Additional performance evaluation and reporting described in the PES 2004b report;
- Groundwater monitoring and reporting; and
- Maintenance of the asphalt surface in the source area.

Total capital costs for this Alternative 1 would be approximately $390,000. The NPV of recurring and future costs over the 30-year project life would be approximately $4,150,000. The total estimated NPV for this alternative is $4,540,000. Refer to Table 14 for a breakdown of capital and projected recurring and future costs for Alternative 1.

10.3 Alternative 2 – Slurry Wall Containment and Gradient Control using ZVI Reactor Vessels

Alternative 2 includes the following components:

- Installing a slurry wall around, and a cap over, all of Parcel G; and
- Gradient control within the Parcel G containment area using ZVI reactor vessels.

Figure 40 provides a conceptual layout of the slurry wall alignment, capped area, and location of the ZVI reactor vessel system.

10.3.1 Cleanup Action Description

10.3.1.1 Overall Conceptual Approach

In this alternative, the entire Parcel G property would be (1) capped and (2) contained by a soil-bentonite slurry wall keyed into the Layer C silt aquitard and equipped with ZVI reactor vessels. The slurry wall would follow the perimeter of Parcel G, and the reactor vessels would be located within the northeast (i.e., downgradient) corner of the wall (Figure 40). The cap would minimize surface water infiltration, the slurry wall would prevent groundwater from passing into the contaminated area, and the ZVI reactor vessels would destroy contaminants in the groundwater that is allowed to exit the containment cell by directing it through the ZVI reactor vessels. This alternative is similar to a funnel-and-gate arrangement, but differs in that the funnel is closed at the top (upgradient boundary) so that flow through both the contaminated area and the ZVI reactor vessels is nearly eliminated except for small amounts of water that may infiltrate the slurry wall and cap, and for flows induced by seasonal changes in water levels in the surrounding aquifer. Minimizing flow through the reactor vessels in this manner significantly reduces the mass of ZVI needed and maximizes its effective treatment life.

Groundwater levels at Parcel G rise and fall seasonally. Due to the large (at least five or six orders-of-magnitude) difference in permeability between the ZVI material and the slurry wall, the reactor vessel system would allow hydraulic heads inside the contained area to adjust to changing conditions while treating any contaminated groundwater that passes through the vessels.

A description of the major components of this alternative is provided below.

10.3.1.2 Slurry Containment Wall

The wall would be approximately 2-ft thick, 1,820 ft long, and extend to an average depth of approximately 40 ft bgs (average depth to Layer C). The slurry used at Parcel G will be a made of on-site soils and bentonite mixed on-site to provide a designed maximum hydraulic conductivity of 1 x 10^{-7} cm/sec. The design of the slurry mix will be based on soil types present and an evaluation of the compatibility of the slurry mix with site groundwater and contaminants. A short portion of the slurry wall (i.e., less than 50 feet in length) will be constructed using a cement/bentonite/soil slurry to facilitate the construction of the ZVI reactor vessel system described below. The permeability of this short section will be designed to have a maximum hydraulic conductivity of 1 x 10^{-6} cm/sec. The slurry wall would be installed using a single-pass trencher. Prior to installing the wall, a focused push-probe investigation will be conducted along portions of the proposed alignment that have not been previously investigated (e.g., along portions of the southern property line) to confirm soil types present and the depth to, and thickness of, Layer C.

10.3.1.3 ZVI Reactor Vessels

The reactor vessels would be constructed such that they would contain sufficient ZVI to provide the required contact time at the maximum anticipated flow velocities through the vessels. The reactor vessel system would consist of the following major components:

- A collection trench located inside the slurry wall near the northeast corner of the containment area which would collect water and route it to the ZVI reactor vessels through a pipe;

- The reactor vessels, which would consist of a series of concrete vaults that would contain the required amount of ZVI;

- A discharge pipe from the reactor vessels that would lead through the slurry wall to the infiltration gallery located outside the wall. The discharge pipe would be equipped with a valve that would allow it be closed to prevent backflow into the containment cell (see discussion below); and

- An infiltration gallery located outside the slurry wall in the northeast corner of Parcel G that would infiltrate the treated groundwater from the ZVI reactor vessels back into the shallow aquifer.

The amount of ZVI required to effectively treat groundwater flowing out of the containment area, is based primarily on: (1) the reaction kinetics of the ZVI with contaminants in site groundwater and, (2) the flow rate of groundwater out of the containment area (i.e., system hydraulics). Based on the evaluation of these factors below and in Appendices G and H, approximately 1,850 cubic feet of ZVI would provide the required contact time and treatment. With this amount of ZVI and the hydraulic parameters defined below, the reactor vessels will provide at least the minimum required residence time of 3.5 days and will effectively treat the groundwater flowing out of the containment area to at or below cleanup levels.

Reaction Kinetics. The reaction kinetics of ZVI with Parcel G contaminants have been investigated through performance of a bench-scale treatability study (Environmental Technologies Inc. [ETI], 1999), a copy of which is included in Appendix G. A sample of groundwater collected from extraction well HYR-1 was shipped to ETI's laboratory in Waterloo, Ontario, where it was used in a series of column tests designed to:

- Determine the degradation rates of VOCs using ZVI;

- Characterize the breakdown products from treatment of VOCs and subsequent degradation of these products; and

- Evaluate changes in inorganic geochemistry to assess the potential for mineral precipitation.

The results of the bench test confirmed that ZVI would treat VOCs in Parcel G groundwater to non-detect levels at calculated half-lives consistent with those measured in other studies. As part of the development of this CAA, ETI reviewed the bench-scale test results and based on a recent study (O'Hannesin et al, 2004), adjusted the half-lives calculated in the bench test by a factor of three to account for the lower temperatures that would be expected in a field application as compared to the bench test.

To calculate the required residence time to achieve cleanup levels, assumptions were made regarding VOC concentrations in groundwater entering the ZVI reactor vessels. For purposes of this evaluation, the following VOC concentrations were assumed: TCE at 4,000 µg/L, cis-1,2-DCE at 5,500 µg/L, and vinyl chloride at 4,000 µg/L. These concentrations were based on maximum concentrations observed in monitoring wells, extraction wells, or push probe borings along the downgradient portion of Parcel G. Because the reactor vessel system uses a collection gallery to collect water prior to treatment, effectively averaging the concentration of VOCs in groundwater from an approximately 100 ft section of the shallow aquifer, it is extremely unlikely that concentrations will be higher than these maximum concentrations observed in single samples. The cleanup levels for these compounds are listed in Table 10. The critical compound that drives the residence time calculations is vinyl chloride, which has a fairly high influent concentration of 4,000 µg/L and a very low cleanup level of 2.4 µg/L. Based on the temperature corrected half-lives and these assumed influent and effluent conditions, the required residence time is calculated to be 3.5 days.

System Hydraulics. The other critical design component of the ZVI reactor vessels is the expected maximum rate at which groundwater would flow out of the containment system. This maximum flow rate combined with the required residence time will determine the volume of ZVI required to achieve effective treatment. An evaluation of the hydraulics of the containment system is presented in Appendix H and summarized below.

To estimate the maximum expected groundwater flow rate out through the ZVI reactor vessels, which is used to design the vessels, the maximum expected water inflows to the containment area were estimated. There are three mechanisms by which water can enter into the containment cell:

- Infiltration of precipitation through the asphalt cap;
- Flow through the slurry wall induced by higher water levels outside the wall compared to inside; and
- Flow upward from the deep aquifer (Layer D) through Layer C due to the upward hydraulic gradient,

Additionally, since the Layer B aquifer within the containment area would communicate with the Layer B aquifer outside of the containment area through the reactor vessel system, the amount of water released from aquifer storage in the containment area during declining water level periods was considered. The infiltration through the surface cap was estimated using analytical methods (see Appendix H, Section H.2) while the other mechanisms described above were estimated using the numerical flow model (see Appendix H, Section H.4). The maximum predicted discharge rate out through the reactor vessel system was 1.1 gpm. The maximum predicted discharge rates are at least an order of magnitude lower than the current Parcel G groundwater extraction rates.

As noted above, the reactor vessel system will be equipped with a valve between the ZVI reactor vessels and in the discharge infiltration gallery. When groundwater levels are falling outside the containment area, the valve will be open and allow groundwater to flow from inside the containment area, through the ZVI reactors, and into the infiltration gallery outside the wall. In the fall when water levels begin to rise, the valve will be closed and prevent the flow of water back into the containment area. By preventing this "backflow" hydraulic heads within the containment area will be lower than they would be if backflow was permitted.

Residence Time. As noted above, the required residence time to treat the maximum anticipated VOC concentrations to the lowest applicable CUL was calculated to be 3.5 days. The volume of ZVI needed to provide the required residence time for flow out through the reactor vessels is based in the following assumptions:

- Maximum flow rate of 1.1 gpm (212 cubic feet per day); and
- A porosity of 0.4 for the pure ZVI material that will be used in the reactor vessels.

Based on these assumptions, 1,850 cubic feet of ZVI would be required.

10.3.1.4 Slurry Wall Installation

The first step of the installation process consists of excavating an approximately 16-ft wide, 2-ft deep bench along the slurry wall alignment. The one-pass trenching machine will operate inside this trench that will also serve to contain the excess slurry that overflows the top of the trench. The trenching begins by lowering the cutting/mixing boom on the trencher until it has reached a vertical position at the appropriate depth. The slurry wall installation will proceed using the combination cutting/mixing boom that will simultaneously cut the trench to the required depth, inject the bentonite slurry into the subsurface through a tube attached to the boom, and mix the bentonite slurry and native soils. This continuous trenching and in situ mixing of the slurry greatly reduces the potential for higher permeability "windows" to form in the slurry wall. As the trencher moves forward, a laser-guided control system will adjust the installation depth to keep the bottom of the slurry wall keyed into the top of Layer C. To provide the structural integrity needed to install the discharge pipe connecting the ZVI reactor vessels to the discharge gallery (see description below), a small section (i.e., less than 50 ft long) of the slurry wall will be constructed using a concrete/bentonite slurry.

Once the slurry wall installation process has been completed, the excess slurry will be removed from the bench, and the bench will be backfilled with native and/or imported soil. It us assumed that the excess slurry and soil and other debris from the construction (e.g., broken asphalt and concrete) could be disposed of off-site as solid waste.

10.3.1.5 ZVI Reactor Vessel Installation

The ZVI reactor vessel system would be constructed after completion of the slurry wall using standard construction techniques and equipment. The groundwater collection trench would be installed just inside the northern side of the slurry wall near the northeast corner (see Figure 40). The trench would be excavated to a depth of approximately 15 ft (above the intermediate silt) and a 6-inch perforated pipe would be installed in the bottom of the trench prior to backfilling the trench with gravel. The collection pipe would lead to a cleanout that would allow for removal of silt that might accumulate in the pipe or cleaning of biogrowth or scale.

The reactor vessels would consist of a series of 8-ft diameter concrete vaults installed to a depth of approximately 22 ft. At this depth, each vault would be able to contain a 10 ft deep bed of ZVI material and keep the ZVI submerged at even historically low water levels. Each vault could contain up to approximately 500 ft^3 if filled to the full 10 ft bed thickness. In order to provide the required 1,850 ft^3 of ZVI, four reactor vessels would be utilized. A fifth vessel, which would remain empty at startup, could be installed as a contingency to provide additional treatment capacity if needed based on performance monitoring results.

The pipe from the collection trench would be connected to the first vault just above the level of the ZVI bed. Water at the bottom of the first ZVI vault would be collected in a perforated pipe and connected to the next vault at a point just above the level of the ZVI bed using solid wall pipe, and so on to the last vault. Accordingly, water would flow from top to bottom of each reactor vessel. ZVI material would be added into the vaults through the open tops prior to placement of concrete covers. Each vault would also have a monitoring access point installed on the interior of the vault on the discharge pipe to allow sampling of the treated groundwater.

From the last reactor vessel, a pipe would be installed through the cement/bentonite portion of the slurry wall and to the location of the infiltration gallery at the northeast corner of Parcel G. The trench used to install the pipe would be backfilled with native soil except for the slurry wall crossing, which would be backfilled using bentonite slurry. This discharge pipe would include a valve, accessible through a 4-ft diameter manhole, which could be used to prevent backflow into the containment area as described above.

Finally, the infiltration gallery would be constructed by excavating an area approximately 10 ft by 30 ft in the northeast corner of the site to a depth of 15 ft (above the intermediate silt), installing a series of perforated pipes in the bottom of the excavation, and backfilling the excavation with gravel.

Most of the construction activities described above include excavation to well below the shallow water table (typically about 10 feet deep during the later summer when construction would occur), and dewatering would be required. Dewatering would be accomplished through a series of temporary well points and the extracted groundwater treated in a temporary system and discharged to the sanitary sewer under the facility's existing permit.

10.3.1.6 Asphalt Cap

Currently, approximately the southern half of Parcel G is covered with the low permeability asphalt cap installed in 1988 as part of the RCRA closure activities. The remaining portion of Parcel G (i.e., the northern half of Parcel G) is currently covered by a combination of asphalt and concrete.

After the slurry wall construction is complete, the portions of the existing low permeability asphalt cap that are damaged during the construction of the slurry wall will be repaired to their original condition. The northern portion of Parcel G will have a new asphalt cover installed in a manner that would result in a continuous cover system over all of Parcel G. Approximately 5,000 to 10,000 cubic yards of imported fill will be used to create adequate surface grades on the new asphalt cover to promote runoff of precipitation. Runoff from the capped areas will be directed into culverts, pipes, or ditches and ultimately into the storm sewer system along 200th Avenue. When the site is redeveloped, buildings and other impervious structures may replace portions of the asphalt cap, and grading and filling for development may replace portions of the filling needed to promote site runoff of precipitation.

10.3.1.7 Performance Monitoring

The main goal of performance monitoring for Alternative 2 will be ensuring that the groundwater exiting the containment area through the ZVI reactor vessels is being treated to achieve cleanup levels. To accomplish this goal, a piezometer would be installed near the infiltration gallery outside the slurry wall. Water levels measured monthly in this piezometer would be used to determine whether water levels outside the slurry wall were falling or rising. As described above, in the late spring and summer when regional water levels drop in the shallow and intermediate aquifer zones, flow would be induced from the collection trench inside the containment cell, through the reactor vessels, and outward into the infiltration gallery. When water levels outside the wall begin to rise, the valve on the discharge side of the reactor vessels would be closed, effectively preventing backflow into the containment cell and keeping water levels inside the containment lower than they would otherwise be.

When the hydraulic gradient is outward and groundwater is flowing out through the reactor vessels, groundwater samples would be collected quarterly to confirm that the required treatment objectives were being achieved. These samples would be collected from the inlet of the first reactor vessel and the discharge pipe leading from the last ZVI reactor vessel to the infiltration gallery. Annually, samples will be collected to evaluate inorganic parameters that may effect the system operation. When gradients are directed into the containment area in the fall and winter and the backflow prevention valve is closed, collection of water quality samples would not be necessary.

10.3.1.8 ZVI Maintenance

The ZVI in the reactor vessels may, over time, require periodic maintenance to maintain its hydraulic properties and/or to augment the ZVI treatment capacity. This need for this type of maintenance is due to the potential for precipitation or other geochemical mechanisms to: (1) partially clog spaces and reducing the hydraulic conductivity of the ZVI in the reactor vessels, and/or (2) partially coat the ZVI particles thereby reducing their reactivity. Available information obtained from analysis of full-scale ZVI-based systems that have been in operation as long as 10 years suggest that these potential issues occur at a gradual rate. Furthermore, depending on the specific conditions present at a given site, the ZVI systems are expected to last 10 to 30 years or more before maintenance activities are required (ITRC, 2005). In most cases observed, these issues occur near the upgradient edge of the ZVI reaction zone. The monitoring necessary to evaluate the maintenance requirements for the ZVI reactor vessels will be defined in the performance monitoring plan developed during system design. However, this is presumed to include (1) periodic monitoring of VOC concentrations at the inlet to the reactor system and at the outlet of the first vessel to detect diminished treatment effectiveness, (2) periodic analysis of relevant inorganic parameters to monitor geochemical evolution of the system, and (3) piezometric monitoring upgradient and downgradient of the reactor vessels to detect gradient increases indicating decreased flow capacity.

Depending on the nature of the issues that may develop over time, maintenance of the ZVI in the reactor vessels may include flushing or jetting of the upstream face of the ZVI bed(s) in the reactor vessels to remove small particulate matter than may be reducing porosity or placing supplemental ZVI into the vessels. For purposes of this FFS, it is assumed that maintenance of the iron in the reactor vessels will be required every 30 years. This time frame is reasonable for this site given the relatively low flow rates that the system will be exposed to as a result of the surface cap and the slurry wall encircling Parcel G.

10.3.2 Cost

For costing purposes, it is assumed that Alternative 2 will be designed and constructed in 2008, and operate for 29 years (2009 through 2037). The existing CMS system will continue operating until construction of the slurry wall begins in mid 2008.

The capital costs would include the cost of designing and constructing the slurry wall, the ZVI reactor vessels, and the capping containment systems. Capital costs for Alternative 2 will be incurred in 2008 and include the following:

- Preparation of design plans and specifications;
- Installing the slurry wall and ZVI reactor vessels;
- Installing the capping system;
- Installing monitoring wells and piezometers; and
- Reporting.

Future and recurring costs include the following costs starting in 2008:

- Periodic maintenance of the ZVI reactor vessels;
- Groundwater monitoring and reporting; and
- Maintenance of the cap in the containment area.

Total capital costs for this Alternative 2 would be approximately $2,100,000. The NPV of recurring and future costs over the 30-year project life would be approximately $820,000. The total estimated NPV for this alternative is $2,920,000. Refer to Table 15 for a breakdown of capital and projected recurring and future costs for Alternative 2.

10.4 Alternative 3 – Slurry Wall Containment and Gradient Control using Groundwater Extraction

Alternative 3 includes the following components:

- Installing a slurry wall around, and an cap over, all of Parcel G;

- Hydraulic gradient control within the containment area using groundwater extraction; and
- Treatment of the extracted groundwater prior to discharge to the sanitary sewer.

Figure 41 provides a conceptual layout of the slurry wall alignment, capped area, and location of the gradient control extraction wells.

10.4.1 Cleanup Action Description

10.4.1.1 Overall Conceptual Approach

This alternative is very similar to Alternative 2, except that that the ZVI reactor vessels used in Alternative 2 for gradient control are replaced with groundwater extraction within the slurry wall containment area. In Alternative 3, the entire Parcel G property would be (1) capped and (2) contained by a soil-bentonite slurry wall keyed into the Layer C silt aquitard. The slurry wall would follow the entire perimeter of Parcel G, and three to five groundwater extraction wells would be installed within the containment area (Figure 41). The cap and slurry wall would deflect the bulk of surface infiltration and groundwater from passing into the contaminated area, and groundwater extraction wells would pump groundwater at a rate sufficient to prevent groundwater from flowing out of the containment area through the slurry wall or Layer C.

A description of the major components of this alternative is provided below.

10.4.1.2 Slurry Containment Wall

The wall would be approximately 2-ft thick and 1,780 ft long and extend to an average depth of approximately 40 ft bgs (average depth to Layer C). The slurry used at Parcel G would be a made of on-site soils and bentonite mixed on-site to provide a designed maximum hydraulic conductivity of 1×10^{-7} cm/sec. The slurry wall would be installed using a single-pass trencher. Prior to installing the wall, a focused push-probe investigation would be conducted along portions of the proposed alignment that have not been previously investigated (e.g., along portions of the southern property line) to confirm soil types present and the depth to, and thickness of, Layer C.

The slurry wall will be installed using the same procedures as described in Alternative 2.

10.4.1.3 Groundwater Extraction Hydraulic Control Wells

The slurry wall would effectively eliminate the movement of VOC-contaminated groundwater from Parcel G. To ensure that contaminated groundwater does not leave the Parcel G containment area, groundwater would be extracted with wells from within the containment cell to ensure maintenance of inward hydraulic gradients across the slurry wall and Layer C.

The rate at which groundwater would be extracted from the containment area to maintain inward flow is estimated in Appendix H, Section H.4. The minimum flow rate that would achieve this objective was estimated at 0.6 gpm. For cost estimating purposes, it is assumed that three extraction wells would installed throughout the containment area; the exact number and location of wells would be determined during the detailed CAA design process. Groundwater would be extracted from each well with a submersible pump and transferred through individual, underground conveyance lines and joined together at an aboveground manifold into a common header. Access ports in the system would allow sampling of individual wells and the combined flow in the header.

O&M requirements of the groundwater extraction system will be detailed in an O&M manual. Specific O&M activities will include inspections and routine maintenance of extraction system components (e.g., conveyance line and pump cleaning, periodic extraction well redevelopment). Over the longer term, individual extraction system components will be replaced as needed including pumps, piping, and the extraction wells themselves if redevelopment fails to maintain well production rates.

10.4.1.4 Groundwater Treatment and Discharge

The extracted groundwater would ultimately be discharged to the sanitary sewer under a King County Waste Discharge Permit. Because of the VOC concentrations in the groundwater inside the slurry wall, it is assumed that the extracted groundwater would require pretreatment prior to discharge. Given the relatively low flow rate of 0.6 gpm (i.e., 860 gallons per day), the groundwater would be treated on a batch basis using air stripping. Extracted groundwater would be collected in a 2,000-gallon receiving tank, and then processed through a small air stripper in approximately 500-gallon batches at a rate of approximately 5 gpm. Emissions from the air stripper would be treated using two activated carbon adsorption vessels. The treated groundwater would be discharged into the sanitary sewer.

O&M requirements of the groundwater treatment system will be detailed in the O&M manual. Specific O&M activities will include inspections and routine maintenance of treatment system components (e.g., air stripper and pump cleaning, periodic replacement of activated carbon). Over the longer term, individual treatment system components will be replaced as needed including pumps, blowers, piping, and valves.

10.4.1.5 Asphalt Cap

Currently, approximately the southern half of Parcel G is covered with the low permeability asphalt cap installed in 1988 as part of the RCRA closure activities. The remaining portion of the Parcel G (i.e., the northern half) is currently covered by a combination of asphalt and concrete that is generally in poor to moderate condition.

After the slurry wall construction is complete, the portions of the existing low permeability asphalt cap that are damaged during the construction would be repaired to their original condition. The northern portion of Parcel G would have a new asphalt cover installed in a manner that would result in a continuous cover system over all of Parcel G. Approximately 5,000 to 10,000 of imported fill would be used to create adequate surface grades on the new asphalt cover to promote runoff of precipitation. Runoff from the capped areas would be directed into culverts, pipes, or ditches and ultimately into the storm sewer system along 200th Avenue. When the site is redeveloped, buildings and other impervious structures may replace portions of the asphalt cap, and grading and filling for development may replace portions of the filling needed to promote site runoff of precipitation.

10.4.1.6 Performance Monitoring

The main goal of performance monitoring for Alternative 3 would be to ensure that groundwater flow is directed into the containment cell. This monitoring would consist of measurement of water levels inside the containment cell, outside the containment cell in Layer B, and outside the containment cell in Layer D. For cost estimating purposes, it is assumed that four piezometers would be installed inside the containment cell, and the water levels measured monthly in these four piezometers would be used to determine an average water level. This would be compared with the measured water levels outside of the slurry wall and in the deep aquifer in Layer D. Based on the results of this monitoring, the pumping rates will be adjusted as necessary to maintain the average groundwater level inside the containment cell is at or below the water levels outside the slurry wall and in the deep aquifer of Layer D.

10.4.2 Cost

For costing purposes, it is assumed that Alternative 3 will be designed and constructed in 2008 and operate for 29 years (2009 through 2037). The existing CMS system will continue operating until construction of the slurry wall begins in 2008.

The capital costs would include the cost of designing and constructing the slurry wall and capping containment systems. Capital costs for Alternative 3 will be incurred in 2008 and include the following:

- Preparation of design plans and specifications;
- Installing the slurry wall;
- Installing the capping system;
- Installing groundwater extraction wells and discharge piping;
- Installing the groundwater and vapor treatment systems;
- Installing monitoring wells and piezometers; and
- Reporting.

Future and recurring costs include the following costs starting in 2008:

- Ongoing operations and maintenance of the hydraulic control groundwater extraction and treatment systems;
- Groundwater monitoring and reporting; and

- Maintenance of the cap in the containment area.

Total capital costs for this Alternative 3 would be approximately $1,610,000. The NPV of recurring and future costs over the 30-year project life would be approximately $2,850,000. The total estimated NPV for this alternative is $4,460,000. Refer to Table 16 for a breakdown of capital and projected recurring and future costs for Alternative 3.

11.0 EVALUATION OF CLEANUP ACTION ALTERNATIVES

This section of the FFS provides a detailed evaluation of the CAAs developed in Section 10. The criteria used for analysis and the approach for evaluating the CAA against these criteria are presented in Sections 11.1 and 11.2. The evaluation of individual CAAs against these criteria is presented in Section 11.3. The comparative evaluation of the retained remedial alternatives for each evaluation criteria is presented in Section 12.1.

11.1 Evaluation Criteria

As noted in Section 8.2.1, MTCA is the primary regulation that outlines the procedure for conducting the FFS. With respect to the criteria and procedure for evaluating CAAs, WAC 173-340-360(2) establishes the following requirements:

Threshold Requirements

- Protect human health and the environment;
- Comply with cleanup standards (WAC 173-340-700 through –760);
- Comply with applicable state and federal laws (WAC 173-340-710); and
- Provide for compliance monitoring.

Other Requirements

- Use permanent solutions to the maximum extent practicable;
- Provide for a reasonable restoration time frame; and
- Consider public concerns.

In addition to these criteria, Ecology’s expectations for cleanup actions listed in WAC 173-340-370 will also be considered. If the evaluation of CAAs conclude that more than one alternative meets the cleanup action selection criteria, a disproportionate cost analysis will be conducted pursuant to WAC 173-340-360(3)(e) to determine if the incremental costs of one alternative over that of a lower cost alternative exceed the incremental degree of benefits achieved by the alternative over that of the other lower cost alternative.

11.2 Approach to Detailed Analysis

The three CAAs developed in Section 10 are similar in several important aspects that will allow for the detailed analysis of CAAs presented in Section 11.3 to focus on those requirements listed above that will differentiate the benefits between the CAAs. The key similarity between the three retained CAAs is that they are all containment alternatives designed to control migration of VOC-containing groundwater at the point of compliance at the downgradient boundary of Parcel G. The rationale for focusing the design of the CAAs in this manner is provided in Section 9.2.3. The discussion in Section 9.2.3 demonstrates that it was not technically feasible to treat the source areas within Parcel G to the required levels such that downgradient containment would not be necessary to meet cleanup levels at the POC. In other words, containment along the downgradient boundary of Parcel G would be required for the foreseeable future with or without source treatment. Based on this conclusion, the evaluation of the restoration timeframe requirement will not be a differentiating factor between the alternatives – all the alternatives compare the same against this requirement and the evaluation of alternatives below will not include a detailed discussion with respect to this requirement.

Other MTCA requirements that are addressed essentially the same for all three CAAs include:

- **Comply with applicable state and federal laws.** All of the CAAs will comply with the applicable legal requirements, including MTCA. Where off-site management and disposal of wastes is required, the applicable solid and dangerous waste regulations will be complied with. For alternatives that include discharge of groundwater to the sanitary sewer, the requirements of a King County Industrial Waste Discharge Permit will be complied with. For Alternatives that have the potential to emit VOCs to the air, the substantive requirements of the Puget Sound Clean Air Agency (PSCAA) regulations would be met.

- **Provide for compliance monitoring.** All CAAs include compliance monitoring to assess the ongoing performance of the alternative and to monitor compliance with cleanup goals.

- **Consideration of Public Concerns.** During the preparation of this FFS, including during the detailed development of the CAAs, BSB has carefully considered input from Hexcel with respect to how the CAAs may or may not effect Hexcel’s site investigation and cleanup activities. Additional consideration of public concerns following submittal of the FFS to Ecology will occur in the context of the public review and comment period.

Therefore, the detailed analysis of CAAs will focus on the following MTCA requirements:

- Protecting human health and the environment;
- Complying with cleanup standards; and
- Using permanent solutions to maximum extent practicable.

The evaluation process for determining whether a cleanup action uses permanent solutions to maximum extent practicable is defined in WAC 173-340-360(3). Since none of the alternatives meet the definition of a permanent cleanup action contained in WAC 173-340-200 (a cleanup action where cleanup standards are met without any further cleanup actions being required), the evaluation of this criteria utilizes a disproportionate cost analysis that focuses on determining which CAA provides the greatest degree of permanence [WAC 173-340-360(3)(e)(ii)(B)]. This evaluation uses the following criteria described in WAC 173-340-360(3)(f) to determine which CAA is the most permanent solution:

- Protectiveness;
- Permanence;
- Cost;
- Effectiveness over the long term;
- Management of short-term risks;
- Technical and administrative implementability; and
- Consideration of public concerns.

The evaluation of these criteria for each of the alternatives is presented in Table 14 and summarized below in Section 11.3. Based on the evaluation of these criteria, and as required by WAC 173-340-360(3)(e)(ii), the alternatives will be ranked from the most to the least permanent solution. Next, alternatives will be compared based on cost to determine if the benefits provided by a higher cost alternative (as defined by the permanence of the alternative) outweigh the incremental increase in cost of the alternative. The alternatives will be compared in this manner and the alternative that provides the best balance of permanence and cost will be selected for implementation. Where two or more alternatives have equal benefits, the less costly alternative will be selected for implementation. This comparative part of the disproportionate cost analysis is described in Section 12.1.

The evaluation of Ecology's expectations for cleanup actions will be addressed for the CAA recommended for implementation in Section 12.2.

11.3 <u>Detailed Analysis of Alternatives</u>

As described above, because of the significant similarities between the three alternatives being evaluated, the detailed analysis of alternatives has been focused on three criteria: protectiveness, compliance with cleanup standards, and the use of permanent solutions to the maximum extent practicable.

The evaluation of the "use of permanent solutions to the maximum extent practicable" criterion is presented in Table 14. Based on this evaluation, the sub-criteria that will be most important in differentiating Alternative 1 from the other alternatives are the permanence, cost, and long-term effectiveness. The permanence sub-criterion addresses the "degree to which the alternative permanently reduces the toxicity, mobility, or volume of hazardous substances." Because all of the alternatives developed as part of this FFS are containment alternatives (see Section 9.2.3 for rationale), the evaluation of the permanence criteria here will focus on how permanent the containment technology or approach is. The long term effectiveness sub-criterion evaluates the "degree of certainty that the alternative will be successful, the reliability of the alternative during the period of time hazardous substances are expected to remain onsite. . ." Similar to the permanence sub-criterion, the evaluation of the long-term effectiveness criteria will focus on the certainty and reliability of the containment technology or approach. These two sub-criteria are discussed further below for each alternative.

The cost sub-criterion will be used as the basis for comparison of the alternatives in the comparative analysis in Section 12 and discussed further in that section.

11.3.1 Alternative 1 – Enhanced Groundwater Extraction System

Alternative 1 consists of an enhanced groundwater extraction system alternative utilizing a total of seven extraction wells located along the downgradient boundary of Parcel G, discharge of extracted groundwater to the King County sanitary sewer system for treatment, and maintenance of the existing capping at Parcel G.

11.3.1.1 Protecting Human Health and the Environment

As described in Section 7, the potential future exposure pathway associated with Parcel G where IHSs have the potential to exceed cleanup levels at the conditional point of compliance is exposure to recreational (fishing) users of the surface water through consumption of aquatic organisms. The potential exposure point for this pathway is where groundwater discharges to surface water. Alternative 1 will achieve containment of VOCs at the downgradient Parcel G property boundary, thereby protecting the receptors for this pathway.

Alternative 1 addresses the potential exposure of subsurface construction workers on-site by ensuring that the potential risks to site workers are adequately assessed prior to and during invasive site work and that adequate protective measures (e.g., personal protective clothing, respiratory protection) are used. The requirement for establishing these procedures will be documented in the implementation plan for the selected cleanup action alternative and placed in a notice on the deed.

Finally, Alternative 1 addresses the possible future exposure pathway for indoor workers in a future Parcel G occupational setting through inhalation of vapors originating from contaminated vadose zone soil and shallow groundwater that may migrate up through a future building floor. This potential pathway is only a concern if future Parcel G development includes construction of habitable structures on Parcel G; such development will have to evaluate this pathway and incorporate engineering controls (e.g., vapor barriers) as appropriate to control potential exposures.

11.3.1.2 Complying with Cleanup Standards

The cleanup standard (i.e., the cleanup level and point of compliance) for this FFS is developed in Section 7.4. The applicable cleanup levels for the three IHSs are listed in Table 10. The point of compliance is the downgradient Parcel G property boundary.

Alternative 1 achieves compliance with this cleanup standard by controlling migration of VOC-containing groundwater from Parcel G to downgradient receptors. Alternative 1 achieves the cleanup standard for protection of future site and indoor workers through application of the appropriate engineering controls and the use of institutional controls to require their use and to evaluate the indoor air pathway if future site development activities result in the construction of a habitable building.

11.3.1.3 Use of Permanent Solutions to Maximum Extent Practicable

Permanence. Alternative 1 uses groundwater extraction to achieve capture of groundwater migrating from Parcel G. This approach has been documented to be effective on numerous sites, including the Parcel G and Hexcel properties. The effectiveness of this alternative will need to be carefully monitored and demonstrated through modeling. Sustaining the required extraction rates requires significant ongoing O&M activities. Therefore, the permanence of Alternative 1 is reduced by the need for significant long-term O&M and monitoring activities.

Long-Term Effectiveness. As noted above, groundwater extraction has been demonstrated to be effective both at the Parcel G property and on numerous other sites. The basis for the design of the enhanced system is described in the PES 2004b report. The system was designed to provide a very robust capture zone for Parcel G. Therefore, the effectiveness of Alternative 1 has a high degree of certainty.

From an operational standpoint, the system has the operational flexibility to maintain capture even if one or more of the extraction wells are out of service for significant periods of time. Therefore, Alternative 1 also has a high degree of certainty from an operational standpoint. Because the effectiveness is ultimately dependent on the ongoing performance of these O&M activities, the permanence of this alternative is somewhat reduced compared to approaches that maintain containment passively or with reduced O&M requirements.

11.3.2 Alternative 2 - Slurry Wall Containment and Gradient Control using ZVI Reactor Vessels

In Alternative 2, the entire Parcel G property would be (1) capped and (2) contained by a soil-bentonite slurry wall keyed into the Layer C silt aquitard and equipped with ZVI reactor vessels. The cap would minimize surface water infiltration, the slurry wall would prevent groundwater from passing into the contaminated area, and the ZVI reactor vessels would destroy contaminants in the small area where groundwater is allowed to exit the containment cell by directing it through the ZVI treatment zone.

11.3.2.1 Protecting Human Health and the Environment

The evaluation of this criterion for Alternative 2 is essentially the same as the discussion above for Alternative 1. Alternative 2 will prevent migration of groundwater containing VOCs at concentrations exceeding cleanup levels at the point of compliance. It will address the potential exposure of subsurface construction workers on-site by ensuring that the potential risks to site workers are adequately assessed prior to and during invasive site work and that adequate protective measures (e.g., personal protective clothing, respiratory protection) are used. Finally, Alternative 2 will prevent potential future exposure of indoor on-site office workers via the indoor air exposure pathway by requiring that any future site development evaluate this pathway and implement the necessary engineering controls to mitigate the potential risks.

11.3.2.2 Complying with Cleanup Standards

As described above for Alternative 1, Alternative 2 achieves compliance with this cleanup standard by controlling migration of VOC-containing groundwater from Parcel G to downgradient receptors. It also achieves the cleanup standard for protection of future site and indoor workers through application of the appropriate engineering controls and the use of institutional controls to require their use and to evaluate the indoor air pathway if future site development activities result in the construction of a habitable building.

11.3.2.3 Use of Permanent Solutions to Maximum Extent Practicable

Permanence. Alternative 2 uses a slurry wall that encircles Parcel G as the primary means of providing containment. The slurry wall is equipped with ZVI reactor vessels along the downgradient edge to allow a relatively small volume of groundwater to flow in and out of the slurry wall containment area thereby minimizing the potential for hydraulic gradients to develop that could induce migration of VOCs through the slurry wall. VOCs in the groundwater flowing through the reactor vessels would be treated to below cleanup levels by the ZVI. Alternative 2 also includes a surface cap that would minimize infiltration of precipitation into the containment cell.

Once emplaced, the slurry wall essentially requires no ongoing O&M and will permanently function passively to provide containment. The ZVI treatment technology has been in full scale commercial use for approximately 10 years, and available information indicates that the ZVI will continue to function for a long period of time (measured in decades) before some kind of maintenance is required to "refresh" the reactor vessels to either return it to its original hydraulic condition and/or augment the treatment capacity. Therefore, with this infrequent and relatively straightforward maintenance requirement, the ZVI reactor vessels will permanently function in a passive manner to treat groundwater exiting the containment cell to below cleanup levels.

Finally, the surface cap will permanently minimize infiltration as long as routine maintenance of the cap (inspections, sealing, periodic replacement of the damaged surfaces) is performed.

Long-Term Effectiveness. The slurry wall technology utilized in Alternative 2 as the primary means of providing containment at Parcel G is a well-demonstrated and conventional technology that has been used effectively at numerous other sites. There is a high degree of certainty that this approach will be effective because once emplaced, the slurry wall provides a significant low permeability physical barrier that will function passively without O&M requirements for the foreseeable future. The key to the effectiveness of the slurry wall is ensuring it is designed correctly to tie into the Layer C aquitard and that the slurry wall is carefully constructed to avoid creating high permeability "windows" in the wall due to incomplete mixing or preparation of the slurry. The information needed to complete the design (lithological information, depth to aquitard, soil properties) are either already available or will be obtained during a focused push-probe investigation that would be conducted along portions of the proposed alignment that have not been previously investigated. The use of the one pass trenching technology will greatly reduce the risks of creating "windows" in the wall, ensure that the slurry is placed at the appropriate depths, and will help ensure that the slurry wall will be a seamless, low permeability barrier to groundwater flow.

There is a similar degree of certainty associated with the function of the ZVI reactor vessels. The effectiveness of the ZVI material in treating the VOCs of concern at the site is well documented, and has been demonstrated for the groundwater at the site through performance of a bench scale study (see Appendix G). The key to the effectiveness of the reactor vessels is designing them to account for the variable groundwater flow through the vessels over the annual cycle. The basis for the groundwater flow hydraulics used for the conceptual ZVI reactor vessels design is discussed in detail in Section 10.3 and is supported by the extensive analysis and modeling provided in Appendix H. By using the worst case flows through the reactor vessels, and using conservative assumptions regarding contaminant concentrations, the design basis for the ZVI reactor vessels is very conservative. This preliminary design will be revisited during the final design process to ensure that the configuration and ZVI content of the reactor vessels are adequate to address the anticipated VOC loading.

The reliability of the slurry wall/ZVI reactor vessels system is also very high. Both components function completely passively and with the exception of the potential need for infrequent "refreshing" of the ZVI reactor vessels (e.g., every 30 years), require no active maintenance. The effectiveness of the alternative is also readily monitored by measuring water levels and collection of water quality samples in and around the reactor vessels. Importantly, the potential changes in the hydraulic properties and treatment effectiveness will occur over a period of years or decades (if at all), and these changes can be readily identified by performance monitoring and appropriate remedies identified, designed, and implemented.

11.3.3 Alternative 3 - Slurry Wall Containment and Gradient Control using Groundwater Extraction

Alternative 3 is similar to Alternative 2, except that that the ZVI reactor vessels used in Alternative 2 for gradient control are replaced with groundwater extraction within the slurry wall containment area. In Alternative 3, the entire Parcel G property would be (1) capped and (2) contained by a soil-bentonite slurry wall keyed into the Layer C silt aquitard. The slurry wall would follow the entire perimeter of Parcel G, and three groundwater extraction wells would be installed within the containment area and pumped at a rate sufficient to prevent groundwater from flowing out of the containment area through the slurry wall or Layer C. Extracted groundwater would be pretreated to reduce VOC concentrations to acceptable levels prior to discharge to the King County sanitary sewer.

11.3.3.1 Protecting Human Health and the Environment

The evaluation of this criterion for Alternative 3 is essentially the same to the discussions above for Alternatives 1and 2.

11.3.3.2 Complying with Cleanup Standards

As described above for Alternatives 1 and 2, Alternative 3 achieves compliance with this cleanup standard by controlling migration of VOC-containing groundwater from Parcel G to downgradient receptors. It also achieves the cleanup standard for protection of future site and indoor workers through application of the appropriate engineering controls and the use of institutional controls to require their use and to evaluate the indoor air pathway if future site development activities result in the construction of a habitable building.

11.3.3.3 Use of Permanent Solutions to Maximum Extent Practicable

The evaluation of this criterion for Alternative 3 is very similar to that described above for Alternative 2, with the primary difference being the replacement of the ZVI reactor vessels with groundwater extraction for hydraulic control. Therefore, the discussion below will focus only on the permanence and long-term effectiveness of the groundwater extraction and treatment system.

Permanence. Alternative 3 uses groundwater extraction from within the slurry wall to provide hydraulic gradient control within the containment area. The extracted groundwater is pretreated on-site with an air stripper and vapor-phase carbon adsorption system prior to discharge to the sanitary sewer. The use of groundwater extraction for gradient control has been documented to be effective on numerous sites, including the Parcel G and Hexcel properties (see discussion for Alternative 1 above). Sustaining the required extraction rates requires significant ongoing O&M of both the extraction and treatment systems. Therefore, the permanence of Alternative 3 is reduced by the need for significant long-term O&M and monitoring activities.

Long-Term Effectiveness. As noted above, groundwater extraction has been demonstrated to be effective both at the Parcel G property and on numerous other sites. The certainty that this approach will be effective is directly related to the consistent operation of the groundwater extraction system. The preliminary basis for the design flow rate of the extraction system is described in Appendix H. Because the groundwater extraction system is operating within a slurry wall containment cell, it will easily provide the required gradient control. Therefore, from a design standpoint, the effectiveness of Alternative 2 has a high degree of certainty.

From an operational standpoint, mechanisms will be put in place to ensure that the required O&M activities are adequately funded and implemented. Therefore, Alternative 3 also has a high degree of certainty from an operational standpoint. Because the effectiveness is ultimately dependent on the ongoing performance of these O&M activities, the permanence of this alternative is reduced compared to approaches that maintain containment passively or with reduced O&M requirements.

12.0 COMPARITIVE EVALUATION AND RECOMMENDED CLEANUP ACTION

In this section, the CAAs developed in Section 10 and evaluated individually in Section 11 are compared against each other for each of the MTCA evaluation criteria. Based on this comparison, the preferred CAA is recommended for implementation. A description of how the preferred CAA meets the MTCA criteria and Ecology expectations is provided.

12.1 Comparison of Alternatives

12.1.1 Protectiveness

All of the alternatives will achieve containment of VOCs at the downgradient Parcel G property boundary, thereby protecting the potential human receptors for the groundwater to surface water pathway. All three alternatives address the potential exposure of subsurface construction workers on-site in the same fashion by ensuring that the potential risks to site workers are adequately assessed prior to and during invasive site work and that adequate protective measures (e.g., personal protective clothing, respiratory protection) are used. Similarly, all three alternatives address the potential future indoor air pathway by requiring that this pathway be evaluated and engineering controls (e.g., vapor barriers) incorporated, as appropriate, to control potential exposures if future Parcel G development includes construction of habitable structures.

12.1.2 Compliance With Cleanup Standards

All three alternatives achieve compliance with the groundwater cleanup standards by controlling migration of VOC-containing groundwater from Parcel G to downgradient receptors. The primary difference between the alternatives is the technology employed to achieve containment.

All three alternatives achieve the cleanup standard for protection of future site and indoor workers through the use of institutional controls to require the use of appropriate engineering controls and evaluation of the indoor air pathway if future site development activities result in the construction of a habitable building.

12.1.3 Compliance with Regulatory Requirements

All of the CAAs will comply with the applicable legal requirements, including MTCA. Where off-site management and disposal of wastes is required, the applicable solid and dangerous waste regulations will govern cleanup activities. Alternatives 1 and 3 include discharge of groundwater to the sanitary sewer; for these alternatives, a King County Industrial Waste Discharge Permit will be obtained and complied with. Alternative 3 also includes emission control equipment to prevent the discharge of VOCs from the groundwater treatment system to the atmosphere; this system will meet the substantive requirements of the PSCAA regulation.

12.1.4 Compliance Monitoring

All CAAs include compliance monitoring to assess the ongoing performance of the alternative and to monitor compliance with cleanup goals. Of the three alternatives, Alternative 1 has the most involved compliance monitoring (see the PES 2004b report for details), with significant water quality sampling, water level monitoring, and numerical modeling required to document compliance with the performance objectives. The compliance monitoring associated with Alternatives 2 and 3 is simpler and the performance objectives easier to document compared to Alternative 1.

12.1.5 Use of Permanent Solutions

The comparative evaluation of this criterion is presented in the last column of Table 14. As noted in Section 11.3, the sub-criteria that are most important in differentiating the three alternatives, and will be used as the basis for the disproportionate cost analysis, are permanence, long-term effectiveness, and cost. These three sub-criteria are discussed below, while the disproportionate cost analysis is presented in Section 12.2.

12.1.5.1 Permanence

As noted in Table 14, the main differentiating factors regarding the permanence of the three alternatives are: (1) the amount and complexity on the long-term O&M activities required to maintain containment and (2) how well the alternative maintains containment should O&M activities be interrupted. Alternative 1 is the most O&M intensive, as it would require the ongoing O&M of seven extraction wells, periodic replacement of the extraction wells, and the associated control and discharge systems. Performance monitoring associated with Alternative 1 is also more intensive than the other two alternatives, and includes significant data evaluation and modeling to demonstrate system performance. Alternative 3 is the next most O&M intensive CAA. Although the slurry wall will function without maintenance, the groundwater extraction and treatment systems will require ongoing O&M similar in nature to Alternative 1 in order to maintain hydraulic control inside the containment cell. Alternative 2 is the least dependent on ongoing O&M actions to maintain its effectiveness in that the encircling slurry wall will provide containment without maintenance and the ZVI reactor vessels function passively with only the potential need for periodic “refreshing” of the reactor vessels every several decades, if at all.

In summary, Alternative 2 rates the highest of the three alternatives under the permanence criterion. Alternative 3 rates lower and Alternative 1 rates the lowest due to their need for significant regular ongoing O&M.

12.1.5.2 Long-Term Effectiveness

As described in Section 11, the main factors evaluated relative to the long-term effectiveness of the three alternatives are: (1) the certainty of success of the alternative and (2) how reliable the alternative is. With respect to the certainty of success factor, there is a high degree of certainty that all three alternatives will be effective at preventing migration of VOCs from Parcel G over the long term.

The reliability of the three alternatives is also high. In general, Alternative 1 is the least reliable because of it requires more O&M compared to Alternatives 2 and 3. The reliability of both Alternatives 2 and 3 is also high due to the use of the slurry wall as the primary mechanism for containment. The differences between Alternatives 2 and 3 is how hydraulic gradients inside the containment cell are managed. The ZVI reactor vessels system used in Alternative 2 functions completely passively and, with the exception of the potential need for infrequent “refreshing” of the ZVI in the reactor vessels (e.g., every 30 years), requires no active maintenance.

The positive aspect of the reliability of Alternative 3’s approach to gradient control is based on the well understood and somewhat simpler technology (groundwater extraction) that has been demonstrated effective over the long term at many sites. On the other hand, the reliability of this approach is adversely affected by the need for ongoing O&M including periodic replacement of the extraction wells and the significant O&M required for the air stripper system.

In summary, Alternative 2 would be the most effective over the long term because it utilizes passive controls that do not require regular O&M. Alternatives 1 and 3, although still effective over the long term, are somewhat less reliable than the Alternative 2.

12.1.5.3 Cost

The costs for the three alternatives are detailed in Tables 14, 15, and 16 and summarized in Table 17. Based on the overall net present value (capital costs plus 30 years of O&M), Alternatives 1 and 3 have essentially the same cost of $4.5 million. The major cost factor for these two alternatives is the costs associated with ongoing O&M of the groundwater extraction systems. Alternative 2, although it has the highest capital costs, has an overall net present value cost of approximately $2.9 million because it does not have high ongoing O&M costs.

12.1.6 Restoration Time Frame

All three alternatives rely on containment at the downgradient Parcel G property boundary to provide protection of human health and the environment and achieve compliance with cleanup standards. The rationale for focusing the development and evaluation of alternatives to those based on containment is provided in Section 9.2.3. As a result, all three alternatives will all have essentially the same restoration time frame and the comparison of the alternatives for this criterion is not a differentiating factor between the alternatives.

12.1.7 Public Acceptance

As noted previously, during the preparation of this FFS BSB has carefully considered input from Hexcel with respect to how the CAAs may or may not effect Hexcel’s site investigation and cleanup activities. Additional consideration of public concerns following submittal of the FFS to Ecology will occur in the context of the public review and comment period.

12.2 Recommendation of Preferred Cleanup Action

Based on the evaluation above, Alternative 2 is somewhat superior to Alternative 3 under the evaluation criteria, including the “use of permanent solutions to maximum extent practicable” criterion. Alternative 1 compares less favorably to the criteria than both Alternatives 2 and 3. Alternative 2 is also the least costly alternative over the long term; Alternative 2 costs

$2.9 million followed by Alternatives 1 and 3 which both cost approximately $4.5 million. Therefore under the MTCA regulations [WAC 173-340-360(e)(ii)(C)], it must be selected as the preferred alternative for implementation at Parcel G.

Ecology Expectations. WAC 173-340-370 outlines a series of eight expectations that Ecology has regarding selection and implementation of cleanup actions. Selection of Alternative 2 for implementation at Parcel G is consistent with these expectations in that it:

- Uses engineering controls (containment) to contain large volumes of materials where treatment is impracticable;
- Minimizes migration of hazardous substances by preventing precipitation and runoff from contacting contaminated soils and waste materials;
- Takes active measures to prevent releases of hazardous substances to surface waters via groundwater discharges; and
- Does not result in a greater overall threat to human health and the environment compared to other alternatives.

There is an expectation or preference for treatment technologies. However, this expectation includes the idea that it is applicable to "areas of hazardous substances that lend themselves to treatment." As discussed in detail in Section 9.2.3, the source area at Parcel G does not lend itself to treatment and, therefore, alternatives based on treatment technologies were not developed or evaluated as part of this FFS. It is also important to note the historical cleanup actions at Parcel G (see Section 5) have included significant treatment of contaminants in both soil and groundwater. Also, the ZVI reactor vessels will provide treatment for the VOCs that pass through it.

12.3 Implementation of Preferred Cleanup Action

12.3.1 Overall Implementation Approach

The final selection and implementation of Alternative 2 as the preferred cleanup action will include the following general steps:

- Finalize the FFS and solicit public input on the cleanup action selection;
- Prepare a Cleanup Action Plan (CAP);
- Based on the CAP, Ecology and BSB will negotiate a consent decree for designing, constructing, and operating the selected alternative;
- Prepare a detailed design of the alternative;
- Following Ecology's approval of the final design, construct the cleanup action (e.g., slurry wall, ZVI reactor vessels, surface cap); and

- Begin long-term operations, maintenance, and compliance monitoring activities.

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LIMITATIONS

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TABLES

ILLUSTRATIONS

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LOGS FOR WATER WELLS WITHIN ONE MILE OF PARCEL G

(Appendix A Provided on the Attached Compact Disc)

APPENDIX B

PARCEL G BORING AND WELL LOGS

(Appendix B Provided on the Attached Compact Disc)

APPENDIX C

PARCEL G WATER LEVELS AND HYDROGRAPHS

(Appendix C Provided on the Attached Compact Disc)

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APPENDIX D

PARCEL G SOIL AND GROUNDWATER CHEMISTRY DATA TABLES

(Appendix D Provided on the Attached Compact Disc)

APPENDIX D TABLES

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APPENDIX E

PARCEL G ROUTINE GROUNDWATER CHEMISTRY DATA TABLES

(Appendix E Provided on the Attached Compact Disc)

APPENDIX F

PARCEL G VOC TIME-TREND PLOTS

(Appendix F Provided on the Attached Compact Disc)

APPENDIX G

BENCH-SCALE TREATABILITY STUDY

APPENDIX H

PRELIMINARY CONTAINMENT AREA HYDRAULIC ANALYSIS