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RI/FS WORK PLAN

Georgia Pacific West Site, Bellingham, WA

Prepared for: Port of Bellingham

Project No. 070188-001-02 • September 10, 2009 Final

Prepared in association with

ANCHOR QEA

and **Pyron Environmental Inc**.

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Contents

List of Tables

List of Figures

List of Appendices

Acronyms and Abbreviations

ALTA	American Land Title Association
ASB	Aerated stabilization basin
bgs	Below ground surface
BNSF	Burlington Northern-Santa Fe Railroad
BTEX	Benzene, toluene, ethylbenzene, and xylenes
Corps	United States Army Corps of Engineers
cPAH	Carcinogenic polycyclic aromatic hydrocarbon
DO	Dissolved oxygen
DOH	Department of Health
Ecology	Washington State Department of Ecology
EIS	Environmental impact statement
EPA	U.S. Environmental Protection Agency
EPH	Extractable petroleum hydrocarbon
ESA	Environmental site assessment
FM	Fire main
FS	Feasibility study
GP	Georgia-Pacific Corporation
mg/kg	Milligrams (of chemical) per kilogram (of soil)
MLLW	Mean lower low water elevation datum
MTCA	Model Toxics Control Act (as implemented under Chapter 173-340 WAC)
mv	Millivolt
NAPL	Non-aqueous phase liquid
NTR	National Toxics Rule
ORP	Oxidation-reduction potential
PAH	Polycyclic aromatic hydrocarbon

PCB	Polychlorinated biphenyl
pH	Measure of acidity and alkalinity, equal to the negative logarithmic value of the hydrogen ion (H^+) concentration
PHREEQC	A public-domain geochemical modeling code
PL	Parking lot
Port	Port of Bellingham
Redox	Oxidation-reduction
Remerc	A proprietary mercury extraction and recovery system
RI	Remedial investigation
RI/FS	Remedial investigation/feasibility study
SBLT	Sequential batch leaching test
SVOC	Semivolatile organic compound
TCLP	Toxicity characteristic leaching procedure
TPH	Total petroleum hydrocarbon
TSS	Total suspended solids
µg/L	Micrograms (of chemical) per liter (of water)
$\mu g/m^3$	Micrograms (of chemical) per cubic meter (of air)
USGS	United Stated Geological Survey
VOC	Volatile organic compound
WAC	Washington Administrative Code
%	Percent

1 Introduction

1.1 Site Description and Background

The Georgia Pacific West Site (Site) is a waterfront industrial property acquired by the Port of Bellingham (Port) from Georgia-Pacific Corporation (GP) in January 2005. The Site, located at 300 West Laurel Street in Bellingham, Washington, encompasses approximately 64 acres on the south side of the Whatcom Waterway. The Site is bordered on the north by the Whatcom Waterway (at mudline), on the east and south by the Burlington Northern-Santa Fe (BNSF) railroad, and on the west by the Bellingham Shipping Terminal and Bellingham Bay (Figure 1). The Encogen Northwest co-generation power plant is located south of the BNSF railroad, south of the central area of the Site. Figure 2 depicts the preliminary Site boundary for the purposes of this Work Plan, and shows adjacent property boundaries obtained from the 2004 American Land Title Association (ALTA) survey and the Whatcom County parcel database. Land ownership within the preliminary Site boundary includes the Port of Bellingham, the State of Washington, and BNSF, and the City of Bellingham has easements for public roads (e.g., Laurel Street).

Note: The figures in this Scoping Plan contain directional references for both true north and “Mill north”, with the “Mill north” axis approximately 45 degrees west of true north (see compass rose on attached figures). For ease of discussion, and consistency with previous environmental reports, the text in this Plan uses “Mill north” as its directional reference. In the “Mill north” reference, the Whatcom Waterway is oriented east-west on the north side of the Site.

The Port is currently undergoing evaluation of potential future land uses, including continued industrial use or potential rezoning to accommodate mixed use redevelopment. Contamination from historic industrial activities on the Site has impacted upland soils and groundwater with a variety of constituents including mercury and other metals and petroleum hydrocarbons.

In 1999 and 2002, GP entered into a pair of Agreed Orders with Washington State Department of Ecology (Ecology) to perform facility decommissioning and then a remedial investigation/feasibility study (RI/FS) for a portion of the property known as the Chlorine Plant (aka Chlor-Alkali area). In addition to decommissioning of the former Chlorine Plant, GP conducted a significant amount of RI/FS and independent cleanup work for the Chlorine Plant area. GP also conducted an environmental assessment for the remaining portion of the property, the Pulp and Tissue Mill, prior to sale of the property to the Port.

Immediately north of the Site, the Port is also initiating the cleanup of sediments in the Whatcom Waterway site under a Consent Decree (No. 07 2 02257 7). The Cleanup Action Plan for the Whatcom Waterway is included as Exhibit B to the Consent Decree, which is available from Ecology’s web site (http://www.ecy.wa.gov/programs/tcp/sites/whatcom/ww_archive.htm). The GP West

Site does not include sediments in the waterway, but the Site cleanup will protect against adverse impact to the waterway including potential recontamination of waterway sediments (e.g., through groundwater discharge to the waterway).

The Port, as current owner of the majority of the Site, has entered a new Agreed Order No. 6834 with Ecology to complete a RI/FS for the Site in accordance with WAC 173-340-350 and the Statement of Work (SOW) and Schedule in the Agreed Order. This RI/FS Work Plan is the first deliverable under the Agreed Order.

1.2 Document Organization

Subsequent sections of this Work Plan are:

Section 2: Project Management Strategy;

Section 3: Site History;

Section 4: Environmental Setting;

Section 5: Preliminary Screening Levels;

Section 6: Previous Environmental Investigations and Independent Cleanup Actions;

Section 7: Preliminary Conceptual Site Model;

Section 8: Data Gaps and Proposed Additional Site Characterization; and

Section 9: References.

Appendix A provides a literature assessment to develop an aquatic life surface water screening level for formaldehyde. Appendix B provides preliminary background information regarding contaminant fate and transport for currently identified contaminants of concern at the Site. Appendices C and D are the Sampling and Analysis Plan (SAP) and Quality Assurance Project Plan (QAPP), respectively, for the RI/FS. Appendix E provides a copy of Ecology’s annotated outline for RI/FS documents. A site-specific Health and Safety Plan (HASP) for the RI/FS work is being prepared under separate cover for submittal to Ecology, in accordance with the Agreed Order,

2 Project Management Strategy

The GP West Site RI/FS is being conducted by Aspect Consulting, LLC (Aspect) on behalf of the Port, in accordance with WAC 173-340-350. Ecology is providing regulatory oversight of the RI/FS activities in accordance with Agreed Order No. 6834.

2.1 Project Team

The project coordinators designated in the Agreed Order are Lucille McInerney, PE, for Ecology, and Brian Gouran, LG, for the Port.

The consultant project team consists of representatives from Aspect and its subconsultants and subcontractors. Aspect's lead personnel and their roles for the RI/FS include:

- Steve Germiat, LHG, is the project manager with final authority and responsibility for the consultant's team activities;
- Jay Chennault, LHG, is the RI task manager, responsible for directing the RI field program and managing and reporting the data; and
- Dave Heffner, PE, is the FS task manager, responsible for directing the FS.

Aspect will also use other licensed hydrogeologists and engineers, and field geologists, for completion of the RI and FS tasks.

Aspect's primary subconsultants for the RI/FS include:

- Anchor QEA, providing assistance with RI/FS Work Plan development, field data collection, RI data analysis and reporting, and development of remedial alternatives in the FS;
- Pyron Environmental, providing assistance with QAPP preparation, analytical laboratory coordination, and data quality validation for newly collected data; and
- Wilson Engineering, providing surveying and civil engineering assistance.

Aspect's primary subcontractors for the project include:

- Columbia Analytical Services, providing analytical laboratory services for soil and water samples;
- Frontier Geosciences, providing analytical laboratory services for mercury soil vapor samples;
- Northwest Probe, providing direct push drilling and construction of soil borings and monitoring wells in the Fill Unit; and
- Cascade Drilling, providing combined hollow stem auger and rotosonic drilling and construction of deep monitoring wells in the Lower Sand.

2.2 RI/FS Objectives

The RI/FS is intended to provide sufficient data, analysis, and evaluations to enable Ecology to select a cleanup action for the Site in accordance with MTCA. To this end, specific objectives of the RI/FS are to:

- Obtain data of sufficient quality and quantity to describe the physical setting and physical properties of site soil, groundwater, and soil vapor (air);
- Determine the nature and extent of contamination in soil, water, and air (soil vapor);

- Characterize the fate and transport of identified contaminants, including how contaminants migrate between media (e.g., soil leaching to groundwater, groundwater discharge to surface water, and volatilization from soil or groundwater to air);
- Use the information collected to assess potential human health and ecological health concerns under current and planned land uses;
- Determine the need for cleanup actions for specific areas of the Site, and identify and evaluate the alternatives for doing so based on specific contaminants and environmental conditions and land use plans in different areas of the site; and
- Report the methods and findings of the RI/FS to Ecology and the local community.

2.3 RI/FS Tasks

The RI/FS will consist of the following primary tasks:

- **Prepare RI/FS Work Plan**. This RI/FS Work Plan describes the planned RI/FS tasks to be accomplished to complete an RI/FS meeting requirements of WAC 173-340-350 in accordance with the Agreed Order. The Work Plan includes a project management strategy, a detailed review of existing Site data and associated data gaps, a SAP and QAPP. The Work Plan will be reviewed and approved by Ecology prior to initiating the RI/FS tasks.
- **Conduct Field Data Collection Program**. Following Ecology approval of the Work Plan, an extensive soil, groundwater, and soil vapor (air) sampling and analysis program will be conducted to supplement the existing Site data and further evaluate environmental conditions within subareas of the Site where data gaps are identified in this Work Plan. Additional hydrogeologic data collection will also be conducted to further refine understanding of groundwater flow conditions as they pertain to protection of the Whatcom Waterway and Bellingham Bay.
- **Evaluate New Data and Prepare RI Report**. The results of the RI field investigation and previous Site investigations will be synthesized in the RI report, describing environmental setting, Site history, nature and extent of contamination, and potential for contaminant transport to off-Site receptors. Soil, groundwater, and soil vapor quality data will be compared to screening levels outlined in this Work Plan, from which potential concerns for human and ecological receptors will be identified. The RI laboratory data will be validated for quality assurance and tabulated, and graphics will be developed illustrating inferred extents and magnitude of contamination in soil, groundwater, and soil vapor. A draft RI will be submitted to Ecology for review (Volume 1 of RI/FS). The draft RI report will be organized in general accordance with the Annotated Outline for RI/FS Reports, a copy of which is included as Appendix F to this Work Plan. Based on Ecology comments received, the draft RI will be revised.

- **Prepare FS Report**. The FS will develop and evaluate cleanup action alternatives to enable a cleanup action to be selected for the Site. A range of remedial technologies applicable to Site contaminants and conditions will initially be evaluated, and appropriate technologies retained. Additional data collection and/or analysis (e.g., contaminant transport modeling, treatability studies, etc.) may be warranted as part of the FS. Applicable remedial technologies will be assembled into remedial alternatives for subareas of the Site that are protective of human health and the environment by controlling risks via each exposure pathway. The relative cost and performance for each alternative will be evaluated in accordance with the requirements specified in WAC 173-340-360. Cleanup levels for contaminants of concern in each media will be proposed, accounting for cross-media transfer. Results of the alternatives evaluation, and identification of a preferred cleanup action, will be summarized in a draft FS Report, which will be submitted to Ecology for review (Volume 2 of RI/FS). The draft FS report will be organized in general accordance with the Annotated Outline for RI/FS Reports (Appendix C to this Work Plan). Based on comments received, the draft FS will be revised.
- **Produce RI/FS for Public Review**. Resolution of comments received on the draft RI and FS reports will be incorporated into a Draft RI/FS for public review.
- **Produce Final RI/FS**. Resolution of public comments received on the Draft RI/FS will be incorporated into a Final RI/FS.

2.4 Data Management

All new validated analytical data to be collected during the RI/FS will be incorporated into the existing project database maintained by Aspect. Exploration coordinates for horizontal position, and monitoring well top-of-casing elevations, will be included in the database. Field parameter measurements collected during groundwater sampling will also be included. All data collected under Agreed Order No. 6834 will be uploaded to Ecology in their EIM database format, as required by the Agreed Order. Field documentation is discussed in the SAP (Appendix C).

2.5 Schedule

The RI/FS will be conducted in accordance with the schedule included in the SOW for Agreed Order No. 6834. Assuming Ecology approval of the RI/FS Work Plan by September 2009, tentative schedule milestones for the RI/FS are as follows:

- Conduct RI field sampling program including the dry-season water sampling event in September-October 2009;
- Conduct the RI wet season water sampling event in March 2010;
- Submit to Ecology the Draft RI report (Volume 1 of RI/FS) by June 2010;
- Resolve comments on Draft RI to Ecology’s satisfaction by August 2010;

- Submit to Ecology the Draft FS report (Volume 2 of RI/FS) by December 2010;
- Resolve comments on Draft FS to Ecology’s satisfaction by March 2011; and
- Submit to Ecology the Draft RI/FS for public review by April 2011.

This schedule is subject to change as the RI/FS progresses. Ecology will be kept informed as to progress of the RI and FS through regular reporting and other communications, in accordance with the Agreed Order. If at any time during the RI/FS process, unanticipated conditions or changed circumstances are discovered that may result in a schedule delay, the Port will bring such information to the attention of Ecology. Pursuant to Section VII.K of the Agreed Order, Ecology will then determine whether a schedule extension is warranted.

3 Site History

In general terms, the Site includes the Chlor-Alkali area (Chlorine Plant) on the west, and the former Pulp and Tissue Mill areas on the east, as shown on Figure 2. The industrial history for each of those primary areas is summarized below, based on information presented in ENSR (1994a) for the Former Chlorine Plant, and in Aspect (2004b) for the former Pulp and Tissue Mill area. Figure 3 depicts general operational areas of the Site, which are referenced throughout this Work Plan.

3.1 Former Chlorine Plant

The former Chlorine Plant used a mercury cell technology to produce chlorine and sodium hydroxide (caustic) for use at the Tissue Mill in bleaching and pulping wood fiber, and for off-site sale. Hydrogen was also produced at the Chlorine Plant and used as fuel in the Tissue Mill. GP constructed the Chlorine Plant in 1965 on approximately four acres of previously undeveloped land. The Chlorine Plant operated from 1965 through 1999.

The following sections summarize relevant historical activities at the former Chlorine Plant, including industrial operations, waste generation and handling, filling of the former Log Pond with sediment dredged from Whatcom Waterway, and previous Agreed Orders with Ecology directing site investigation and remediation.

3.1.1 Former Chlorine Plant Operations

Chlorine and caustic were produced at the plant using the closed-loop deNora mercury cell process. Chlorine gas was generated electrolytically from a saturated solution of sodium chloride (brine). The pH of the input brine solution was increased by adding caustic to precipitate impurities such as calcium and magnesium, and then reduced again by addition of hydrochloric acid prior to entering the electrolytic cells. The precipitated impurities were removed from the brine by settling and filtering. The removed solids were a waste product managed by GP.

The mercury cells were rectangular steel troughs having a slight downward slope from inlet to outlet. The electrolytic cell contains a cathode consisting of mercury flowing on the bottom of the trough from inlet to outlet (the brine floated on top of the mercury), and titanium anodes along the full length of the cell.

At the anode (positively charged), chlorine gas was evolved from negatively charged chloride ions in the brine; the chlorine gas was extracted from the cell.

At the cathode (negatively charged), elemental sodium was evolved from positively charged sodium ions in the brine. The sodium combined with the mercury forming an amalgam leaving the cell and traveling to a decomposer filled with graphite. In the decomposer, graphite served as the anode and amalgam served as the cathode. The amalgam and water flowing through the cell came into direct contact with the graphite. The sodium-mercury amalgam was decomposed by water with the formation of sodium hydroxide, the reformation of mercury, and the production of hydrogen gas. Having passed through the cell, the brine was stripped of residual chlorine and returned to the brine saturator to be re-saturated with salt. The mercury was reused within the cell.

At the mercury cell inlet and outlet, the mercury could be exposed to the atmosphere. To prevent its volatilization, the mercury was covered with flowing water, referred to as seal water. The seal water was initially discharged to the Log Pond until 1970, when a recycling system was installed.

3.1.2 Former Chlorine Plant Waste Generation and Handling

According to ENSR (1994a), mercury-containing wastes generated at the former Chlorine Plant over its history included:

1. **Brine treatment wastes:** Solids from saturators and from clarifier/brine filter backwash.
2. **Mercury seal water:** Water covering the mercury to prevent its volatilization.
3. **Hydrogen condensate:** Water condensed from hydrogen gas from its cooling.
4. **Chlorine condensate:** Water condensed from chlorine gas from its cooling.
5. **Caustic wastes:** Caustic filter backwash (after 1970).
6. **Stormwater runoff:** Mercury-containing runoff from the vicinity of the Chlorine Plant.
7. **Cell flushing water:** Brine discharged daily from the mercury cells to flush accumulated solids.
8. **Cell room cleaning water:** Water used to wash the cell exteriors and flush the cell building floors to sewer.
9. **Leaks and spills:** Accidental leaks and spills anywhere in the Chlorine Plant.

A generalized chronology of GP's management of the Chlorine Plant process wastes is as follows:

- **1965-1970:** Discharged wastewaters directly to the GP Log Pond which, at that time, extended inland adjacent to the Chlorine Plant.
- **1970:** Implemented process improvements to reduce waste discharge to the Log Pond, including recirculation/reuse of process fluids within the Plant and construction of an earthen wastewater settling basin between the Chlorine Plant and the Log Pond to reduce suspended solids prior to discharge.
- **1973:** Improved the settling basin, including filtration of effluent to further reduce solids prior to discharge.
- **1974:** Constructed wastewater improvements to reduce pollutant discharges to the settling basin.
- **1976:** Removed accumulated solids from the wastewater settling basin and chemically stabilized the solids by a proprietary process (Chemfix) using 2.4 percent by volume sodium silicate and 1.7 percent by volume Portland cement. Approximately 8,000 cubic yards of this material were contained within an area of approximately 2 acres (Chemfix Area on Figure 3). The solidified Chemfix material extends to a depth of approximately 4 to 5 feet below current grade, and is covered with (from bottom up) a layer of bank run fill; a geotextile membrane (DuPont Typar®, lapped and glued, and extending beyond the lateral extent of Chemfix); a 6-inch layer of sand; and two layers of asphalt totaling 5 to 6 inches in thickness. An Ecology Order from 1977 specifies maintenance requirements for the cover material over the Chemfix area.
- **1980:** Closed the settling basin and filled it with clean fill. Constructed a new wastewater collection sump and surge storage tank to replace the settling basin surge capacity.
- **1980-1992:** Implemented further improvements to reduce mercury concentrations discharged, including routing all wastewater to the aerated stabilization basin (ASB) north of the Whatcom Waterway, and decommissioning of the Chlorine Plant outfall to the Log Pond.
- **1993:** Constructed a chemical extraction and recovery system ("Remerc process") to recover mercury from brine sludges and wastewater treatment plant sludges. The Remerc process met the RCRA universal treatment standards for pretreating the wastes prior to landfilling as listed hazardous waste (K071 and K106).
- **1999:** Closed the Chlorine Plant.

3.1.3 Whatcom Waterway Dredging (1974)

In 1974, GP implemented a dredging project within the Whatcom Waterway, consistent with Ecology requirements. The project removed surface sediments from within the

Whatcom Waterway by dredging, and placed the dredged materials within a portion of the former Log Pond in order to construct a land-based log handling facility. GP constructed an earthen dike around about 8 acres of the Log Pond northeast of the Chlorine Plant. Sediments from the Log Pond and Whatcom Waterway were hydraulically dredged and placed in the diked area. The dredge fill was topped with gravel and paved with asphalt, creating new upland area. The City of Bellingham developed an Environmental Impact Statement (EIS) and issued a Shorelines Management Permit for the project. The Army Corps of Engineers also issued a permit for the project. It appears that the bulkhead along the now-filled former Log Pond shoreline remains in place, which may locally influence flow of shallow groundwater.

3.1.4 Previous Agreed Orders

Following closure of the Chlorine Plant in 1999, planned remediation of the Chlorine Plant site was to occur in two phases, each conducted under an Agreed Order with Ecology. The first phase was conducted under Ecology Agreed Order DE TC99 I035 (1999), which required the decommissioning and demolition of the Chlorine Plant’s processing machinery. That phase of the project was completed in 2000. The second phase, under Agreed Order DE 02 TCPIS-472 (2002), required completion of a RI/FS for the Chlor-Alkali site. The RI/FS activities conducted under that Agreed Order are described in Section 6.1.1.

3.2 Former Pulp and Tissue Mill

The GP Mill manufactured bleached sulfite pulp for internal production of tissue and toweling, and for sale as market pulp. The facility contained six individual plants producing primary sulfite pulp, Permachem pulp, sulfuric acid, chlorine, sodium hydroxide, alcohol, and lignosulfonate products. Sulfite waste liquor, a byproduct of pulping, was converted into ethanol and salable lignin products. Lignin, a byproduct of pulping, was converted into salable products through various production steps. One of the lignin byproducts produced at the Site was drilling mud containing chromium as an additive.

The following sections summarize the development history, operations, and waste generation and handling at the former Pulp and Tissue Mill. This operational history of the former is from the Phase 2 Environmental Assessment for the Pulp/Tissue Mill property (Aspect, 2004b). The operational history was developed based on review of GP’s historical information and interviews with GP employees, and was reviewed by GP for accuracy.

3.2.1 Development History

In 1926, the San Juan Pulp Company opened the first pulp mill on five acres of tideland within the footprint of the current mill property. The mill was designed to make use of pulp logs and fiber leftovers from a local wood box plant and several lumber mills. Three years later, the business was reorganized as the Puget Sound Pulp and Timber Company. During the late 1930s, the pulp mill underwent significant expansion. In 1943, the Defense Plant Corporation constructed a chemical byproducts plant to produce ethyl alcohol from wood sugars found in sulphite waste liquor produced by the pulp mill. The

Puget Sound Pulp and Timber Company later purchased this plant. In 1946 and 1947, the company added a log barking and chipping plant and a paperboard manufacturing plant to its operations. Also in 1947, a laboratory research group was established to determine ways of converting waste lignin materials into useful products. Later that year, the first facilities to extract such products were installed. Lignin products produced included chromium-containing oil well drilling mud thinners, vanilla flavoring, animal feeds, adhesives, pharmaceuticals, dust retardants, fuel pellets, solvents, ferromagnetic liquids, and many other products.

In the early 1950s, two bleaching stages were added to the pulping process. Two additional stages were added later to produce very bright and strong pulp. In 1958, Puget Sound Pulp and Timber acquired the adjacent tissue manufacturing operations of Pacific Coast Paper Mills. In 1963, the company merged with the GP. GP expanded the plant in 1965 by constructing the mercury cell Chlorine Plant as previously described in Section 3.1.

Throughout the 1970s and 1980s, GP continued to upgrade the facility by adding a pulp washer, additional digesters, power substations, wood-handling installations, warehousing, byproduct expansions, and chip plants. It also provided primary and secondary treatment of its wastewater. The pulp mill and associated chemical plants were closed in 2001 and the tissue mill was closed at the end of 2007.

3.2.2 Former Pulp and Tissue Mill Operations

During the 1980s, the mill produced an average of 760 tons per day of bleached sulfite pulp and an average of 40 tons per day of Permachem pulp (for production of tissue paper). The mill had nine batch digesters for pulping. According to Ecology records, the facility also produced some byproducts and chemicals, including concentrated lignin products, ethyl alcohol, sulfuric acid (80 tons per day), chlorine (220 tons per day), and caustic soda (250 tons per day). Approximately 15 percent of the chlorine and sodium hydroxide produced at the facility was used for internal plant consumption; the balance was sold on the open market. Sulfite waste liquor, a byproduct of pulping, was converted into ethanol and salable lignin products.

One of the lignin byproducts produced at the site was drilling mud containing chromium as an additive. Most of the chromium was supplied as chromium dioxide. The chromium dioxide product was supplemented with chromic acid wastes from plating facilities. According to EPA 1987 records, the facility was receiving approximately 5,000 gallons per month of hexavalent chromium-containing acid wastes, which were stored in a 30,000 gallon tank east of the Lignin Plant Mill A Warehouse. This source of chromium was discontinued in the late 1980s. Prior to the 1980s, liquid chromium (sodium bichromate) was brought in by barge and stored in 100,000 gallon and 150,000 gallon tanks located behind Warehouse Number 2. The liquid chromium in these tanks was transported to the Lignin Plant via an underground pipeline (dashed line on Figure 3).

3.2.3 Pulp and Tissue Mill Waste Generation and Handling

According to a 1992 EPA RCRA Facility Assessment report, the GP facility generated 750 tons per year of listed mercury-containing wastes associated with chlorine plant operations and ignitable wastes in the form of waste oils, solvents, and degreasers. The facility generated large volumes of non-hazardous solid wastes including primary clarifier sludge (mostly fiber), log-sorting debris (mostly sand and dirt), general mill waste (e.g., paper, wood), and process waste (primarily hog fuel boiler grate ash and limestone spalls). Ecology and facility records indicate that solid wastes were disposed at off-site facilities.

Before installation of primary and secondary treatment systems, process wastewaters were discharged through various outfalls directly into the Whatcom Waterway. In the early 1970s, the sewer lines from hydraulic barking, Permachem and sulfuric acid production, pulp digesters and screening, tissue paper making and converting, and pulp drying operations were rerouted to the newly constructed primary clarifier to receive primary treatment (solids settling). When the aerated stabilization basin (ASB) located across the waterway was completed in 1979, the rest of the process sewers were rerouted and these wastewaters, along with effluent from the primary clarifier, received secondary (biological) treatment.

4 Environmental Setting

The environmental setting of the Georgia Pacific West Site has been well documented in previous investigations including the Chlorine Plant RI and FS (ENSR, 1994a and 1994b), the subsequent FS for the Chlor-Alkali site (Aspect, 2004a), the Phase 2 environmental site assessment for the Former Pulp and Tissue Mill (Aspect, 2004b), and the storm drainage concept report for the New Whatcom Redevelopment project (KPFF, 2008). This section summarizes available information on the Site environmental setting.

4.1 Location and Physical Setting

The Site is located adjacent to Bellingham Bay and the Whatcom Waterway on Puget Sound in western Whatcom County. Whatcom Creek originates from Lake Whatcom and drains to the Whatcom Waterway. The Site is bordered on the north by the Whatcom Waterway, on the east and south by the Burlington Northern-Santa Fe (BNSF) railroad, and on the west by the Bellingham Shipping Terminal and Bellingham Bay. The Whatcom Waterway is used by several species of salmon (Chum, Coho, Chinook) and trout (cutthroat and steelhead). Other marine fish, mammals, and waterfowl also use Bellingham Bay and the Whatcom Waterway.

The Site is built on reclaimed land formed by filling a tidal flat area of the Whatcom Creek Delta. Filling has been accomplished from the early 1900s through the 1970s. The fill material was placed by a variety of parties, and includes hydraulic fill placed during 1912 and 1913 by the Corps of Engineers, general construction material obtained from upland areas (upland fill) around Bellingham, and hydraulic fill (dredge fill) placed by GP during dredging in the 1970s. The fill varies in thickness from approximately 10 to 18 feet across the Site. Underlying the fill is approximately 15 feet of native tidal flat deposits consisting predominantly of silty sand and silt.

The Site is relatively flat, with land surface elevations generally ranging from 14 to 16 feet above mean lower low water (MLLW). Elevations rise rapidly to approximately 200 feet above MLLW to the south of the Site, south of Cornwall Avenue. To the east of the Site, elevations change more gradually to typical elevations of approximately 50 feet above MLLW. Most of the Site is covered by pavement with some remaining buildings from the mill and chlorine plant.

Average annual rainfall for the area is approximately 37 inches per year (PRISM 1971-2000 data; www.prism.oregonstate.edu). Average monthly precipitation ranges from 1.4 inches in August to 5.8 inches in November.

Apart from minor overland flow directly into the Whatcom Waterway, stormwater generated on the Site is collected in catch basins and conveyed via pipes that converge at a pump station on the north edge of the Site, adjacent to the City of Bellingham's Laurel Street stormwater outfall. From the pump station, the stormwater is pumped via force main beneath the waterway to the Aerated Stabilization Basin (ASB) north of the waterway, for treatment and discharge via the NPDES-permitted outfall. The ASB treatment system and associated outfall has been permitted since they were constructed in the late 1970s when the pulp mill was in full operation. The discharge is sampled in accordance with the NPDES permit requirements. The City of Bellingham conveys stormwater collected from other areas of downtown through the Site, beneath Laurel Street, to their NPDES-permitted outfall to the waterway; that outfall does not convey any stormwater from the Site. The Port is currently evaluating the condition of the existing stormwater system on Site and how the system may be changed as site redevelopment occurs in the future.

4.2 Hydrogeologic Conditions

The three hydrogeologic units of interest beneath the Site include, from surface down, a Fill Unit consisting of several different types of upland and dredge fill materials, a low-permeability Tidal Flat Aquitard, and a Lower Sand Unit. The Fill Unit contains a shallow water table aquifer, whereas the Lower Sand is a confined aquifer, which is hydraulically separated from the Fill Unit aquifer by the intervening Tidal Flat Aquitard. Fill Unit and Lower Sand groundwater beneath the Site ultimately discharges to the marine environment of Whatcom Waterway or Bellingham Bay. Bedrock contours beneath the Site have been defined during previous geotechnical studies and vary from less than 30 feet below ground surface (bgs) in portions of the Pulp/Tissue Mill area, to greater than 135 feet bgs in portions of the Chlor-Alkali area. Additional detail on the unconsolidated units overlying the bedrock is provided below.

4.2.1 Fill Unit

Soils within approximately 15 to 18 feet of ground surface are comprised of fill materials ranging from imported upland sand and gravel to silty dredge fill, with localized areas of wood and construction debris (e.g., bricks, concrete tile, metal, and plastic). The Fill Unit contains a shallow unconfined (water table) water-bearing zone, perched upon the underlying native tidal flat deposits.

The water table within the Fill Unit is generally closer to ground surface in the southern portion of the Site, and becomes gradually deeper approaching the waterway. During dry season conditions (August 2004), the Fill Unit water table occurred at depths typically ranging from 3 to 6 feet below ground surface (bgs) across most of the Tissue Mill area, but 7 to 9 feet bgs along the Whatcom Waterway. Across the Chlor-Alkali area, the water table depth ranges from about 1 to 3 feet bgs in the southwestern corner to greater than 10 feet bgs near the Log Pond. ENSR (1994a) reported that Fill Unit groundwater beneath the Chlori-Alkali area was not appreciably influenced by tidal fluctuations, except in one well nearest the Log Pond (Law-1). Data collected during the Tissue Mill Phase 2 ESA indicates that Fill Unit groundwater adjacent to the waterway does respond minimally to tidal fluctuations (Aspect, 2004b).

Hydraulic conductivity testing (slug testing) performed by ENSR (1994a) found that the Fill Unit beneath the Chlor-Alkali area had estimated hydraulic conductivities ranging over four orders of magnitude (2×10^{-6} to 2×10^{-2} cm/sec), consistent with a wide range of fill material types. Estimated groundwater velocities in the Fill Unit ranged from 3 to 10 feet per year.

Fill Unit groundwater beneath the Site ultimately discharges to the Whatcom Waterway or Bellingham Bay. Groundwater flow directions in the Fill Unit appear to be influenced by the presence of historical bulkhead structures. The available information indicates that these structures remain along parts of the former shoreline that existed prior to the 1974 filling with Whatcom Waterway and Log Pond dredge materials of the area immediately south of the current Log Pond. The historical bulkheads form a 3-sided box, with two north-south trending arms (perpendicular to Whatcom Waterway) and one east-west trending arm between them (parallel to Whatcom Waterway; Figure 4). Based on ENSR’s (1994a) RI groundwater level data, the north-south trending portions of the former bulkhead structure apparently remain in place, and create groundwater divides within the Fill Unit. Where present, the east-west portion of the former bulkhead structure may impede, but does not prevent, groundwater flow toward the Log Pond.

Figure 4 also depicts the interpreted Fill Unit groundwater flow directions for low tide conditions measured in July 2004 within the Pulp/Tissue Mill portion of the Site (Aspect, 2004b). The data indicated that the highest water table elevations in this area occurred in a northwest-southeast trending divide across the parcel center, as indicated by diverging flow direction arrows on Figure 4. Most of the area is paved and the source of recharge to sustain this groundwater divide is uncertain, and warrants further investigation through site-wide water level monitoring. The Fill Unit may be receiving recharge from the uplands generally south of Cornwall Avenue; leaking water lines or sewer lines across the Site may also be a recharge source. The July 2004 water level data indicate that Fill Unit groundwater flows from this groundwater divide both northeast to Whatcom Waterway and southwest toward Cornwall Avenue. Groundwater flowing to the southwest may be moving toward subsurface utility corridors (permeable backfill) beneath Cornwall Avenue or the large topographic depression south of it. In either case, the Fill Unit groundwater ultimately makes its way into the marine waters of Whatcom Waterway or Bellingham Bay. The groundwater flow directions within the Fill Unit, including presence of absence of the groundwater divide, will be confirmed as part of the RI.

4.2.2 Tidal Flat Aquitard Unit

A native tidal flat deposit underlying the Fill Unit is comprised of roughly 15 feet of low permeability clayey silt and silty sand that acts as an aquitard impeding movement of groundwater between the overlying Fill Unit and the underlying Lower Sand Unit. Groundwater levels are typically 3 to 7 feet higher in the Fill Unit than in the Lower Sand, indicating the effectiveness of the Tidal Flat as an aquitard between the water-bearing units (ENSR, 1994a). Geotechnical laboratory testing of three samples of the aquitard material indicated a relatively low vertical hydraulic conductivity in the range of 2 to 4 x 10^{-6} cm/sec (ENSR, 1994a).

4.2.3 Lower Sand Unit

Underlying the Tidal Flat Aquitard is a marine sand unit, which was deposited on top of bedrock. The Lower Sand is thinnest to the south, adjacent to the bluff south of the Site, and thickens toward the north. ENSR (1994a) determined that groundwater in the Lower Sand flows generally north, toward the Log Pond and waterway. Groundwater levels in the Lower Sand are tidally influenced. Hydraulic conductivity testing performed by ENSR (1994a) estimated Lower Sand Unit hydraulic conductivities ranging within one order of magnitude (7 x 10^{-4} to 5 x 10^{-3} cm/sec), indicating more uniform lithology than the Fill Unit. Groundwater velocity in the Lower Sand was estimated at about 25 feet per year, more than twice the groundwater velocity estimated for the Fill Unit.

5 Preliminary Screening Levels

For the purposes of the Site RI/FS, analytical data from soil, groundwater, and air (soil vapor) will be compared to respective soil, water, and air quality criteria under MTCA (Chapter 173-340 WAC). In this section, preliminary screening levels are established for soil, groundwater, and air (soil vapor).

5.1 Soil

To address direct contact with soil, current and planned uses of the Site must be understood. The past and current use of the Site is industrial and meets the requirement of a “traditional industrial use” under the MTCA regulations (WAC 173-340-745). The Port’s future use of the Site could be industrial or another use (for example, mixed use), and the redevelopment planning is ongoing. Since the future land use has not yet been determined, the Site soil sample data in the RI/FS will be compared against MTCA soil screening levels for both unrestricted and industrial land uses, including:

- Unrestricted Land Uses: MTCA soil cleanup levels for unrestricted land use (the more stringent of Method A unrestricted soil cleanup levels and standard Method B direct contact soil cleanup levels) and, where applicable, MTCA ecological indicator soil concentrations for protection of wildlife; and

- Industrial Land Uses: MTCA soil cleanup levels for industrial land use (the more stringent of Method A industrial soil cleanup levels and standard Method C direct contact soil cleanup levels).

In addition to direct contact with soil, the soil screening level also needs to address soil leaching to groundwater and soil volatilization to air. For the principal Site contaminants of concern determined from the existing data, soil concentrations protective of direct contact and soil leaching are considered to be also protective of air quality.

Table 1 presents preliminary soil screening levels for the constituents of potential concern at the Site, based on the existing data summarized in Section 6. The listed soil screening levels for the soil-to-groundwater pathway are based on conservative default MTCA parameters, and do not factor in Site-specific information. However, as presented in Section 6, previous Site investigations included leaching test data that indicate mercury soil concentrations greater than 24 mg/kg are protective of Site groundwater. The appropriate mercury soil cleanup level will be further evaluated during the RI, using a weight of evidence approach integrating the Site-specific leaching test data and groundwater quality data in accordance with WAC 173-340-747.

5.2 Groundwater

Discharge to marine water, not drinking water, is proposed to be the highest beneficial use for Site groundwater. Groundwater in the Fill Unit is not a practicable source of potable water. This determination is based on the following three factors, in accordance with MTCA requirements (WAC 173-340-720[2]):

1. **The Fill Unit does not serve as a current source of drinking water.** The Site has been and is being supplied with potable water from City of Bellingham, and this will continue for future Site redevelopment. Whatcom County Health Department will not approve private wells if located within the water service area of an approved public water system, which is the case for the Site.
2. **Groundwater in the Fill Unit contains elevated concentrations of naturally occurring inorganic constituents.** The existing data document that Site groundwater in the Fill Unit is naturally of poor quality, with sodium, chloride, sulfate, manganese, and electric conductivity exceeding state drinking water standards. Despite sodium chloride brine being used in the Chlorine Plant historically, elevated sodium and chloride is attributable to natural groundwater quality within fill dredged from the marine environment (Aspect, 2004a).
3. **Contamination in Fill Unit groundwater will not be transported to an aquifer that is a potential drinking water source.** There are no drinking water wells downgradient of the Site, and the existing Site groundwater quality data demonstrate that the Lower Sand has not been adversely impacted by downward transport of dissolved mercury from the Fill Unit.

In addition to Whatcom County's prohibiting private water wells on the Site, it is highly unlikely that the state Department of Health (DOH) would permit a well in the Fill Unit as a public water supply source. The Fill Unit has limited saturated thickness (5 to 10 feet) and relatively low average permeability, so would not be a reliable source in terms of yield. Pumping a Fill Unit well in sufficient quantity to serve as a public supply source might create sufficient drawdown to induce intrusion of saline water from the waterway. Furthermore, given the shallow water table condition, we expect that DOH would designate the Fill Unit as groundwater under the influence of surface water (GWI), thus requiring highly expensive treatment (filtration) to meet federal surface water treatment requirements.

Based on the collective information, Site groundwater is not a practicable source of potable water, now or in the future, relative to continuing to obtain potable water supply from the City of Bellingham.

Protection of Surface Water

Considering the factors presented above, RI/FS groundwater quality data will be compared against groundwater screening levels based on protection of marine surface water, namely the more stringent of standard Method B surface water cleanup levels based on human consumption of fish, and state surface water quality standards for protection of aquatic organisms (marine chronic standards in WAC 173-201A-240).

Note that the marine aquatic life chronic criterion for mercury in surface water is 0.94 µg/L, based on the latest update of the National Toxics Rule (NTR), which has been incorporated into the state Surface Water Quality Standards (Chapter 173-201A WAC). As discussed in the NTR, compliance with mercury bioaccumulation criteria are based on separate tissue analyses. In the Whatcom Waterway area, all fish and shellfish tissue samples are below the EPA bioaccumulation criterion of 0.3 milligrams per kilogram (mg/kg) of mercury (wet weight; Anchor Environmental and Hart Crowser, 2000). The RI/FS will include a review of available information to assess whether the NTR chronic value is protective of surface water quality and sediment quality. The NTR chronic value is the basis for a preliminary Site groundwater screening level.

Currently, no state or federal ambient water quality criteria exist for formaldehyde, which has been detected in Site groundwater. Based on a comprehensive review of existing literature, a concentration of 1,600 µg/L formaldehyde is proposed as protective of aquatic life in marine water, and is thus the basis for the proposed formaldehyde groundwater screening level in the Site RI/FS (refer to Anchor Environmental, 2008b; included in Appendix A).

Detailed procedures have been developed by the U.S. Army Corps of Engineers (Corps), the U.S. Environmental Protection Agency (EPA), and others to evaluate groundwater/surface water/sediment interactions at and near the sediment mudline (e.g., Palermo et al., 1998). As part of the Engineering Design Report for the GP Log Pond cap (Anchor Environmental, 2000), several of the simpler fate and transport processes (i.e., chemical dissolution, groundwater transport, and hydrodynamic dispersion) included in the Corps/EPA models were incorporated into a conservative modeling-based evaluation. The Log Pond cap design evaluation thus provides information relevant to assessments of fate and transport of Fill Unit groundwater that may discharge into the Log Pond, Whatcom Waterway, and/or Bellingham Bay. Model input parameters and model results are summarized in the Engineering Design Report for the Log Pond Cleanup/Habitat Restoration (Anchor Environmental, 2000).

Based on the modeling, the maximum sediment porewater concentration that may be discharged into surface waters was predicted to be attenuated by at least a factor of 10, compared with adjacent groundwater concentrations located within tens of feet of the shoreline (Anchor Environmental, 2000). Post-construction monitoring data within the Log Pond area confirmed the model predictions (Anchor Environmental, 2001b). A similar attenuation factor was also reported at the nearby Central Waterfront site (RETEC, 2001; AECOM-Environment, 2009), further corroborating model results.

However, for the purposes of this Work Plan, the preliminary groundwater screening levels are established as the more stringent surface water criterion, with no attenuation factor. Table 1 presents the preliminary groundwater screening levels for the constituents of potential concern at the Site, based on the existing data summarized in Section 6. The RI will include data analysis, including integration of previous Site-specific modeling efforts as appropriate, to evaluate attenuation of groundwater contaminant concentrations prior to discharge to marine water.

5.3 Air (Soil Vapor)

The preliminary screening levels against which soil vapor sampling results will be compared are set at 10 times the corresponding MTCA standard Method B air cleanup levels. This is justified based on EPA's Subsurface Vapor Intrusion Guidance (EPA, 2002), which allows the use of a 10-fold (0.1) slab attenuation factor to conservatively estimate indoor air concentrations using soil vapor sampling results. For example, the screening level for mercury in soil vapor is therefore 1.4 µg/m^3 (10 times the 0.14 µg/m^3 standard Method B air cleanup level).

6 Previous Environmental Investigations and Independent Cleanup Actions

Starting in the early 1990s, GP conducted a series of site investigations and independent cleanup actions at the Property, the majority of which were conducted in the former Chlor-Alkali area. In 2004, a comprehensive environmental assessment of the Tissue Mill area was also conducted. In total, more than 580 soil samples and 130 groundwater samples have been collected from the Site for chemical analysis.

Section 6.1 provides a summary of the environmental investigations and independent cleanup actions conducted for the former Chlorine Plant and the former Pulp and Tissue Mill. Section 6.2 summarizes the current understanding of soil and groundwater contamination for each of those main areas of the Site. Table 2 is a matrix summarizing the specific characterization activities conducted in each of the prior Site environmental investigations. Figure 5 illustrates locations of the existing Site explorations, organized by previous investigation. The figure also depicts approximate locations of completed independent cleanup actions on the Site.

6.1 Previous Environmental Investigations and Cleanups

This section summarizes environmental data from previous Site investigations, including comparison of the data against preliminary screening levels described in Section 5 to define contaminants of concern and associated data gaps to be addressed in the RI.

The existing Site data demonstrate that mercury is a primary contaminant of concern at the Site. As described in Section 5.1, the most stringent mercury soil screening level (1 mg/kg) is based on soil leaching to groundwater, derived using conservative, non-Site-specific parameters. However, previous Site investigations included leaching test data (described below) that indicate soil mercury concentrations greater than 24 mg/kg are protective of Site groundwater. Therefore, for the purposes of this Work Plan, the existing Site mercury soil data summarized below is evaluated relative to 24 mg/kg to help focus data gaps analysis toward areas with higher mercury concentrations.

The appropriate mercury soil cleanup level will be further evaluated during the RI, using a weight of evidence approach integrating the Site-specific leaching test data and groundwater quality data in accordance with WAC 173-340-747.

6.1.1 Former Chlorine Plant

Whatcom Waterway Dredging (1974)

As described in Section 3.1.3, GP implemented a dredging project within the Whatcom Waterway in 1974, consistent with Ecology requirements. The project removed surface sediments from within the Whatcom Waterway by dredging, and placed the dredge materials within a portion of the former Log Pond in order to construct a land-based log handling facility.

Settling Basin Cleanup (1976-77)

As described in Section 3.1.2, GP removed accumulated solids from the wastewater settling basin in 1976 and chemically stabilized the solids using the Chemfix process. The treated materials were contained within an area of approximately 2 acres as shown on Figure 3. An Ecology Order from 1977 specifies maintenance requirements for the cover material over the Chemfix area.

Preliminary Site Assessment (Law Environmental, 1992)

Law Engineering conducted an assessment of mercury concentrations in soils and groundwater throughout the area surrounding the former Chlorine Plant. The site assessment included collection of 123 soil samples from 25 soil borings, 16 hand-augered borings, and 8 surface grab samples, as well as 16 groundwater samples from 8 monitoring wells – all for analysis of mercury.

The soil sampling locations included the following (Figure 5):

- 16 hand-augered borings (“HA-“ series) advanced generally to depths of 3.5 feet, with soil samples collected at depth intervals of 0 to 0.5 feet, 1.5 to 2.0 feet, and, at all but three locations, 3.0 to 3.5 feet. Fifteen of these borings (HA-1 through HA-15) were advanced near the southeast corner of the mercury cell building, and one (HA-16) was advanced beneath the two above-ground brine tanks northwest of the cell building.
- 25 hollow-stem-augered borings (“STB-“ series), 20 of which were in the immediate area of the Chlorine Plant and 5 of which (STB-1, -2, -3, -12, and -15) were within the 1974 dredge fill area north of the plant that was being used for log storage. Within these borings, generally two to four soil samples were collected to depths ranging from 9 to 16.5 feet.
- 8 hand-augered borings (BK-1 through BK-8) intended to document area background mercury soil concentrations. The borings were located across the entire Georgia Pacific West Site, and included sampling of the upper 0.5 feet of soil at each location.

The Law (1992) soil sampling documented elevated soil mercury concentrations within the Chlorine Plant area, specifically in three areas:

- North of the brine sludge tanks, the highest mercury concentration (33,000 mg/kg) was observed in a sample of saturated soil (below water table).
- Near the cell building’s southeast corner, mercury concentrations showed variable concentrations up to 4,000 mg/kg in surface soils, with consistent decreasing concentrations with depth in the upper 3.5 feet of soil.
- Beneath the elevated brine tanks, mercury concentrations up to 300 mg/kg were detected in the upper 2 feet of soil, with a 62 mg/kg concentration to a depth of 3.5 feet.

Eight of the borings were completed as groundwater monitoring wells in the Fill Unit. The monitoring well numbers corresponded to the soil boring numbers (e.g., STB-1/MW-1). The monitoring wells were sampled twice (May and July 1992) for total and dissolved (filtered) mercury, total suspended solids (TSS), and total dissolved solids (TDS) to assess the quality of the shallowest water-bearing unit. The dissolved mercury concentrations ranged from non-detect to 4 µg/L.

Laurel Street Pipe Rack Soil Assessment and Removal (Law/Crandall, 1993)

During the 1992 construction of above-ground utility pipelines between the cogeneration power plant and GP’s mill, the construction contractor encountered demolition debris within a footing excavation at the Laurel Street Pipe Rack, just west of the main facility gate. The debris was suspected as discarded from the Chlorine Plant. Soil containing the debris was stockpiled separately from other excavated soils, and construction was halted. Six samples were collected from stockpiled soil and analyzed for total mercury and leachable mercury by the toxicity characteristic leaching procedure (TCLP). Based on where the debris was observed, Law/Crandall collected 33 soil samples within two excavations (pipe rack and underground pipeline trench) for mercury, and conducted air quality monitoring for mercury to assess worker safety.

The six soil samples collected from the excavated soil stockpile had total mercury concentrations ranging from 16 to 100 mg/kg, but no detectable (<5 µg/L) leachable mercury by TCLP.

Four of the 16 soil samples collected within the pipe rack excavation had total mercury concentrations above 24 mg/kg (maximum of 14,000 mg/kg), all of which were in shallow soil along the western sidewall. Samples collected below the bottom of the 4- to 7-foot-deep excavation contained mercury concentrations up to 0.4 mg/kg. Of the 17 soil samples collected within the underground pipeline excavation, six samples clustered near the excavation’s northeast corner exceeded 24 mg/kg total mercury; the maximum detected concentration of 1,100 mg/kg was detected approximately 1 foot below the bottom of the 5-foot-deep excavation. Based on the available data, these concentrations remain in place and define a localized soil mercury “hot spot” adjacent to the Laurel Street Pipe Rack.

72 Catch Basin Investigation and Soil Removal Action (ENSR, 1993)

In preparation for GP’s construction of a mercury extraction and recovery system (“Remerc process”) for Chlorine Plant sludges, ENSR conducted detailed characterization of subsurface soil mercury concentrations near the 72 Catch Basin. The investigation included four hand-augered borings (B-1 through B-4) and twelve hollow-stem-augered borings (BT-I through BT-XII), all located within an approximately 30- by 40-foot area. The hollow-stem borings were advanced to the Tidal Flat Aquitard Unit (maximum depth of 16.5 feet). One additional surface soil sample was collected at the southeast corner of the cell building. A total of 44 soil samples were submitted for analysis of total mercury, and two soil samples with relatively high total mercury concentrations were submitted for analysis of leachable mercury by TCLP.

Subsurface soils at 10 of the 12 boring locations contained mercury concentrations above 24 mg/kg (maximum of 12,000 mg/kg at a depth of 7.5 to 9 feet in boring BT-XI). The surface soil sample at the cell building southeast corner contained 5,200 mg/kg mercury. None of the materials sampled designated as characteristic hazardous waste, since all TCLP mercury results were below 200 µg/L.

In April 1993, prior to construction of the Remerc facility, GP directed removal and off-site disposal of approximately 217 cubic yards of mercury-contaminated soils from the 72 Catch Basin area, and from along the east and south walls of the cell building (Figure 5). Following soil removal, detected residual soil mercury concentrations within the excavations ranged to 100 mg/kg within the 72 Catch Basin area, and up to 65 mg/kg adjacent to the cell building. Soil in the vicinity of the sample containing mercury at a concentration of 12,000 mg/kg was apparently not excavated.

Remedial Investigation (ENSR, 1994a)

Following the investigation and independent cleanup actions described above, GP conducted a remedial investigation for the former Chlorine Plant in accordance with

MTCA. The RI included considerable sampling and analysis and hydrogeologic data collection, as summarized in Table 2, and discussed below.

Scope of RI Data Collection

The RI included collection of the following data:

- Soil sampling from 38 soil borings conducted in two phases ("ESB-" and "EMW-" series). Thirty-five of these borings were completed to the approximate bottom of the Fill Unit (explorations with "S" as a suffix in exploration ID). Two of the borings (ESB-20S and ESB-31S) were completed within the footprint of the Chemfix Area. Three of the borings (EMW-28D, EMW-29D, EMW-30D) were advanced to depths of approximately 45 feet, penetrating through the Tidal Flat Aquitard into the Lower Sand.
- Laboratory analysis of selected subsurface soil samples from the borings for total mercury, TCLP mercury, mercury speciation (total, elemental, and organic [methyl] mercury), conventional parameters (total organic carbon [TOC], chloride, sulfide), and physical parameters (hydraulic conductivity, porosity, grain size, and bulk density). Two samples of the Chemfix material were analyzed for leachable mercury by TCLP, one of which was also analyzed using a modified TCLP analysis with Fill Unit groundwater as the leaching solution.
- Sampling the upper foot of soil beneath the mercury cell building floor, using five hand-augered borings advanced through holes cored in the concrete slab floor.
- Analysis of total mercury in 24 shallow soil samples collected from 12 locations (D1 through D9 and B1 through B3) along the stormwater runoff swale north of the BNSF railroad tracks. One sample was also collected from sediment accumulated in a concrete trench that the stormwater swale drains to.
- Installing and developing 23 of the site soil borings as groundwater monitoring wells ("EMW-" series). Twenty of the monitoring wells are screened within the Fill Unit (EMW-1S through EMW-20S), and three are screened within the Lower Sand (EMW-28D, EMW-29D, and EMW-30D).
- Conducting two rounds of groundwater sampling, in July and December 1993, in the site monitoring wells installed by ENSR and four wells previously installed by Law (1992). All groundwater samples were analyzed for dissolved mercury and field parameters (temperature, pH, specific electric conductance, dissolved oxygen, oxidation-reduction potential, and salinity). Selected samples were also analyzed for conventional water quality parameters (TDS, TOC, alkalinity, chloride, sulfate, sulfide, calcium, magnesium, manganese, potassium, and sodium) and mercury speciation (total, elemental, methyl, dimethyl, and acid labile mercury). A third round of groundwater sampling was conducted in February 1994 at the two wells (EMW-13S and EMW-19S) with highest detected dissolved mercury concentrations.

- Conducting four rounds of manual water level measurements in the site monitoring wells over a range of tide stages (August 26, August 31, and December 13, 1993, and February 18, 1994).
- Conducting 72-hour tidal studies using continuous-reading data loggers in Fill Unit monitoring wells EMW-1S, -3S, -4S, -5S, -7S, -9S, -10S, -13S, and Law-1, Lower Sand monitoring wells EMW-28D and -30D, and in the Log Pond. The tidal study measurements were made in three separate groups of wells. Wells EMW-5S, -7S, -10S, -28D, and -30D were monitored August 23-26, 1993, Wells Law-1, EMW-1S and -3S were monitored August 31-September 3, 1993. Wells EMW-4S, -9S, and -13S were monitored September 3-7, 1993.
- Conducting hydraulic conductivity testing (slug testing) of 17 Fill Unit monitoring wells, and the three Lower Sand monitoring wells. In addition, the vertical hydraulic conductivity of the Tidal Flat Aquitard Unit was measured using laboratory permeameter testing of three samples of the material.

RI Results

SOIL MERCURY DATA

Based on the findings of the previous investigations and the RI data collection, ENSR (1994a) identified nine areas with soil mercury concentrations above 24 mg/kg:

1. Along the south and east walls of the mercury cell building (up to 65 mg/kg).
2. The 72 Catch Basin area (up to 12,000 mg/kg).
3. Beneath the brine tanks northwest of the cell building (up to 300 mg/kg).
4. The former wastewater settling basin north of the cell building (up to 200 mg/kg).
5. At monitoring well Law-5, just east of the former settling basin (up to 39 mg/kg).
6. At soil boring STB-18, immediately southeast of the cell building (up to 85 mg/kg).
7. The stormwater runoff swale located between the cell building and the BNSF railroad (up to 530 mg/kg).
8. The Laurel Street pipe rack (up to 14,000 mg/kg).
9. The Chemfix area (up to 5,800 mg/kg).

Relatively low mercury concentrations were detected in the five soil samples collected beneath the cell building floor slab (2.5 to 12 mg/kg). Figures 6 and 7 show the distribution of mercury concentrations detected in samples of unsaturated soil (above water table) and saturated soil (below water table), respectively; note that the figures include samples collected subsequent to the 1994 RI. On Figures 6 and 7, soil mercury concentrations above and below 24 mg/kg are color coded differently.

LEACHABLE SOIL MERCURY (TCLP TESTING)

Concentrations of leachable soil mercury determined from the TCLP testing of samples collected during the RI ranged from non-detect (<0.2 µg/L) to 27 µg/L in soil samples with total mercury concentrations up to 200 mg/kg. Two samples of Chemfix material with total mercury concentrations of 2,500 and 5,800 mg/kg had TCLP leachable mercury concentrations of 5.6 and 30 µg/L, respectively. In addition, four soil samples collected from the 72 Catch Basin and cell building areas prior to the ENSR (1993) soil cleanup had TCLP mercury ranging from non-detect (<0.2 µg/L) to 62 µg/L in soil samples with total mercury concentrations up to 12,000 mg/kg.

Note that TCLP is a highly aggressive leaching procedure, designed to simulate acidic, corrosive conditions in a municipal landfill, and the test likely overstates metals leachability relative to leachability associated with ambient precipitation or groundwater at the site. Therefore, ENSR (1994a) also evaluated the Chemfix leachability using a modified TCLP leaching test that used Fill Unit groundwater from the site (from monitoring well EMW-1S) as the leaching solution instead of the standard TCLP solution. Using this modified test, the Chemfix sample with 2,500 mg/kg total mercury had leachable mercury detected at 3.2 µg/L, roughly half that from the standard TCLP test. The leachable mercury concentrations from the leaching tests represent aqueous concentrations at the leachate release point within the mercury source material; resulting dissolved mercury concentrations in groundwater downgradient would be lower because of dilution and attenuation processes.

Table 3 presents TCLP leaching test data from ENSR (1994a), as well as TCLP data for other soil samples from the GP (1998) independent soil cleanup described below. Preliminary statistical regression analysis of the TCLP data suggests that, on average, a soil mercury concentration at or above 70 mg/kg would produce a TCLP leachate concentration of 0.94 µg/L – i.e., 70 mg/kg mercury in soil should be protective of Site groundwater quality. As part of the RI, the collective leaching test data will be evaluated together with other Site data to develop a weight of evidence determination of Site-specific soil mercury concentrations protective of groundwater, in accordance with MTCA (WAC 173-340-747).

GROUNDWATER MERCURY DATA

Figure 8 presents the dissolved mercury data, with corresponding groundwater pH measurements, to date for Site monitoring wells (including data collected after the 1994 RI). During two rounds of RI groundwater sampling and analysis, eight of 24 Fill Unit monitoring wells sampled had detectable concentrations (above 0.2 µg/L) of dissolved mercury. Detectable mercury in Fill Unit groundwater occurred in proximity to the Chlorine Plant and former wastewater settling basin north of it, with concentrations ranging from 0.22 µg/L at EMW-2S to 460 µg/L at EMW-19S, and immediately downgradient of the Laurel Street Pipe Rack (21 to 180 µg/L at EMW-13S). Dissolved mercury was not detected in any of the three Lower Sand monitoring wells.

The groundwater sampling also documented relatively low dissolved oxygen (DO) and oxidation-reduction potential (ORP) in most locations. In Fill Unit monitoring wells, the measured DO was below 3 milligrams per liter (mg/L) except during one of two sampling events at EMW-9S and EMW-10S, and both sampling events at EMW-11S (all located on the north side of the log/chip storage area), and in one of two sampling rounds at

EMW-2S (northwest of the cell building). Measured ORP generally corresponds to the DO in relative terms, with positive values (more oxidizing) measured in wells EMW-9S, EMW-10S, and EMW-11S (26 to 244 millivolts [mv]), and negative values (more reducing) measured in most other wells (-7 to -300 mv), although there was variability. Measured salinity values typically ranged from 200 to 32,000 mg/L in Fill Unit wells, but were up to 274,000 mg/L at EMW-3S. In the three Lower Sand monitoring wells, measured DO ranged between 1.4 and 3.7 mg/L, and salinity ranged from 900 to 6,700 mg/L.

STORMWATER MERCURY DATA

Because stormwater runoff from the Chlorine Plant is a potential pathway for transport of mercury into the Log Pond or Bellingham Bay, the RI evaluated runoff volume and mercury concentrations in runoff to estimate annual mass loading to the Log Pond. Three drainage basins were defined for the Chlor-Alkali area: (1) the chip and log storage area; (2) the area south of the chip storage area to the BNSF railroad, between the Chlorine Plant and Million Gallon Tanks; and (3) the Chlorine Plant area.

At that time, runoff from basin 1 flowed to a local depression, where it infiltrated and then flowed subsurface to the Log Pond. Runoff from basin 2 flowed to the stormwater swale immediately north of the BNSF railroad, from where a pump station conveyed it to the ASB north of the waterway for treatment and discharge through GP's NPDES-permitted outfall. Runoff from basin 3 was collected and treated in the Chlorine Plant wastewater treatment system and then conveyed to the ASB and NPDES-permitted outfall.

Samples of stormwater from drainage basins 1 and 2 were collected, with detected dissolved mercury concentrations of 1.9 and 12 µg/L, respectively. A sample from basin 3 was not collected. Based on these measurements, estimated discharge of mercury via runoff from basins 1 and 2 was estimated at 0.12 and 0.34 pounds per year, respectively.

In 1995, GP built a stormwater sump in the log/chip storage area to collect stormwater runoff from the area (basin 1) and convey it to the ASB. An asphalt berm was also built around the chip pad to direct stormwater flow from this area away from the Log Pond and to the new sump.

MERCURY SPECIATION ANALYSES

Mercury speciation testing was conducted on five samples of Site soil from the Fill Unit, Tidal Flat Aquitard, and Lower Sand, and four samples of Site groundwater from the Fill Unit. The speciation testing for soil included total mercury, elemental mercury, and methyl mercury; for groundwater samples, analysis for dimethyl mercury and acid labile(1) mercury were added. The analytical results from the mercury speciation testing are presented in Table 4.

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[1] Acid labile mercury: "Easily reducible," includes inorganic complexes, labile organic associations, elemental mercury, and labile particulate mercury; doesn't include methylmercury and dimethylmercury. Labile = amenable to change.

The RI mercury speciation analyses documented that mercury in soil and groundwater is nearly completely in the divalent form (as mercury sulfide or mercury chloride), with elemental and organic (methyl and dimethyl) forms of mercury comprising less than 1 percent of the total mercury mass.

The finding that mercury at the Site is predominantly in the inorganic divalent form has been verified in subsequent speciation testing conducted for the RI Addendum; however, mercury can occur in the elemental form within the highly alkaline core of the caustic plume (Anchor Environmental, 2003b), as described below.

Feasibility Study (ENSR, 1994b)

Following completion of the RI, ENSR prepared a feasibility study (FS) to evaluate remedial alternatives for mercury-impacted soil, groundwater, and stormwater at the Chlor-Alkali site (ENSR, 1994b). The FS delineated four operable units at the site, and, for each, evaluated a range of remedial alternatives relative to MTCA cleanup criteria. Technologies included in the remedial alternatives included:

- Enhanced inspection and recordkeeping program to address potential releases of waste material from the Chlorine Plant;
- Soil excavation with off-site disposal;
- Soil capping;
- Groundwater extraction and treatment using GP’s existing on-site treatment systems;
- Groundwater monitoring; and
- Site grading and construction of new stormwater collection and conveyance system to control stormwater drainage.

Additional Independent Remedial Actions at Site

Following the initial RI Report (ENSR 1994a), GP independently conducted remedial actions and associated performance monitoring within the Chlor-Alkali area. The approximate locations of these remedial action areas are depicted on Figure 5. A brief description of these independent remedial actions is presented below.

Chlor-Alkali Facility Spill Independent Remedial Action (GP, 1998)

Following a 1997 spill of waste materials at the site, GP performed an independent remedial action that resulted in the removal and off-site disposal of materials containing elevated mercury concentrations. A total of 957 tons of mercury-impacted soil were excavated to depths of up to 18 inches, and properly disposed of off-site. Eight post-excavation verification soil samples indicate residual total mercury concentrations ranging from 1 to 119 mg/kg, and leachable (TCLP) mercury concentrations at or below 0.5 µg/L.

Independent Remedial Actions during Infrastructure Improvements (1999 to 2002)

Over the period from 1999 through 2002, GP performed various infrastructure improvements to the former Chlorine Plant that included infrastructure decommissioning and demolition, and soil excavation and off-site disposal. The larger excavation areas are shown in different colors on Figure 5. The infrastructure excavations included the following:

1. **Fire Main and Parking Lot Excavations (1999).** The fire main (FM) excavation was required for emergency repair of a failed fire main on the east side of the former Chlorine Plant cell building wall. The parking lot (PL) excavation, south of the Chlorine Plant, was required for the installation of a fiber optic cable in the former Plant parking lot.
2. **Beer Well Excavation (December 1999).** This excavation for the installation of a large beer well is shown in light blue near the Laurel Street Pipe Rack. Five soil samples were collected from the excavation, and composited for TCLP mercury analysis. TCLP-leachable mercury was not detected (< 1 µg/L) in the composite sample. The soil samples were not analyzed for total mercury.
3. **Post-Demolition Chlorine Plant Sewer Installation (December 2000).** The excavation for the new sewer extended down the old roadway north and west of the former Chlorine Plant cell building, the approximate area of which is shown in blue. The excavation soils were sampled at five different locations and tested for both total and TCLP mercury. The highest total mercury detected was 120 mg/kg, though its location from within the excavation is not certain. The majority of the soil came from the excavation along the west side of the cell building.
4. **Gas Turbine Foundation and Gas Pipeline Excavations (June 2001).** The approximate location of the excavation for the gas turbine foundation is shown in purple near the center of the site. The gas pipeline trench excavation is shown in light brown south of the gas turbine foundation excavation.
5. **Gas Line Feed (GLF) Excavation (June 2001).** This portion of the gas pipeline trench is shown in yellow near the intersection of Laurel Street and Cornwall Avenue.

Mercury Cell Building Decommissioning

In accordance with Agreed Order DE TC99 I035, GP conducted decommissioning and demolition of mercury process materials, equipment, and debris from the mercury cell building in 2000. A demolition plan was developed (Foster Wheeler, 2000a), and was approved by Ecology prior to demolition activities. Numerous samples of materials within the cell building were initially analyzed for toxicity characteristic leaching procedure (TCLP) mercury to designate the materials for appropriate disposal. Based on the data, stack wood and concrete columns/pillars in the building designated as characteristic dangerous waste, and those materials were managed as such during demolition (Foster Wheeler, 2000b).

The majority of building materials were removed during the 2000 demolition; however, the building foundation, framing, and internal support remain in place. To support the Port's planning for future demolition of the remaining cell building, sampling and mercury analysis of the remaining structural materials was conducted in 2007. The supplemental sampling and analysis confirms that the mercury cell building is a residual source of mercury on the Site, with total mercury concentrations up to 358 mg/kg and

TCLP mercury concentrations above the characteristic dangerous waste criterion in the building walls and selected other materials (Anchor Environmental, 2008a).

Supplemental Groundwater Sampling and Analysis, 2000 and 2001

To update the baseline groundwater quality characterization supporting design of the Log Pond cap, Anchor Environmental sampled nearshore monitoring wells adjacent to the Log Pond (Law-1, EMW-8S, and EMW-9S) in April 2000 (Anchor Environmental, 2000). In addition, two temporary shallow wellpoints were installed within the intertidal zone of the Log Pond, to better characterize groundwater mercury concentrations discharging to the mudline. Dissolved mercury concentrations in the monitoring wells were lower than those measured in 1993 during the ENSR (1994a) RI. One of two wellpoints had detectable dissolved mercury concentration of 0.080 µg/L.

Anchor also completed an additional round of groundwater sampling at ten site monitoring wells in April 2001, in accordance with the original supplemental RI/FS Work Plan for the Chlor-Alkali site (Anchor Environmental, 2001a). Wells sampled were AMW-1, AMW-2, AMW-3, EMW-1S, EMW-2S, EMW-3SR (replacement for EMW-3S), EMW-13S, EMW-14S, EMW-15S, and EMW-19S.

RI Addendum (Anchor Environmental, 2003b)

Under the terms of Agreed Order DE 02 TCPIS-472, Anchor Environmental conducted supplemental RI sampling and analysis as an addendum to the 1994 RI. The supplemental sampling and analysis was conducted in accordance with a Sampling and Analysis Plan Addendum (Anchor Environmental, 2003a) approved by Ecology. The RI Addendum accomplished the following at the Chlor-Alkali site:

- Completed characterization of the extent of mercury soil contamination, focused on previously inaccessible or unexplored areas;
- Characterized speciation of mercury in soil and soil gas (vapor) in areas of elevated soil mercury concentrations, focusing on the Chemfix Area; and
- Determined the leachability of mercury in the Chemfix materials under different acid/base conditions.

The RI Addendum included soil sampling and soil vapor sampling at 18 soil boring locations (AS-1 through AS-18; Figure 5). The soil borings were advanced to depths of 10 feet or refusal (6 feet at AS-3) using a Geoprobe direct push drilling rig. The continuous core was divided into 2.5-foot segments, each of which was sampled for total mercury analysis (39 samples total).

Within a few feet of each soil boring, Frontier Geosciences, under subcontract to Anchor, conducted sampling and analysis of mercury in soil vapor, including speciation analysis for total, elemental, and organic (dimethyl) mercury. They advanced a soil gas probe to a depth of 1.5 feet, and connected the probe via new Teflon tubing to a Jerome 431-X meter for direct reading analysis of mercury in soil vapor. At soil borings AS-3 and AS-7, and Chemfix Area borings AS-12 through AS-15, soil vapor testing for mercury was also conducted using a Lumex RA915+ mercury vapor analyzer capable of measuring low-level elemental mercury, as well as using a sorbent trap to allow for analysis of total mercury. After completion of the Lumex and sorbent trap sampling, a Draeger hand pump and Carbotraps were used to collect soil gas for analysis of dimethyl mercury.

In addition, soil vapor was sampled using the Lumex at a background location near Chuckanut Bay, an area identified as having no known development or mercury releases and which had previously been used as a background sampling location for the Whatcom Waterway site. Total mercury, elemental mercury, and dimethyl mercury were not detected in soil vapor from the background location.

The Jerome meter readings were not consistent with the more reliable Lumex and sorbent trap mercury data collected at the same time. This was concluded to be a result of matrix interferences with the meter, some of which include chlorine, nitrogen dioxide, hydrogen sulfide, and organic sulfur compounds. The Jerome readings were considered not reliable, and were rejected in favor of the Lumex and sorbent trap data.

The soil and soil vapor data are described below for areas outside the Chemfix Area and for the Chemfix material.

Sampling and Analysis Outside of Chemfix Area

Fourteen of the 18 soil borings (AS-1 through -11, and AS-16 through -18) were completed in areas of the site outside the Chemfix Area (Figure 5). Total mercury concentrations exceeding 24 mg/kg were detected in one or more soil samples from three of these borings: AS-2 just west of the mercury cell building, AS-3 near the 72 Catch Basin area, and AS-10 within the Laurel Street Pipe Rack area. Two soil samples with elevated total mercury concentrations (5- to 6-foot sample from AS-3, and 0- to 2.5-foot sample from AS-10) were submitted for analysis of methyl mercury to further document speciation of the total mercury. Consistent with the ENSR (1994a) data, methyl mercury comprised a very small fraction (less than 0.1 percent) of the total mercury in soil (Table 4).

Total mercury detected in soil vapor from the AS-3 location was approximately 720 $\mu g/m^3$, well above the 1.4 $\mu g/m^3$ air screening level. The speciation analyses documented that mercury in soil vapor is predominantly elemental mercury, which is its volatile form. The elevated concentration of mercury in soil vapor at AS-3 is attributed to its location within the caustic plume, where elemental mercury is inferred to occur under very high pH conditions.

Chemfix Area Sampling and Analysis

Four of the 18 soil borings (AS-12, -13, -14, and -15) were completed within the footprint of the Chemfix Area. In accordance with the Sampling and Analysis Plan for the project, a composite sample of the Chemfix was collected from the four locations and submitted for chemical analysis of total mercury, and for mercury leachability analysis using the sequential batch leaching test (SBLT) under variable pH conditions. Collection of continuous cores from four locations provided a more representative sample of the Chemfix material than available from the previous sampling efforts. The average soil mercury concentration in the four-location composite sample of Chemfix material, collected at depths of approximately 1 to 5 feet below grade, was approximately 10 mg/kg.

Mercury in vapor associated with the Chemfix material was analyzed at the four borings AS-12, -13, -14, and -15, drawing vapors from the Chemfix material below the geotextile liner. Total and elemental mercury vapor concentrations at the four locations were below the 1.4 µg/m^3 screening level, with detectable concentrations only at AS-13 (0.721 µg/m^3 elemental; 0.779 µg/m^3 total).

The Chemfix composite sample was submitted for leachability testing using the sequential batch leaching test (SBLT) methods developed by the Army Corps of Engineers (Myers et al, 1996), and run at four different pHs: 3, 7, 9, and 12. To best represent site-specific leachability, Site groundwater was used as the leaching solution for three of the tests. Groundwater with pH approximately 12 was obtained from monitoring well AMW-3. Based on discussion with Ecology, the leaching solution for the two intermediate pH values was obtained from monitoring well EMW-1S, with measured pH 7.2; an additional volume of water was collected and adjusted by the laboratory to pH 9 prior to testing. A laboratory-prepared leaching solution at pH 3 was used to simulate leaching under an aggressive acidic leaching environment. Mercury concentrations in the leaching solutions were measured to differentiate mercury contributions from the leaching solution from that leached from the Chemfix. The four different pH tests were run for four days, with effluent samples collected each day for analysis of total and elemental mercury.

The Chemfix SBLT results, corrected for measured mercury concentrations in the leaching solutions, are presented in Table 5. Based on the average leachable concentrations over the 4-day SBLT testing, mercury leaches from the Chemfix material at highest concentrations using pH 12 leachant (average of 164 µg/L). The effluent from the pH 9 SBLT had an average leachable mercury concentration of about 1.5 µg/L over the four days of leaching, with the highest observed concentration on the fourth day. The effluent from the pH 6-7 SBLT, approximating typical site groundwater pH outside the caustic plume area, had an average leachable mercury of essentially zero (negative when corrected for influent concentrations), but it was observed to increase slightly to 0.2 µg/L over the four days. At pH 3, the leachable mercury concentrations decreased over the four days of testing, with an average leachable mercury concentration of 0.1 µg/L. Elemental mercury comprised less than 0.1 percent of the total leachable mercury. The greater mercury leachability observed at pH 12 is consistent with higher dissolved mercury concentrations associated with higher groundwater pH in the Caustic Plume portion of the Site, as described in Section 6.2.1.

Ecology Review of RI Addendum (Ecology, 2004)

Ecology reviewed the RI Addendum and provided the following comments (Ecology, 2004):

- Elevated mercury concentrations persist in site soil, but no new areas of mercury contamination were found.
- The mercury concentration in soil vapor exceeds the MTCA air cleanup level at one soil boring located within the core of the caustic plume.
- The Chemfix material does not show an affinity to leach mercury under normal pH conditions.

- Characterization of the mercury/caustic groundwater plume remains incomplete along the southwest boundary of the site, and it was likely that the plume continues off of GP's property. Therefore, further characterization of the mercury plume off site is required.
- Once characterization of the caustic plume along the southwestern site boundary is complete, the development of cleanup levels in the Feasibility Study should take into account the ecological receptors found in the Log Pond adjacent to the site. The Feasibility Study must look at all possible cleanup scenarios, including both destructive treatment technologies as well as removal technologies (WAC 173-340-200 and -350).

Draft Feasibility Study (Aspect, 2004a)

Under the terms of Agreed Order DE 02 TCPIS-472, an updated FS was prepared, incorporating the results from GP's independent cleanup actions and additional site characterization activities completed since the 1994 FS (Aspect, 2004a).

Additional Groundwater Characterization

As part of the FS, additional characterization was conducted for the mercury/caustic plume along the southwestern portion of the site, as required by Ecology in their review of the RI Addendum (Ecology, 2004). Specifically, the groundwater characterization addressed the following objectives:

- Complete characterization of the extent of elevated groundwater pH conditions within the shallow groundwater zone along the western boundary of the site;
- Collect groundwater samples at or beyond the edge of the high pH groundwater zone to complete characterization of dissolved mercury concentrations within this area of the site; and
- Collect soil samples at or beyond the edge of the high pH groundwater zone to complete characterization of soil total mercury concentrations within this area of the site.

In May 2004, sampling was conducted along four equally spaced transects ("ATW" explorations on Figure 5) radiating generally southwest from boring AS-2, located near the former caustic filter house. Exploration locations were marked in three concentric arcs at approximately 150-foot spacings, beginning 150 feet from boring AS-2 (i.e., arcs approximately 150, 300, 450, and 600 feet southwest of it, labeled A, B, C, and D, respectively). Locations along the 150-foot arc were assumed to likely be within the zone of impacted groundwater, therefore the borings began along arc B, 300 feet downgradient from AS-2. At each location, a sample of saturated soil was collected and a grab groundwater sample was collected from a temporary well screen.

Using sampling criteria outlined in the Sampling and Analysis Plan prepared for the field effort (Anchor Environmental, 2004), the extent of mercury concentrations above the 0.94 µg/L preliminary screening level in groundwater was delineated along three of four transects. However, it was not bounded along transect 2, where 2.9 µg/L dissolved mercury was detected at temporary well ATW-C2 despite having only slightly alkaline ph (7.7). Total mercury concentrations in samples of saturated soil collected during this groundwater characterization were below 0.1 mg/kg, indicating that the saturated portion of the Fill Unit matrix in the area tested does not contain elevated mercury concentrations. Therefore, the dissolved mercury detected at these locations is a result of advective transport in groundwater. The additional delineation of the caustic plume from the field effort was incorporated into the evaluation of remedial alternatives.

Remedial Technologies Evaluated

The 2004 FS evaluated remedial alternatives assuming continued industrial use of the Site (thus industrial soil cleanup levels), and was intended to provide sufficient analysis to enable Ecology to select a cleanup action alternative that is protective of human health and the environment for that site use. The FS identified three areas (Areas 1, 2, 3) requiring cleanup of mercury-impacted media to achieve protectiveness for a future industrial site use. Area 1 is the area of elevated mercury and pH in soil and groundwater at and downgradient of the former Chlorine Plant (Caustic Plume). Area 2 is mercury-containing subsurface soils within the Laurel Street Pipe Rack area. Area 3 is mercury-containing surface soils within the Stormwater Swale that runs along the BNSF railroad tracks on the south side of the Site.

The FS evaluated the following remedial technologies for mercury-impacted soil and groundwater:

- Soil excavation and off-site disposal;
- Soil treatment using the Remerc process;
- Soil stabilization using the Chemfix process;
- Soil capping;
- Groundwater extraction and treatment;
- Groundwater containment using sheet pile walls;
- In situ neutralization/stabilization;
- Groundwater treatment using permeable reactive barrier; and
- Electrochemical remediation.

6.1.2 Former Pulp and Tissue Mill Area

Phase 2 Environmental Site Assessment (Aspect, 2004)

In 2004, Aspect completed a Phase 2 environmental site assessment (ESA), to support transfer of the property to the Port of Bellingham. The site assessment focused on the former Pulp and Tissue Mill portion of the site, and included completion of 7 surface soil samples, 55 soil borings, and 14 monitoring wells, chemical analysis of soil and groundwater samples from the explorations, and inspection of indoor electrical transformers, for that area.

In the Phase 2 ESA, soil and/or groundwater characterization was conducted in the following operational areas of the former Mill, which are labeled on Figure 3 (the exploration ID prefix used for each area is included in parentheses):

- Alcohol Plant (AP-);
- Bunker C Tank (BC-);
- Bag House (BH-);
- Chip Dump/Cambio Area (CD-);
- Cornwall Warehouse (CW-);
- Electrical Transformers (ET-);
- Fuel House (FH-);
- General Fill/Sewer Lines across the parcel (GF-);
- Lab Building (LB-);
- Lignin Plant (LP-);
- Lignin Warehouse (LW-);
- Million Gallon Tanks (MG-);
- Sodium Bichromate Tank and Chromium Pipeline (SC-); and
- Truck Shop/Oil Storage (TS-).

In the assessment, soil sampling and analysis was targeted to constituents of potential concern associated with each of the primary identified operational areas. Where groundwater sampling was conducted, the groundwater sample analyses generally included a more comprehensive suite of constituents including gasoline-, diesel-, and oil-range total petroleum hydrocarbons (TPH), 11 dissolved metals (arsenic, cadmium, hexavalent chromium, total chromium, copper, iron, lead, manganese, mercury, nickel, zinc), volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs) including polynuclear aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), formaldehyde, alcohols, and conventionals (nitrate, nitrite, sulfate, total suspended solids [TSS]), and field parameters including electrical conductance, dissolved oxygen [DO], oxidation/reduction potential (ORP), temperature, and turbidity. Trivalent chromium (chromium III) concentrations were calculated by subtracting hexavalent chromium (chromium VI) values from the reported total chromium results.

The existing soil and groundwater quality data are summarized below by defined operational area of the former Mill (listed in alphabetical order). For reference throughout the area-specific discussions, Figures 9 presents TPH and carcinogenic polynuclear aromatic hydrocarbons (cPAHs) soil concentrations and highlights those exceeding soil screening levels. Figure 10 presents detected Site groundwater concentrations that exceed preliminary groundwater screening levels, based on the most recent groundwater data from across the Site. On Figure 10, higher concentrations – those exceeding five times the preliminary screening level – are color coded to help illustrate higher concentration areas.

Alcohol Plant Area

SOIL QUALITY DATA

Two soil borings (AP-MW01 and -SB01) were installed and sampled next to the alcohol storage area located west of the plant. Four soil samples were analyzed for VOCs, alcohols, and total metals.

None of the four soil samples contained contaminant concentrations in exceedance of the MTCA unrestricted or industrial screening levels. Low concentrations of several VOCs were detected in sample AP-MW01-3 (including acetone, carbon disulfide, and methylene chloride) but no alcohol compounds were detected. The detected VOCs are common laboratory contaminants and may not actually be present in the sample.

GROUNDWATER QUALITY DATA

Monitoring well AP-MW01 was installed next to the Alcohol Plant. Based on the groundwater flow directions interpreted from August 2004 water level measurements, existing well EMW-13S is also located approximately 200 feet downgradient of the Alcohol Plant (Figure 4).

No constituents were detected in the groundwater sample from monitoring well AP-MW01 at concentrations above preliminary groundwater screening levels.

Bag House Area

SOIL QUALITY DATA

Two borings (BH-SB01 and -SB02) were installed along the eastern and western sides of the Bag House to assess potential impacts associated with the emission and handling of boiler ash. Four soil samples plus one duplicate were analyzed for total metals and dioxins/furans. Selected samples were also analyzed for TPH, benzene, toluene, ethylbenzene, and xylenes (BTEX), PAHs, and PCBs.

Both soil samples tested for dioxins and furans from boring BH-SB02 located east of the Bag House exceed the MTCA unrestricted soil screening level of 11 picograms per gram (pg/g), or 1.1 x 10^{-5} mg/kg, which is calculated as the total toxic equivalent concentration (TEC) of 2,3,7,8-TCDD in accordance with WAC 173-340-708[8][d][iii]. All detected concentrations were below the MTCA industrial soil screening level of 1,500 pg/g, or 1.5 x 10^{-3} mg/kg.

Sample BH-SB02-1, which was collected at a depth of 0 to 4 feet, contained a 2,3,7,8-TCDD (TEC) concentration of 22 pg/g and contained primarily the less toxic octa-chlorinated dioxin congener (OCDD). Higher concentrations of dioxins and furans were observed in the field duplicate samples submitted from the 4- to 8-foot depth interval (720 and 1,130 pg/g 2,3,7,8-TCDD (TEC) in duplicate samples). Both of these samples consisted primarily of tetra-, penta-, and hexa- chlorinated dioxin congeners. Soil sampled in this depth interval was described as a dark brown to black, silty, gravelly sand with plastic debris. Given the difference in relative distributions of dioxin and furan congeners observed in the two BH-SB02 sampling intervals, it appears that they may be derived from different sources.

Total 2,3,7,8-TCDD (TEC) concentrations in the two soil samples analyzed in boring BH-SB01, located west of the Bag House, were relatively low (less than 2 pg/g) and did not exceed the unrestricted soil screening level.

Elevated concentrations of TPH were also observed in boring BH-SB02 (Figure 9). Diesel- and oil-range hydrocarbons were detected at concentrations of 1,890 to 2,120 mg/kg in the 4- to 8-foot depth interval. Bunker C-like hydrocarbon distributions were observed in soil samples collected within the 8- to 12-foot (6,942 mg/kg TPH) and 12- to 16-foot (1,466 mg/kg TPH). It is possible that the hydrocarbons observed within these deeper depth intervals are derived from the former Bunker C storage tank located approximately 50 feet to the southeast of boring BH-SB02.

No groundwater quality data were collected specific to the Bag House area.

Bunker C Tank–Clarifier Area

SOIL QUALITY DATA

Three soil borings (BC-MW01, -SB01, and -SB02) were installed to evaluate potential releases of Bunker C fuel oil from a historical unlined tank. Eight soil samples were analyzed for TPH and six samples were tested for total metals. Three soil samples were also analyzed for PAHs and PCBs.

TPH as Bunker C residual was encountered in all 3 borings at concentrations ranging up to 97,000 mg/kg. Shallow soils in the former footprint of the tank contained high levels of Bunker C indicating that the tank likely leaked. The Bunker C fuel oil appears to have migrated down to the water table (approximately 8 feet below ground surface at the time of drilling) and spread laterally. It appears that the Bunker C plume spread to the northwest towards boring BH-SB02 and possibly to the boring GF-SB20 location located approximately 200 feet to the northeast of the former tank location (Figure 9).

In addition to containing TPH concentrations above Method A unrestricted and industrial soil screening levels (based on groundwater protection), the concentration of total cPAHs exceeded the MTCA unrestricted screening level of 0.1 mg/kg in samples BC-MW01-5 (0.20 mg/kg) and BC-SB02-3 (0.62 mg/kg). Total cPAH concentrations were calculated using toxicity equivalent factors (TEF) in accordance with WAC 173-340-708(8)(e). Total naphthalenes, which is defined as the sum of naphthalene, 1-methylnaphthalene, and 2-methylnaphthalene, also exceeded the Method A unrestricted and industrial soil screening level (5 mg/kg based on protection of drinking water) in sample BC-SB01-2 (5.7 mg/kg) and BC-SB02-3 (34.4 mg/kg). Both cPAHs and naphthalenes are commonly associated with Bunker C along with other petroleum and pyrogenic products.

No metals exceedances of unrestricted or industrial screening levels were encountered in soil samples tested from this area.

GROUNDWATER QUALITY DATA

Bunker C residual was observed during drilling of monitoring well BC-MW01 on the downgradient edge of the former Bunker C tank location (adjacent the Whatcom Waterway). An accumulation (several inches) of Bunker C product was observed in the completed monitoring well during the August 2004 sampling. In limited observations at that time, petroleum sheen was not observed on the waterway adjacent to this area. The presence of product prevented development of this well; therefore, the groundwater sample collected was highly turbid (TSS of 6,580 mg/L).

As expected, elevated TPH quantified as Bunker C (6,700 µg/L) was detected in the groundwater sample from BC-MW01. No VOCs, PCBs, or SVOCs other than PAHs were detected. Low concentrations of PAHs were detected – individual noncarcinogenic PAHs (ncPAHs) up to 1.7 µg/L and individual cPAHs up to 0.49 µg/L. The calculated total cPAH concentration, applying toxicity equivalency factors (TEFs) in accordance with MTCA (WAC 173-340-708[8][e]), is 0.16 µg/L, which is marginally above the preliminary groundwater screening level (0.15 µg/L). Because cPAHs have very low solubility, the detections are likely biased high by the elevated sample turbidity.

The conventionals data demonstrate reducing groundwater conditions at this location (0.8 mg/L DO, redox potential of -125 millivolts [mv], and detectable nitrite). Despite the reducing conditions, detected dissolved metals concentrations were below respective preliminary groundwater screening levels. The analytical reporting limit for hexavalent chromium (chromium VI) was elevated (112 µg/L); however, the dissolved total chromium concentration (which includes chromium III plus chromium VI) was only 5 µg/L, well below the preliminary groundwater screening level for chromium VI (250 µg/L). The hexavalent chromium reporting limit for this and several other site water samples was elevated because of the lab's dilution required to compensate for the color of the water sample (hexavalent chrome analysis is colorimetric).

In addition to well BC-MW01, a groundwater grab sample for dissolved metals analysis was collected from boring GF-SB20, located between the Clarifier and the waterway (Figure 10). No dissolved metals were detected in this sample at concentrations above preliminary groundwater screening levels.

Chip Dump/Cambio Area

SOIL QUALITY DATA

In order to evaluate potential environmental impacts associated with the operation of hydraulic equipment and the former presence of a Switch House containing electrical transformers, four soil borings (CD-SB01, -SB02, -SB03, and -SB04) were installed and sampled. Nine soil samples were analyzed for total metals and TPH. Four samples were also analyzed for PAHs and PCBs.

Elevated concentrations of diesel- and oil-range hydrocarbons were detected in boring CD-SB02 located next to an area that formerly contained hydraulic piston equipment. Most of the hydrocarbons detected in CD-SB02 soils appear to be derived from a surficial release of an oil product. TPH concentrations in CD-SB02 soils decrease from 3,850 mg/kg in the upper four feet to less than 50 mg/kg in the 12- to 16-foot depth interval (Figure 9). However, trace amounts of oil was observed in soils by Aspect's field geologist within this bottom depth interval.

TPH concentrations measured in the other three borings installed in the Chip Dump/Cambio area do not exceed MTCA unrestricted or industrial soil screening levels. No physical evidence of petroleum contamination (odor, staining) was observed in borings CD-SB01, -SB03, and –SB04. It is possible that diesel- and oil-range hydrocarbons detected in these borings may be at least partially derived from natural organics (e.g., wood chips). The concentration of total cPAHs in sample CD-SB04 (0.21 mg/kg) slightly exceeds the unrestricted screening level of 0.1 mg/kg. The presence of elevated cPAH concentrations relative to lower molecular weight PAHs is often caused by the presence of pyrogenic or combustion sources (e.g., burned wood, coal).

No PCBs were detected in the four soil samples tested.

Mercury was detected in sample CD-SB02-1 (0- to 4-foot depth interval) at a concentration (3.1 mg/kg) below 24 mg/kg. This sample is within the 1974 dredge spoil fill area, and mercury concentrations in the two deeper samples collected from the boring were below 0.3 mg/kg. Other metal concentrations observed in the Chip Dump/Cambio Area were below respective unrestricted screening levels and generally within the range of expected regional background concentrations.

No monitoring wells were installed specific to the Chip Dump Area during the Phase 2 ESA. However, groundwater was sampled at monitoring wells around the periphery during the Phase 2, and groundwater quality data exist for the area from the previous Chlor-Alkali investigations, as described in previous sections of this Work Plan (and see Figure 10).

Electrical Transformers

Two soil borings (ET-SB01 and -SB02) and three surface soil samples (ET-SS01, -SS02, and SS03) were collected to evaluate potential releases of PCB-containing transformer oils. Boring ET-SB01 was installed next to a former transformer storage area located east of the Chip Screen Building (Figure 9). Seven soil samples were analyzed for TPH and PCBs. Two soil samples were also analyzed for total metals.

No physical evidence of oil releases was observed in the soil boring samples. PCBs were not detected in samples ET-SB01-1 (0 to 4 feet) and ET-SB01-2 (4 to 8 feet). TPH concentrations detected in these soil samples were well below unrestricted and industrial screening levels. Because boring ET-SB01 was also located along the chromium pipeline corridor, soil samples from the boring were also tested for metals. Metals concentrations in the samples were within the range of expected regional background concentrations and did not exceed unrestricted or industrial soil screening levels.

Soil boring ET-SB02 was installed at the former electrical substation area located northeast of the Tissue Plant. No physical evidence of oil releases was observed in the soil boring samples and PCBs were not detected in the two soil samples submitted for chemical analysis. TPH concentrations detected in boring ET-SB02 soil samples were well below unrestricted and industrial screening levels.

Three surface soil samples (ET-SS01, -SS02, and –SS03) were collected within the existing electrical substation located northwest of the main office building (Figure 9). No evidence of oil releases was observed in the gravelly soils and measured TPH concentrations were well below unrestricted and industrial screening levels. PCB Aroclors 1248, 1254, and 1260 were detected in the surface soil samples at concentrations ranging from 0.045 to 0.27 mg/kg. Total PCB concentrations, which were calculated by summing both detected Aroclor concentrations along with one-half the detection limit values for non-detected Aroclors, ranged from 0.153 (ET-SS03) to 1.47 mg/kg (ET-SS02). Although the calculated Total PCB concentration for ET-SS02 slightly exceeds the unrestricted soil screening level of 1 mg/kg, the sample only contained 0.27 mg/kg of detected Aroclors. Elevated detection limits in this sample are responsible for the exceedance of the unrestricted soil screening level.

Fuel House

SOIL QUALITY DATA

Two borings (FH-MW01 and -SB01) were installed at the former locations of diesel and gasoline USTs. Four soil samples were analyzed for TPH, volatile aromatics, and total metals.

No physical evidence of fuel contamination was observed in the borings. TPH concentrations reported in the four soil samples analyzed were well below unrestricted and industrial screening levels. No VOCs were detected and total metals concentrations were within the range of expected regional background concentrations.

GROUNDWATER QUALITY DATA

Monitoring well FH-MW01 was installed immediately downgradient of the Fuel House. No TPH (gasoline-, diesel- or oil-range), VOCs, or PAHs were detected in the groundwater sample collected from this well. The pH of the groundwater from FH-MW01 was acidic (4.1), likely attributable to its position downgradient of the Acid Plant (well GF-MW02, next to the Acid Plant, had groundwater pH of 3.3 as discussed below). Despite the low pH, the detected dissolved metals concentrations at FH-MW01 were below respective preliminary groundwater screening levels (Figure 10).

General Fill Quality/Sewer Lines

SOIL QUALITY DATA

Twenty soil borings (designated with GF- prefix) were installed in areas scattered across the Pulp and Tissue Mill area including three borings in the Receiving Building area (former Co-Op Warehouse) to evaluate general soil quality conditions and assess impacts associated with potentially leaking sewer lines. A total of 45 soil samples were analyzed from the borings, typically for total metals and TPH. The uppermost soil sample collected from boring GF-SB08, which was located next to a former electrical substation east of the Oiler Shop, was also analyzed for PCBs.

In general, soil quality in the General Fill borings complied with both unrestricted and industrial screening levels. Fill soils generally lacked physical evidence of obvious petroleum or solvent contamination. Hydrocarbon-like odors were observed in borings GF-SB09 and GF-SB20, and “sweet” odors were encountered in borings GF-MW01 and GF-SB04. Debris (including bricks, wood, and styrofoam) was occasionally observed in the fill. Hydrogen sulfide odors were also encountered, but are likely due in part to buried organic-rich sediments.

No VOCs were detected at concentrations exceeding unrestricted or industrial soil screening levels, including in sample GF-MW01-4 which reportedly exhibited a “sweet” odor.

Concentrations of metals in soil samples analyzed from the General Fill borings were generally below unrestricted and industrial screening levels. however, east of the Converting Number 3 Building, the 293 mg/kg lead concentration detected in the 8- to 12-foot soil sample from boring GF-SB14 exceeds the 250 mg/kg unrestricted soil screening level but is well below the 1,000 mg/kg industrial screening level. No other samples collected in the vicinity of GF-SB14 exceed lead screening levels. At GF-MW02, adjacent to the former Acid Plant and where elevated dissolved lead was detected in groundwater (see below), the highest soil lead concentration detected was 94 mg/kg.

A TPH concentration of 3,100 mg/kg as Bunker C was detected in boring GF-SB20-2 (4 to 8 feet). No petroleum sheen or odor was observed in this sample although sheen and odor was identified in the 12- to 16-foot depth interval. It is possible that historical releases of Bunker C from the former tank located approximately 200 feet southwest of the boring have become adsorbed onto the organic-rich matrix present in the GF-SB20 area. TPH concentrations in samples collected in the 0- to 4-foot and 12- to 16-foot depth intervals in boring GF-SB20 are below 200 mg/kg and do not appear to be derived from a Bunker C-like product (Figure 9).

GROUNDWATER QUALITY DATA

Monitoring well GF-MW01 provides groundwater quality data along the Whatcom Waterway, in a location adjacent to the City of Bellingham sewer line running beneath Laurel Street. It is also downgradient of the chrome pipeline as discussed above. The groundwater sample from this well had no detected concentrations above preliminary groundwater screening levels.

Monitoring well GF-MW02 is located next to the Acid Plant, and shows the lowest groundwater pH measured at the site (3.3). The detected concentration of dissolved lead (750 µg/L) exceeded its preliminary groundwater screening level, which is attributed to the acidic conditions in this area (both soil and groundwater). The elevated dissolved lead concentration observed at GF-MW02 does not persist roughly 270 feet downgradient at well FH-MW01 (Figure 10) even though acidic groundwater (pH 4.1) does.

Lab Building

SOIL QUALITY DATA

One soil boring (LB-MW01) was installed adjacent to the sewer line exiting the Laboratory Building to evaluate whether potential leaks may have impacted soil or groundwater quality in the area. Two soil samples from the boring were analyzed for VOCs, SVOCs, TPH, and total metals. No physical evidence of contamination was observed during the installation and sampling of boring LB-MW01. Soil concentrations were below unrestricted and industrial soil screening levels.

GROUNDWATER QUALITY DATA

Monitoring well LB-MW01 was installed on the presumed downgradient side of the Lab Building. However, the August 2004 groundwater elevation data indicate the Lab Building straddles the groundwater divide, with the groundwater elevation in LB-MW01 being the highest measured on the parcel (Figure 4). All detected constituent concentrations in the LB-MW01 groundwater sample were below preliminary groundwater screening levels.

Lignin Plant "Mill A"

SOIL QUALITY DATA

Nine borings were installed in areas where chromium and other additives were stored and/or handled. Eighteen soil samples were analyzed for metals, hexavalent chromium, TPH, PAHs, and SVOCs. One sample from each boring was also tested for formaldehyde.

Elevated concentrations of metals, particularly chromium and manganese, were encountered in Lignin Plant soils. Both of these metals were reportedly added to lignin for a variety of products including drilling mud. Total chromium concentrations in Lignin Plant soils ranged up to 382 mg/kg (sample LP-MW01-1). In general, the highest chromium concentrations were observed in shallow soils (upper four feet). Most of the chromium appears to be in the less toxic trivalent (Cr III) form. The highest hexavalent chromium concentration measured in Lignin Plant soils was only 2.14 mg/kg (LP-SB05-3), which is below the unrestricted and industrial soil screening level of 19 mg/kg. Trivalent chromium concentrations, which were calculated by subtracting hexavalent chromium values from the reported total chromium results, are all below the unrestricted and industrial soil screening level of 2,000 mg/kg.

The total lead concentration of 604 mg/kg in sample LP-SB03-1 (0 to 4 feet) is the only metal exceedance of unrestricted soil screening levels in the Lignin Plant area. This occurrence of lead appears to be relatively isolated. The 4- to 8-foot sample from this boring contained only 8 mg/kg lead, and none of the adjacent borings (including boring SC-MW02) contained lead concentrations above the unrestricted screening level.

No physical evidence of petroleum accumulations was observed in any of the Lignin Plant borings. Measured TPH concentrations are all below unrestricted and industrial screening levels. The total cPAH concentration in sample LP-SB04-1 (0.23 mg/kg) slightly exceeds the unrestricted screening level of 0.1 mg/kg but is below the industrial screening level of 2 mg/kg. PAH concentrations measured in all of the other Lignin Plant soil samples do not exceed unrestricted or industrial screening levels.

Formaldehyde, which was reportedly applied to lignin products as a biocide, was detected in most of the Lignin Plant soil samples tested at concentrations ranging from 5.6 to 299 mg/kg. Formaldehyde concentrations in 6 of the 8 samples tested (not counting sample duplicate) exceed the unrestricted soil screening level of 33 mg/kg, with two samples more than two times the screening level (120 mg/kg at LP-SB05-1, and 299 mg/kg at LP-SB04-2). None of the sample concentrations exceed the industrial screening level of 4,380 mg/kg. All other SVOCs detected in Lignin Plant soils were below respective unrestricted and industrial soil screening levels.

GROUNDWATER QUALITY DATA

Monitoring wells LP-MW01 and LP-MW02 were located, along with SC-MW02 discussed above, to provide groundwater quality data in the presumed downgradient direction of the Lignin Plant. Based on inferred groundwater flow directions from the 2004 water level data, well SC-MW02 is located on a groundwater divide and wells LP-

MW01 and LP-MW02 are located downgradient (north) of the divide. Well LW-MW01, intended to be downgradient of the Lignin Warehouse, is instead downgradient (south) of the Lignin Plant and is included in this summary of groundwater quality data for the Lignin Plant area.

Several dissolved metals, including arsenic, cadmium, chromium III, copper, lead, mercury, and nickel were detected in groundwater samples from one or more of these wells. However, only dissolved copper at SC-MW02, LP-MW02, and LW-MW01, and dissolved nickel at LW-MW01, exceed the preliminary groundwater screening levels.

The chlorinated solvents tetrachloroethene (PCE), trichloroethene (TCE), cis-1,2 dichloroethene (cis-DCE) and vinyl chloride were also detected (25, 5.4, 12, and 13 µg/L, respectively) in groundwater at LP-MW01. Only the PCE concentration exceeds the preliminary groundwater screening level. These compounds were not detected in soil samples or groundwater from the other monitoring wells across the mill area, and might be attributable to a localized release of PCE in the Lignin Plant. TCE, cis-DCE, and vinyl chloride are commonly biological breakdown products of PCE that can occur under reducing groundwater conditions (via reductive dechlorination) such as those found beneath the Site.

Other organic constituents, including pentachlorophenol and phenol at LW-MW01 and total cPAHs at LP-MW01, were detected at concentrations below preliminary groundwater screening levels.

Lignin Warehouse “Mill B”

Soil Quality Data

Five soil borings and four surface soil sampling explorations were installed in the Lignin Warehouse area to evaluate potential impacts associated with the spillage of dry lignin products and waste liquor. Fourteen soil samples were analyzed for total metals, hexavalent chromium, PAHs, and SVOCs. One sample from each boring and the four surface soil samples were also tested for formaldehyde.

The concentrations of metals in Lignin Warehouse subsurface soils are fairly similar to that observed at the Lignin Plant. Total chromium concentrations in Lignin Warehouse subsurface soils ranged up to 844 mg/kg (sample LW-SB03-1). In general, the highest chromium concentrations were observed in shallow soils (upper 4 feet). Chromium concentrations in surface soil samples collected along the rail spur located north of the warehouse (LW-SS01, -SS02, and –SS03) and in the northeastern corner rail entrance (LW-SS04) ranged up to 1,560 mg/kg. As observed in the Lignin Plant Area, chromium appears to be predominantly in the less toxic trivalent (Cr III) form. Hexavalent chromium concentrations in Lignin Warehouse surface and subsurface soils are less than 1 mg/kg and are well below the unrestricted and industrial screening level of 19 mg/kg. Trivalent chromium concentrations are also all below the unrestricted and industrial screening level of 2,000 mg/kg.

The only metal concentration to exceed unrestricted or industrial screening levels in Lignin Warehouse soils was cadmium (11 mg/kg) in sample LW-MW01-2 (2.5 to 4 feet).

The cadmium exceedance appears to be relatively isolated since none of the adjacent samples exceed the unrestricted screening level.

No physical evidence of petroleum accumulations was observed in any of the Lignin Warehouse borings, but abundant wood and other organic material was present in subsurface soils. As shown on Figure 9, several soil samples contained total cPAH concentrations above the unrestricted screening level including LW-SB03-1 (0.83 mg/kg), LW-SB03-2 (1.03 mg/kg), LW-SS02 (3.19 mg/kg), and LW-SS03 (29.4 mg/kg). The total cPAH concentrations in surface soil samples LW-SS02 and LW-SS03 collected along the rail spur also exceed the 2 mg/kg industrial screening level. The elevated cPAHs in soil along the rail spur are likely associated with creosote-treated railroad ties.

Formaldehyde was detected in all of the Lignin Warehouse soil samples tested at concentrations ranging from 6.5 to 261 mg/kg, similar to that observed in the Lignin Plant area. Formaldehyde concentrations in 3 of the 9 samples tested (not counting sample duplicate) exceed the 33 mg/kg unrestricted soil screening level. None of the samples exceed the industrial screening level of 4,380 mg/kg. All other detected SVOC concentrations were below unrestricted and industrial screening levels.

GROUNDWATER QUALITY DATA

Well LW-MW01 was installed in the presumed downgradient direction of the Lignin Warehouse. Based on inferred groundwater flow directions from the 2004 water level data, LW-MW01 is apparently downgradient of the Lignin Plant and cross-gradient of the Lignin Warehouse. The groundwater quality data from this well are discussed above for the Lignin Plant.

A groundwater grab sample was collected from boring LW-SB04 on the east (downgradient) end of the warehouse and analyzed for dissolved metals, excluding hexavalent chromium. Well CW-MW01, south of Cornwall Avenue and intended as an upgradient monitoring well for the site, is generally downgradient of the warehouse based on the 2004 water level data (Figure 4). All constituent concentrations from these two groundwater samples were below preliminary groundwater screening levels.

Million Gallon Storage Tank Area

SOIL QUALITY DATA

Four borings were installed and sampled to evaluate potential petroleum releases associated with storage and distribution of fuels. One of the Million Gallon Tanks, Tank #2 located just west of the northeastern corner of the eight tanks, was used for storage of fuel oil. Several fueling areas were also located east of the tank area. Nine soil samples were submitted for chemical analysis of total metals, TPH, and BTEX.

Soil testing results and exploration observations indicate the presence of a more limited petroleum release in the Million Gallon Tank Area relative to the Bunker C Tank-Clarifier Area (Figure 9). Hydrocarbon odors were observed at the base of the hand-augered boring MG-SB01, which was installed inside of the Million Gallon Tank enclosure. However, the hand auger hit refusal at 3 feet and could not be advanced to greater depths. The TPH concentration observed in the sample collected at the 2- to 3-foot depth interval (MG-SB01-2) exhibited a TPH concentration of only 196 mg/kg and was not quantified as Bunker C. Hydrocarbon-like odors were also observed in boring

MG-MW01 located north of the Million Gallon Tank area. TPH quantified as Bunker C was detected in Sample MG-MW01-4 (7.5 to 9 feet) at a concentration of 2,700 mg/kg (Figure 9). TPH as Bunker C was also encountered in groundwater sampled at this location (see below). Oil-range hydrocarbons were detected in boring MG-SB02 located east of the tank farm at a concentration (2,400 mg/kg) exceeding the unrestricted and industrial screening level of 2,000 mg/kg. However, these hydrocarbons do not appear to be derived from Bunker C and are located in shallow soils (0 to 4 feet) well above the top of the water table. No other exceedances of petroleum screening levels were observed in the Million Gallon Storage Tank Area. No gasoline-range hydrocarbons or BTEX were detected in the Million Gallon Tank Area soil samples submitted for analysis.

Total metals concentrations in soil samples collected from the Million Gallon Tank Area borings were below unrestricted and industrial screening levels.

GROUNDWATER QUALITY DATA

Monitoring well MG-MW01 was installed on the presumed downgradient edge of the former Million Gallon Tank area. Based on the inferred August 2004 groundwater flow directions, the north edge of the tank area and well MG-MW01 occur along the groundwater divide (Figure 4). Existing wells EMW-12S and EMW-16S, located just east and north respectively of the tank area, were also sampled for this investigation.

The groundwater sample from MG-MW01 contained TPH, quantified as Bunker C, at a concentration of 1.2 mg/L. Gasoline-range TPH was not detected in this sample. The sample also had detected concentrations of total cPAHs (0.22 µg/L TEF), slightly above the preliminary groundwater screening level.

Immediately to the north of the former tank farm, the groundwater sample from well EMW-16S had detectable gasoline- and diesel-range TPH, with concentrations of 0.42 and 0.5 mg/L, respectively. Concentrations of benzo(a)pyrene (2.8 µg/L) and total cPAHs (4.5 µg/L TEF-adjusted) exceeded preliminary groundwater screening levels. Immediately to the east of the former tank farm, the groundwater sample from well EMW-12S had no detectable TPH or PAHs.

Elevated concentrations of dissolved arsenic, nickel, chromium III, and hexavalent chromium were detected in one or more of the three wells around this area. Only dissolved arsenic at wells EMW-12S (80 µg/L) and EMW-16S (42 µg/L) exceed the preliminary groundwater screening levels.

Sodium Bichromate Tank and Pipeline

SOIL QUALITY DATA

Seven borings were installed to evaluate potential releases of sodium bichromate from two above-ground storage tanks (ASTs) located south of Warehouse #2 and along the underground pipeline which extended from the tanks to the Lignin Plant (Figure 2). Fourteen soil samples were analyzed for total metals, hexavalent chromium, and TPH. Several samples were also tested for VOCs and SVOCs, including PAHs.

Total metals concentrations in soil samples collected from the Sodium Bichromate area borings are generally below unrestricted and industrial screening levels. Lead was detected in sample SC-SB04-1 (0 to 4 feet) at a concentration (557 mg/kg) exceeding the 250 mg/kg unrestricted screening level but below the 1,000 mg/kg industrial screening level. The concentration of lead in sample SC-SB04-2 collected within the same boring at a depth of 4 to 8 feet was only 76 mg/kg, indicating the unrestricted exceedance is vertically bounded.

Chromium concentrations in the borings were below unrestricted and industrial screening levels. Total chromium concentrations in subsurface soils ranged from 16 mg/kg (SC-MW01-1) to 1,050 mg/kg (SC-SB01-2). The highest chromium concentrations occur at the SC-SB01 location east of the former chromium AST locations and at SC-MW02 located near the terminus of the pipeline in the Lignin Plant area. Chromium appears to be predominantly in the less toxic trivalent (Cr III) form. Hexavalent chromium concentrations in subsurface soils are less than 3 mg/kg and are well below the unrestricted and industrial screening level of 19 mg/kg.

A solvent-like odor was reported during installation of boring SC-MW02; however, detected concentrations of VOCs in soil samples from the boring were below unrestricted and industrial screening soil levels.

A TPH concentration of 5,700 mg/kg was detected in the uppermost sample (0.5 to 2 feet) collected in boring SC-MW01, but no evidence of petroleum staining or odors was observed. It is possible that this hydrocarbon occurrence, which was quantified by the laboratory as a mixture of Bunker C and oil, is associated with the overlying asphalt layer or was the result of a surface release prior to the area being paved.

The 0.21 mg/kg cPAH concentration measured in sample SC-SB03-2 (4 to 8 feet) slightly exceeds the 0.1 mg/kg unrestricted screening level but not the 2 mg/kg industrial screening level. The source of PAHs in this sample appears to be creosote-treated wood. Fragments of creosote-treated wood were observed in the boring. Carbazole and dibenzofuran, which are commonly found in creosote, were also detected in the sample at concentrations below respective screening levels.

GROUNDWATER QUALITY DATA

Monitoring well SC-MW01 was installed along the waterway, downgradient of the liquid chrome tank formerly located south of Warehouse No. 2. Well SC-MW02 was located next to, and presumed immediately downgradient of, the chrome pipeline near its terminus within the Lignin Plant. The August 2004 groundwater elevation data indicate that the pipeline at this location and well SC-MW02 are near the center of the apparent groundwater divide running across the center of this parcel (Figure 4). Thus, the well may not be downgradient of the pipeline, at least not throughout the entire year if the divide changes position somewhat seasonally. Groundwater quality data for SC-MW02 are discussed in the Lignin Plant section. Based on this groundwater flow pattern, other monitoring wells are positioned downgradient of, and in relatively close proximity to, the chrome pipeline. These include wells GF-MW01, FH-MW01, GF-MW02, and AP-MW01 (Figure 5).

Well SC-MW01, located downgradient of the former chrome tank along the waterway, had no dissolved metals or organic compounds detected above groundwater screening levels. However, this well had very low electrical conductance (90 µS/cm), is nearly saturated with dissolved oxygen (8.7 mg/L), and apparently did not respond to tidal fluctuations during 2004 measurements, suggesting it may be affected by a leaking subsurface water line or other source of freshwater.

Wells located downgradient of and relatively close to the chrome pipeline away from the Lignin Plant/Lignin Warehouse area have relatively low dissolved chromium concentrations. Wells GF-MW01, FH-MW01, GF-MW02, and AP-MW01 had dissolved chromium concentrations ranging from 10 to 30 µg/L, well below the preliminary groundwater screening level. Although water within well SC-MW01 does not appear to be representative of groundwater quality, well GF-MW01 (10.4 µg/L dissolved chromium) is generally downgradient of the former chrome tank and would be expected to detect a large release from that tank to groundwater if one had occurred.

The groundwater quality data suggest that the chrome pipeline and former chrome tank are not significant sources of chromium to shallow groundwater beneath the Tissue Mill area. Although elevated chromium concentrations have been detected (e.g., within the Lignin Plant), all concentrations are below preliminary groundwater screening levels.

Truck Shop/Oil Storage Area

SOIL QUALITY DATA

Three borings were installed in the vicinity of the Truck Shop and Oil Storage area to evaluate potential releases of petroleum, solvents, or metals associated with historical vehicle maintenance activities. Six soil samples were analyzed for total metals and TPH. Three samples were also selected for analysis of PAHs and PCBs.

No physical evidence of petroleum or solvent contamination was observed in the borings. TPH and PAH, and metals concentrations detected in the samples are all below unrestricted and industrial screening levels. No PCBs were detected in the samples.

GROUNDWATER QUALITY DATA

Monitoring well TS-MW01 was installed on the downgradient edge of the Truck Shop. The groundwater sample contained no constituents above preliminary groundwater screening levels.

Cleanup of Petroleum Contaminated Soil at Million Gallon Tanks (RETEC, 2007)

In November and December 2006, prior to demolition of the Million Gallon Tanks, GP removed a limited area of petroleum-contaminated soil adjacent to the Million Gallon Tank formerly used for storage of Bunker C fuel oil (Tank #2). The independent cleanup action included a limited test pit investigation, followed by excavation and off-site disposal of accessible grossly contaminated soil, post-excavation confirmation soil sampling and analysis, and excavation backfill using clean gravel over a marker layer.

Eleven test pits (TP-1 through TP-11; Figure 5) were initially excavated to a 4-foot depth around Tank 2 and the north side of the adjacent Tank 1 (TP-4 hit refusal on a concrete footing at 1 foot). Soils from the test pits were screened for presence of petroleum compounds using visual and olfactory evidence and a PID. The test pit investigation delineated an area of shallow soil grossly contaminated with Bunker C in the area between Tanks 1 and 2. Outside of test pit TP-8 where gross contamination was observed, minor apparent petroleum staining, odor, and/or sheen was reported in test pits TP-2, TP-3, TP-9, and TP-10.

Nearly 31 tons of contaminated soils were excavated from the area, to an average depth of approximately 2 feet. The excavated soils were stockpiled on plastic and sampled for diesel- and oil-range TPH. Oil-range petroleum was detected at concentrations up to 20,600 mg/kg in the samples. GP designated the soils as state dangerous waste based on toxicity (WT02), and disposed of it at the Chemical Waste Management Northwest Subtitle C landfill in Arlington, Oregon.

Following soil excavation, five confirmation soil samples were collected from the excavation (4 from sidewalls, 1 from bottom) and analyzed for diesel- and oil-range TPH. Four of five samples had detected petroleum concentrations below the 2,000 mg/kg unrestricted soil screening level for diesel- and oil-range petroleum. Assuming the presence of a single petroleum type (Bunker C), one confirmation soil sample, SS-2-1.5, contained 2,105 mg/kg TPH between the diesel and oil ranges, thus marginally exceeding the 2,000 mg/kg unrestricted and industrial soil screening level. The screening level (MTCA Method A) is conservative, particularly for Bunker C, and is based on preventing accumulation of separate-phase petroleum product on the water table. No separate-phase product was reported during the confirmation sampling, nor in the 2004 Phase 2 ESA sampling of downgradient monitoring well MG-MW01. The soil excavation was lined with plastic and backfilled with clean gravel to grade.

Geotechnical Exploration (GeoEngineers, 2007)

GeoEngineers (2007) conducted a geotechnical exploration program to support the feasibility evaluation for relocating approximately 4,000 feet of BNSF mainline railroad track running through the Site to an alignment south of the Site (south of Cornwall Avenue). They completed eleven geotechnical soil borings, seven along the proposed realignment (BRR-1 through -7) and four along Laurel Street and its southern easement (BB-1 through -4) where a new bridge over Cornwall Avenue and the realigned railroad has been proposed as part of the project (borings in and near the Site are shown on Figure 5). The borings were advanced to depths ranging from 13 to 44 feet, and all but two encountered bedrock. Field screening for contamination was conducted (visual and PID), but no chemical testing was conducted. There was no evidence of volatiles based on the PID screening, and the only evidence of contamination reported was a slight petroleum sheen in one soil sample collected from boring BRR-1, located just east of the Lignin Warehouse. No piezometers were installed. The study report provides geologic logs and geologic cross sections along two transects south of the Site.

6.2 Summary of Existing Site Soil and Groundwater Quality Data

This section briefly summarizes the current understanding of nature and extent of soil and groundwater contamination at the Site, based on the extensive existing data described in the preceding section and the screening levels outlined in Section 5. Although screening levels may be adjusted as a result of the Site-specific data collected during the RI, this current understanding is the basis for defining subareas for the Site, and for identifying data gaps. Because the Former Chlorine Plant and Former Pulp/Tissue Mill areas of the Site had distinct operations and generally distinct contaminants, the conditions in each area are described below separately. However, data collected across the entire Site are incorporated into each discussion as appropriate.

6.2.1 Former Chlor-Alkali Area

Soil Quality

From the aggregate previous soil sampling conducted across the Site, Figure 6 depicts soil mercury concentrations in unsaturated soil (Fill Unit vadose zone), based on data from soil samples that, at the time of drilling, were determined to be above the water table. Figure 7 depicts mercury concentrations from samples of saturated soil (aquifer matrix of Fill Unit and Lower Sand). Multiple depths were tested at many of the sampling locations; however, Figures 6 and 7 display only the maximum detected values in unsaturated soil and saturated soil, respectively. As described in the second paragraph of Section 6.1, the existing Site mercury soil data are evaluated in this Work Plan relative to 24 mg/kg to help focus data gaps analysis toward areas with higher mercury concentrations. To that end, Figures 6 and 7 depict in different colors soil mercury concentrations above 24 mg/kg versus below 24 mg/kg.

Within the Fill Unit, soil mercury concentrations exceeding 24 mg/kg are restricted to the former Chlor-Alkali area, which includes the Chlorine Plant, the log/chip storage areas (nearshore confined dredge fill area) north of it, the Stormwater Swale south of it, the Chemfix Area, and the Laurel Street Pipe Rack area. Localized areas where soil mercury detections above 24 mg/kg remain include:

- Along the south and east sides of the Cell Building (up to 65 mg/kg in unsaturated soil);
- On the northwest side of the Cell Building (up to 300 mg/kg mercury in unsaturated soil);
- In the area of the former settling basin and the 1998 soil removal action (up to 140 mg/kg remain in unsaturated soils, and up to 200 mg/kg in deeper saturated soils);
- Within the area of the former 72 Catch Basin area (up to 12,000 mg/kg in saturated soils);
- Around the Laurel Street Pipe Rack (up to 14,000 mg/kg in unsaturated soil);
- In the Stormwater Swale south of the former Chlorine Plant (up to 530 mg/kg in surface soils); and
- Within the Chemfix Area, where a pair of samples had mercury concentrations of 2,600 and 5,800 mg/kg, but the later sample of material composited from across the area had a concentration of 10 mg/kg.

The RI data indicate generally nondetectable soil mercury concentrations in the Tidal Flat Aquitard and Lower Sand Units, except for one anomalous 4.5 mg/kg detection in EMW-30D (samples above and below it were non-detect).

Groundwater Quality

Figure 8 displays the dissolved mercury data, with corresponding groundwater pH measurements, collected from Site monitoring wells to date.

Based on the most recent groundwater sampling and analysis data, the extent of Fill Unit groundwater containing dissolved mercury concentrations above the 0.94 µg/L preliminary groundwater screening level is limited to the area surrounding the Former Chlorine Plant. During the 2004 groundwater sampling efforts conducted for the Chlor-Alkali site FS and the Pulp/Tissue Mill Phase 2 ESA, the only detectable dissolved mercury concentrations in groundwater east of the Million Gallon Tanks area was at monitoring wells LW-MW01 (0.3 µg/L) and LP-MW01 (1.6 µg/L) adjacent to the Lignin Warehouse and Lignin Plant, respectively.

The presence of elevated dissolved mercury appears to be associated with high pH (alkaline) groundwater at the Site resulting from historical release of caustic. As discussed in Anchor Environmental (2003b), mercury at the Site occurs predominantly as divalent mercury complexed with sulfide under neutral or low pH (acidic) conditions. In moderate pH conditions, the mercury may precipitate as a highly insoluble mercuric sulfide or may co-precipitate with insoluble iron sulfides, and thus have limited environmental mobility. In fact, sulfide precipitation was historically used on Site to remove dissolved mercury from the chlorine plant process wastewater. Conversely, where high pH (pH 10 to 12) groundwater occurs, sulfide is no longer the stable form of sulfur, and the mercury is expected to occur in its more mobile elemental form. The higher groundwater mercury concentrations in the southwest end of the Site are therefore attributable to a predominance of dissolved elemental mercury with a lack of mercuric sulfide precipitation as a removal mechanism for mercury.

The May 2004 supplemental groundwater characterization partially delineated the western extent of dissolved mercury concentrations in the Fill Unit greater than the 0.94 µg/L preliminary groundwater screening level (Aspect, 2004a). Along transect 2, groundwater at the farthest downgradient exploration ATW-C2 contained 2.9 µg/L dissolved mercury, despite having only a slightly alkaline pH of 7.7.

For Site monitoring wells that have a long-term record of groundwater sampling, there are variable temporal trends for dissolved mercury concentrations. For example, at EMW-13S, located at the Laurel Street Pipe Rack area, detected dissolved mercury concentrations ranging from 21 to 180 µg/L in 1993-1994 (ENSR, 1994a) declined to 0.24 µg/L in 2001, and less than 0.1 µg/L in 2004. At the Site monitoring well with highest detected dissolved mercury, EMW-19S downgradient of the mercury cell building, concentrations declined from 460 µg/L in 1993-1994 to 94 µg/L in 2001 (not sampled in 2004). Concentrations were comparable at EMW-15S when sampled in 1993 (1.3 µg/L) and 2001 (2.8 µg/L). Wells where dissolved mercury concentrations increased between 1993 and 2001 are EMW-1S (non-detect to 3.9 µg/L), EMW-2S (0.5 to 10 µg/L), and EMW-14S (0.96 to 50 µg/L) (Figure 8).

6.2.2 Former Pulp/Tissue Mill Area

Soil Quality

There are a number of occurrences of oil-range TPH, cPAHs, and some metals within Fill Unit soils at concentrations above unrestricted or industrial soil screening levels (Figure 9). However, the primary soil quality issues identified in the Pulp/Tissue Mill Area include:

- **Bag House Area.** Dioxins and furans are present at concentrations exceeding the unrestricted direct contact screening level in subsurface soil samples containing debris and collected east of the Bag House.
- **Bunker C Tank Area.** Bunker C has been released from the former tank and appears to have migrated toward the Bag House Area and possibly to the area northeast of the Clarifier.
- **Lignin Plant/Lignin Warehouse**. Maximum formaldehyde concentrations up to 299 mg/kg in soils adjacent to the Lignin Plant and Lignin Warehouse exceed the 33 mg/kg unrestricted soil screening level. Formaldehyde concentrations in groundwater are well below the preliminary groundwater screening level, indicating the residual soil concentrations are not a significant source to groundwater. Formaldehyde is highly soluble, with a very low Henry’s Law constant, such that the observed groundwater concentrations (up to 38 µg/L) are not expected to represent a vapor (indoor air) concern. The highest observed soil concentrations (299 mg/kg at Lignin Plant; 150 mg/kg at Lignin Warehouse) occur in samples with saturated soil, so that formaldehyde would be expected to partition primarily into groundwater (aqueous phase).
- **Million Gallon Tank Area.** A localized release of Bunker C product adjacent to the former fuel oil tank in this area was cleaned up in 2007. Soil quality beneath the bottom of the former tank, now demolished, has not been evaluated.

Detected mercury concentrations in unsaturated and saturated soils across the Pulp/Tissue Mill Area are less than 1 mg/kg (Figures 6 and 7).

Groundwater Quality

The most recent (2004) groundwater elevation data indicate a groundwater divide through the center of the Pulp/Tissue Mill area, from which groundwater flows both toward Whatcom Waterway to the north and toward Cornwall Avenue to the south (refer to Figure 4). Despite this, the number and distribution of monitoring wells on the Site provide coverage to document groundwater quality downgradient of the primary operational areas of potential environmental concern. Figure 10 depicts all constituent concentrations detected in Site wells that exceed the preliminary groundwater screening levels based on surface water protection (Table 1).

Bunker C non-aqueous phase liquid (NAPL) was observed on the water table beneath the Bunker C tank. Accordingly, elevated dissolved-phase TPH and cPAH groundwater concentrations slightly above the 0.15 µg/L preliminary groundwater screening level are present in this location. Groundwater immediately downgradient of the Million Gallon Tanks contains concentrations of cPAHs above the preliminary groundwater screening level.

Downgradient of the Lignin Plant, several chlorinated VOCs were detected at well LP-MW01, with tetrachloroethene (PCE) and vinyl chloride exceeding the preliminary groundwater screening levels. Chlorinated VOCs were not detected in soils or groundwater elsewhere on the Site, and the source of the groundwater detection at LP-MW01 is uncertain.

A range of dissolved metals including arsenic, cadmium, copper, lead, mercury, nickel, and zinc were detected at concentrations above respective preliminary groundwater screening levels based on surface water protection. These detections are expected to be, at least in part, a result of the natural reducing groundwater conditions in the Fill Unit. The greatest number of metals exceeding screening levels were detected in well GF-MW02, located immediately downgradient of the former Acid Plant. Groundwater downgradient of the former Acid Plant is acidic (pH 3.3 and 4.1 at wells GF-MW02 and FH-MW01, respectively), which contributes to metals dissolution and mobility in groundwater. No dissolved metals concentrations exceeded groundwater screening levels in monitoring wells positioned closest to the waterway (SC-MW01, GF-MW01, BC-MW01, GF-SB01).

Hexavalent chromium was not detected in Site groundwater, except for a single detection suspected to be an analytical artifact. Hexavalent chromium was reported at a concentration equal to the 224 µg/L reporting limit in the 2004 groundwater sample from well EMW-16S, located generally downgradient of the Million Gallon Tanks. As described in Aspect (2004b), the hexavalent chromium analytical method for water involves colorimetric quantification; in Fill Unit groundwater colored from organics (tannins), the method sensitivity is reduced. Like other wells on the Site, groundwater conditions at EMW-16S are reducing (-225 mv ORP and 0.7 mg/L DO); therefore, the presence of the oxidized (hexavalent) form of chromium in groundwater seems unlikely.

6.3 Site Subareas for RI/FS

Based on the screening of existing Site soil and groundwater data described above, Figure 11 depicts locations of “Site subareas” identified for the RI/FS. The subareas identified have soil and/or groundwater contamination that is expected to warrant evaluation of remedial action alternatives in the FS or, if appropriate, interim cleanup actions within the context of the RI/FS process.

The identified Site Subareas include:

- **Caustic Plume.** This is the area of soil and groundwater impacted by high pH and mercury adjacent to the former Chlorine Plant. The extent of soil mercury exceeding soil screening levels based on direct contact is sufficiently defined for the area. However, the downgradient extents of mercury in groundwater, and the characteristics of its subsurface transport, are currently not well defined. In addition, there is limited data to assess potential risks to indoor air from mercury in soil vapor under future redevelopment scenarios.

- **Chemfix and Confined Nearshore Fill Areas.** Detectable mercury concentrations exist in the confined nearshore dredge fill soils and the Chemfix material located within it. Current groundwater quality data are lacking to address protection of surface water via groundwater transport of dissolved mercury.
- **Laurel Street Pipe Rack.** Elevated soil mercury concentrations remain in this area. Additional information is required to better define the lateral and vertical extents of mercury-impacted soil, and to sufficiently address protection of surface water via groundwater transport of dissolved mercury.
- **Million Gallon Tanks Area.** A limited volume of petroleum-contaminated soil was cleaned up in this area previously. Now that the tanks are demolished, additional information is required to better define the extent of petroleum-impacted soil and to sufficiently address protection of surface water via groundwater transport of petroleum hydrocarbons.
- **Bunker C Tank Area.** The previous sampling documented the presence of separate-phase Bunker C product at the water table, and petroleum-impacted soil at distance from the former tank. Additional information is required to better define the extent of petroleum-impacted soil, including along the waterway bulkhead, and to sufficiently address protection of surface water via groundwater transport of petroleum hydrocarbons.
- **Acid Area.** Acidic pH and elevated dissolved metals concentrations are documented in groundwater downgradient of the former Acid Plant. Additional information is required to sufficiently address protection of surface water via groundwater transport of dissolved metals.
- **Stormwater Swale south of former Chlorine Plant**. Shallow soils in this Subarea contain mercury concentrations above the unrestricted soil screening level within a well-defined area. The detected soil mercury concentrations are low enough (up to 530 mg/kg) that, based on TCLP mercury data from elsewhere on the Site, it is likely that the soils would not designate as characteristic dangerous waste if excavated. Sufficient information exists to evaluate remedial alternatives for this Subarea during the FS, and additional data collection is not proposed for it as part of the RI/FS.

Outside of the Site subareas, there is relatively widespread, lower-level soil contamination typical of industrial properties (e.g., oil-range petroleum and cPAHs above unrestricted soil screening levels). In addition, groundwater in the Fill Unit throughout the Site has reducing geochemical conditions conducive to elevated dissolved metals concentrations.

7 Preliminary Conceptual Site Model

This section presents a preliminary conceptual site model (CSM), including known or suspected contaminants at the Site based on the existing information described above, a description of general contaminant transport and attenuation processes, and potential exposure pathways for each of the Site subareas. The preliminary CSM is developed to assist in identifying data gaps to be addressed in the RI, and will be updated as needed during the RI/FS to include newly collected data. The updated CSM can be used to guide development of cleanup standards and assist in development of remedial alternatives in the FS.

7.1 Known and Suspected Contaminants

Known and suspected contaminants in soil and groundwater were identified based on a comparison of detected contaminant concentrations to the most conservative of the respective screening levels presented in Section 5.

Contaminants in **soil** with concentrations exceeding the soil screening levels for industrial and/or unrestricted land use include:

- **Organics**
    - TPH, primarily as Bunker C with lesser concentrations of oil and diesel
    - Formaldehyde
    - Total cPAHs
    - Total PCBs
    - Total dioxins/furans
- **Metals**
    - Cadmium
    - Lead
    - Mercury

Contaminants in **groundwater** with concentrations exceeding the preliminary groundwater screening levels based on protection of marine surface water receptors include:

- **Organics**
    - TPH as free product (Bunker C)
    - PCE
    - Vinyl chloride
    - cPAHs
    - PCB aroclor 1248

- **Metals**
    - Arsenic
    - Cadmium
    - Chromium VI
    - Copper
    - Lead
    - Mercury
    - Nickel
    - Zinc

7.2 Chemical Fate and Transport Mechanisms

A number of physical, chemical, and biological processes will affect fate and transport of the organic and inorganic (metals) constituents detected in soil and groundwater at the Site. Mechanisms controlling the fate and transport of organic constituents include dissolution to groundwater of constituents bound to soil particles or present as free phase product; volatilization from soil, groundwater, or free product to soil vapor; sorption of dissolved phase constituents in groundwater to organic matter on soil particles; and biodegradation and chemical (abiotic) transformation.

The occurrence, fate, and transport of metals are strongly controlled by geochemical conditions, particularly redox and pH. Under certain geochemical conditions, chemical reactions including precipitation, co-precipitation, and sorption to organic matter or mineral grains can remove dissolved metals from groundwater. Conversely, under certain conditions, metals may be dissolved from the mineral grains and mobilized on groundwater. Because mercury volatilizes under typical temperature and pressure conditions at the Site, volatilization of mercury to the vapor phase may also occur.

Physical processes, such as diffusion, dispersion, and dilution with unimpacted groundwater will act to attenuate both organic and inorganic constituent concentrations in groundwater. For example, previous modeling of site groundwater discharge of mercury to the Log Pond, which accounted for groundwater advection and chemical diffusion, indicates that mercury concentrations in groundwater will be attenuated by a factor of at least ten across the sediment-surface water interface. Tidally-induced dispersion and increased biodegradation (for organics) or chemical precipitation (for metals) would likely increase the attenuation near the shoreline.

As described in Section 6.1, previous mercury speciation analyses conducted on Site soil and groundwater suggest that methylated mercury compounds (i.e. monomethylmercury, dimethylmercury) are not present in Site soil, soil vapor or groundwater in significant quantities. In general, mercury species partitioning in the soil-sorbed, aqueous, and vapor phases occurs as follows: in soil and groundwater, inorganic divalent mercury (Hg^{II}) is the primary species; elemental mercury (Hg^{0}) is the predominant volatile species, with dimethylmercury sometimes present in vapor to a minor degree (Wallschlager et al., 1995). Methyl mercury species form more commonly in anaerobic sediments and water columns of marine and freshwater environments, both abiotically and by microbial methylation of inorganic mercury (Revis et al., 1990; EPA, 1997). Increases in the proportion of methyl mercury are generally a result of anoxic (i.e. highly reducing) conditions, presence of methane, high organic matter content, and slightly acidic pHs (Cappon, 1987; Wallschlager et al., 1995; EPA, 1997). The ratio of methyl to total mercury ratios are about 0.1 percent in some floodplain soils (Wallschlager et al., 1995a). Higher methyl/total mercury ratios, between about 3 to 5 percent, have been identified in acidic garden soils and compost (Cappon, 1987). At the Site, previous mercury speciation investigations determined that methyl mercury species comprise less than 1 percent of total mercury in soil, soil vapor and groundwater, for all samples analyzed (ENSR, 1994a; Anchor Environmental, 2003b; refer to Section 6.1), which is consistent with the literature information. Therefore, the methylated mercury compounds are not considered constituents of concern for the Site.

Appendix B provides additional detail regarding fate and transport mechanisms potentially applicable for contaminants of concern at the Site. This information will be updated based on additional data collected during the RI/FS.

7.3 Exposure Pathways

An exposure pathway describes the mechanisms by which human or ecological exposure to site contaminants can occur under baseline site conditions, assuming no remedial action or protective control is in place. To be considered complete, an exposure pathway must have:

- An identified source of contaminants;
- A mechanism for contaminant release and transport from the source;
- An exposure route where contact with the contaminant can occur; and
- A receptor that can be exposed to the contaminant.

An exposure pathway is considered complete if a human or ecological receptor can be exposed to a contaminant via that pathway.

This section describes generic exposure pathways for contaminants in soil and groundwater at the Site. The following section will relate these pathways to specific constituents detected at concentrations above screening levels in individual site areas.

7.3.1 Soil

Assuming the full range of potential future land uses, current and future potentially complete exposure pathways for soil within the vadose zone (i.e., above the water table) include:

- Workers contacting contaminated soils (skin contact or incidental ingestion) and/or inhaling contaminated soil particles or vapors during excavation or other construction-related activities, if no worker protection controls are in place;

- Residents contacting contaminated soils and/or inhaling contaminated soil particles or vapors in the future, if no controls are in place to restrict use of the site; and
- Terrestrial ecological receptors contacting contaminated soils in the future, if no controls are in place.

In addition to these pathways, contaminants in soil can leach to groundwater, acting as a secondary source. Therefore, the soil to groundwater pathway must also be considered in areas where there is a potentially complete groundwater exposure pathway.

7.3.2 Groundwater

Assuming the range of potential future land uses, current and future potentially complete exposure pathways for groundwater include:

- Residents and workers in buildings inhaling indoor air contaminated – via vapor intrusion – by the volatilization of contaminants from shallow groundwater;
- Workers contacting contaminated groundwater during excavation or other construction-related activities;
- Direct exposure for aquatic ecological receptors in Bellingham Bay and Whatcom Waterway, if groundwater contaminants discharge to surface water; and
- Humans consuming aquatic ecological receptors contaminated by discharges to surface water.

As discussed in Section 5.2, groundwater at the Site is not a practicable source of potable water, either currently or under likely future conditions. As such, human use of groundwater at the Site for drinking water purposes is not considered a current or future potentially complete pathway.

7.4 Conceptual Site Model by Site Subarea

Based on the long-term industrial use of the Site and the extensive existing Site data, the current conceptual site model includes a widespread distribution of moderate to low concentrations of common “industrial contaminants” in soil (e.g., heavy-range TPH, PAHs, some metals), and generally low-level concentrations multiple dissolved metals in groundwater associated with reducing geochemical conditions in the aquifer. Superimposed on the Site-wide conditions are several areas of higher-risk contamination associated with specific former industrial activities on the Site – the Site subareas identified for the purposes of scoping the RI/FS.

The following sections briefly summarize the contaminants and potentially complete exposure pathways for identified Site subareas, where contamination in soil and/or groundwater is documented from the existing data.

7.4.1 Caustic Plume Area

This area includes groundwater with elevated mercury concentrations and alkaline pH levels associated with operations of the former Chlorine Plant. We are aware of no records of a release of free-phase mercury at the Chlorine Plant, and free-phase mercury has not been encountered during various independent cleanup actions in the area. Elevated soil mercury concentrations have been detected in soil, some of which has been cleaned up, but, based on the existing data, elevated mercury concentrations remain in soil (see Figures 6 and 7). Given the localized high concentrations of mercury in groundwater, and the historical use of mercury in Chlorine Plant operations, it is suspected that a source of leachable mercury in soils remains. An elevated mercury soil vapor concentration was detected in the area of the former 72 Catch Basin, where the highest soil mercury concentrations on Site have been detected.

In this area, all soil and groundwater exposure pathways are potentially complete, including the potential for inhalation of mercury vapors volatilized from soils and groundwater.

7.4.2 Chemfix Area

This area includes mercury-impacted former settling basin sludge/sediment that has been chemically stabilized. Average mercury concentrations in the remediated Chemfix material are about 10 mg/kg, with localized concentrations detected up to 5,800 mg/kg. Note that these concentrations are detected after analytical laboratory digestion using a very strong acid solution; it does not mean the mercury is mobile under ambient environmental conditions. In fact, TCLP tests indicate little leachable mercury in the bulk of the stabilized soils (up to 0.2 µg/L based on a 2003 composite sample), with higher leachable mercury concentrations (up to 3.2 µg/L) in materials with considerably higher total mercury concentrations. Mercury was not detected in groundwater from monitoring wells located downgradient from the Chemfix Area. Despite the lack of groundwater detections to date, the TCLP mercury results indicate that, at least locally, the soil to groundwater leaching pathway may be complete and result in groundwater concentrations exceeding screening levels.

The 2003 sampling within the Chemfix Area documented mercury soil-vapor concentrations below the air screening level in four sample locations, indicating the vapor inhalation pathway is not complete.

Based on these results, soil and groundwater exposure pathways excluding vapor inhalation are potentially complete in the Chemfix Area.

7.4.3 Laurel Street Pipe Rack Area

This area includes mercury-contaminated soil and debris discovered during construction of footings for above-ground utility pipelines. The presence of elevated mercury in soil is likely due to disposal of mercury-containing debris from the former Chlorine Plant. The available data indicate that mercury-contaminated soils represent a localized “hot-spot”, with detected total mercury concentrations of up to 14,000 mg/kg. Mercury-contaminated soils were partially excavated to accommodate construction, but mercury-contaminated soil remains in place.

Long-term groundwater sampling at monitoring well EMW-13S, located near the apparent center of the area of impacted soil, indicates a decline in groundwater mercury concentrations from a peak of 180 μg/L in 1993, soon after some mercury-contaminated soils and debris were excavated, to nondetectable concentrations (less than 0.1 μg/L) in 2004. Although groundwater quality appears to be recovering, based on the historical groundwater impacts, leaching of mercury from soil to groundwater is considered a potentially complete pathway. Because of the localized high soil mercury concentrations (two samples above 1,000 mg/kg), and absence of soil vapor measurements, the soil-to-vapor pathway is a potentially complete pathway.

Based on the available data and the remaining mercury-contaminated soil at the Laurel Street Pipe Rack Area, all soil and groundwater exposure pathways are potentially complete.

7.4.4 Million Gallon Tank Area

This area consists of Bunker C-contaminated soil and cPAH-contaminated groundwater at and downgradient from the former Million Gallon Tank #2, in which Bunker C fuel oil was historically stored (spent liquor from the Lignin Plant was reportedly stored in the other tanks). Total cPAH concentrations in groundwater exceed preliminary groundwater screening levels. Surface water criteria, and thus preliminary groundwater screening levels based on them, are not available for petroleum mixtures like Bunker C. Free-phase product was not observed in this area. There is some uncertainty about groundwater flow directions in this area, although groundwater likely ultimately flows toward and discharges to the Whatcom Waterway.

The available data indicate that petroleum-contaminated soils may be leaching cPAHs and impacting groundwater quality immediately downgradient of the Tank #2 location. cPAHs and the other compounds making up heavy oil mixtures have high molecular weights and low volatility, therefore vapor-phase migration of the heavy oil and cPAHs is not expected to be a potential exposure pathway. All other pathways, including direct contact and ecological receptors pathways, are potentially complete.

7.4.5 Bunker C Tank Area

This area is located adjacent to the Whatcom Waterway at the location of a former Bunker C oil storage tank. Soil and groundwater in this area are contaminated with Bunker C and total cPAHs, and free-phase Bunker C product (NAPL) has been observed on the water table. Total cPAH concentrations in groundwater exceed preliminary groundwater screening levels. Surface water-based screening levels for petroleum mixtures like Bunker C are not available, although discharges to surface water resulting in a sheen are not allowed under the state water quality standards (Chapter 173-201A WAC).

Diesel- and cPAH-contaminated soil was also detected in one boring located at the former Bag House, approximately 50 feet northwest of the Bunker C tank. The diesel and cPAHs detected in this boring may be related to releases from the nearby former Bunker C storage tank.

Groundwater in this area is expected to flow toward and discharge to the Whatcom Waterway. In limited observations during the 2004 site investigation, petroleum sheen was not observed on the waterway adjacent to this area, suggesting that free-phase product was likely not discharging to the waterway.

Based on these data, free-phase product and Bunker C contaminated soils are impacting groundwater quality downgradient of the Bunker C Tank Area, and may have resulted in soil contamination across a larger area, potentially extending downgradient to the waterway bulkhead. Volatilization and vapor-phase migration of the heavy oil and cPAHs is not expected to be a potential exposure pathway. All other exposure pathways, including direct contact and ecological receptor pathways, are potentially complete.

7.4.6 Acid Plant Area

Groundwater samples collected from well GF-MW02, adjacent to the former Acid Plant, identified acidic groundwater (pH 3.3) and, likely as a result, concentrations of several dissolved metals above preliminary groundwater screening levels. The vapor pathway is not expected to be complete for heavy metals, apart from mercury, which has not been identified as a compound of concern within the Acid Plant Area. The remaining direct contact and ecological receptor pathways are potentially complete.

7.4.7 Stormwater Swale Area

This area consists of the stormwater drainage swale between the Chlorine Plant cell building and the BNSF railroad, which historically collected stormwater runoff from the Chlorine Plant area. Mercury concentrations of up to 530 mg/kg were detected in surface soil in this area. The data indicate that concentrations decrease rapidly with depth; soil samples collected at a 2-foot depth had mercury concentrations below 6 mg/kg. There is some uncertainty about groundwater flow directions in this area; however, 1993 groundwater elevation data indicate flow generally to the north (ENSR, 1994a). Mercury was not detected in 6 of 7 groundwater samples collected from the three closest wells located downgradient from the Stormwater Swale (Law-6, EMW-4S, EMW-6S), with a single mercury detection of 0.3 μg/L in the last of four samples collected from former well Law-6 located nearest the former Chlorine Plant.

Based on the shallow depth of mercury-impacted soil, the rapid decrease in mercury concentrations with depth, and the lack of identifiable groundwater impacts related to the Stormwater Swale soils, the soil-to-groundwater leaching pathway and the groundwater exposure pathways do not appear to be complete. The remaining pathways, including human direct contact, vapor inhalation, and ecological receptor pathways are all potentially complete.

7.4.8 Miscellaneous Pulp/Tissue Mill Areas

The previous site investigation of the Pulp/Tissue Mill identified isolated areas of soil containing TPH, total cPAHs, dioxins/furans, formaldehyde, and PCB concentrations above screening levels, in addition to those described above. Similarly, isolated groundwater monitoring locations with total cPAHs, chlorinated VOCs, and dissolved metals concentrations above preliminary groundwater screening levels were also identified. Given the collective data, these miscellaneous screening level exceedances are not identified as Site subareas for the RI/FS, but are described here for completeness.

Soil

The isolated areas of soil with constituent concentrations above screening levels include detected TPH (Bunker C) in shallow soil from boring SC-MW01 located near the former sodium bichromate tanks and away from other known TPH areas, PCBs in surface soil near one of the former electrical transformers at the former electrical substation, dioxins/furans at one location at the former Bag House, cPAHs primarily near the former Lignin Plant and Warehouse, and formaldehyde in soils adjacent the former Lignin Plant. Groundwater quality data do not show any apparent impacts related to these areas of soil contamination, which is not unexpected given Bunker C, PCBs, and cPAHs' low mobility; dioxins/furans were not analyzed for in groundwater but they have extremely low mobility. Therefore, the soil-to-groundwater leaching pathway does not appear to be complete for these constituents based on the data. The soil vapor pathway for these areas is also likely not complete, based on the low volatility of these contaminants. The apparently potentially complete pathways for these areas of soil contamination are human direct contact and terrestrial ecological receptors.

Formaldehyde concentrations detected in Site groundwater are well below the preliminary groundwater screening level, indicating the residual soil concentrations are not a significant source to groundwater. The highest observed soil concentrations occur in samples with saturated soil, so that formaldehyde would be expected to partition primarily into the groundwater (aqueous phase), rather than the vapor phase. Direct contact with soil is a potentially complete pathway.

As described in the Electrical Transformers discussion (Section 6.1.2), the marginal exceedance for total PCBs in soil is solely the result of including one-half of the elevated analytical detection limits for six of seven Aroclors in the summation. PCBs are therefore not considered a constituent of concern for soil in this area and are not carried forward in this Work Plan.

Groundwater

The chlorinated VOCs PCE and vinyl chloride were detected in groundwater at a concentration above preliminary groundwater screening levels at well LP-MW01, located at the former Lignin Plant. PCE and vinyl chloride are relatively volatile, and the groundwater to vapor inhalation pathway is potentially complete. The worker contact with groundwater and ecological receptor pathways are also potentially complete.

The metals arsenic, cadmium, chromium VI, copper, lead, nickel, and zinc were each detected in one or more Pulp/Tissue Mill area wells at dissolved concentrations exceeding preliminary groundwater screening levels. The groundwater metals exceedances appear to be at least partially related to dissolution from aquifer minerals under reducing groundwater conditions. The vapor pathway is not expected to be complete for these metals. The remaining worker contact and ecological receptor pathways are potentially complete.

8 Data Gaps and Proposed Additional Site Characterization

This section identifies gaps in information required to define the nature and extent of Site contamination in the RI, for the purpose of developing and evaluating protective and practicable remedial alternatives for the Site in the FS. Once the data gaps are identified, additional site characterization is proposed to address them. The section is organized by presenting data gaps associated with the Site subareas identified above, followed by miscellaneous areas/locations within the Pulp/Tissue Mill Area warranting collection of additional information for specific constituents. Additionally, this section presents description of a tiered assessment of stormwater conveyance systems traversing the Site. Tables 6, 7, and 8 summarize the proposed sampling and analysis by medium (groundwater, soil, soil vapor, respectively).

In general, the data gaps and additional characterization focus on contaminant transport and potential exposure via groundwater (surface water protection) and vapor pathways. Little additional information is warranted to characterize soil contamination based on potential soil direct contact exposure under future Site redevelopment scenarios. Substantial soil data already exist, and the nature and extent of soil contamination posing a potential direct contact risk under either industrial or mixed-use land uses is understood sufficiently for the purpose of evaluating Site remedial alternatives to address that potential exposure.

This section describes the sampling objectives and the rationale for the RI/FS sampling approach, based on the data gaps analysis. Note that the data collection program may be adjusted as the program progresses and additional information is collected. The work described below will be conducted in accordance with the procedures outlined in the Sampling and Analysis Plan (Appendix C) and Quality Assurance Project Plan (Appendix D) included in this RI Work Plan and prepared in accordance with the SOW for Agreed Order No. 6834.

8.1 Confirm Groundwater Flow Directions Using Existing Wells

8.1.1 Redevelop Existing Site Monitoring Wells

Aspect performed a site reconnaissance in October 2008 to locate and observe the condition of as many of the existing Site monitoring wells as possible. Considerable demolition of structures has occurred on the Site since the wells were last monitored (2004 or prior). In addition, in late 2006, monitoring wells AP-MW01 and EMW-9S were decommissioned, and protective monuments were replaced for monitoring wells EMW-1S, EMW-10S, EMW-11S, EMW-20S, and AMW-3 (RETEC, 2007b). Based on the results of the reconnaissance, Site monitoring wells that are no longer usable for future site characterization are displayed in gray (as opposed to blue for usable wells) on figures in this Work Plan.

The first task proposed for the RI is redevelopment of existing monitoring wells on the Site to ensure they are usable for their intended purposes in the RI/FS. For each existing well, we would use overpumping and gentle surging to remove sediment or scale accumulated within the well to ensure that the screen is in acceptable hydraulic connection with the water-bearing formation. Following the redevelopment effort, any well that is determined to not be in suitable condition will not be used for the RI/FS data collection. Those wells will be targeted for decommissioning in accordance with Chapter 173-160 WAC and, if warranted for the purposes of completing the Site RI/FS, replacement.

All of the usable existing monitoring wells will be surveyed by a licensed surveyor relative to a common datum (x, y, z) being used for the Whatcom Waterway cleanup work. All new monitoring wells subsequently installed for the RI will also be surveyed by a licensed surveyor relative to the same datum.

8.1.2 Determine Site-Wide Groundwater Flow Directions

After redeveloping the Site monitoring wells, one round of concurrent water level measurements will be collected from the usable existing wells, and groundwater elevations determined using the new survey information. A groundwater elevation contour map for the Fill Unit will be developed to determine groundwater flow directions across the Site, and thus confirm or revise the existing interpretations of flow direction.

With this information, the proposed new explorations described in the following subsections will be sited and utility checks conducted for each location. Consequently, exploration locations proposed in this Work Plan may be adjusted based on revisions to groundwater flow direction interpretation and/or logistical access considerations determined in this first task.

Additional groundwater elevation data will be collected during the groundwater quality sampling proposed in the following sections. Two rounds of groundwater sampling will be performed under wet and dry season conditions. A round of groundwater level measurements will be collected during each sampling event, and will include all usable existing and proposed monitoring wells.

8.1.3 Tidal Study

A 72-hour tidal study will be conducted to evaluate effects of tidal fluctuations on groundwater levels in the Fill Unit and Lower Sand and thereby assess resulting changes in groundwater flow directions throughout the tidal cycle, and to provide additional estimates of aquifer hydraulic conductivity. The tidal study will be conducted using 8 Fill Unit monitoring wells (existing wells LAW-1 and EMW-10S, and proposed wells CP-MWA3, CP-MWC3, CP-MWA1, CF-MW02, AA-MW02, AA-MW03 described in Sections 8.2, 8.3 and 8.7), as well as 3 Lower Sand wells (existing well EMW-29D and proposed wells CP-MW04 and CP-MW-05 described in Section 8.2). The list of wells may be changed based on the outcome of the well reconnaissance and redevelopment described in Section 8.1.1. Concurrent measurements of water levels wells in the Fill Unit and Lower Sand will also allow assessment of how vertical gradients between the aquifer units change with tidal fluctuation. Data logger instrumentation of the wells for the tidal study is outlined in the SAP (Appendix C).

The tidal data from each well will be analyzed using the method of Serfes (1991) to derive a tidally-averaged groundwater elevation for the study period. The data from all wells can be used to map the net (tidally averaged) groundwater flow direction and hydraulic gradients. Aquifer hydraulic conductivity will be estimated from the tidal study data using the stage ratio and time lag methods of Ferris (1963).

8.2 Caustic Plume

The following data gaps are identified for the Caustic Plume area:

1. Document the current dissolved mercury concentrations in Fill Unit groundwater. This includes evaluating potential concentration changes over time at specific wells, and defining the downgradient extent of concentrations above the groundwater screening level.
2. Better understand the fate and transport of dissolved-phase mercury, including the Fill Unit's capacity to neutralize the alkaline pH and thus presumably limit transport of mercury in the aqueous phase.
3. Confirm dissolved mercury concentrations in Lower Sand groundwater.
4. Better define the magnitude and spatial distribution of mercury concentrations in soil vapor throughout the Caustic Plume footprint.

The following subsections outline the proposed RI/FS exploration program to address these data gaps. Figure 12 shows proposed explorations for the Caustic Plume Area.

8.2.1 Distribution and Fate/Transport of Mercury in Fill Unit Groundwater

The site characterization activities proposed in the RI to address identified data gaps 1 and 2 are described below.

Thirteen new Fill Unit monitoring wells will be installed to provide, with the existing wells, a comprehensive assessment of the spatial extent of dissolved mercury, and its attenuation occurring along groundwater flow paths toward the marine water receptors. The existing wells AMW-3, EMW-19S, AMW-2, EMW-2S, and EMW-14S will be used to help document higher pH and dissolved mercury concentrations within the core of the Caustic Plume.

The new monitoring wells would include nine wells aligned along three transects extending to the west and northwest – similar to the temporary well transect approach used for the 2004 FS - to define dissolved mercury and geochemical trends with downgradient distance from the source area (denoted as Transects A through C; Figure 12). The multiple transects provide sufficient coverage to account for uncertainty associated with the current understanding of groundwater flow directions in the western area of the Caustic Plume Area.

Along each transect, the easternmost (most upgradient) new monitoring well would be installed near the extent of low-level dissolved mercury (1 to 5 µg/L) as inferred from current data (wells CP-MWA1, CP-MWB1, and CP-MWC1). On each transect, a shoreline monitoring well will be installed adjacent to Bellingham Bay (CP-MWA3, CP-MWB3, and CP-MWC3) to document groundwater quality near the point of compliance for surface water protection. An intermediate-distance well will be installed along each of the three transects (CP-MWA2, CP-MWB2, and CP-MWC2).

In addition to the wells on these transects, four new Fill until monitoring wells will be installed. Monitoring well CP-MW01 would be installed to document mercury concentrations along the southwestern corner of the Caustic Plume. Monitoring wells CP-MW02 and CP-MW03 would be installed along the northern side of the Plume, providing intermediate points upgradient of existing wells AMW-1 and Law-MW1 along the Log Pond shoreline. Monitoring well CP-MW06 will be installed to provide an additional groundwater monitoring point near the inferred core of the caustic plume.

At the new Fill Unit monitoring well locations, one sample of saturated soil from within the screened interval depth of the monitoring well will be analyzed for total mercury. One sample of unsaturated soil from borings CP-MWA1, -MWA2, -MWB1, -MWB2, -MW-C1,–MWC2, and –MW06 will also be analyzed for total mercury to further characterize the distribution of mercury in soils that may represent a source of leachable mercury to groundwater, and to allow for correlation of soil mercury concentrations and soil vapor mercury concentrations (described in Section 8.2.3).

The thirteen new monitoring wells and twelve existing monitoring wells (AMW1, Law-1, EMW-14S, EMW-2S, AMW-2, EMW-19S, AMW-3, EMW-1S, EMW-4S, EMW-15S, EMW-7S, and EMW-8S) in the Fill Unit will be sampled twice (dry and wet seasons) for dissolved mercury and field parameters pH, DO, Eh, temperature, and electrical specific conductance to define current magnitude and distribution of groundwater pH and dissolved mercury. The data from existing wells will also provide evaluation of groundwater quality changes occurring over the past 15 years.

In addition, supplemental geochemical analyses of saturated Fill Unit soil (aquifer matrix) and groundwater along the Transects A, B, and C will provide data to evaluate the fate and transport characteristics of mercury from the Caustic Plume source area to downgradient locations along a presumed reaction path. A reaction path represents the chemical reactions that occur as groundwater and soil interact to bring the system towards chemical equilibrium. The reaction path can involve precipitation of minerals from solution, dissolution of mineral phases, exchange of gases, adsorption, etc. The conceptual site model involving the mercury reaction paths can be refined using known equilibrium relationships in geochemical modeling.

The field data collection for defining the current equilibrium state of the system, and refining the conceptual site model of the reaction path, would involve analyzing the two rounds of groundwater samples from a series of wells for a suite of general water quality parameters including major cations, major anions, alkalinity, redox pairs (e.g., sulfate/sulfide) and total dissolved solids. The additional water quality analyses will be conducted for samples from the nine new transect monitoring wells, new well CP-MW06 and existing wells EMW-14S, EMW-2S, AMW-2, EMW-19S, AMW-3 within the apparent core of the plume, as well as new well CP-MW03 and existing well Law-1 aligned along a potential northern groundwater flowpath toward the Log Pond.

In addition, one sample of saturated Fill Unit soil from four borings positioned along the inferred plume centerline will be collected for mineralogical evaluations using x-ray diffraction, and potentially optical microscopy and scanning electron microscopy techniques. Samples of saturated soil (aquifer matrix) from each new boring in the Caustic Plume area will be archived until the new soil data and wet-season groundwater data (primarily mercury and pH) are evaluated. Field screening measurements of soil pH will also be conducted on samples of saturated soil to assist with the sample selection. Once the collective data are available and the conceptual model of the caustic plume distribution is refined, the four samples of aquifer matrix material will be selected for mineralogic analysis. The purposes of the solid phase mineralogic data would be to:

- Identify the framework mineralogy of the fill material in contact, and interacting, with Site groundwater;
- Identify minerals that may dissolve or precipitate along the reaction path; and
- Identify if textural relationships exist that would indicate surface complexation and exchange mechanisms are important in either limiting the neutralization capacity of the fill materials, or limiting the solubility of mercury.

Hydraulic conductivity testing (slug testing) will be performed in each of the nine new transect monitoring wells to provide additional hydraulic conductivity estimates for the Fill Unit aquifer, specifically for this western area where such data are currently lacking. These data will be used to refine estimates of groundwater velocity, and thus advective transport of dissolved mercury in groundwater in this subarea.

As a component of the FS, the collective geochemical data can be used in computer-based geochemical modeling, using the United Stated Geological Survey (USGS)-developed code PHREEQC (Parkhurst and others, 2008), to identify the important reactions that occur along a groundwater flowpath that could potentially neutralize the alkaline plume and limit the solubility of mercury. The results of modeling can be used to make inferences concerning neutralization capacity of the Fill Unit soils at the Site compared to the amount of apparent source material associated with the mercury plume, and provide an indication of the ability of Fill Unit materials to naturally attenuate the plume as it moves toward surface water discharge areas. The results of the modeling can also be used to test potential remedial technologies in a desktop setting, including:

- Injection of neutralizing agents in liquid form to the source area;
- Passive interaction with solid materials in a reactive barrier wall, or funnel and gate system; and/or
- Combinations of the two above.

These technologies would be evaluated using irreversible reactions in PHREEQC such as mixing solutions and adding fixed amounts of reactants to the source solutions. The calculations will provide an indication of the amount of reactant required to neutralize the solution, and will also provide an indication of the solubility and speciation of mercury in the final phase assemblage under different scenarios. The results of the calculations can also be used as an aid in designing potential laboratory and field scale pilot testing for remediation of the Caustic Plume. Depending on the results of the RI evaluation, such testing could be conducted during the FS, if there is sufficient uncertainty on specific technologies, or potentially deferred until the remedial design phase.

8.2.2 Lower Sand Soil and Groundwater Quality

ENSR (1994a) installed three deep monitoring wells, EMW-28D, -29D, and -30D, screened within the Lower Sand. Of those, well EMW-30D, located northeast of the former Chlorine Plant near the Log Pond, could not be located in the field during our October 2008 reconnaissance. Wells EMW-28D located north of the former mercury cell building, and EMW-29D located north of the former Chlorine Plant just upgradient of the Log Pond, appear to be in usable condition.

Two new Lower Sand monitoring wells, CP-MW04 within the Caustic Plume core adjacent to the former 72 Catch Basin hot spot, and CP-MW05 in the footprint of the former wastewater settling basin (Figure 12), will be installed to evaluate potential for downward migration of mercury from the Fill Unit through the Tidal Flat Aquitard into the Lower Sand. Soil samples will also be collected from each deep boring to provide a detailed vertical profile of mercury concentrations in soil through the Fill Unit, Tidal Flat Aquitard, and into the Lower Sand.

The new deep wells will be drilled by specialized methods, including use of a conductor casing to seal off the Fill Unit, to limit the chance for contaminant carry down during drilling through the aquitard, as detailed in the SAP (Appendix C).

Total drilling depth for wells CP-MW04 and CP-MW05 is expected to be about 40 feet bgs. In both borings, split-spoon samples will be collected at 5-foot intervals during hollow-stem auger drilling of the upper 20 feet (the expected drilling depth of the conductor casing). While drilling below the conductor casing bottom using a sonic drill rig, continuous soil cores will be recovered at 4 foot intervals to the final drilling depth. One soil sample will be collected from each split-spoon sample (e.g., 2.5 to 4 feet, 7.5 to 9 feet, etc.) and from a one-foot interval of each recovered 4-foot core (e.g., 2 to 3 feet, 6 to 7 feet, etc.) for analysis of total mercury. Based on the expected total drilling depth and sampling interval, this will result in collection of nine soil samples for total mercury analysis from both deep borings.

For each deep boring, drilling will be stopped at the 40-foot depth while rush-turnaround mercury analyses are conducted for the bottom soil sample collected (38 to 39 foot depth). The lab results will determine whether to continue drilling and soil sampling deeper (if total mercury concentration is above 5 mg/kg) or install the monitoring well (if total mercury concentration is at or below 5 mg/kg).

The two new Lower Sand monitoring wells CP-MW04 and CP-MW05, and existing Lower Sand well EMW-28D located on the north side of the mercury cell building, will be sampled for dissolved mercury and field parameters during the wet and dry season groundwater sampling rounds. Existing Lower Sand monitoring well EMW-29D, located northeast of the Caustic Plume, is being sampled as part of the Chemfix/Nearshore

Confined Fill Area (Section 8.3), but the data can be of use for both areas. Hydraulic conductivity testing (slug testing) will also be performed in new wells CP-MW04 and CP-MW05 to provide additional hydraulic conductivity estimates and refine estimates of groundwater flow rates for the Lower Sand aquifer.

8.2.3 Mercury in Soil Vapor

The 2003 data from boring AS-3, advanced in the 72 Catch Basin area where the highest soil mercury has been detected, indicate localized soil vapor mercury concentrations well above the 1.4 $\mu g/m^3$ air screening level. Additional soil vapor mercury measurements are required to better define the distribution of mercury concentrations in soil vapor throughout the Caustic Plume footprint.

Soil vapor samples will be collected from ten boring locations in and around the Caustic Plume expected to span an expected range of soil and groundwater mercury concentrations: CP-MWA1, CP-MWB1, CP-MWC1, CP-MWA2, CP-MWB2, CP-MWC2, CP-MW01, CP-MW02, CP-MW03, and CP-MW06.

Soil vapor from each of the boring locations will be analyzed for both elemental and total mercury, using similar sampling and analysis methods to those employed during the RI Addendum (Anchor Environmental, 2003b). Because the mercury vapor sampling procedure can last hours at each location, the vapor samples will be collected from a soil gas probe advanced in a separate borehole located within approximately 3 feet of the soil boring/monitoring well location where corresponding soil and groundwater data will be collected. The soil vapor probes will be installed to a depth of 1.5 feet, with a short gas intake at the bottom. The surface penetration will be sealed with bentonite slurry to limit intrusion of atmospheric air into the soil gas sample. Vapors will be pulled by a low-flow vacuum pump through dedicated Teflon tubing to mercury collectors. Elemental mercury concentrations will be measured in the field using the Lumex RA-915+ field analyzer. Total mercury will be sampled using a modification of EPA Method 30B, involving pumping soil vapor through a chemically impregnated carbon sorbent trap for up to 16 hours (overnight) and analyzing the sorbent trap in the laboratory using EPA Method 1631.

The soil vapor mercury concentrations will be correlated with concentrations of mercury detected in soil and groundwater at the corresponding explorations.

8.3 Chemfix and Confined Nearshore Fill Areas

The identified data gap for the Confined Nearshore Fill area (includes the Chemfix area) is documenting current dissolved mercury concentrations to assess groundwater quality and potential contaminant transport to surface water. The existing data document mercury soil vapor concentrations from the Chemfix material below the air screening level, so this is not an exposure pathway of concern.

The following subsection outlines the proposed RI/FS exploration program to address these data gaps. Figure 13 shows proposed explorations for the Chemfix and Confined Nearshore Fill Areas.

The existing data for the Chemfix material indicate variable total mercury concentrations, which, based on the 2003 composite sampling, average about 10 mg/kg. Soil mercury concentrations above 24 mg/kg within the rest of the Confined Nearshore Fill are generally limited to the area of the former wastewater settling basin. Leachability testing in which the Chemfix material is leached using Site groundwater in the range of pH 6 to 7 (typical of conditions surrounding the Chemfix Area) indicates leachable mercury up to 0.2 µg/L based on the 2003 composite sample, but up to 3.2 µg/L for a 1993 grab sample that contained 2,500 mg/kg total mercury (ENSR, 1994a; Anchor Environmental 2003b).

To supplement existing groundwater and leachability testing data, current groundwater quality will be assessed using appropriately located monitoring wells. The fill materials (including dredged materials and the Chemfix material) have now been in place for more than 30 years, providing sufficient time to assess long-term response of groundwater quality to the presence of the fill materials. During the 1993 RI groundwater sampling, dissolved mercury was not detected in any of the monitoring wells located within the Confined Nearshore Fill area, downgradient of the Chemfix area (EMW-7S, EMW-8S, EMW-9S, EMW-10S, EMW-20S).

For the RI, two new monitoring wells (CF-MW01 and CF-MW02) will be installed in the Fill Unit immediately downgradient of the Chemfix Area (Figure 13). Two rounds of groundwater samples (wet and dry seasons) will be collected from the new wells CF-MW01 and CF-MW02, and existing wells EMW-7S, EMW-8S (already proposed for sampling for the Caustic Plume), EMW-20S, EMW-10S, as well as existing Lower Sand well EMW-29D, and will be analyzed for dissolved mercury and field parameters.

8.4 Laurel Street Pipe Rack

Mercury-contaminated soil exists at the Laurel Street Pipe Rack area, likely as a result of unauthorized disposal of mercury-containing debris from the former Chlorine Plant. The available information indicates elevated soil mercury concentrations exist within a relatively localized area and at a depth accessible by a conventional excavator. Therefore, soil excavation and off-site disposal is a possible cleanup approach for this area. Long-term groundwater sampling at monitoring well EMW-13S, located near the center of the impacted soil area, indicates declining groundwater mercury concentrations over time.

The following data gaps are identified for the Laurel Street Pipe Rack area:

1. Better document the lateral and vertical extent of elevated soil mercury concentrations, to allow refined evaluation of soil volumes requiring cleanup. Boring AS-10 had the highest soil mercury concentration in the 7.5- to 10-foot sample, with no deeper samples collected. In the EMW-13S boring, 58 mg/kg mercury was detected in the 10- to 11.5-foot soil sample, and 2.8 mg/kg mercury was detected in the 15- to 16.5-foot soil sample.

2. Document a TCLP mercury concentration for the impacted soil to confirm whether it might designate as characteristic dangerous waste, if excavated.

3. Document the current dissolved mercury concentrations in Fill Unit groundwater within and immediately downgradient of the impacted soil area.

The elevated soil mercury concentrations might generate soil vapor mercury concentrations of concern in this hot spot area, but remedial measures to address direct contact and soil leaching pathways are expected to adequately address vapor, so no additional characterization of mercury soil vapor is proposed at this time. The following subsections outline the proposed RI/FS exploration program to address these data gaps. Figure 14 shows proposed explorations for the Laurel Street Pipe Rack area.

8.4.1 Extent of Soil Mercury Impacts

Five direct-push soil borings will be advanced to depths of 20 feet, around the perimeter of the inferred area of mercury-impacted soil (PR-MW01 and PR-SB02 through PR-SB05; Figure 14). In each boring, five soil samples will be collected for total mercury analysis from depth intervals of approximately 1 to 2, 5 to 6, 9 to 10, 13 to 14, and 17 to 18 feet bgs, or as sample recovery allows. The soil borings in this area will be done early in the field program, and the soil samples will be submitted for rush turnaround lab analyses, so that additional borings can be conducted if needed to bound the extent of soil mercury above screening levels. If two or more soil samples contain total mercury concentrations above 24 mg/kg, the two soil samples with highest total mercury detections will also be submitted for TCLP mercury analysis.

8.4.2 Mercury Concentrations in Groundwater

The existing data indicate that elevated soil mercury concentrations occur somewhat downgradient (north) of existing monitoring well EMW-13S (e.g., at boring AS-10). Soil boring PR-MW01, located on the northern edge of the inferred area of soil impact, will therefore be completed as a monitoring well to document the immediately downgradient groundwater quality. Two rounds of groundwater samples (wet season and dry season) will be collected from wells EMW-13S and PR-MW01 for analysis of dissolved mercury and field parameters.

8.5 Million Gallon Tanks Area

Minor Bunker C contamination was detected in soils around the Million Gallon Tank #2 (Bunker C storage) during 2004 soil borings drilled in accessible locations when the Tanks were in place. Outside of the 2007 independent soil cleanup area, minor apparent petroleum staining, odor, and/or sheen was reported in test pits TP-2, TP-3, TP-9, and TP-10. Since that 2007 cleanup effort, the Tanks have been demolished.

The following data gaps are identified for the Million Gallon Tanks Area:

1. Better document the lateral and vertical extent of TPH and associated cPAHs in soils around Tank 2, to allow evaluation of soil volumes potentially requiring cleanup.
2. Calculate a Site-specific risk-based TPH concentration protective of groundwater quality and direct contact under unrestricted and industrial Site uses.
3. Determine the lateral extent of petroleum hydrocarbons in groundwater adjacent to the Tanks.

The following subsections outline the proposed RI/FS exploration program to address these data gaps. Figure 15 shows proposed explorations for the Million Gallon Tanks Area.

8.5.1 Extent of Soil Petroleum Impacts

Seven soil borings (MG-SB04 through –SB10) will be advanced surrounding and in the center of the Former Tank 2, and on the east side of Tank 1 where some visual evidence of petroleum was noted in the 2007 test pits (Figure 15). Four soil samples will be collected from each boring, one at a depth of approximately 1 to 2 feet, the second straddling the water table observed at the time of drilling, and the third and fourth approximately 3 to 4 feet and 6 to 7 feet below the water table, respectively. If the water table is observed shallower than 3 feet during drilling, one sample will be collected to straddle the water table and the second and third samples approximately 3 and 6 feet deeper, respectively. If the Tidal Flat Aquitard is encountered, a sample can be collected to straddle its contact with the Fill Unit. The soil samples will be analyzed for diesel- and oil-range petroleum hydrocarbons and PAHs.

8.5.2 Risk-Based Petroleum Concentrations

Two soil samples from the new borings containing higher concentrations of TPH will be submitted for extractable petroleum hydrocarbons (EPH) analysis, to allow for calculation of risk-based soil cleanup levels based on direct contact and leaching to groundwater, in accordance with MTCA, using Ecology’s MTCATPH spreadsheet, in accordance with MTCA (WAC 173-340-740(3)(b)(iii)(B)(III); WAC 173-340-745(5)(b)(iii)(B)(III); WAC 173-340-900 Table 830-1).

8.5.3 Extent of Groundwater Impacts

Two rounds of groundwater sampling (wet season and dry season) will be conducted at existing monitoring wells MG-MW01 (immediately downgradient of former Tank #2), EMW-12S and EMW-6S (located east and west, respectively, of the former Tanks), and EMW-16S (located north-northeast of the former tanks), as well as proposed new monitoring wells CF-MW01 and CF-MW02 located on the downgradient edge of the Chemfix Area (Figure 15). If separate-phase petroleum product is observed in a monitoring well during sampling, a groundwater sample will not be collected, but thickness of the product accumulation will be measured. If no separate-phase product is observed in a monitoring well, a groundwater sample will be collected from it for analysis of diesel- and oil-range petroleum hydrocarbons, PAHs, total suspended solids (TSS), and field parameters.

8.6 Bunker C Tank Area

Bunker C contamination, including separate-phase product on the water table, exists in the Bunker C Tank Area adjacent to the Whatcom Waterway. The Bunker C contamination appears limited in depth to approximately the seasonally low water table, but may have spread laterally to the northeast and northwest up to the waterway bulkhead.

The following data gaps are identified for the Bunker C Tank-Clarifier Area:

1. Better document the lateral extent of Bunker C and associated cPAHs in soil, to allow refined evaluation of soil volumes requiring cleanup.
2. Calculate a Site-specific risk-based concentration for the Bunker C protective of groundwater quality and direct contact under unrestricted and industrial Site uses.
3. Confirm the lateral extent of separate-phase and dissolved-phase petroleum hydrocarbons in groundwater.
4. Assess geotechnical and structural (bulkhead) considerations for conducting soil excavation immediately adjacent to the waterway, if necessary.

The following subsections outline the proposed RI/FS exploration program to address these data gaps. Figure 16 shows proposed explorations for the Bunker C Tank Area.

8.6.1 Extent of Soil Impacts

Seven soil borings, two completed as monitoring wells, will be advanced in the Bunker C Tank Area to define lateral extents of Bunker C contamination in soil and groundwater.

The two monitoring wells would be installed to document groundwater quality along inferred locations of Fill Unit groundwater discharge to the waterway: BC-MW02 just northwest of the former Bunker C tank and BC-MW03 east-northeast of it (Figure 16).

From those two borings, and from the five borings BC-SB03 through BC–SB07, four soil samples would be collected from depths of approximately 4 to 5 feet; straddling the water table (e.g. 8 feet bgs at BC-MW01 in 2004) or, if observed, smear zone above the water table; 3 to 4 feet below the water table; and 6 to 7 feet below the water table or straddling the contact of the Tidal Flat Aquitard if encountered. Borings BC-SB03, -SB04, and -SB05 are intended to define the western, southern, and eastern extents of Bunker C contamination in soil around the former tank. Because these borings are intended to find the lateral extent of soil contamination, they will be relocated farther from the tank, for soil sampling, if gross contamination is observed at the proposed locations. Borings BC-SB06, BC-SB07, BC-MW02, and BC-MW03 provide soil quality data along the shoreline (Figure 16). The soil samples would be analyzed for diesel- and oil-range petroleum hydrocarbons and PAHs.

8.6.2 Risk-Based Petroleum Concentrations

Two soil samples from the new borings containing moderate to higher concentrations of Bunker C contamination will be submitted for extractable petroleum hydrocarbon (EPH) analysis, to allow for calculation of risk-based soil cleanup levels based on direct contact and leaching to groundwater, using Ecology’s MTCATPH spreadsheet.

8.6.3 Extent of Groundwater Impacts

Two rounds of groundwater sampling (wet season and dry season) will be conducted at monitoring wells BC-MW01, BC-MW02, and BC-MW03. If separate-phase petroleum product is observed in a monitoring well during sampling, a groundwater sample will not be collected, but thickness of the product accumulation will be measured. If no separate-phase product is observed in a monitoring well, a groundwater sample will be collected from it for analysis of diesel- and oil-range petroleum hydrocarbons, PAHs, total suspended solids (TSS), and field parameters.

8.6.4 Geotechnical/Bulkhead Structural Evaluation

Shoreline geotechnical work completed in support of the ongoing Whatcom Waterway remedial design work will be used as appropriate to assess geotechnical and/or bulkhead issues that may affect cleanup approach for the Bunker C area. This information would be factored into the development and evaluation of remedial alternatives in the FS.

8.7 Acid Plant Area

A single round of groundwater sampling in 2004 documents low pH and concentrations of various dissolved metals above preliminary groundwater screening levels in two monitoring wells: GF-MW02 with pH 3.3 located adjacent to the former Acid Plant, and FH-MW01 with pH 4.1 located roughly 270 feet downgradient. The low pH in this area may be exacerbating metals mobility within the reducing groundwater. Metals exceedances were not detected in the existing monitoring wells located further downgradient, along the waterway shoreline, suggesting the dissolved metals may be attenuating prior to discharge to the waterway.

The following data gaps are identified for the Acid Area:

1. Better document the lateral extent and potential seasonal fluctuation of the low pH and dissolved metals concentrations in groundwater to the north, along the shoreline, and on the east where the former Tissue Mill buildings prevented installation of monitoring wells during the Phase 2 ESA.
2. Document whether soils in the former Acid Plant area represent a potential ongoing source of acidity to the Fill Unit groundwater.
3. Better understand the fate and transport of dissolved-phase metals, including the Fill Unit’s capacity to neutralize the acidic pH and thus presumably limit transport of metals in the aqueous phase.

The following subsections outline the proposed RI/FS exploration program to address these data gaps. Figure 17 shows proposed explorations for the Acid Area.

8.7.1 Extent of Low pH/Dissolved Metals in Groundwater

Five new monitoring wells (AA-MW01 through AA-MW05; Figure 17) will be installed to define the lateral extent of low pH and associated dissolved metals in groundwater in this area. Wells AA-MW01 and AA-MW02 will be installed along the waterway shoreline to assess dissolved metals concentrations approaching discharge to surface water. Wells A-MW03 and AA-MW05 are intended to define the eastern and western extents of the low pH groundwater. Well AA-MW04 will be installed to define groundwater conditions within the footprint of the former Acid Plant.

The five new monitoring wells and existing wells GF-MW01, FH-MW01, GF-MW02, LB-MW01, TS-MW01, and proposed new well BC-MW02, will be sampled twice (wet and dry seasons) for dissolved metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc) and field parameters including pH. Dissolved iron and manganese do not exceed groundwater screening levels, but will be analyzed to provide additional information on geochemical conditions.

8.7.2 Source Area Assessment

To assess whether soils within the former Acid Plant Area represent a potential ongoing source of acidic leaching, four soil samples will be collected during drilling of AA-MW04, located within the footprint of the former Acid Plant Area (Figure 17). Two soil samples will be collected at depth intervals above the water table observed at time of drilling (e.g., 1 to 2 and 4 to 5 feet), one will be collected just below the water table (e.g., 7 to 8 feet), and one will be collected approximately 3 feet below the water table (e.g., 10 to 11 feet). Each soil sample will be analyzed for soil pH and total metals (arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc). During drilling, we will observe for evidence of acidic discharge (e.g., soil bleaching or deterioration).

8.7.3 Fate/Transport of Dissolved Metals

Supplemental geochemical analyses will provide data to evaluate the fate and transport characteristics of metals from the Acid Plant Area to downgradient locations along a presumed reaction path. This would involve analyzing the two rounds of groundwater samples from selected monitoring wells AA-MW04, GF-MW02, FH-MW01, AA-MW01, and AA-MW02 for a suite of general water quality parameters including major cations, major anions, alkalinity, redox pairs, and total dissolved solids.

If warranted in the FS, the collective geochemical data could be used in computer-based geochemical modeling, using the USGS developed code PHREEQC (Parkhurst and others, 2008), to identify the important reactions that occur along a groundwater flowpath that could potentially neutralize the acidic plume and limit the solubility of dissolved metals. The results of modeling can be used to make inferences concerning neutralization capacity of the Fill Unit soils at the Site, and provide an indication of their ability to naturally attenuate the plume as it moves toward surface water discharge areas.

8.8 Data Gaps for Pulp/Tissue Mill Miscellaneous Areas

This section outlines additional data collection proposed to further assess the nature and extent of miscellaneous contaminants observed in soil or groundwater within the Pulp/Tissue Mill Area.

8.8.1 Chlorinated Solvents at Well LP-MW01 (Lignin Plant)

Groundwater from well LP-MW01 will be sampled twice (dry and wet seasons) for VOCs, which includes the chlorinated solvent VOCs previously detected above preliminary groundwater screening levels. The dry season sample will be collected during the first round of site-wide groundwater level measurements (see Section 8.1.2), prior to the start of other soil and groundwater quality sampling activities at the site. If chlorinated solvents are detected in this well at concentrations above preliminary groundwater screening levels, additional soil and groundwater sampling will be performed to delineate the extent of chlorinated solvent impacts near the Lignin Plant. Wet season groundwater sampling of well LP-MW01 will be performed regardless of the results of the dry season groundwater sampling.

If additional characterization is warranted, six direct-push borings would be advanced in the vicinity of well LP-MW01. Two borings would be located generally upgradient and four borings would be located generally downgradient of well LP-MW01, determined after site-wide groundwater flow directions have been reevaluated. Three soil samples would be collected from each boring, one at a depth of 1 to 2 feet, one straddling the water table at time of drilling, and one from approximately 3 to 4 feet below the water table. This sampling scheme can be adjusted, and deeper sampling conducted, if warranted based on field screening (e.g., PID) information. One groundwater grab sample would also be collected from each boring as a screening tool for groundwater quality. Soil and groundwater samples would be analyzed for VOCs, including chlorinated solvents.

If the direct-push boring investigation indicates the presence of a chlorinated solvent plume in this area, three permanent monitoring wells would be installed and sampled for VOCs during the dry and wet season. The locations of monitoring wells would be determined in consultation with Ecology. In addition, two soil vapor samples would be collected to assess the potential for chlorinated solvents in groundwater to impact indoor air under future land use scenarios. The soil vapor samples would be collected at locations with the highest detected total chlorinated solvent concentrations based on the soil and groundwater grab sampling, and would be analyzed for VOCs.

8.8.2 Groundwater Metals Exceedances Outside Subareas

One or more dissolved metals (arsenic, copper, and nickel) were detected in groundwater samples from five wells at concentrations exceeding respective preliminary groundwater screening levels. These wells (EMW-12S, EMW-16S, LP-MW01, LW-MW01, and SC-MW02) are located outside the subareas discussed previously for which groundwater quality sampling and analysis for metals are proposed (e.g., the Acid Area). In addition, dissolved hexavalent chromium was reported in the EMW-16S sample at a concentration approaching its groundwater screening level, but the result is suspected as an analytical artifact (Section 6.2.2). To verify the dissolved metals concentrations for the purpose of assessing protection of surface water, wells EMW-12S, EMW-16S, LP-MW01, LW-MW01, and SC-MW02 will be sampled twice (wet and dry seasons) for dissolved metals (arsenic, cadmium, chromium III, chromium IV, copper, lead, mercury, nickel, and zinc) and field parameters.

8.8.3 Analyses for Dioxins/Furans in Soils

The available Site data indicate the potential for concentrations of dioxins/furans in Fill Unit soil at concentrations above the unrestricted soil screening level. The Site data indicate concentrations below the industrial soil screening level, so a high concentration source is not apparent. To further assess the extent and range of concentrations in soil, three additional soil samples will be analyzed for dioxins/furans.

To help bound the extent of dioxins/furans detected at existing boring BH-SB02, analysis for dioxins/furans will be added for the 4- to 5-foot soil sample proposed from soil boring BC-SB03, located approximately 80 feet southeast of BH-SB02 (Figure 16). To provide a geographic distribution of analyses across the Site, dioxins/furans analyses will also conducted for 4- to 5-foot soil samples collected from proposed boring PR-MW01 on the north side of the Laurel Street Pipe Rack area (Figure 14) and boring CP-MW03 on the north side of the Caustic Plume (Figure 12).

8.9 Stormwater Conveyance Evaluation

The Site includes operational and historical stormwater outfalls. Notably, the City of Bellingham's Laurel Street stormwater pipe conveys off-Site stormwater across the Site, beneath Laurel Street, to a City outfall at the waterway. A subsurface pipe conveys Site stormwater along the same general alignment beneath Laurel Street, but at shallower depth (on top of the City's pipeline), to a pump station at the waterway. From the pump station, the Site stormwater is pumped beneath the waterway to the Aerated Stabilization Basin for permitted treatment and discharge. Where the conveyance system occurs below the water table, permeable pipe bedding and backfill surrounding the pipe can provide a preferential conduit for groundwater flow.

The Port is in process of mapping the existing stormwater catch basins and conveyance system at the Site, and surveying their invert elevations. From this information, pipes generally below the water table can be mapped. Using the mapping/survey information, the RI will include a tiered assessment of stormwater conveyance system as potential preferential conduits for groundwater transport to the waterway. The tiered assessment is as follows:

- The first tier of the assessment will be field observations of stormwater catch basins and/or outfalls that are fed by on-Site pipelines positioned at or below the dry season water table. Flow from the outfalls during the dry season, when there has been no appreciable precipitation for the preceding week or more, is likely attributable to groundwater inflow;
- If such flow is confirmed, the second tier will be to measure flow volumes (cubic feet per second) at accessible upstream and downstream points in the pipeline to estimate gain or loss of flow across the pipe length, attributable to inflow from groundwater or outflow to groundwater; and
- If groundwater inflow is indicated, the third tier will include sampling and analysis of water in the pipe at accessible upstream and downstream points along the pipeline. If sufficient pipe flow exists, upstream and downstream samples will be collected at two times, for analysis of total and dissolved metals, diesel- and oil-range TPH, SVOCs, and TSS. The data will be evaluated against surface water criteria, and, assuming groundwater inflow/outflow is indicated for a pipeline(s), will be compared to groundwater quality data from nearby monitoring wells. A specific plan regarding sampling locations, methods, and analyses would be discussed with Ecology prior to conducting the sampling.

9 References

AECOM-Environment, 2009, Remedial Investigation/Feasibility Study, Central Waterfront Site, Bellingham, Washington, Ecology review draft, in preparation.

Anchor Environmental, 2000, Engineering Design Report, Interim Remedial Action, Log Pond Cleanup/Habitat Restoration, Whatcom Waterway Site, Bellingham, Washington, July 2000.

Anchor Environmental, 2001a, Georgia Pacific West, Inc. Former Chlor-Alkali Facility, Supplemental Remedial Investigation/Feasibility Study Work Plan/Sampling and Analysis Plan.

Anchor Environmental, 2001b, Year 1 Monitoring Report, Operations, Maintenance And Monitoring Plan, Interim Remedial Action, Log Pond Cleanup/Habitat Restoration, Bellingham, Washington, December 2001.

Anchor Environmental, 2003a, Soil Assessment – RI/FS Addendum Work Plan/Sampling and Analysis Plan, Georgia Pacific West, Inc. Former Chlor-Alkali Facility, Bellingham, Washington, April 2003.

Anchor Environmental, 2003b, Soil Assessment – Data Report, Remedial Investigation/Feasibility Study Addendum, Georgia Pacific West, Inc. Former Chlor-Alkali Facility, Bellingham, Washington, October 2003.

Anchor Environmental, 2004, Sampling and Analysis Plan, Focused Groundwater Characterization, Former Chlor-Alkali Facility Feasibility Study, Georgia Pacific West, Inc., Bellingham, Washington, April 2004.

Anchor Environmental, 2008a, Former Chlor-Alkali Cell Building Pre-Demolition Sampling, Results of Building Materials Mercury Testing, January 14, 2008.

Anchor Environmental, 2008b, Review of Scientific Literature and Recommended Surface Water Screening Level for Formaldehyde – Mill Site RI/FS, December 10, 2008, Included as Appendix A to this Work Plan.

Anchor Environmental and Hart Crowser, 2000, Final Remedial Investigation/Feasibility Study, Whatcom Waterway Site, Bellingham, Washington, July 25, 2000.

Aspect, 2004a, Draft Feasibility Study, Former GP Chlor/Alkali Facility, Bellingham, Washington, Agency Review Draft, Prepared in association with Anchor Environmental, July 19, 2004.

Aspect, 2004b, Phase 2 Environmental Assessment, Georgia-Pacific Bellingham Operations, September 3, 2004.

Aspect, 2009, RI/FS Scoping Plan, Former GP Mill Property, Bellingham, Washington, February 17, 2009.

Cappon, C. J., 1987, “Uptake and Speciation of Mercury and Selenium in Vegetable Crops Grown on Compost-Treated Soil”, Water, Air and Soil Pollution, 34:353-361.

Ecology, 2004, Letter from Paul Skillingstad to Chip Hilarides, Georgia-Pacific, regarding review of Draft Soil Assessment Data Report, Remedial Investigation, Feasibility Study Addendum for the former Chlor-Alkali Plant, January 20, 2004.

ENSR, 1993, 72 Catch Basin and Cell Building Draft Cleanup Report, June 1993.

ENSR, 1994a, Chlorine Plant Remedial Investigation, Georgia-Pacific Corporation, Bellingham, Washington, July 1994.

ENSR, 1994b, Chlorine Plant Feasibility Study, Georgia-Pacific Corporation, Bellingham, Washington, ENSR 3060-023-520.

EPA, 1997, Report to Congress Volume III: Fate and Transport of Mercury in the Environment, EPA-452/R-97-005, Office of Air Quality Planning & Standards and Office of Research and Development.

EPA, 2002, OSWER Draft Guidance for Evaluating the Vapor Intrusion to Indoor Air Pathway from Groundwater and Soils (Subsurface Vapor Intrusion Guidance), EPA530-D-02-004, November 2002.

Ferris, J.G., 1963, Cyclic Water-Level Fluctuations as a Basis for Determining Aquifer Transmissibility, in Methods of Determining Permeability, Transmissivity, and Drawdown, USGS Water Supply Paper 1536-I, pp. 305-318.

Foster Wheeler Environmental Corporation, 2000a, Georgia-Pacific West Inc. Bellingham Site Chlor/Alkali Facility Demolition Plan, May 2000.

Foster Wheeler Environmental Corporation, 2000b, Georgia-Pacific West Inc. Bellingham Site Chlor/Alkali Facility Demolition Completion Report, December 2000.

GeoEngineers Inc., 2007, Geotechnical Engineering Services, City of Bellingham Railroad Relocation Feasibility Analysis Project, Bellingham, Washington, July 17, 2007. Appendix D to Washington State, Bellingham Waterfront Rail Relocation Project, Final Report, prepared by HDR Inc., October 2007.

Georgia Pacific Inc. (GP), 1998, Chlorine Plant Excavation Project, July 31, 1998.

KPFF Engineers, 2008, New Whatcom Redevelopment Project, Storm Drainage Concept Report, September 2008 Final Report.

Law Environmental, Inc., 1992, Soil and Ground-Water Preliminary Site Assessment Report, Georgia-Pacific Corporation Chlor/Alkali Plant, Bellingham, Washington, September 3, 1992.

Law/Crandall Inc., 1993, Site Assessment and Mercury Vapor Monitoring, Laurel Street Pipe Rack Excavation and Pipeline Trench Area, Georgia-Pacific Corporation, Bellingham, Washington, January 11, 1993.

Myers, T.E., J.M. Brannon, B.A. Tardy, D.M. Townsend, 1996, Leachate Testing and Evaluation for Estuarine Sediments, Prepared for US Army Corps of Engineers, Technical Report D-96-1, March 1996.

Palermo, M., Maynord, S., Miller, J., and Reible, D., 1998, "Guidance for In-Situ Subaqueous Capping of Contaminated Sediments," EPA 905-B96-004, Great Lakes National Program Office, Chicago, Illinois.

Parkhurst, D.L., Appello C.A.J., 2008, PHREEQC for Windows version 2.15.06, September 22, 2008.

RETEC, 2001, Remedial Investigation/Feasibility Study, Roeder Avenue Landfill.

RETEC, 2007a, Oversight and Soil Sampling – Test Pit Investigation and Limited Removal of Petroleum Contaminated Soil – Tank Farm at Former GP Chlor-Alkali Facility – Bellingham, Washington, March 2, 2007.

RETEC, 2007b, Groundwater Monitoring Well Repair and Abandonment at Former GP Chlor-Alkali Facility, Bellingham, Washington, March 12, 2007.

Revis, N. W., Osborne, T. R., Holdsworth, G., Hadden, C., 1990, Mercury in Soil: A Method for Assessing Acceptable Limits, Archive of Environmental Contamination Toxicology, 19:221-226.

Serfes, M.E., 1991, Determining the Mean Hydraulic Gradient of Ground Water Affected by Tidal Fluctuations, Ground Water, v. 29, no. 4, July-August 1991.

Wallschlager, D., Wilken, R. D., 1997, Wallschlager and Wilken on Flood Plaine and Mercury. In Environmental Toxicology and Risk Assessment: Modeling and Risk Assessment. Dwyer, F. J., Dwyer, J. J., Doane, T. R., Hinman, M. L., ASTM Committee E-47 on Biological Effects and Environmental Fate, ASTM International, Sixth Edition, pp. 179-196.

Wallschlager, D., Hintelmann, H., Evans, R. D., Wilken, R. D.,1995, Volatilization of dimethylmercury and elemental mercury from River Elbe floodplain soils, Water Air and Soil Pollution, Vol. 80, pp. 1325-1329.

Limitations

Work for this project was performed and this report prepared in accordance with generally accepted professional practices for the nature and conditions of work completed in the same or similar localities, at the time the work was performed. It is intended for the exclusive use of Port of Bellingham for specific application to the referenced property. This report does not represent a legal opinion. No other warranty, expressed or implied, is made.

Table 1 - Preliminary Soil and Groundwater Screening Levels for Constituents of Potential Concern

GP West Site RI/FS Work Plan

Soil Screening Levels

Chemical Name	Soil to Groundwater Pathway*	Method A-Soil (Unrestricted)	Method A-Soil (Industrial)	Method B-Soil (Unrestricted)	Method C-Soil (Industrial)
Metals					
Hexavalent Chromium in mg/kg	19	19	19	240	10,500
Chromium III in mg/kg	4,860,000	2,000	2,000	120,000	5,250,000
Total Mercury in mg/kg	1.0	2	2	24	1,050
TPH					
Diesel Range Hydrocarbons in mg/kg	2,000	2,000	2,000		
Oil Range Hydrocarbons in mg/kg	2,000	2,000	2,000		
PAHs					
Benzo(a)anthracene in mg/kg					
Benzo(a)pyrene in mg/kg	2	0.1	2	0.14	18
Benzo(b)fluoranthene in mg/kg					
Benzo(k)fluoranthene in mg/kg					
Chrysene in mg/kg					
Dibenz(a,h)anthracene in mg/kg					
Indeno(1,2,3-cd)pyrene in mg/kg					
Total cPAHs (TEF) in mg/kg	2	0.1	2	0.14	18
Semivolatiles					
Formaldehyde in mg/kg	0.12			33	4,380
Dioxins/Furans					
Total 2,3,7,8 TCDD (TEF) in mg/kg	1.6E-03			1.1E-05	1.5E-03

<u>Notes:</u>

*: Soil screening levels based on soil-to-groundwater pathway are based solely on conservative default MTCA parameters (not Site-specific). As part of the RI, additional evaluation of the soil-to-groundwater pathway will be conducted to incorporate Site-specific information.

**: Formaldehyde surface water standard is derived based on literature (see Appendix A).

Groundwater Screening Levels

Chemical Name	Surface Water Criteria		Preliminary Groundwater Screening Level
	Method B-Surface Water	173-201A WAC Surface Water	
Metals			
Dissolved Arsenic in µg/L	5	36	5
Dissolved Cadmium in µg/L	20	9.3	9.3
Dissolved Hexavalent Chromium in µg/L	486	50	50
Dissolved Chromium III in µg/L	243,000		243,000
Dissolved Copper in µg/L	2,660	3.1	3.1
Dissolved Lead in µg/L		8.1	8.1
Dissolved Mercury in µg/L		0.94	0.94
Dissolved Nickel in µg/L	1,100	8.2	8.2
Dissolved Zinc in µg/L	16,500	81	81
TPH			
Diesel Range Hydrocarbons in µg/L			
Oil Range Hydrocarbons in µg/L			
Volatile Organics			
Tetrachloroethene in µg/L	4.2		4.2
Trichloroethene in µg/L	56		56
Vinyl Chloride in µg/L	3.7		3.7
PAHs			
Naphthalene in µg/L	4,940		4,940
Benzo(a)anthracene in µg/L			
Benzo(a)pyrene in µg/L	0.03		0.03
Benzo(b)fluoranthene in µg/L			
Benzo(k)fluoranthene in µg/L			
Chrysene in µg/L			
Dibenz(a,h)anthracene in µg/L			
Indeno(1,2,3-cd)pyrene in µg/L			
Total cPAHs (TEF) in µg/L	0.03		0.03
Semivolatiles			
Formaldehyde in µg/L**		1,600	1,600
PCBs			
Aroclor 1016 in µg/L	0.0058	0.03	0.0058
Aroclor 1221 in µg/L		0.03	0.03
Aroclor 1232 in µg/L		0.03	0.03
Aroclor 1242 in µg/L		0.03	0.03
Aroclor 1248 in µg/L		0.03	0.03
Aroclor 1254 in µg/L	0.0017	0.03	0.0017
Aroclor 1260 in µg/L		0.03	0.03
Total PCBs in µg/L			

Table 2 - Matrix of Data Collection Activities from Previous Investigations

GP West Site RI/FS Work Plan

Data Collection Activity	Law (1992)	Law/ Crandall (1993)	ENSR (1993)	ENSR (1994a)	GP Independ. Cleanups (1998-2002)	Anchor (2000)	Anchor (2001)	Anchor (2003b)	Aspect (2004a)	Aspect (2004b)	RETEC (2007)	Total
No. of soil borings	16		12	38				18	8	55		147
No. of hand-augered soil borings	25		4									29
No. test pits											11	11
No. of surface samples	8									7		15
No. of post-excavation confirmation soil spls		33	4								5	42
Mercury TCLP analyses		yes		yes								yes
Mercury SBLT testing								yes				yes
No. of soil samples analyzed chemically	123	33	38	136	8			60	7	171	5	581
No. of Fill Unit monitoring wells	8			20			3		16*	14		45
No. of Lower Sand monitoring wells				3								3
No. of groundwater samples analyzed chemically	20			58		5	10		16	23		132
No. of stormwater samples analyzed chemically				3								3
Mercury vapor monitoring		yes		yes				yes				yes
Mercury speciation analyses, soil				yes				yes				yes
Mercury speciation analyses, groundwater				yes								yes
Mercury speciation analyses, soil vapor								yes				yes
Water level measurements/GW flow direction	yes			yes						yes		yes
Hydraulic conductivity/GW velocity estimates**				yes								yes

Notes:
TCLP: Toxicity Characteristic Leaching Procedure
SBLT: Sequential Batch Leaching Tests
*: Includes 11 temporary monitoring wells (one-time sample).
**: Conducted for Fill Unit, Tidal Flat Aquitard, and Lower Sand.

Table 3 - TCLP Mercury Data from Previous Investigations

GP West Site RI/FS Work Plan

Location	Sample Depth (ft)	Soil Total Mercury (mg/kg)	Leachable Mercury by TCLP (mg/L)	
Soil Samples from Fill Unit				
EMW-2S	5-6.5	4.2	0.0002	
EMW-13S	10-11.5	58	0.011	
WSB-14S	10-11.5	200	0.027	
ESB-15S	10-11.5	56	0.0089	
ESB-16S	10-11.5	31	0.0048	
BT-I	10-11.5	330	0.0039	
BT-III	5-6.5	120	0.0002	U
BT-XI	7.5-9	12,000	0.048	
CB (cell bldg)	0.5-0.8	5,200	0.062	
Site 1	0-0.5	38	0.0005	
Site 2	0-0.5	42	0.0001	U
Site 3	0-0.5	82	0.0007	
Site 4	0-0.5	10	0.0001	U
Site 5	0-0.5	21	0.0001	U
Site 6	0-0.5	1	0.0003	
Site 7	0-0.5	18	0.0001	U
Site 8	0-0.5	119	0.0005	
Samples of Chemfix Material				
ESB-20S	2-3.5	2,500	0.0032	a
ESB-20S	2-3.5	2,500	0.0056	
ESB-20S	5-6.5	5,800	0.030	

Notes:

a: Modified TCLP analysis using site groundwater (from EMW-1S) as leaching liquid.

b: TCLP analysis was also performed for a 14-15.5-foot soil sample from EMW-30D, but total mercury was not reported for the sample. Leachable mercury was not detected (<0.0002 mg/L) in the TCLP leachate.

c: A TCLP mercury concentration of 0.2 mg/L designates a waste as characteristic dangerous waste (WAC 173-303-090(8)).

Table 4 - Mercury Speciation Data from Previous Investigations

GP West Site RI/FS Work Plan

ENSR (1994a) Data

Soil Samples

Location	Sample Depth (ft)	Unit	Total Mercury	Elemental Mercury		Methyl Mercury	
			(mg/kg)	(mg/kg)	% of total mercury	(mg/kg)	% of total mercury
EMW-7S	10-11.5	FU	0.7000	0.00002 U	< 0.003%	0.00488	0.7%
EMW-30D	10-11.5	FU	0.0346	0.00002 U	< 0.06%	1.5E-05	0.04%
ESB-17S	10-11.5	FU	1.5323	0.0015	0.1%	0.00184	0.1%
EMW-28D	18-19.5	TA	0.0417	0.00002 U	< 0.05%	4E-06	0.01%
EMW-28D	28-29.5	LS	0.0407	0.00002 U	< 0.05%	7E-06	0.02%

Groundwater Samples

Location	Unit	Total Mercury	Elemental Mercury		Methyl Mercury		Dimethyl Mercury		Acid Labile Mercury	
		(ug/L)	(ug/L)	% of total mercury	(ug/L)	% of total mercury	(ug/L)	% of total mercury	(ug/L)	% of total mercury
EMW-2S	FU	7.744	0.000176	0.002%	0.06125	0.8%	5E-06	0.0001%	0.00601	0.1%
EMW-5S	FU	4.460	0.000003 U	< 0.0001%	0.01362	0.3%	1.3E-05	0.0003%	0.0028	0.1%
EMW-10S	FU	0.501	0.00150	0.3%	0.00086	0.2%	0.00001 U	< 0.002%	0.0093	2%
Law-1	FA	8.324	0.000516	0.006%	0.07306	0.9%	0.0003	0.004%	0.341	4%

Anchor Environmental (2003b) Data

Soil Samples

Location	Sample Depth (ft)	Unit	Total Mercury	Methyl Mercury	
			(mg/kg)	(mg/kg)	% of total mercury
AS-03S0-C	5-6	FU	118	0.0870	0.07%
AS-10SO-A	0-2.5	FU	30.6	0.00312	0.01%
Chemfix composite	1-5	Chemfix	10.2	0.00346	0.03%

Soil Vapor Samples

Location	Sample Depth (ft)	Unit	Total Mercury	Elemental Mercury		Methyl Mercury	
			(ng/m3)	(ng/m3)	% of total mercury	(ng/m3)	% of total mercury
AS3	1.3-1.5	FU	720,308	877,650	122%	360	0.05%
AS7	1.3-1.5	FU	158 U	451 U	NC	8.4	NC
AS12	1.3-1.5	Chemfix	142 U	683 U	NC	2.5	NC
AS13	1.3-1.5	Chemfix	779	721	93%	2.5	0.3%
AS14	1.3-1.5	Chemfix	143 U	529 U	NC	5.8	NC
AS15	1.3-1.5	Chemfix	117 U	938 U	NC	1.1	NC

Notes:

U: Not detected at associated detection limit.

NC: Not calculated, since total mercury below detection limit.

FU: Fill Unit. TA: Tideflat Aquitard. LS: Lower Sand.

Table 5 - Previous Sequential Batch Leaching Test Data for Chemfix Material

GP West Site RI/FS Work Plan

	Elemental Mercury (ug/L)		Total Mercury (ug/L)	
	unfiltered	filtered	filtered	Influent Corrected
Average Influent / Extractant				
pH 3	N/AP	N/AV	0.137	---
pH 6-7	N/AP	0.064	0.959	---
pH 9	N/AP	N/AV	0.893	---
pH 12	N/AP	*	42.2	---
Effluent from pH 3 leaching				
Day 1	0.00043	0.0001	0.441	0.304
Day 2	0.000998	0.000059	0.375	0.238
Day 3	0.000595	-0.00003	0.137	0.000
Day 4	0.000318	0.000000	0.0491	-0.088
Average	0.000586	0.000031	0.25	0.113
Effluent from pH 6-7 leaching				
Day 1	0.0018	0.00009	0.418	-0.541
Day 2	0.000264	0.000000	0.863	-0.096
Day 3	0.000149	0.000104	1.13	0.172
Day 4	0.000000	-0.000019	1.17	0.21
Average	0.000553	0.000045	0.895	-0.064
Effluent from pH 9 leaching				
Day 1	0.00124	0.00003	2.42	1.53
Day 2	0.000576	0.000128	1.81	0.913
Day 3	0.000798	0.00046	2.17	1.28
Day 4	0.000206	0.000224	2.98	2.09
Average	0.000705	0.000211	2.35	1.45
Effluent from pH 12 leaching				
Day 1	0.0303	0.0378	395	353
Day 2	0.00662	0.0282	187	144
Day 3	0.0105	0.0077	43.2	0.966
Day 4	0.00239	0.00492	199	157
Average	0.0124	0.0197	206	164
SBLT blank	0.00015	0.00033	0.00131	---

Notes:

Data from Anchor Environmental (2003b).
* A negative number was calculated; refer to Appendix B of Anchor Environmental (2003b).
** Calculated using the Day 1 result, all other results calculated using an average value
N/AP = not applicable
N/AV = not available / not analyzed
N.S. = the mercury leached was insignificant; a Kd was not calculated.

Table 6 - Summary of Proposed Soil Sampling and Analysis

GP West Site RI/FS Work Plan

Exploration Location ID	Sample Depth Interval	Total Metals and Soil pH	Total Mercury	Aquifer Matrix Mineralogy*	PAHs	Diesel- and Oil-Range TPH	EPH	TCLP Mercury	Dioxins and Furans
Caustic Plume Area									
CP-MWA1	unsaturated zone		X						
	screened interval		X						
CP-MWA2	unsaturated zone		X						
	screened interval		X						
CP-MWA3	screened interval		X						
CP-MWB1	unsaturated zone		X						
	screened interval		X						
CP-MWB2	unsaturated zone		X						
	screened interval		X						
CP-MWB3	screened interval		X						
CP-MWC1	unsaturated zone		X						
	screened interval		X						
CP-MWC2	unsaturated zone		X						
	screened interval		X						
CP-MWC3	screened interval		X						
CP-MW01	screened interval		X						
CP-MW02	screened interval		X						
CP-MW03	4' to 5'								X
	screened interval		X						
CP-MW04	2.5' to 4'		X						
	7.5' to 9'		X						
	12.5' to 14'		X						
	17.5' to 19'		X						
	22' to 23'		X						
	26' to 27'		X						
	30' to 31'		X						
	34' to 35'		X						
	38' to 39'		X						
CP-MW05	2.5' to 4'		X						
	7.5' to 9'		X						
	12.5' to 14'		X						
	17.5' to 19'		X						
	22' to 23'		X						
	26' to 27'		X						
	30' to 31'		X						
	34' to 35'		X						
	38' to 39'		X						
CP-MW06	unsaturated zone		X						
	saturated zone		X						
Laurel Street Pipe Rack Area									
PR-MW01	1' to 2'		X						
	4' to 5'								X
	5' to 6'		X						
	9' to 10'		X						
	13' to 14'		X						
	17' to 18'		X						
PR-SB02	1' to 2'		X						
	5' to 6'		X						
	9' to 10'		X						
	13' to 14'		X						
	17' to 18'		X						
PR-SB03	1' to 2'		X						
	5' to 6'		X						
	9' to 10'		X						
	13' to 14'		X						
	17' to 18'		X						

Table 6 - Summary of Proposed Soil Sampling and Analysis

GP West Site RI/FS Work Plan

Exploration Location ID	Sample Depth Interval	Total Metals and Soil pH	Total Mercury	Aquifer Matrix Mineralogy*	PAHs	Diesel- and Oil-Range TPH	EPH	TCLP Mercury	Dioxins and Furans
Laurel Street Pipe Rack Area (continued)									
PR-SB04	1' to 2'		X						
	5' to 6'		X						
	9' to 10'		X						
	13' to 14'		X						
	17' to 18'		X						
PR-SB05	1' to 2'		X						
	5' to 6'		X						
	9' to 10'		X						
	13' to 14'		X						
	17' to 18'		X						
(highest Hg detect)								X	
(second Highest Hg detect)								X	
Million Gallon Tanks Area									
MG-SB04	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB05	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB06	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB07	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB08	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB09	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
MG-SB10	1' to 2'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
(highest TPH detect)							X		
(second highest TPH detec)							X		
Bunker C Tank Area									
BC-MW02	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
BC-MW03	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
BC-SB03	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
BC-SB04	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			

Table 6 - Summary of Proposed Soil Sampling and Analysis

GP West Site RI/FS Work Plan

Exploration Location ID	Sample Depth Interval	Total Metals and Soil pH	Total Mercury	Aquifer Matrix Mineralogy*	PAHs	Diesel- and Oil-Range TPH	EPH	TCLP Mercury	Dioxins and Furans
Bunker C Tank Area (continued)									
BC-SB05	4' to 5'				X	X			X
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
BC-SB06	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
BC-SB07	4' to 5'				X	X			
	water table/smear zone				X	X			
	3' to 4' below water table				X	X			
	6' to 7' below water table				X	X			
(highest Bunker C detect)							X		
(second highest Bunker C detec)							X		
Acid Plant Area									
AA-MW04	1' to 2'	X							
	4' to 5'	X							
	just below water table	X							
	3' to 4' below water table	X							

Notes:
Proposed analyses at each sample location are denoted by "X".
Metals proposed for analysis include arsenic, cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc.
TPH - total petroleum hydrocarbons. PAHs - polycyclic aromatic hydrocarbons. EPH - Extractable petroleum hydrocarbons.
Two soil samples each from the Million Gallon Tanks and Bunker C Tank Areas with high TPH concentrations will also be analyzed for EPH.
*: Four soil samples to be analyzed for aquifer mineralogy will be selected following evaluation of new soil and groundwater data (mercury and pH).

Table 7 - Summary of Proposed Groundwater Sampling and Analysis

GP West Site RI/FS Work Plan

Well ID	Existing or Proposed Well	Site Subarea(s)	Dissolved Metals	Dissolved Mercury	Conven-tionals	VOCs	TSS	PAHs	Diesel- and Oil-Range TPH
AA-MW01	Proposed	Acid Area	X		X				
AA-MW02	Proposed	Acid Area	X		X				
AA-MW03	Proposed	Acid Area	X						
AA-MW04	Proposed	Acid Area	X		X				
FH-MW01	Existing	Acid Area	X		X				
GF-MW01	Existing	Acid Area	X						
GF-MW02	Existing	Acid Area							
LB-MW01	Existing	Acid Area	X						
TS-MW01	Existing	Acid Area	X						
BC-MW01	Existing	Bunker C Tanks					X[1]	X[1]	X[1]
BC-MW03	Proposed	Bunker C Tanks					X[1]	X[1]	X[1]
BC-MW02	Proposed	Bunker C Tanks/Acid Area	X				X[1]	X[1]	X[1]
AMW-1	Existing	Caustic Plume		X					
AMW-2	Existing	Caustic Plume		X	X				
AMW-3	Existing	Caustic Plume		X	X				
CP-MW01	Proposed	Caustic Plume		X					
CP-MW02	Proposed	Caustic Plume		X					
CP-MW03	Proposed	Caustic Plume		X	X				
CP-MW06	Proposed	Caustic Plume		X	X				
CP-MWA1	Proposed	Caustic Plume		X	X				
CP-MWA2	Proposed	Caustic Plume		X	X				
CP-MWA3	Proposed	Caustic Plume		X	X				
CP-MWB1	Proposed	Caustic Plume		X	X				
CP-MWB2	Proposed	Caustic Plume		X	X				
CP-MWB3	Proposed	Caustic Plume		X	X				
CP-MWC1	Proposed	Caustic Plume		X	X				
CP-MWC2	Proposed	Caustic Plume		X	X				
CP-MWC3	Proposed	Caustic Plume		X	X				
EMW-01S	Existing	Caustic Plume		X					
EMW-02S	Existing	Caustic Plume		X	X				
EMW-04S	Existing	Caustic Plume		X					
EMW-14S	Existing	Caustic Plume		X	X				
EMW-15S	Existing	Caustic Plume							
EMW-19S	Existing	Caustic Plume		X	X				
Law-1	Existing	Caustic Plume		X	X				
EMW-07S	Existing	Caustic Plume/Chemfix		X					
EMW-08S	Existing	Caustic Plume/Chemfix		X					
CP-MW04	Proposed	Caustic Plume/Lower Sand		X					
CP-MW05	Proposed	Caustic Plume/Lower Sand		X					
EMW-28D	Existing	Caustic Plume/Lower Sand		X					

Table 7 - Summary of Proposed Groundwater Sampling and Analysis

GP West Site RI/FS Work Plan

Well ID	Existing or Proposed Well	Site Subarea(s)	Dissolved Metals	Dissolved Mercury	Conven-tionals	VOCs	TSS	PAHs	Diesel- and Oil-Range TPH
EMW-10S	Existing	Chemfix		X					
EMW-20S	Existing	Chemfix		X					
EMW-29D	Existing	Chemfix/Lower Sand		X					
CF-MW01	Proposed	Chemfix/Million Gal Tank		X			X[1]	X[1]	X[1]
CF-MW02	Proposed	Chemfix/Million Gal Tank		X			X[1]	X[1]	X[1]
EMW-13S	Existing	Laurel Street Pipe Rack		X					
PR-MW01	Proposed	Laurel Street Pipe Rack		X					
EMW-6S	Existing	Million Gal Tank					X[1]	X[1]	X[1]
MG-MW01	Existing	Million Gal Tank					X[1]	X[1]	X[1]
EMW-12S	Existing	Million Gal Tank/Misc.	X				X[1]	X[1]	X[1]
EMW-16S	Existing	Million Gal Tank/Misc.	X				X[1]	X[1]	X[1]
LP-MW01	Existing	Misc.	X			X[2]			
LW-MW01	Existing	Misc.	X						
SC-MW02	Existing	Misc.	X						

Notes:
Proposed analyses at each sample location are denoted by "X".
Dissolved metals proposed for analysis include arsenic, cadmium, chromium (hexavalent and total), copper, lead, mercury, nickel, and zinc. Samples from the Caustic Plume and Acid Areas will also be analyzed for dissolved iron and manganese.
Conventionals include major cations, major anions, alkalinity, redox pairs, and total dissolved solids.
VOCs - volatile organic compounds.
TSS - total suspended solids.
PAHs - polycyclic aromatic hydrocarbons.
TPH - total petroleum hydrocarbons.

[1] If separate-phase product is present a groundwater sample will not be collected.

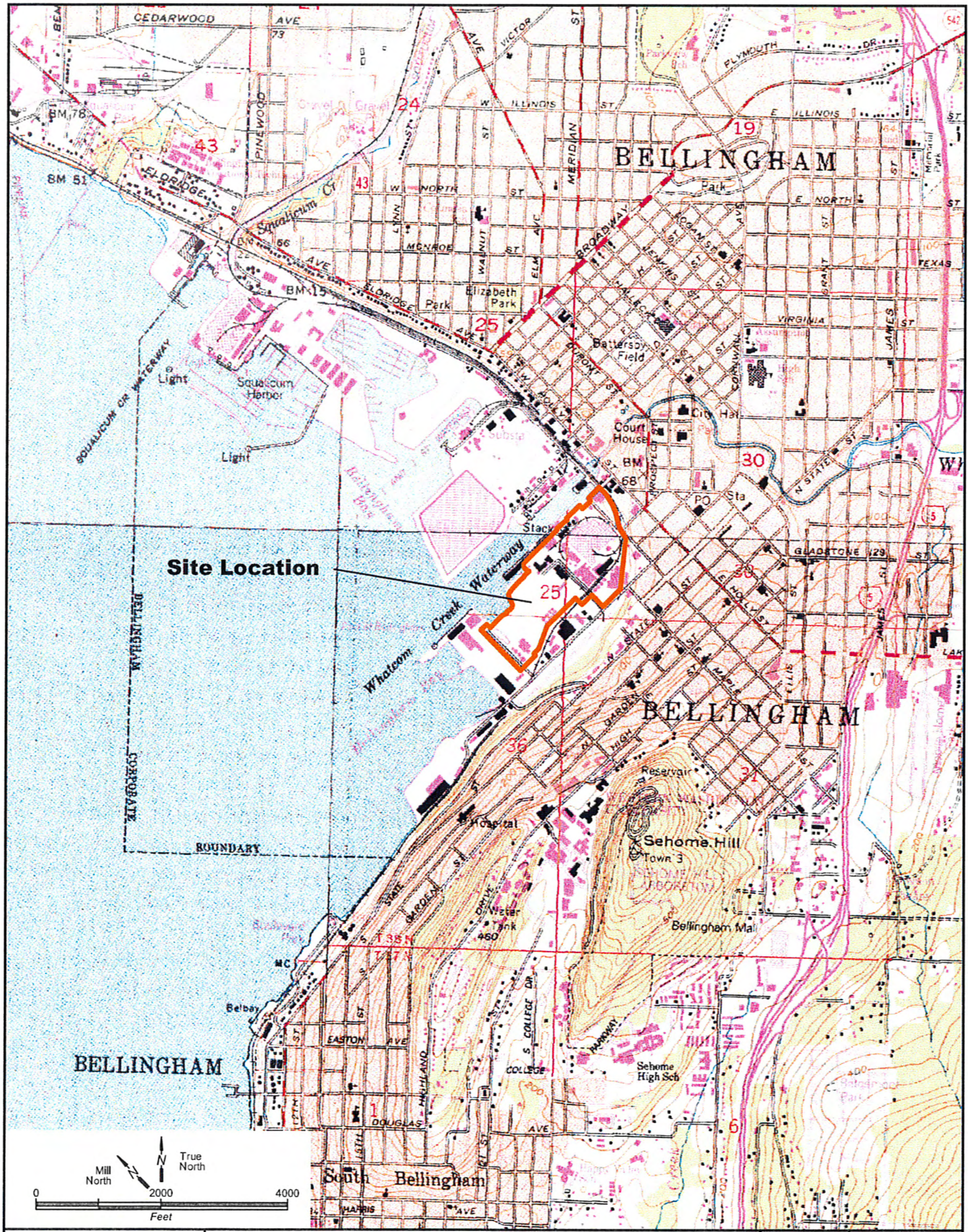
[2] Additional soil and groundwater sampling for VOCs will be performed if warranted based on sampling results from this well, as described in the text.

Table 8 - Summary of Proposed Soil Vapor Sampling and Analysis

GP West Site RI/FS Work Plan

Exploration Location ID	Site Subarea	Mercury
CP-MWA1V	Caustic Plume	X
CP-MWA2V	Caustic Plume	X
CP-MWB1V	Caustic Plume	X
CP-MWB2V	Caustic Plume	X
CP-MWC1V	Caustic Plume	X
CP-MWC2V	Caustic Plume	X
CP-MW01V	Caustic Plume	X
CP-MW02V	Caustic Plume	X
CP-MW03V	Caustic Plume	X
CP-MW06V	Caustic Plume	X

Notes:
Proposed analyses at each sample location are denoted by "X".
"V" suffix in exploration ID denotes that it is a soil vapor probe, located in close proximity to the corresponding exploration.



Site Vicinity Map

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE:	July 2009
DESIGNED BY:	SJG
DRAWN BY:	SCC
REVISED BY:	SCC
PROJECT NO.	070188
FIGURE NO.	1

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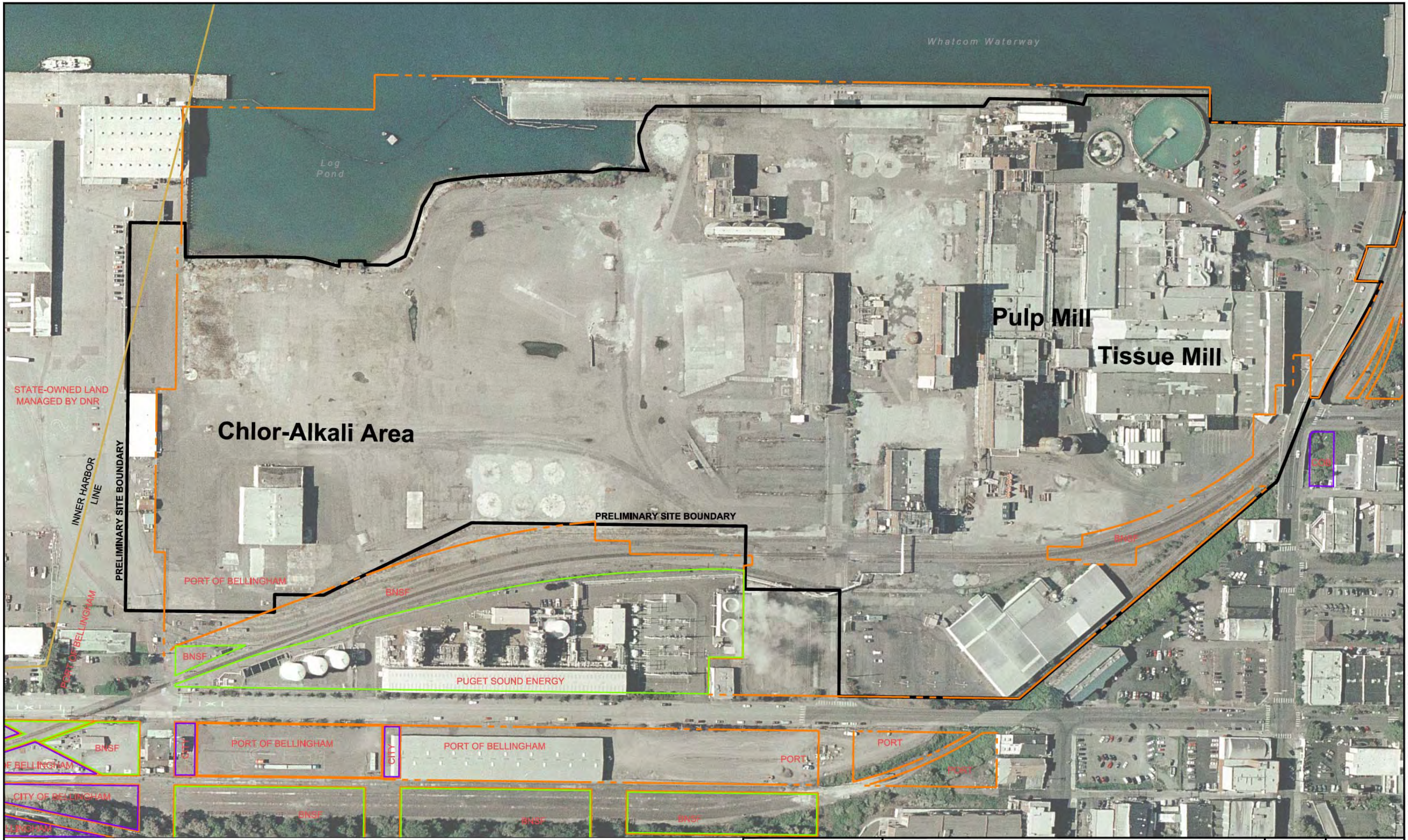
Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\070188-01 Site Vicinity Map.dwg



Property boundary from ALTA survey (David Evans and Associates, 2004) and Whatcom County property parcel database (Port of Bellingham)

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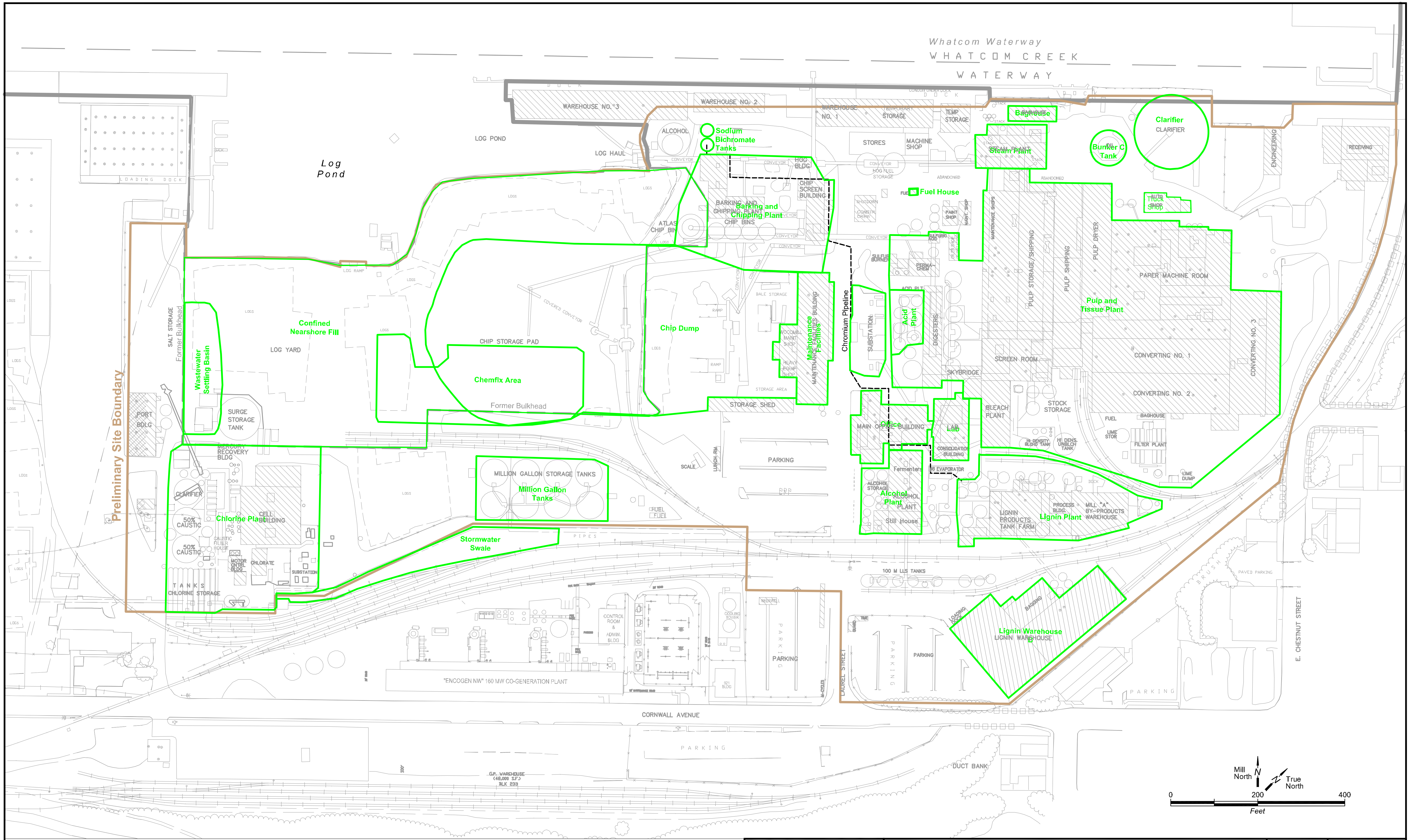
Preliminary Site Boundary and Adjacent Property Boundaries

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE:	September 2009
DESIGNED BY:	SJG
DRAWN BY:	SCC
REVISED BY:	SCC
PROJECT NO.	070188
FIGURE NO.	2

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-09 RI-FS Final\Preliminary Site Boundary-Aerial.dwg



LEGEND

🟩 Lab — General Operational Area

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General Operational Areas

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE:	July 2009
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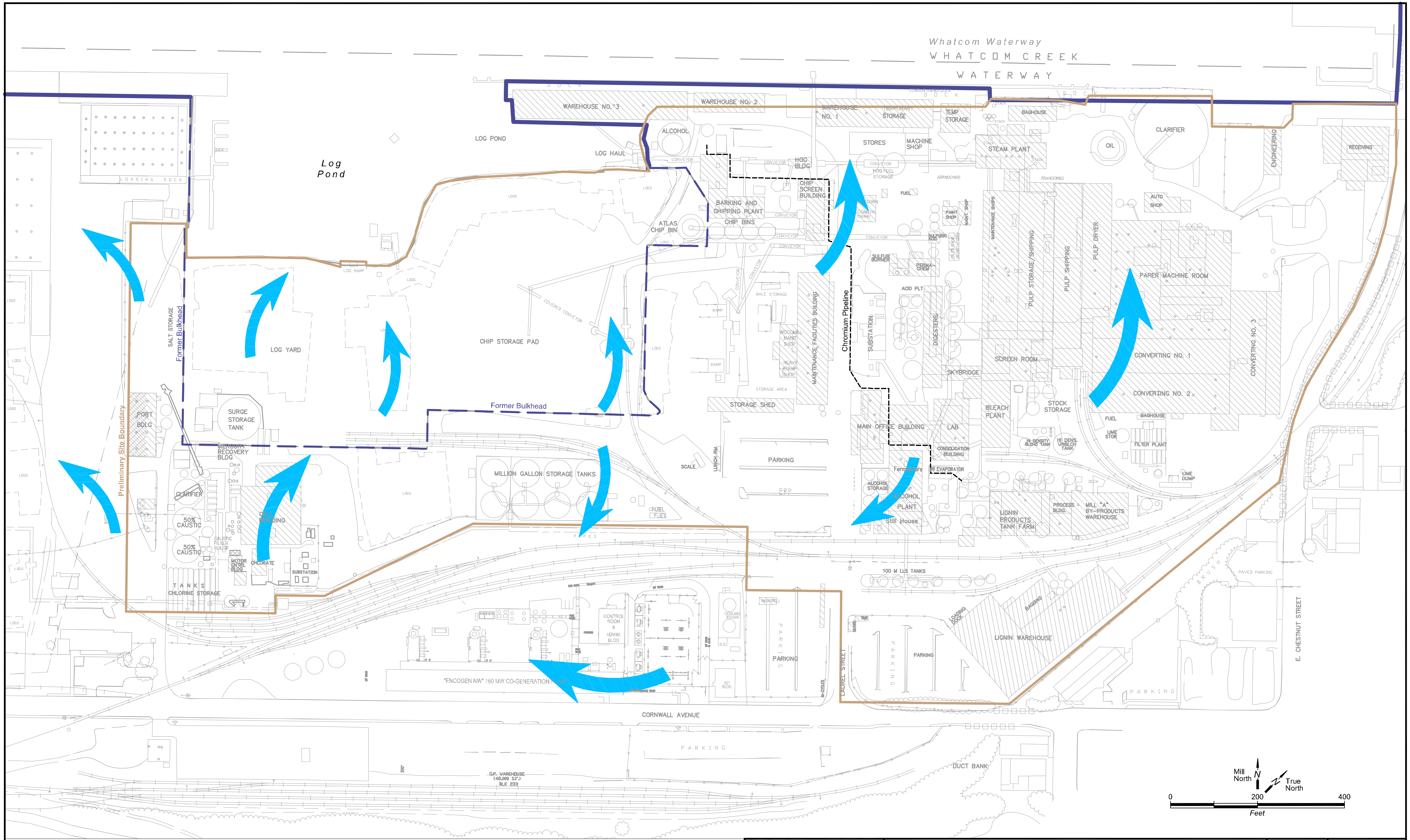
DRAWN BY:	SCC
REVISED BY:	SCC
PROJECT NO.	070188
FIGURE NO.	3

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\General Operational Areas.dwg



LEGEND

- Monitoring Wells
- Decommissioned Monitoring Wells
- Generalized Groundwater Flow Direction

Generalized flow directions based on existing information from ENSR (1994a) and Aspect Consulting (2004b)

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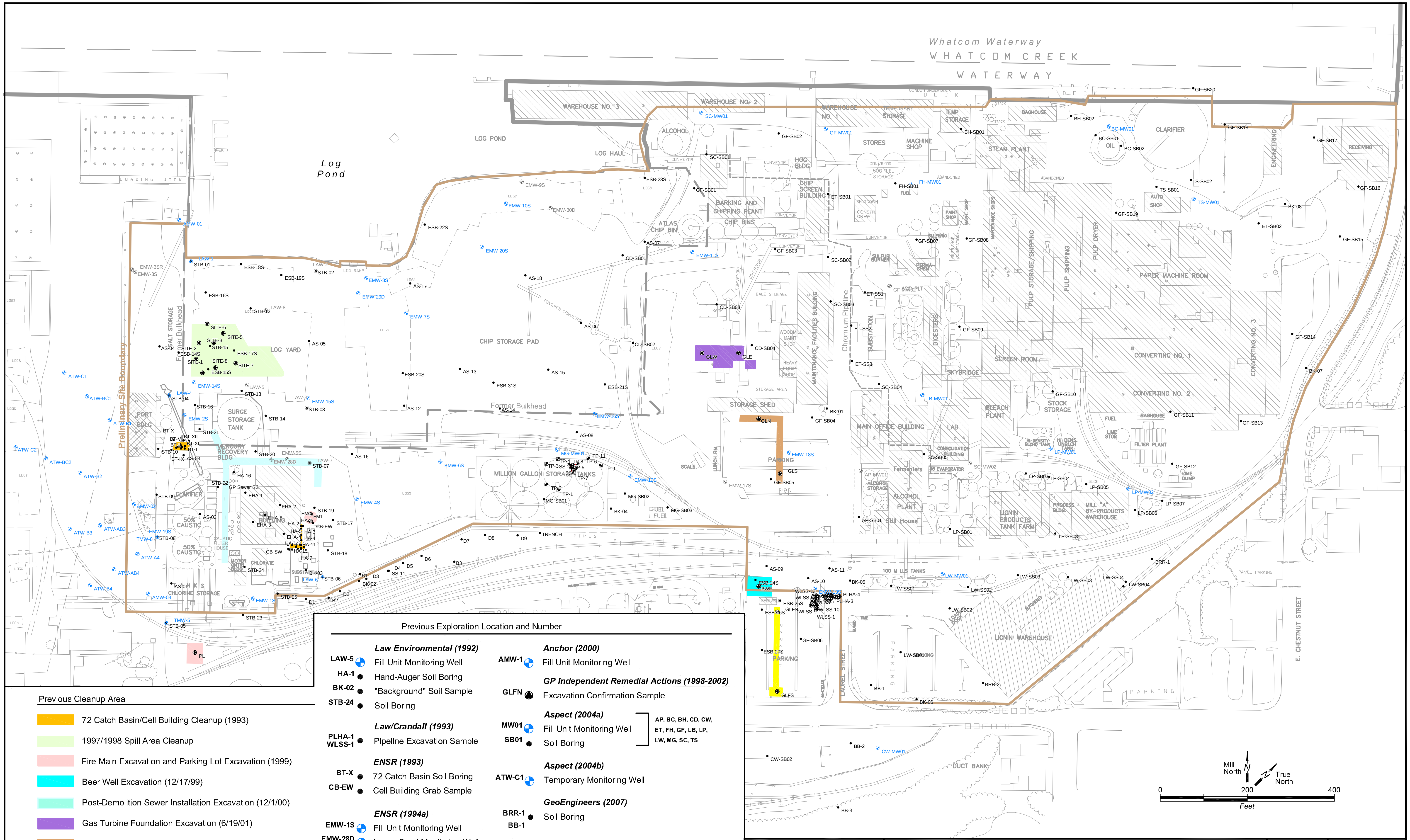
Generalized Groundwater Flow Directions for Fill Unit

Georgia-Pacific West Site RI/FS

Bellingham, Washington

DATE:	July 2009	PROJECT NO.
DESIGNED BY:	SJG	070188
DRAWN BY:	SCC	FIGURE NO.
REVISED BY:	SCC	4

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\GW Flow Direction.dwg



Previous Cleanup Area

- 🟧 72 Catch Basin/Cell Building Cleanup (1993)
- 🟩 1997/1998 Spill Area Cleanup
- 🟥 Fire Main Excavation and Parking Lot Excavation (1999)
- 🟦 Beer Well Excavation (12/17/99)
- 🟦 Post-Demolition Sewer Installation Excavation (12/1/00)
- 🟪 Gas Turbine Foundation Excavation (6/19/01)
- 🟫 Gas Line Trench Excavation (6/19/01)
- 🟨 Gas Line/Feed Excavation (6/28/02)
- 🟥 Million Gallon Tank Cleanup (12/06)

Previous Exploration Location and Number

Law Environmental (1992)

LAW-5 ⊕	Fill Unit Monitoring Well
HA-1 ●	Hand-Auger Soil Boring
BK-02 ●	"Background" Soil Sample
STB-24 ●	Soil Boring

Law/Crandall (1993)

PLHA-1 WLSS-1 ●	Pipeline Excavation Sample

ENSR (1993)

BT-X ●	72 Catch Basin Soil Boring
CB-EW ●	Cell Building Grab Sample

ENSR (1994a)

EMW-1S ⊕	Fill Unit Monitoring Well
EMW-28D ⊕	Lower Sand Monitoring Well
EHA-1 ●	Hand-Auger
ESB-17S ●	Soil Boring
SS-11 D1 B1 ●	Surface Soil Sample

Anchor (2000)

AMW-1 ⊕	Fill Unit Monitoring Well

GP Independent Remedial Actions (1998-2002)

GLFN ●	Excavation Confirmation Sample

Aspect (2004a)

MW01 ⊕	Fill Unit Monitoring Well	AP, BC, BH, CD, CW, ET, FH, GF, LB, LP, LW, MG, SC, TS
SB01 ●	Soil Boring	

Aspect (2004b)

ATW-C1 ⊕	Temporary Monitoring Well

GeoEngineers (2007)

BRR-1 BB-1 ●	Soil Boring

Retec (2007)

TP-1 ■	Test Pit
SS-1 ●	Excavation Confirmation Sample

Note: Decommissioned wells are displayed in gray.

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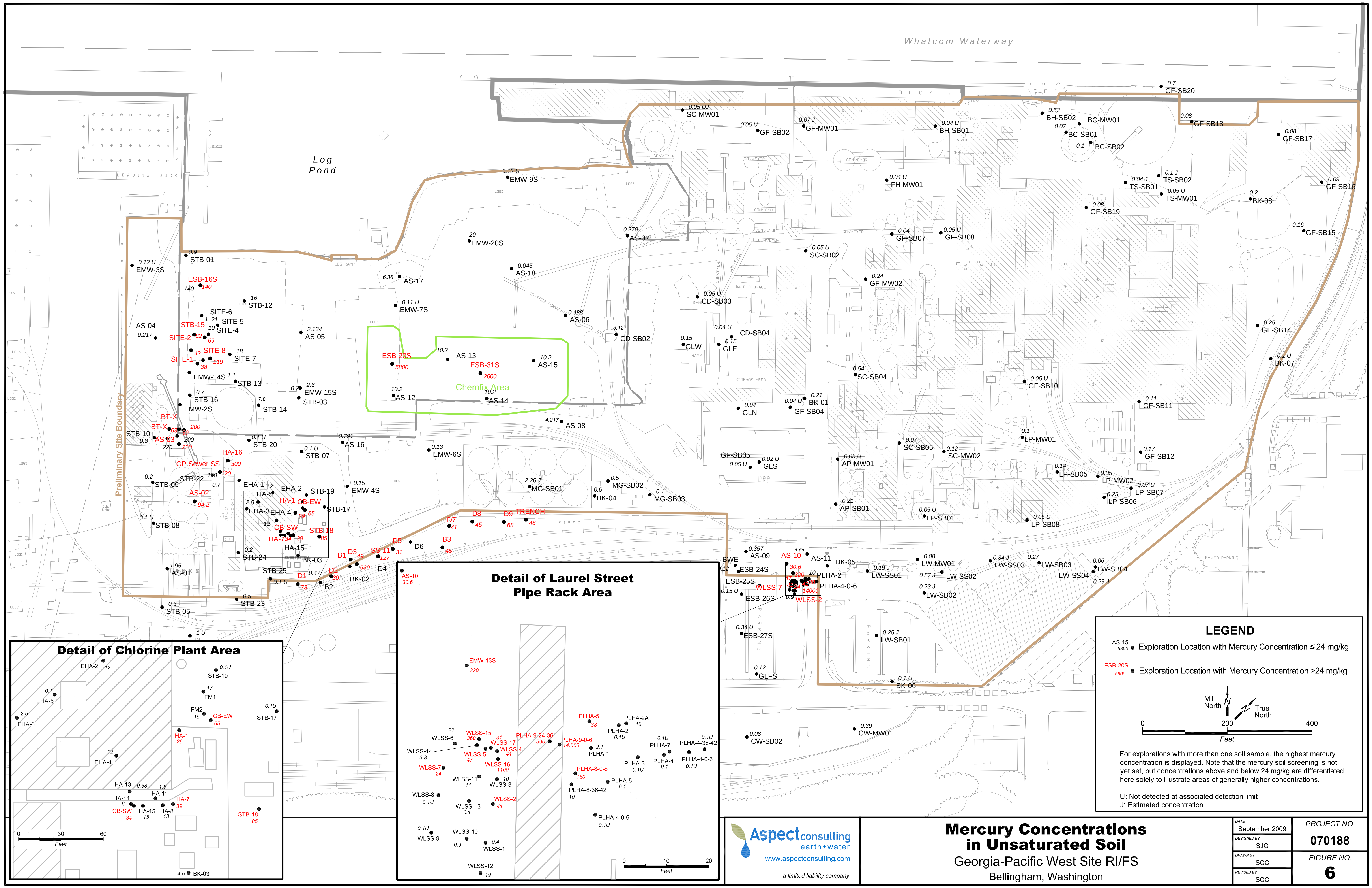
Locations of Previous Explorations and Cleanup Actions

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: July 2009	*PROJECT NO.* 070188
DESIGNED BY: SJG	
DRAWN BY: SCC	*FIGURE NO.* 5
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\Locations of Previous Explorations.dwg



LEGEND

AS-15 5800 ● Exploration Location with Mercury Concentration ≤ 24 mg/kg

ESB-20S 5800 ● Exploration Location with Mercury Concentration >24 mg/kg

Mill North N True North

0 200 400

Feet

For explorations with more than one soil sample, the highest mercury concentration is displayed. Note that the mercury soil screening is not yet set, but concentrations above and below 24 mg/kg are differentiated here solely to illustrate areas of generally higher concentrations.

U: Not detected at associated detection limit
J: Estimated concentration

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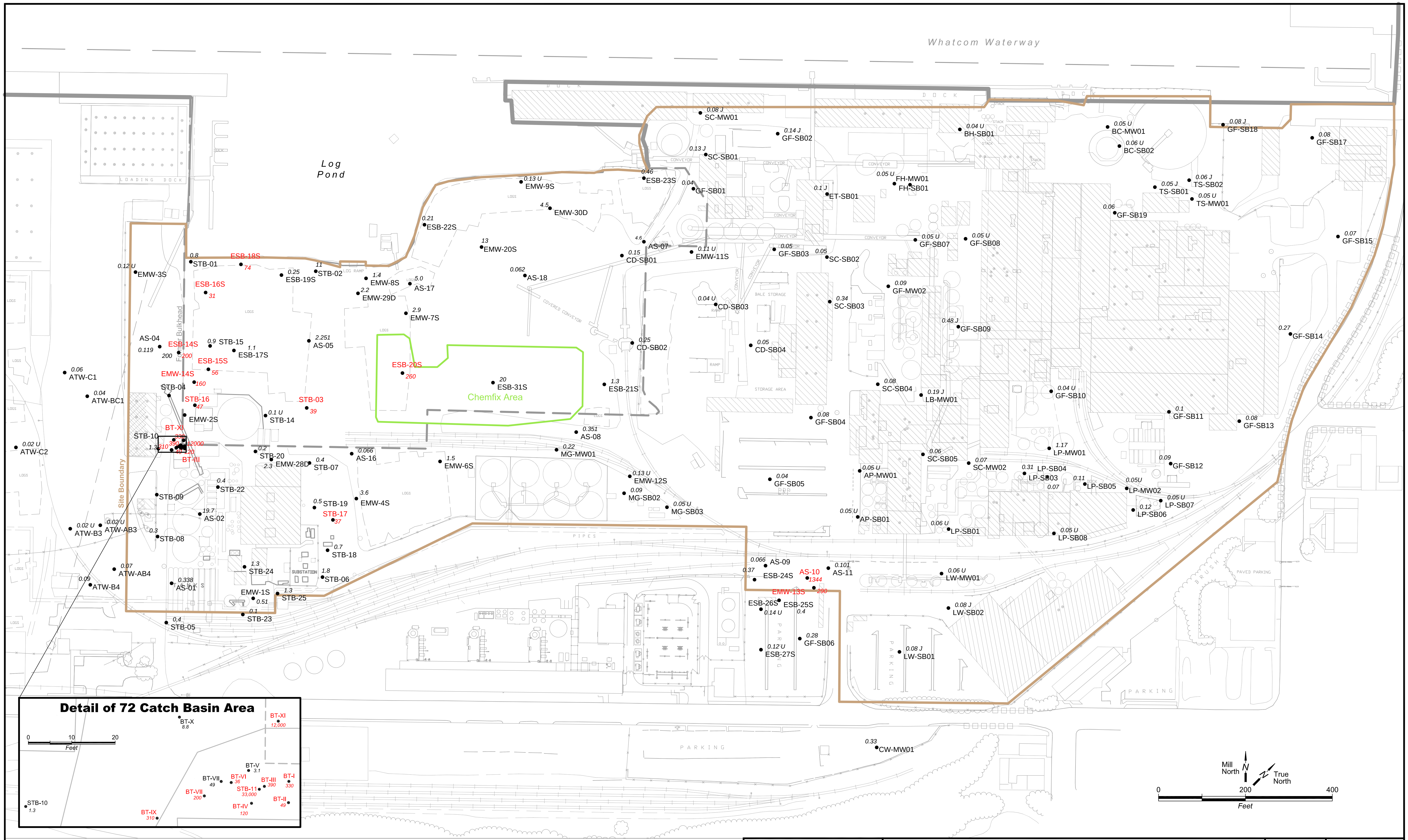
Mercury Concentrations in Unsaturated Soil

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: September 2009	PROJECT NO. 070188
DESIGNED BY: SJG	
DRAWN BY: SCC	FIGURE NO. 6
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-09 RI-FS Final\Mercury_GT24mg_Unsat_Soil.dwg



LEGEND

AS-15 5800 ●	Exploration Location with Mercury Concentration ≤ 24 mg/kg
ESB-20S 5800 ●	Exploration Location with Mercury Concentration >24 mg/kg

For explorations with more than one soil sample, the highest mercury concentration is displayed. Note that the mercury soil screening is not yet set, but concentrations above and below 24 mg/kg are differentiated here solely to illustrate areas of generally higher concentrations.

U: Not detected at associated detection limit
J: Estimated concentration

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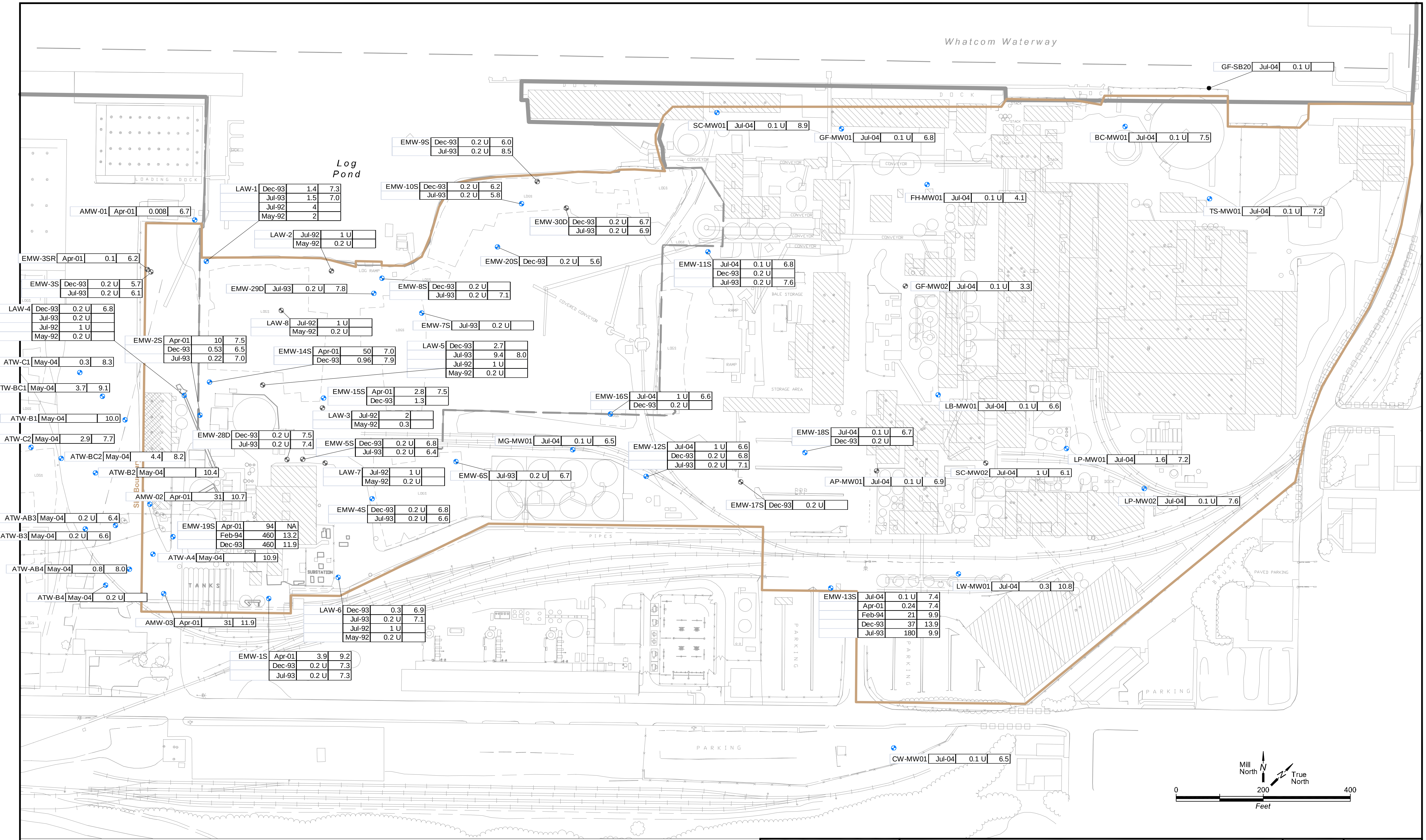
Mercury Concentrations in Saturated Soil

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: September 2009
DESIGNED BY: SJG
DRAWN BY: SCC
REVISED BY: SCC

PROJECT NO. 070188
FIGURE NO. 7

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-09 RI-FS Final\Mercury_GT24mg_Sat_Soil.dwg



LEGEND

Well No.	Sample Date	Dissolved Mercury in ug/L	pH
EMW-3S	Dec-93	0.2U	5.7
	Jul-93	0.2U	6.1

Note: Decommissioned Wells are displayed in Gray

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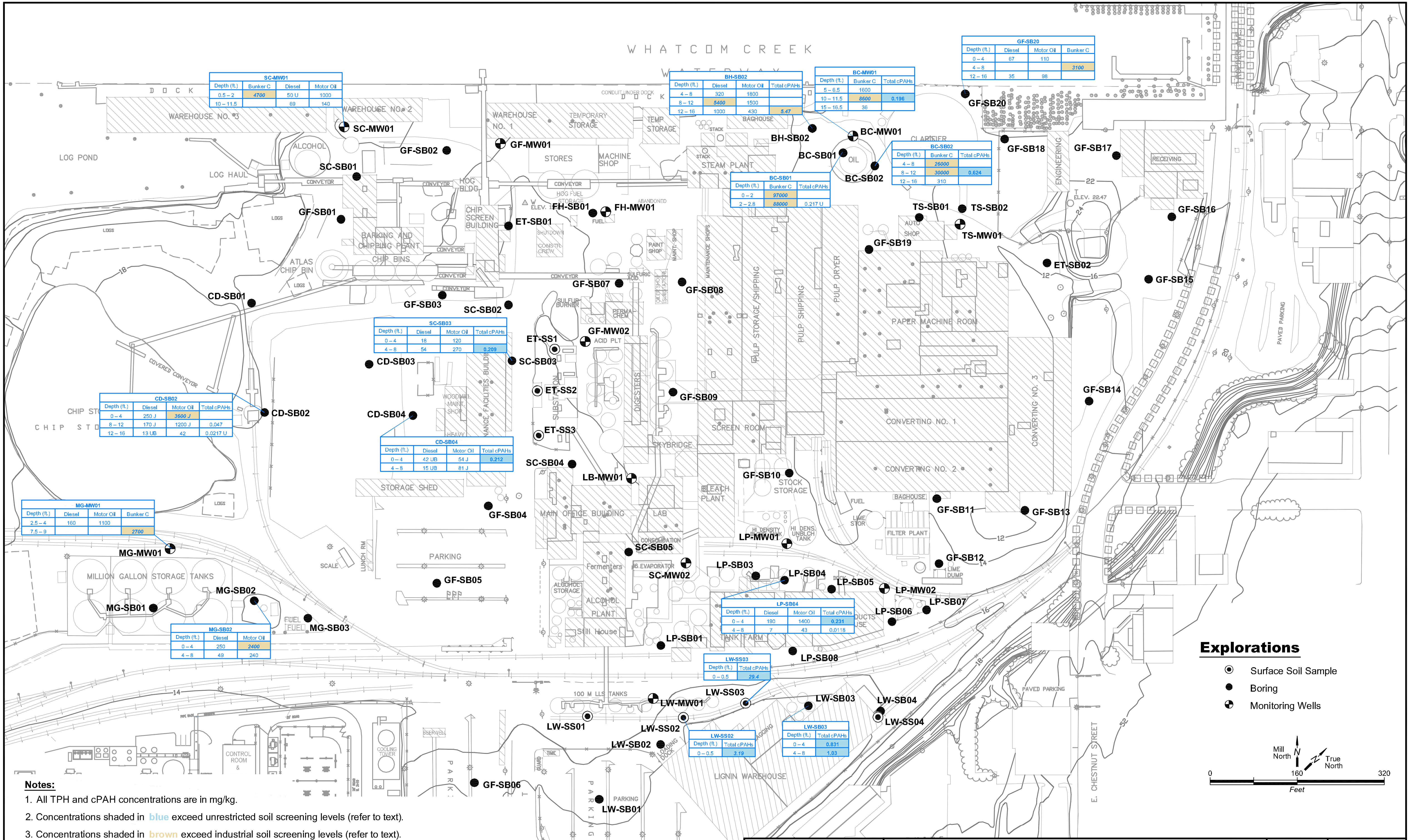
Dissolved Mercury Concentrations and pH in Groundwater

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: February 2009
DESIGNED BY: SJG
DRAWN BY: SCC
REVISED BY: SCC
PROJECT NO. 070188
FIGURE NO. 8

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\Mercury_pH_GW.dwg



SC-MW01

Depth (ft.)	Bunker C	Diesel	Motor Oil
0.5 – 2	*4700*	50 U	1000
10 – 11.5		69	140

BH-SB02

Depth (ft.)	Diesel	Motor Oil	Total cPAHs
4 – 8	320	1800	
8 – 12	*5400*	1500	
12 – 16	1000	430	*5.47*

BC-MW01

Depth (ft.)	Bunker C	Total cPAHs
5 – 6.5	1600	
10 – 11.5	*8600*	**0.196**
15 – 16.5	36	

GF-SB20

Depth (ft.)	Diesel	Motor Oil	Bunker C
0 – 4	67	110	
4 – 8			*3100*
12 – 16	35	98	

BC-SB02

Depth (ft.)	Bunker C	Total cPAHs
4 – 8	*26000*	
8 – 12	*30000*	**0.624**
12 – 16	310	

BC-SB01

Depth (ft.)	Bunker C	Total cPAHs
0 – 2	*97000*	
2 – 2.8	*88000*	0.217 U

SC-SB03

Depth (ft.)	Diesel	Motor Oil	Total cPAHs
0 – 4	18	120	
4 – 8	54	270	**0.209**

CD-SB02

Depth (ft.)	Diesel	Motor Oil	Total cPAHs
0 – 4	250 J	*3600 J*	
8 – 12	170 J	1200 J	0.047
12 – 16	13 UB	42	0.0217 U

CD-SB04

Depth (ft.)	Diesel	Motor Oil	Total cPAHs
0 – 4	42 UB	54 J	**0.212**
4 – 8	15 UB	81 J	

MG-MW01

Depth (ft.)	Diesel	Motor Oil	Bunker C
2.5 – 4	160	1100	
7.5 – 9			*2700*

MG-SB02

Depth (ft.)	Diesel	Motor Oil
0 – 4	250	*2400*
4 – 8	49	240

LP-SB04

Depth (ft.)	Diesel	Motor Oil	Total cPAHs
0 – 4	190	1400	**0.231**
4 – 8	7	43	0.0118

LW-SS03

Depth (ft.)	Total cPAHs
0 – 0.5	*29.4*

LW-SS02

Depth (ft.)	Total cPAHs
0 – 0.5	*3.19*

LW-SB03

Depth (ft.)	Total cPAHs
0 – 4	**0.831**
4 – 8	**1.03**

Explorations

◉	Surface Soil Sample
●	Boring
◕	Monitoring Wells

Notes:

1. All TPH and cPAH concentrations are in mg/kg.
2. Concentrations shaded in blue exceed unrestricted soil screening levels (refer to text).
3. Concentrations shaded in brown exceed industrial soil screening levels (refer to text).
4. For an exploration with a soil TPH or cPAH exceedence, all of the soil TPH and total cPAH data for that exploration are posted (exceedence or not).
5. Explorations with no concentrations posted have no soil samples with TPH/cPAH exceedences.
6. This figure was originally produced in color. Black and white reproduction may result in loss of information.

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Screening Level Exceedences for TPH/cPAH in Soil

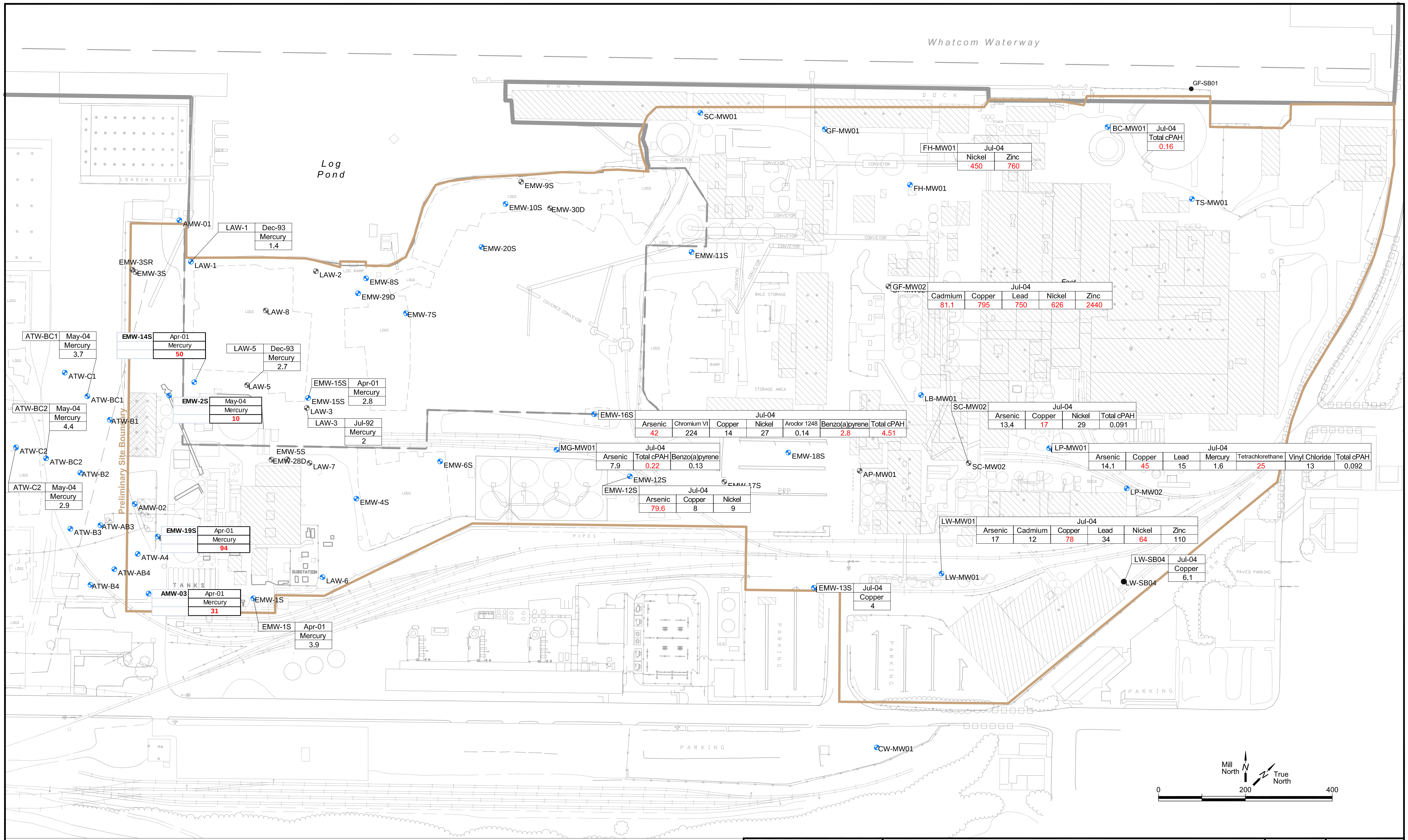
Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: July 2009
DESIGNED BY: SJG
DRAWN BY: JRS
REVISED BY: SCC

PROJECT NO.
070188

FIGURE NO.
9

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\Screening Level Exceedances-TPH.dwg



LEGEND

Well No.	Sample Date		Concentration in ug/L
	Jul-04		
EMW-12S	Arsenic	Copper	Nickel
	79.6	8	9

Data are from the most recent groundwater sampling at each well (sampling date is displayed).

For illustration purposes, higher concentrations (exceeding 5x the screening level) are highlighted in red.

Wells with no concentrations displayed have no exceedances of these screening levels.

Decommissioned Wells are displayed in gray

GF-SB01 and LW-SB04 are soil borings from which a groundwater grab sample was collected.

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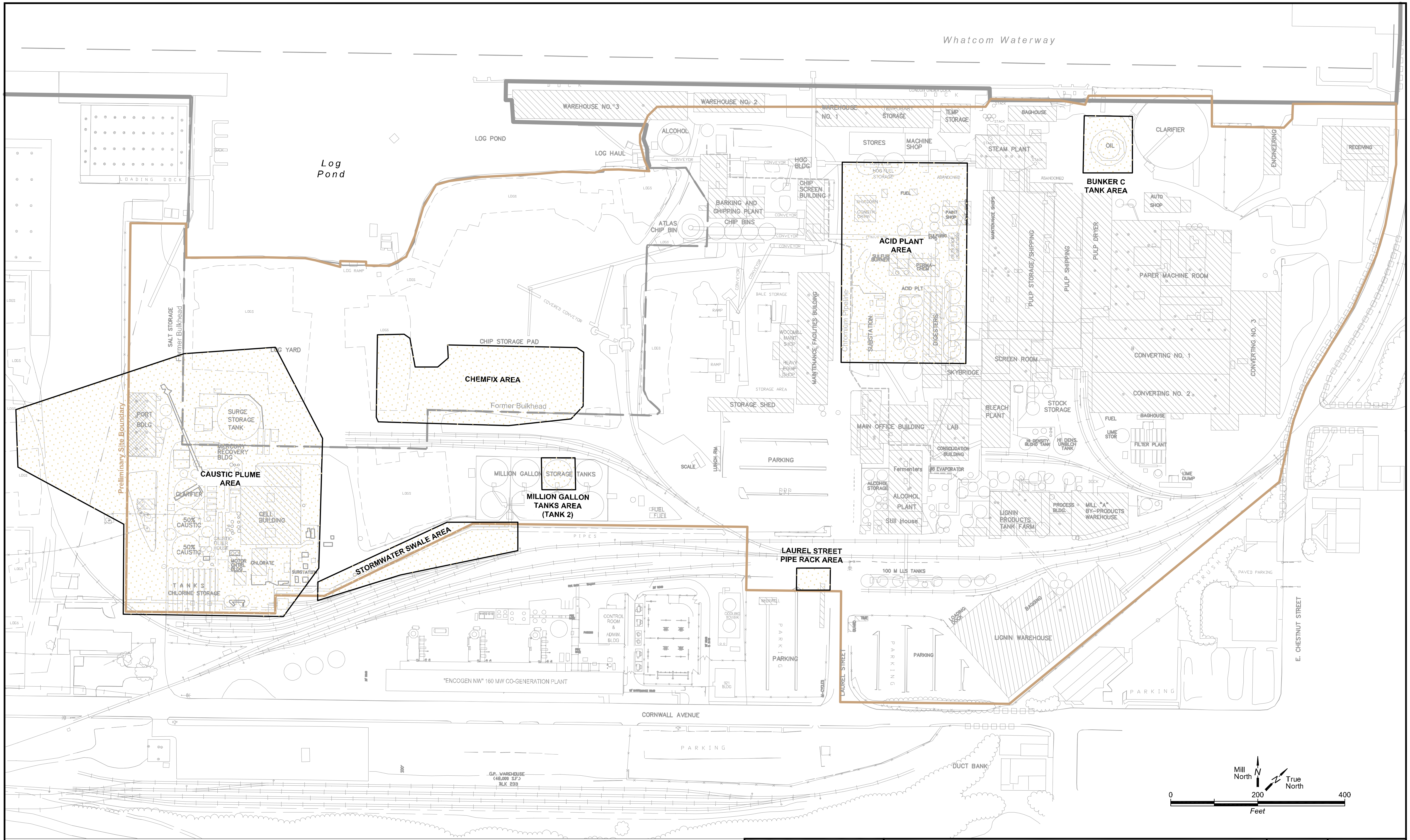
Exceedances of Preliminary Groundwater Screening Levels

Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: September 2009
DESIGNED BY: SJG
DRAWN BY: SCC
REVISED BY: SCC

PROJECT NO. 070188
FIGURE NO. 10

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-09 RI-FS Final\GW_Exceedances_Preliminary.dwg



LEGEND

Lab	Site Subarea

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Site Subareas for RI/FS

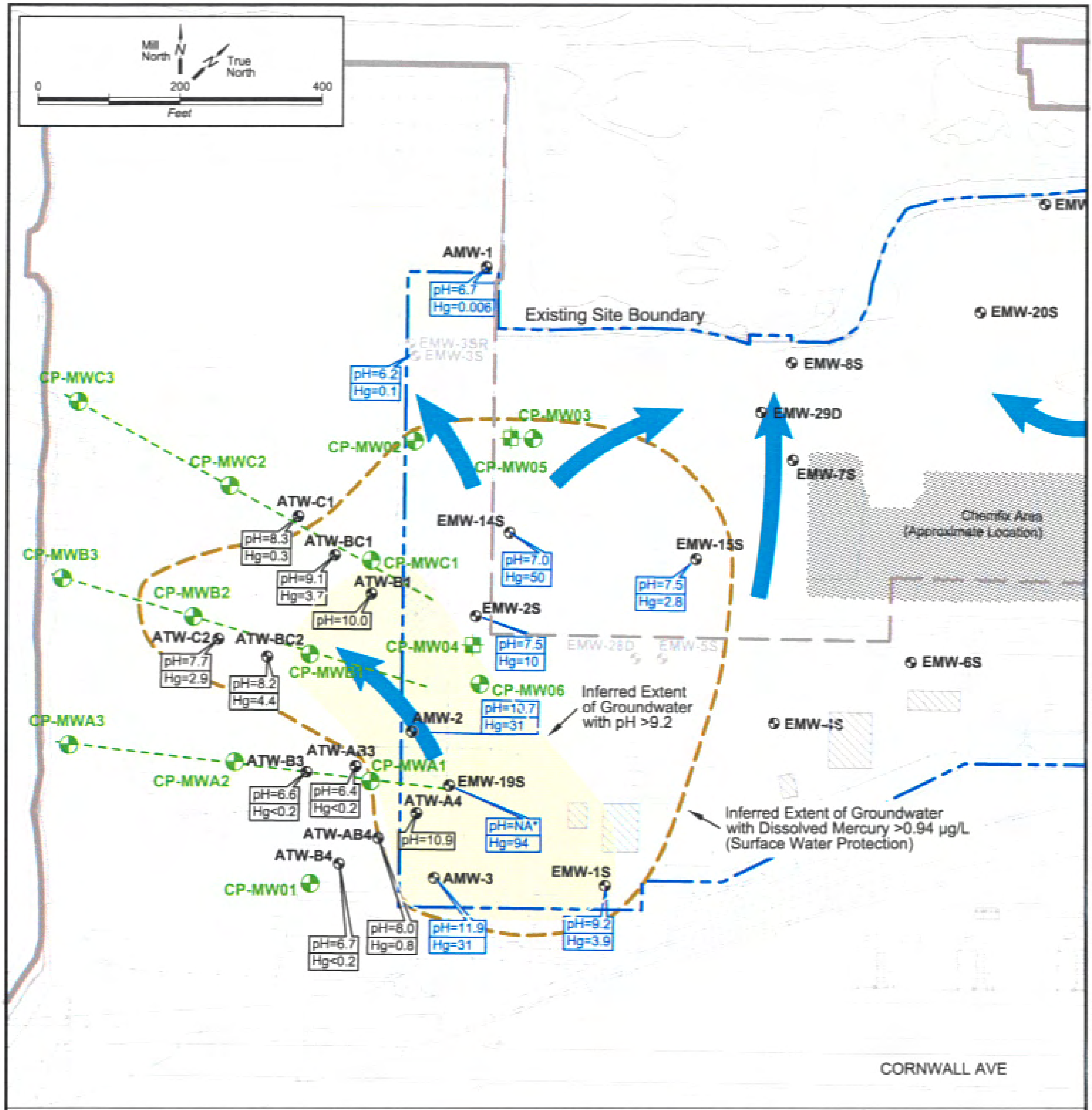
Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: July 2009
DESIGNED BY: SJG
DRAWN BY: SCC
REVISED BY: SCC

PROJECT NO.
070188

FIGURE NO.
11

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\Site Subareas.dwg



Existing Exploration Location and Number

AMW-1	Shallow Monitoring Well
EMW-1S	Shallow Monitoring Well
ATW-B2	May 2004 Temporary Monitoring Well
pH=9.1 Hg=3.7	April 2001 Sampling Data
pH=9.1 Hg=3.7	May 2004 Sampling Data
— — —	Current or Former Bulkhead

NA* pH meter not providing reliable data. pH assumed >10.

Groundwater Flow Direction

Proposed Explorations

CP-MW01	Monitoring Well (Fill Unit)
CP-MW04	Monitoring Well (Lower Sand)
CP-SB01 ●	Soil Boring

Notes:

1. Wells shown without data had dissolved mercury concentrations <2 µg/L.
2. Decommissioned wells are displayed in gray.

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Proposed Explorations for Caustic Plume Area

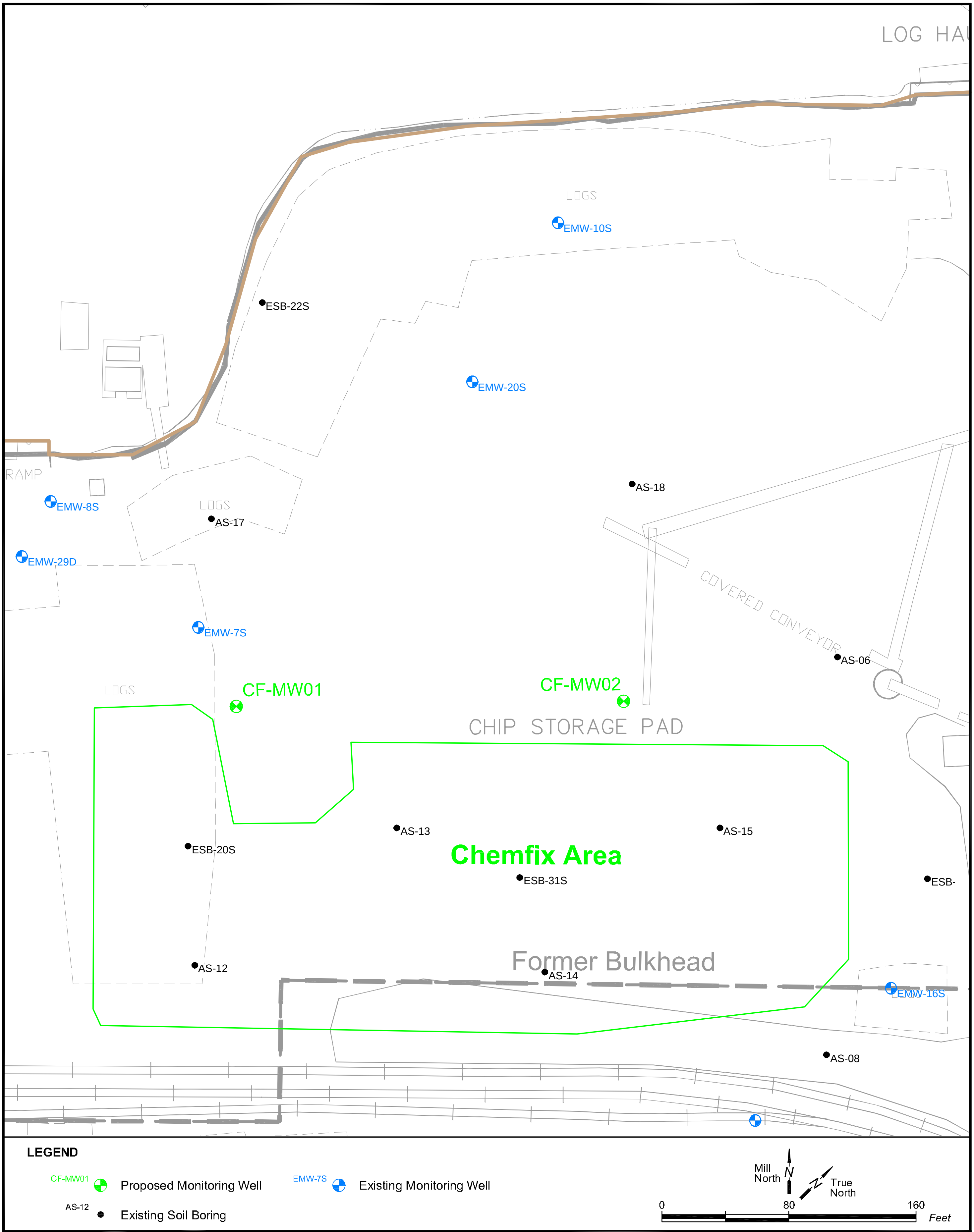
Georgia-Pacific West Site RI/FS
Bellingham, Washington

DATE: September 2009
DESIGNED BY: SJG
DRAWN BY: SCC
REVISED BY: SCC

PROJECT NO. 070188

FIGURE NO. 12

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-09 RI-FS Final\Proposed Explorations-Caustic Plume-redone.dwg



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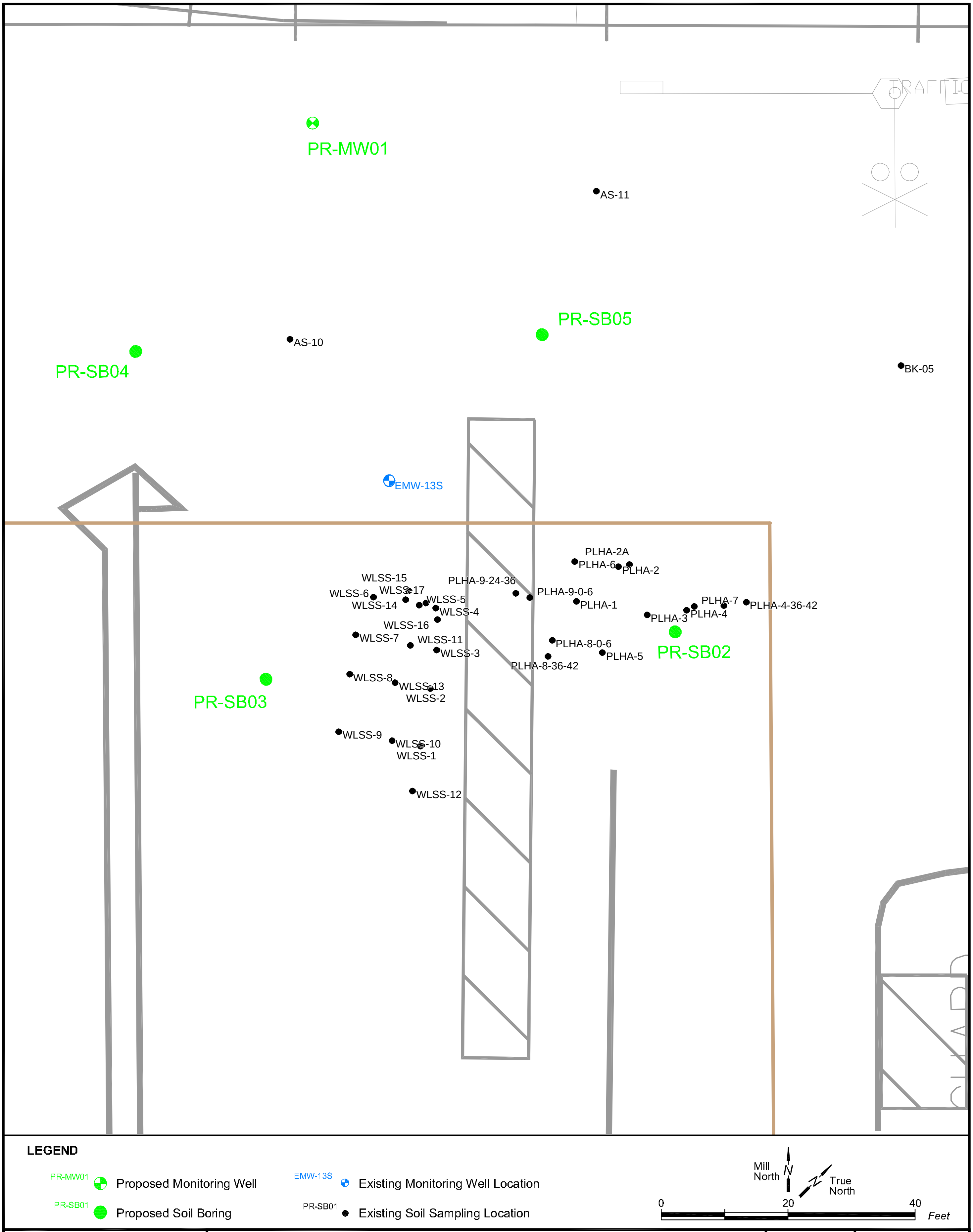
Proposed Explorations for Confined Nearshore Fill/Chemfix Area

Georgia-Pacific West RI/FS
Bellingham, Washington

DATE: July 2009	PROJECT NO. 070188
DESIGNED BY: SJG	
DRAWN BY: SCC	FIGURE NO. 13
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\PropExplorations-Chemfix.dwg



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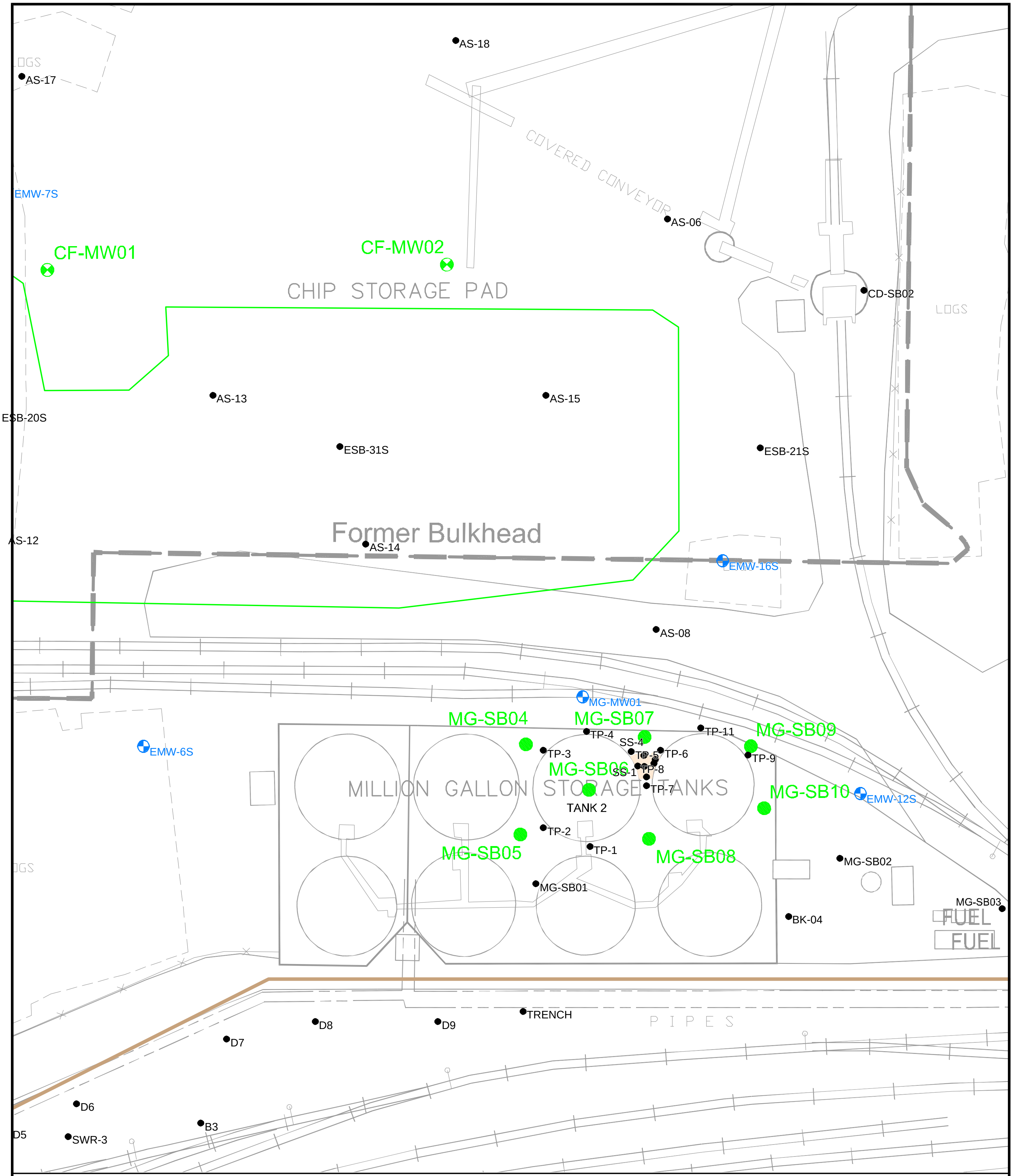
Proposed Explorations for Laurel Street Pipe Rack Area

Georgia-Pacific West RI/FS
Bellingham, Washington

DATE: July 2009	PROJECT NO. 070188
DESIGNED BY: SJG	
DRAWN BY: SCC	FIGURE NO. 14
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\PropExplorations-Laurel Street Pipe Rack Area.dwg



LEGEND

CF-MW01	Proposed Monitoring Well	MG-MW01	Existing Monitoring Well	▨	Soil Cleanup Area (2006)
MG-SB04 ●	Proposed Soil Boring	MG-SB01 ●	Existing Soil Exploration		

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Proposed Explorations for Million Gallon Tanks Area

Georgia-Pacific West RI/FS

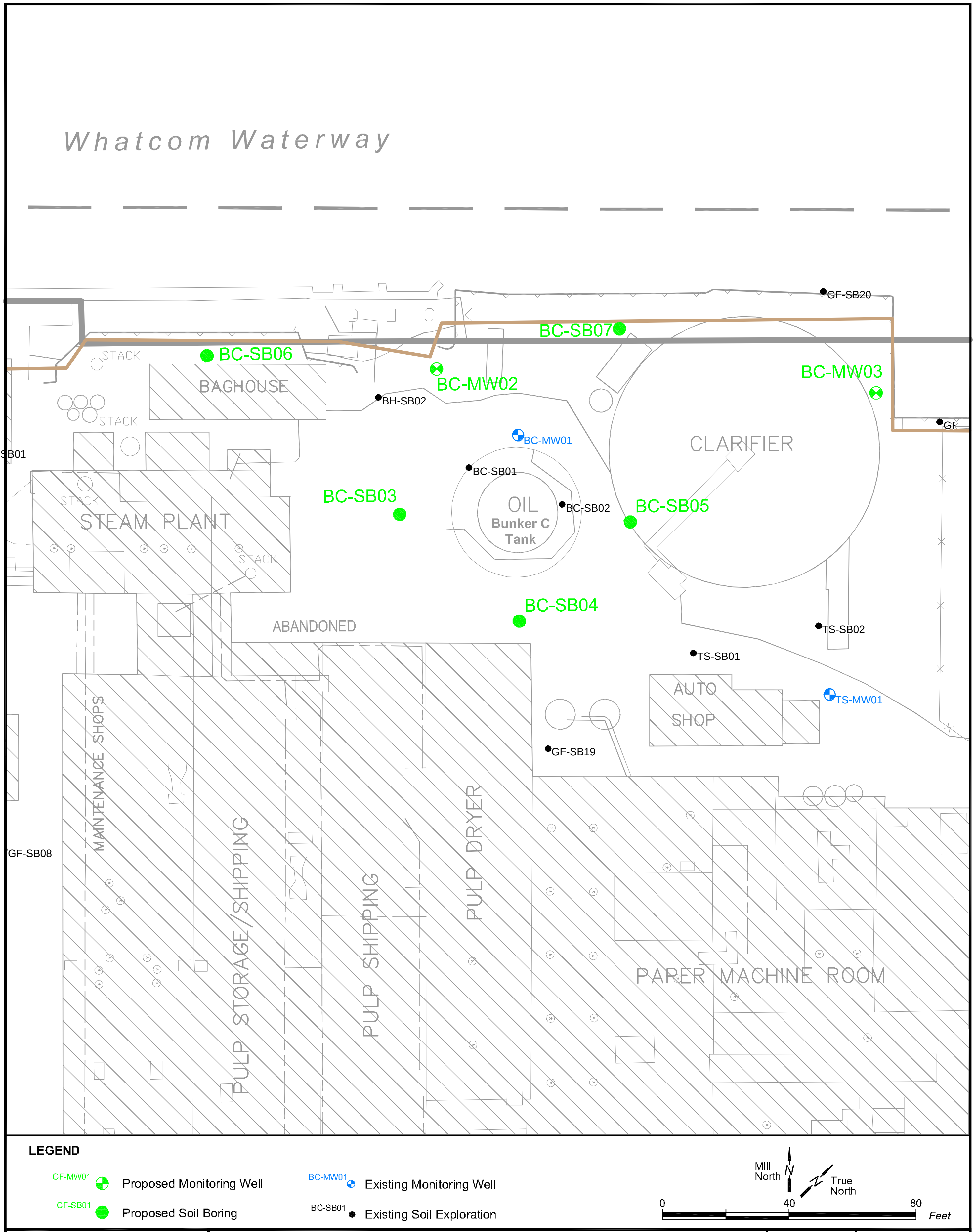
Bellingham, Washington

DATE:	July 2009
DESIGNED BY:	SJG
DRAWN BY:	SCC
REVISED BY:	SCC

PROJECT NO.
070188

FIGURE NO.
15

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\PropExplorations-Million Gallon Tanks Area.dwg



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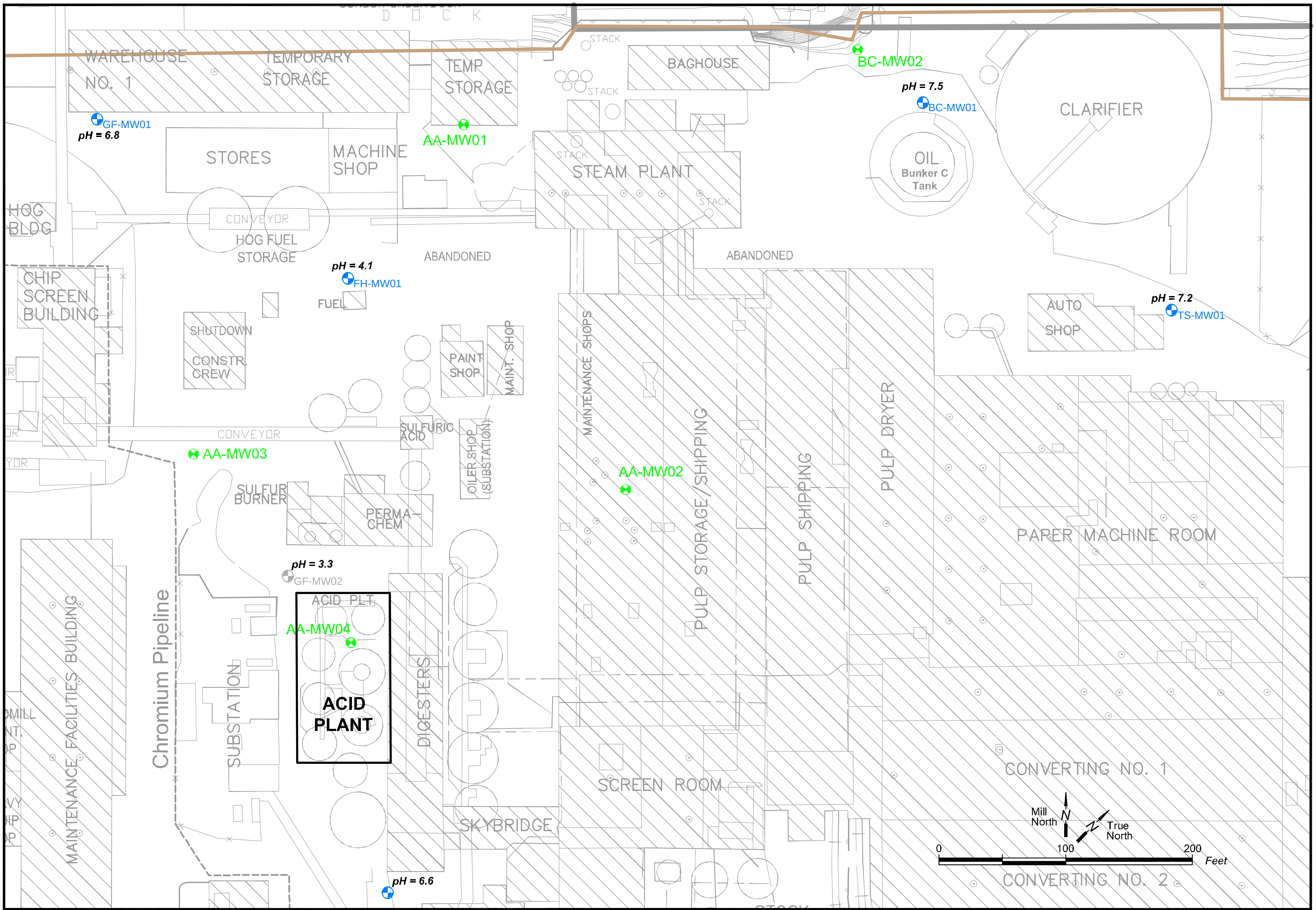
Proposed Explorations for Bunker C Tank Area

Georgia-Pacific West RI/FS

Bellingham, Washington

DATE: July 2009	PROJECT NO. 070188
DESIGNED BY: SJG	
DRAWN BY: SCC	FIGURE NO. 16
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2008-10 RI-FS\PropExplorations-Bunker C Tank Area.dwg



AA-MW01 ●	Proposed Monitoring Well
FH-MW01 ●	Existing Monitoring Well
GF-MW02 ●	Existing Monitoring Well (Decommissioned)
pH = 7.2	Groundwater pH Measurements from July 2004 Sampling.

Aspect consulting
earth+water
www.aspectconsulting.com
a limited liability company

Proposed Explorations for Acid Area

Georgia-Pacific West RI/FS
Bellingham, Washington

DATE:	July 2009
DESIGNED BY:	SJG
DRAWN BY:	SCC
REVISED BY:	SCC
PROJECT NO.	070188
FIGURE NO.	17

Q:\Port of Bellingham\070188 Former GP Mill Property\2009-06 RI-FS Final\PropExplorations-Acid Area.dwg

APPENDIX A

Development of Marine Water Screening Level for Formaldehyde

Prepared by Anchor Environmental LLC

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Memorandum

To: Steve J. Germiat, Aspect Consulting, L.L.C.

From: Dan Hennessey & Melissa Haury, Anchor Environmental, L.L.C.

CC: Mark Larsen & David Keith, Anchor Environmental, L.L.C.

Date: December 10, 2008

Re: Review of Scientific Literature and Recommended Marine Surface Water Screening Level for Formaldehyde – Mill Site RI/FS

The purpose of this investigation was to use existing data and previously conducted analysis to justify marine aquatic life surface water quality criteria for formaldehyde at the Georgia Pacific Bellingham Mill Site.

Formaldehyde is produced by both anthropogenic and natural sources. Combustion processes account directly or indirectly for most of the formaldehyde entering the environment. Formaldehyde is also used in fish hatcheries as an effective control of external parasites on fish, including protozoans and monogenetic trematodes (Piper and Smith, 1973). One study found that formalin (liquid formulation of 37% formaldehyde gas dissolved in water) can be delivered to fish in hatcheries as an indefinite bath at a concentration of 15 to 25 mg/l (Francis-Floyd, 1996).

Currently, no national ambient water quality criteria exist for formaldehyde. The Washington State Department of Ecology (Ecology) has created Cleanup Levels and Risk Calculation (CLARC), a web-based compendium of technical information related to the establishment of cleanup levels under the Model Toxics Control Act (MTCA) Cleanup Regulations, Chapter 173-340 WAC. Currently, the MTCA Method A groundwater cleanup level (based on presumption of drinking water use – not applicable to the Mill site) for formaldehyde is 0.001 mg/L. However, CLARC does not provide a surface water cleanup level for formaldehyde.

In *Derivation of ambient water quality criteria for formaldehyde*, Hohreiter and Rigg (2000) derived an acute toxicity value (Criteria Maximum Concentration (CMC)) of 4.58 mg/l and a chronic toxicity value

(Criterion Continuous Concentration (CCC)) of 1.61 mg/l. These values were derived in accordance with USEPA methodology for calculating national ambient water quality criteria as described in *Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses* (50 CFR 307922, 29 July 1985) (Stephan et al., 1985.) This study conducted an extensive literature search to assemble available acute and chronic toxicity data for formaldehyde. Quality of available acute data was evaluated per EPA guidance requirements, and poor or uncertain data was rejected. The data retained and used in criteria calculations included acute toxicity data for 12 species of fish, 3 species of amphibians, and 11 species of aquatic invertebrates.

Bioaccumulation is not expected to be significant enough to warrant concern or consideration because formaldehyde is rapidly metabolized (Casanova et al. 1988) and has a low octanol/water partition coefficient (log Kow = 0.35) (SRC 1995). Experiments performed on a variety of fish and shrimp showed no evidence of the bioaccumulation of formaldehyde (Sills and Allen, 1979; Hose and Lightner 1980). Because data indicate that bioaccumulation of formaldehyde is not significant, further quantitative evaluation of potential bioaccumulation is unnecessary to develop surface water quality criteria for formaldehyde.

One limitation apparent in the data collected by Hohreiter and Rigg (2000) was the lack of available and appropriate chronic toxicity data. However, the EPA guidance allows for a final chronic toxicity value to be calculated using acute toxicity data and limited chronic toxicity data by dividing the final acute value by a final acute-chronic ratio (ACR). Hohreiter and Rigg (2000) used the geometric mean of three family-specific ACRs used to calculate the final chronic value of 1.61 mg/L.

The derivation performed by Hohreiter and Rigg (2000) focused on data pertaining to freshwater organisms. Studies investigating formaldehyde toxicity to marine organisms would be ideal to apply to the marine aquatic habitat adjacent to the Mill Site. However, formaldehyde toxicity data for marine organisms is scarce. Birdsong & Avault (1971) investigated formaldehyde toxicity to juvenile marine pompano (*Trachinotus carolinus*). They found with 24-, 48-, and 72-h LC50 values of 28.8, 27.3, and 25.6 mg/l, respectively, in 30% salinity. Furthermore, their study demonstrated that salinity (10, 20, 30%) did not significantly affect the tolerance of fish to formaldehyde.

Table 1
Formaldehyde acute toxicity to marine and freshwater organisms

Biological organism (scientific name)	Biological organism (common name)	Duration/Endpoint	Value (mg/L formaldehyde)	Ref.
Fish (freshwater)				
Morone saxatilis	Striped bass fingerlings	96-h LC50 @ 0% salinity	1.8	16
Morone saxatilis	Striped bass fingerlings	96-h LC50 @ 5% salinity	5	16
Morone saxatilis	Striped bass fingerlings	96-h LC50 @ 10% salinity	5.7	16
Morone saxatilis	Striped bass fingerlings	96-h LC50 @ 15% salinity	4	16
Morone saxatilis	Striped bass fingerlings	96-h LC50	10	11,12
Morone saxatilis	Striped bass fry	96-h LC50	15	11,12
Morone saxatilis	Striped bass fingerlings	96-h LC50	7	23
Morone saxatilis	Striped bass fry	96-h LC50	11.1 - 27.8	2
Ameiurus melas	Black bullhead	96-h LC50	25.1	2
Ictalurus punctatus	Channel catfish	96-h LC50	26.5	2
O. mykiss	Rainbow trout	96-h LC50	29	2
Puntius gonionotus	Silver barb	96-h LC50	27 – 32	6
Salvelinus namaycush	Lake trout	96-h LC50	40.3	2
Cyprinus carpio	Common carp	96-h LC50	42.7 – 51.6	6
Channa striatus	Snakehead fish	96-h LC50	59.2 – 66.9	6
O. mykiss	Rainbow trout fingerlings	96-h LC50	49.6 - 58.5	1
L. cyanellus	Green sunfish	96-h LC50	69.8	2
Lepomis macrochirus	Bluegill	96-h LC50	29.6 - 50.4	2
Anguilla americana	Eels	96-h LC50	81	
Fish (saltwater)				
Sphoeroides annulatus	Bullseye puffer	72-h LC50	29.23	8
Pinctada fucata martensii	Pearl oyster (1-yr old)	96-h LC50 at 20 degrees C	7.7	21
Pinctada fucata martensii	Pearl oyster (1-yr old)	96-h LC50 at 25 degrees C	5.3	21
Pinctada fucata martensii	Pearl oyster (2-yr old)	96-h LC50 at 20 degrees C	10.2	21
Pinctada fucata martensii	Pearl oyster (2-yr old)	96-h LC50 at 25 degrees C	6.4	21
Salmo salar	Atlantic salmon	96-h LC50	69.8	2
Crustacean				
Cypridopsis vidua	Seed shrimp	96-h LC50	54.4 - 68.6	7
Palaemonetes kadaikensis	Freshwater prawn	96-h LC50	188	2
Daphnia pulex	Polychaete	96-h LC50	5.8	22
Daphnia magna	Polychaete	96-h LC50	7.6	14
Shellfish				
Corbicula	Asiatic clam	96-h LC50	50.8	2
Helisoma	Snail	96-h LC50	37.51	2

Takayanagi et. al. (1999) determined the acute toxicities of formaldehyde to one- and two-year-old pearl oysters, *Pinctada fucata martensii*. The 96 h-LC50 values were 7.7 mg/l at 20°C and 5.3 mg/l at 25°C for the one-year-old pearl oyster. It was 10.2 mg/l at 20°C and 6.4 mg/l at 25°C for the two-year-old pearl oyster. Fajer-Avila et. al. determined that the 72-h LC50 value to bullseye puffer fish was 29.2 mg/l formaldehyde. Reardon & Harrell (1990) reported 96-h LC50 values of 1.8, 5.0, 5.7, and 4.0 mg/l in water with 0, 5, 10, and 15% salinity, respectively. Salinity may have an effect on the tolerance of striped bass to formaldehyde. Although the fish had been acclimated to water with a salinity of 10–30% prior to testing, they were most tolerant of formaldehyde water with a salinity of 9–10%. Since controls were not affected by the changes in salinity, there may be a compounded effect of chemical and environmental (e.g., salinity) interaction on fish survival.

Thus, the toxicity data available for marine organisms appears to demonstrate a slightly lower tolerance to formaldehyde than freshwater organisms (see Table 1.) However, in general, acute toxicity data between freshwater and marine water organisms is comparable. It is notable that formaldehyde toxicity to fish does not seem to vary significantly when water quality parameters other than salinity (such as temperature, pH, and hardness) are varied (Hohreiter and Rigg, 2000). Furthermore, the USEPA has exhibited a precedent of applying fresh surface water toxicity reference values to marine water when marine aquatic toxicity data is not available, indicating the relevance of freshwater criteria to marine habitat.

In conclusion, the derivation performed by Hohreiter and Rigg (2000) is a thorough analysis, inclusive of a wide range of studies. Furthermore that it is reasonable and appropriate to apply their criteria to surface marine water aquatic life determinations. Based on the foregoing, a concentration of 1.61 mg/L is appropriate for use as a formaldehyde surface water screening value during the Mill site project.

REFERENCES

1. Bills, TD. 1974. Toxicity of formalin, malachite green, and the mixture to four life stages of rainbow trout. Graduate College, Univ.Wisconsin, La Crosse, WI

2. Bills, TD, Marking, LL, Chandler, JH. 1977. Formalin: Its Toxicity to Nontarget Aquatic Organisms, Persistence, and Counteraction. Investigations in Fish Control No. 73, U.S. Dept. of the Interior, Wash. D.C.

3. Bills, TD, Marking, LL, Howe, GE. 1993. Sensitivity of Juvenile Striped Bass to Chemicals Used in Aquaculture. US Fish and Wildlife Service. Resource Publication 192. Washington DC.

4. Birdsong CL, Avault JV. 1971. Toxicity of certain chemicals to juvenile pompano. The progressive fish-culturist, 33(2): 76–80.

5. Casanova M, Heck HD, Everitt JI, et al. 1988. Formaldehyde concentrations in the blood of Rhesus monkeys after inhalation exposure. Food Chem Toxicol 26:715-716.

6. Chinabut, S, C Limsuwan, K Tonguthai, T Pungkachonboon. 1988. Toxic and sublethal effect of formalin on freshwater fishes. Network of Aquaculture Centres in Asia.

7. Cooney, JD, Bourgoin, MI. 2001. Comparative toxicity of formaldehyde to freshwater daphnids (*Ceriodaphnia dubia* and *D. pulex*), ostracods (*Cypridopsis vidua*), and fathead minnows(*Pimephales promelas*), in preparation.

8. Fajer-Avila, EJ, Abdo-de la Parra, I, Aguilar-Zarate, G, Contreras-Arce, R, Zaldivar-Ramirez, J, Betancourt-Lozano, M. 2003. Toxicity of formalin to bullseye puffer fish (Spoeroides annulatus Jenyns, 1843) and its effectiveness to control ectoparasites. Aquaculture 223: 41 - 50.

9. Francis-Floyd, Ruth. 1996. Use of Formalin to Control Fish Parasites. College of Veterinary Medicine, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, Gainesville, 32611.

10. Hose JE, Lightner DV. 1980. Absence of formaldehyde residues in Penaeid shrimp exposed to formalin. Aquaculture 21:197-201.

11. Hughes, JS. 1973. Acute toxicity of thirty chemicals to striped bass (Morone saxatilis). La. Dep. Wildl. Fish. 315-343-2417, 15.

12. Hughes, JS. 1975. Striped bass, Morone saxatilis (Walbaum), Culture investigations in Louisiana with Notes on Sensitivity of Fry and Fingerlings to Various Chemicals. Louisiana Wildlife and Fisheries Comm. Fisheries Bulletin No. 13

13. Lyman WJ. 1982. Adsorption coefficient for soils and sediments. In: Lyman WJ, Reehl WF, Rosenblatt DH, ed. Handbook of chemical property estimation methods: Environmental behavior of organic compounds. New York: McGraw-Hill Book Company, 4-1 to 4-33.

14. Nazarenko, IV. 1960 Effect of formaldehyde on aquatic organisms. Trudy Vsesoyuznogo Gidrobiologicheskogo Obshchestva 10, 170-174.

15. Piper, RG, Smith CE. 1973. Factors influencing formalin toxicity in trout. Prog. Fish-Cult. 35 (2), 78 – 81.

16. Reardon I.S. and Harrell R.M. 1990. Acute toxicity of formalin and copper sulfate to striped bass fingerlings held in varying salinities. Aquaculture vol. 87 (3-4) pp. 255-270

17. Sills JB, Allen JL. 1979. Residues of formaldehyde undetected in fish exposed to formalin. Prog Fish Cult 41:67-68.

18. Stephan CE, Mount DI, Hansen DJ, Gentile JH, Chapman GA, Brungs WA. 1985. Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses. USEPA. Office of Research and Development, Washington, DC.

19. Swann RL, Laskowski DA, McCall PJ, et al. 1983. A rapid method for the estimation of the environmental parameters octanol/water partition coefficient, soil sorption constant, water to air ratio, and water solubility. Residue Rev 85:17-28.

20. SRC. 1995. Syracuse Research Corporation. Octanol-Water Partition Coefficient Program (KOWWIN, Version 1.37, Serial L0148). Chemical Hazard Assessment Division, Environmental Chemistry Center, Syracuse, NY.

21. Takayanagi, K, Sakami T, Shiraishi M and H Yokoyama. 1999. Acute toxicity of formaldehyde to the pearl oyster Pinctada fucata martensii. National Research Institute of Aquaculture, 422-1.

22. Tisler, T, Zagorc-Koncan, J. 1997. Comparative assessment of toxicity of phenol, formaldehyde, and industrial wastewater to aquatic organisms. Water, Air, Soil Pollution. 97 (3-4), 315-322.

23. Wellborn, TL. 1969. The toxicity of nine therapeutic and herbicidal compounds to striped bass. Prog. Fish-Cult. 31 (1) 27-32.

APPENDIX B

Chemical Fate and Transport Mechanisms

Chemical Fate and Transport Mechanisms

This section describes the major factors affecting fate and transport of the organic constituents and metals detected in soil and groundwater at the Site. In addition to the chemical-specific discussion of fate and transport provided below, other processes such as diffusion, dispersion, and dilution with unimpacted groundwater will act to attenuate constituent concentration in groundwater. For example, previous modeling of Site groundwater discharge of mercury to the Log Pond, which accounted for groundwater advection and chemical diffusion, indicates that mercury concentrations in groundwater will be attenuated by a factor of at least ten across the sediment-surface water interface. Tidally-induced dispersion and increased biodegradation (for organics) or chemical precipitation (for metals) would likely increase the attenuation.

Organics

The primary mechanisms controlling the fate and transport of organic constituents include dissolution to groundwater of constituents bound to soil particles or present as free phase product; volatilization from soil, groundwater, or free product to soil vapor; sorption of dissolved phase constituents in groundwater to organic matter on soil particles; and biodegradation and abiotic transformation. The following sections briefly summarize these processes as they relate to the organic constituents detected at the Site.

TPH, Total cPAHs, and Naphthalenes

Detections of TPH (primarily Bunker C heavy fuel oil) at concentrations greater than the screening levels for soil were limited to the Million Gallon Tank and the Bunker C Tanks areas. Free-phase product is present on the water table beneath the Bunker C Tanks, and elevated dissolved-phase TPH occurs in groundwater downgradient from the Million Gallon Tanks and Bunker C Tanks. Elevated total cPAH concentrations in groundwater also occur downgradient of these locations, and elevated total naphthalenes were detected downgradient of the Million Gallon Tanks. Naphthalenes (non-carcinogenic PAHs) and cPAHs are commonly associated with Bunker C.

Bunker C has a relatively high viscosity, limiting the potential for free-phase product to migrate a significant distance in soil under ambient temperatures. However, it appears that Bunker C fuel oil present in soil and as a free-phase product on the water table is dissolving and leaching to groundwater, along with associated cPAHs and naphthalenes. These dissolved-phase constituents are then able to migrate downgradient toward the waterway. Downgradient migration is attenuated to some degree via sorption to organic material in the aquifer matrix, biodegradation, and dilution by mixing with unimpacted groundwater, although the extent of attenuation at the Site is not known.

Sorption of organic constituents to organic material in the aquifer matrix can be described by the organic carbon partitioning coefficient (Koc). A high Koc indicates strong sorption to the solid phase, and low mobility. Naphthalene is moderately mobile in groundwater, with a Koc of about 1,190 L/kg, while the cPAHs are relatively immobile, with a Koc for benzo(a)pyrene of about 970,000 L/kg (WAC 173-340-900, Tables 747-4 and 747-1). Similarly, the heavy petroleum fraction that makes up Bunker C is also relatively immobile.

Naphthalene biodegrades rapidly under aerobic conditions. The cPAHs also biodegrade under aerobic conditions, although at much slower rates than naphthalene (Aronson, et al., 1999). Under the anaerobic conditions that predominate in groundwater at the Site, cPAHs are not expected to biodegrade significantly, although some biodegradation of naphthalenes is still expected (Aronson and Howard, 1997).

Volatilization of TPH, cPAHs, and naphthalenes and migration through soil vapor is not expected to be a significant transport mechanism.

Volatile Organic Compounds (VOCs)

The chlorinated VOCs PCE and vinyl chloride were detected at concentrations above preliminary screening levels in groundwater at one location - Lignin Plant monitoring well LP-MW01. The chlorinated VOCs TCE and cis-1,2-DCE was also detected at LP-MW01, but at concentrations lower than the screening levels. No soil source has been identified for these detected VOCs.

The VOCs that exceed groundwater screening levels are relatively mobile in groundwater, with Koc values ranging from about 19 to 265 L/kg (WAC 173-340-900, Table 747-1). Based on these Koc values, any VOCs sorbed to the soil matrix are expected to readily leach and migrate with groundwater flow.

PCE, TCE, cis-1,2-DCE, and vinyl chloride all biodegrade under anaerobic conditions, although the rate of vinyl chloride degradation is limited (Aronson and Howard, 1997). Vinyl chloride can also biodegrade via oxidation reactions in nitrate- and iron-reducing redox conditions, but degrades most readily under aerobic conditions. The chlorinated VOCs biodegrade via sequential reductive dechlorination, with PCE biodegrading to form TCE, which biodegrades to produce the DCE isomers, then vinyl chloride, and finally ethene. Based on the redox conditions at the Site, it is expected that some biodegradation of the chlorinated VOCs should be occurring.

The VOCs, whether sorbed to the soil matrix or dissolved in groundwater, are expected to volatilize readily when exposed to air. If the chlorinated VOCs are confirmed in groundwater, transport through soil in the vapor phase is a potential transport mechanism that will need to be considered for the VOCs.

Dioxins/Furans and PCBs

Total dioxins/furans and PCBs were detected in soil at concentrations greater than unrestricted soil screening levels at one or more location each. PCBs were also detected in groundwater at a concentration greater than screening level at one location. Dioxins were not analyzed for in groundwater. Dioxins in soil were detected near the former Bag House, while PCBs in soil were detected near the former Electrical Transformers. PCBs in groundwater were detected at well EMW-16S, located near the former log pond and downgradient from the Million Gallon Storage Tanks. A potential soil source for the detected PCBs in groundwater has not been identified, but given PCBs low solubility and mobility may be attributable to suspended solids in the sample.

Dioxins and PCBs exhibit very low mobility, with Koc values for individual PCB Aroclors ranging from about 110,000 to 820,000 L/kg (WAC 173-340-900, Table 747-1) while the Koc for 2,3,7,8-TCDD, a dioxin congener, has been estimated as greater than 30,000,000 L/kg (U.S Department of Health and Human Services, 1998). Based on these Koc values, PCBs and dioxins are expected to sorb strongly to organic matter in soil, with virtually no leaching to groundwater.

PCBs and dioxins are persistent in soil, with minimal potential for biodegradation. PCBs and dioxins are nonvolatile and migration via soil vapor is not a significant transport mechanism at the Site.

Metals

Metals detected in groundwater at concentrations exceeding preliminary screening levels include arsenic, cadmium, chromium (trivalent and hexavalent), copper, lead, manganese, mercury, nickel, and zinc. With the exception of chromium and mercury, there is no evidence that these metals were used extensively in operations at the Site. Exceedances of screening levels for metals in soil are limited to mercury on the Chlorine Plant portion of the Site, and isolated detections of cadmium and lead on the Tissue Plant portion of the Site.

In groundwater, concentrations of arsenic, copper, manganese, nickel and zinc above preliminary screening levels are relatively wide-spread on the Tissue Plant portion of the Site. These metals were not analyzed for on the Chlorine Plant portion of the Site. Elevated concentrations of mercury in groundwater are primarily limited to the Chlorine Plant portion of the Site, with the highest concentrations occurring in the Caustic Plume area.

Geochemical conditions, particularly redox and pH, strongly control the occurrence, fate, and transport of metals. Generally reducing groundwater conditions are observed in the Fill Unit aquifer, as indicated by the low measured dissolved oxygen concentrations (typically less than 1 to 2 mg/L) and redox potential (typically -100 to -300 mV). Groundwater pH at the Site is typically near neutral conditions (6 to 8 pH units), although strongly alkaline conditions (pH up to 12) are encountered in the Caustic Plume area and acidic conditions (pH 3 to 4) are encountered in two wells in the Acid Plant area.

Mechanisms expected to control fate and transport of metals at the Site, in the context of Site geochemical conditions, are discussed in the following sections. Mercury and chromium, which were used in plant operations and have the most wide-spread occurrences, are discussed in separate sections, followed by the remaining metals.

Mercury

Mercury fate and transport is strongly controlled by ambient geochemical conditions in soil and groundwater. Compared to many other metals, the geochemistry of mercury is relatively complex because mercury exists in different oxidation states under the range of oxidation-reduction potentials possible in the environment, and due to the potential for a number of chemical reactions involving mercury. Some of these reactions include volatilization, precipitation, co-precipitation, and sorption to organic matter and mineral phases, among others. Because mercury volatilizes under typical temperature and pressure conditions at the Site, mercury is the only metal for which transport through soil in the vapor phase will need to be considered.

Based on prior Site characterization as described in ENSR (1994a), mercury is present in Site soils predominantly in the divalent form (Hg^{+2}) and, depending on the local oxidation-reduction potential, is likely in the form of mercuric sulfide or chloride complexes (or solids). Mercury speciation analyses of soil samples show that less than one percent of the mercury present in these soils is present as either methylmercury or elemental mercury. Similarly, the largest proportion of mercury (98 percent) detected in nearshore groundwater and sediments of the adjacent Log Pond is present in complexed ionic forms (i.e., divalent mercury) rather than methylated or elemental forms (Bothner et al. 1980; ENSR 1994a). The lack of methylmercury has been confirmed during 2008 sediment sampling conducted as part of the Whatcom Waterway Pre-Remedial Design Investigation. Those data indicate that methylmercury comprises, on average, less than 1 percent of total mercury in waterway sediment.

To further characterize mercury speciation at this Site, methyl and total mercury were analyzed during the 2003 RI Addendum in the two soil samples containing the highest total mercury concentrations, and also in the Chemfix material (Anchor Environmental, 2003b). These analyses indicated that less than 0.07 percent of the total mercury at the Site is present as methylmercury. These results are consistent with prior analyses of mercury speciation in soil and sediment samples.

Under the slightly reducing redox and near neutral pH conditions throughout most of the Site, mercury is predicted to be present predominantly as divalent mercury complexed with sulfide (e.g., $HgHS_2$). The solubility and transport of divalent mercury complexes in the former Chlorine Plant area is likely to be strongly controlled by sorption and precipitation reactions involving sulfide phases. In the presence of sulfide, mercury may precipitate as a highly insoluble mercuric sulfide (HgS) or may co-precipitate with iron sulfides.

In Caustic Plume area of the Site, where the groundwater pH is elevated (e.g., up to pH 11 to 12), mercury concentrations in the groundwater are also elevated (ENSR 1994a; Aspect Consulting, 2004a). Under such alkaline pH conditions, sulfide (and associated mercuric sulfide complexes) is no longer the stable form of sulfur, and the form of mercury expected to be present is the more soluble, and more mobile, elemental form. Higher groundwater mercury concentrations at alkaline locations may result from a shift to greater proportions of elemental mercury and the absence of sulfide precipitation as a removal mechanism for mercury (Anchor Environmental, 2003b).

Chromium

One groundwater sample had a reported hexavalent chromium concentration of 224 μg/L, and several other samples had detection limits greater than the protection of surface water-based screening levels for hexavalent chromium. As discussed previously, the hexavalent chromium analytical method for water involves colorimetric quantification.

Site groundwater is commonly colored from dissolved organics, which reduces the method sensitivity, resulting in increased detection limits for hexavalent chromium.

Liquid chromium was reportedly used in the Lignin Plant area, including deliveries of hexavalent chromium into the 1980s, and both trivalent and hexavalent chromium may have been released to soil and groundwater during site operations. Based on geochemical conditions, it is unlikely that significant concentrations of hexavalent chromium persist in Site groundwater. Within a pH range of 6 to 8 hexavalent chromium is only stable under strongly oxidizing conditions with a redox of approximately +500 mV or greater (Drever, 1997). Under the generally reducing conditions at the Site, the less soluble and less toxic trivalent chromium is the stable species. Measured redox and dissolved oxygen in the well where hexavalent chromium was reportedly detected were -224 mV and 0.67 mg/L, respectively. These conditions are not consistent with the presence of hexavalent chromium and the detected concentrations may be due to analytical interferences.

Other Metals

Redox and pH conditions exert a strong influence on the speciation and mobility of several other metals, including arsenic, iron, and manganese. Higher concentrations and greater mobility are associated with reducing conditions under near-neutral pH. Similarly, low pH, as occurs at the Acid Plant area, also results in increased concentrations and mobility. Under moderately or highly oxidizing conditions, dissolved iron will be present as ferric iron and will form relatively insoluble oxide and oxyhydroxide compounds. Metals such as arsenic, chromium, copper, lead, and zinc are strongly complexed with the iron oxides and oxyhydroxides, with near complete adsorption occurring at near-neutral pH values. The adsorbed metals are present as co-precipitants in the iron-containing minerals. In native aquifer materials exposed to reducing conditions and/or low pH, the ferric iron converts to the more soluble ferrous form. Dissolution of the iron-containing minerals under these conditions can result in the release and dissolution of co-precipitated metals. This has been identified as one of the major sources of naturally occurring arsenic in groundwater (Kelly et al., 2005), and is a probable mechanism that has resulted in observed concentrations of several metals in groundwater at the Site, particularly those metals not reportedly used in site operations.

APPENDIX C

Sampling and Analysis Plan

This Appendix describes field sampling and Quality Control (QC) procedures to be followed during the RI/FS data collection. The main body of the RI/FS Work Plan describes the locations and rationale for the proposed sampling and analyses. Additional information on laboratory analytical methods, sample containers, and sample holding times are provided in the Quality Assurance Project Plan (QAPP), included as Appendix D of the RI/FS Work Plan.

Direct Push Soil Borings

Aspect Consulting will subcontract with a Washington-licensed resource protection well driller to complete direct push soil borings within the Fill Unit and into the Tidal Flat Aquitard Unit. Soil borings will be advanced using a direct push (i.e. Geoprobe) rig and will be sampled on a continuous basis. Each boring will be advanced to collect samples at depth intervals specified in the RI Work Plan or as determined by field screening. Samples are collected in disposable 1.5-inch-diameter plastic liners (4-foot lengths). The liners are opened by a stainless steel blade to access the sample.

A geologist from Aspect Consulting will oversee the drilling activities and preparation of geologic logs for each of the explorations completed. The field representative will visually classify the soils in accordance with ASTM Method D 2488 and record soil descriptions, field screening results, and other relevant details (e.g., staining, debris, odors, etc.) on the boring log form (see forms in Attachment C-1).

In addition to field observations, the field representative will screen each soil sample using a PID to monitor the presence of volatile organic compounds (VOCs). All soil samples to be submitted for VOC analyses will be collected in accordance with EPA Method 5035A. The soil aliquot for VOC analysis will be collected from the undisturbed soil sample core using a laboratory-supplied modified disposable plastic syringe as required by the 5035A method, and placed in pre-weighed laboratory supplied vials.

For all other analyses, the soil samples will be removed from the sampler using a stainless steel spoon and placed in a stainless steel bowl for homogenization with the stainless steel spoon. Gravel-sized material greater than approximately 0.5 inch will be removed from the sample during mixing. A representative aliquot of the homogenized soil will be placed into certified-clean jars supplied by the analytical laboratory.

Each soil boring not completed as a monitoring well will be decommissioned with hydrated granular bentonite.

Soil Borings into Lower Sand Unit

Soil borings extending through the Tidal Flat Aquitard Unit into the Lower Sand will be completed in a two-phase process to limit the chance of contaminant carry down from the overlying Fill Unit. The process involves drilling and sealing a conductor casing into the upper part of the aquitard unit, and then drilling through the conductor casing through the rest of the aquitard and into the underlying Lower Sand. The general steps in drilling the Lower Sand soil borings are as follows:

- Mobilize a hollow stem auger drill rig and advance a 10.25-inch inside diameter (ID) hollow-stem auger into a competent, silty portion of the aquitard (e.g., 20-foot depth);
- While advancing the auger, collect soil samples at 2.5-foot intervals using the Standard Penetration Test (ASTM D-1586-84). If soil samples are targeted for VOC analyses will be collected in accordance with EPA Method 5035A prior to homogenization for the other analyses, as described above for direct push borings;
- Place an 8-inch steel casing within the auger to the boring depth (conductor casing);
- Pump a cement-bentonite seal around the 8-inch conductor casing, as the auger is withdrawn, and allow the seal to cure a minimum of 24 hours;
- Pour an approximately 3-foot layer of bentonite slurry in the bottom of conductor casing, prior to advancing the lower portion of the borehole;
- Mobilize a rotosonic (sonic) drill rig to advance 6-inch borehole through the conductor casing to total depth (e.g., to 40 feet or deeper if deemed appropriate by field observations); and
- Below the conductor casing, collect soil samples at defined intervals from the continuous core produced by sonic drilling.

The total depth of each boring will depend on soil mercury concentrations near the bottom of the boring. For each deep boring, drilling will be stopped at the 40-foot depth while rush-turnaround mercury analyses are conducted for the bottom soil sample collected (38 to 39 foot depth). The lab results will determine whether to continue drilling and soil sampling deeper (if total mercury concentration is above 5 mg/kg) or install the monitoring well (if total mercury concentration is at or below 5 mg/kg).

Soils will be classified, and soil samples collected, using the same basic procedures as described for direct push soil borings in Section C1. The Lower Sand borings are planned for completion as monitoring wells, as described in Section C4.

Soil Mercury Vapor Sampling

Soil vapor from selected boring locations will be analyzed for both elemental and total mercury, using similar sampling methods to those employed during the RI Addendum (Anchor Environmental, 2003b) but with improved analytical methods. Because the mercury vapor sampling procedure can last hours at each location, the vapor samples will be collected from a soil gas probe advanced in a separate borehole located within approximately 3 feet of the soil boring/monitoring well location where corresponding soil and groundwater data will be collected. The soil vapor probes will be installed to a depth of 1.5 feet, with a short gas intake at the bottom. The surface penetration will be sealed with bentonite slurry to limit intrusion of atmospheric air into the soil gas sample.

Vapors will be pulled from the soil probe by a low-flow vacuum pump through dedicated Teflon tubing to mercury collectors. Elemental mercury concentrations will be measured in the field using the Lumex RA-915+ field analyzer. The results of the elemental mercury field analysis will be used to identify the appropriate run times and flow rates for total mercury soil-vapor sampling. Total mercury will be sampled using a modification of EPA Method 30B, which involves pumping soil vapor through a chemically impregnated carbon sorbent trap for up to 16 hours (overnight) and analyzing the sorbent trap in the laboratory using EPA Method 1631. EPA Method 30B Laboratory Performance Demonstration Study is provided as Attachment C-2 to this Appendix. Appendices to this demonstration study are not included in Attachment C-2, but are available from Aspect upon request.

Monitoring Well Installation, Development, and Testing

Monitoring Well Installation

Selected soil borings (described above) will be completed as monitoring wells. The monitoring wells will be constructed by a licensed resource protection well driller and in accordance with Chapter 173-160 WAC. An Aspect field geologist will oversee and document installation of each monitoring well, including completion of an As-Built Well Completion Diagram (see Attachment C-1).

New Fill Unit monitoring wells will be constructed with 2-inch-diameter, threaded Schedule 40 PVC slotted screen and blank casing. Well screens will be 0.020-inch slot (20-slot) or 0.030-inch slot (30-slot) and 5 feet in length. Screens will be pre-packed with 10/20 silica sand and an annular seal consisting of bentonite chips will be placed above the filter pack. If drilling conditions prevent installation of a 2-inch-diameter filter-packed well, 1-inch-diameter pre-packed wells may be installed.

New Lower Sand monitoring wells will be constructed with 2-inch-diameter, threaded Schedule 40 PVC slotted screen and blank casing. Well screens will be 0.020-inch slot (20-slot) or 0.030-inch slot (30-slot) and 5 feet in length. An artificial filter pack consisting of 10/20 silica sand will be placed around the well screen, and an annular seal consisting of bentonite chips will be placed above the filter pack, within the conductor casing.

A concrete surface seal will be set at grade for each new monitoring well. The finished monitoring wells will be protected with a steel flush-mount monument.

Well screen depths will be determined based on the field conditions, although wells to be completed in the Fill Unit will generally be less than 20 feet deep and wells to be completed in the Lower Sand Unit will generally be greater than 30 feet deep. Wells intended to identify impacts from petroleum releases (e.g., at the Million Gallon Tanks and Bunker C Tanks areas) will be screened across the water table.

Monitoring Well Development

Following installation, each new monitoring well will be developed to remove fine-grained material from inside the well casing and filter pack, and to improve hydraulic communication between the well screen and the surrounding water-bearing formation. Well development will be performed using a submersible electric pump gently surged the entire length of the well screen. Each well will be developed until visual turbidity is reduced to minimal levels until a maximum of 10 casing volumes of water has been removed.

Each existing monitoring well will be redeveloped to remove fine-grained material or scale accumulated within the well casing and to improve hydraulic communication between the well screen and the surrounding water-bearing formation. Well re-development will be performed using the same procedures and criteria as for the new monitoring wells.

Following the redevelopment effort, any well that is determined to not be in suitable condition (e.g., evidence of damaged screen or casing, such as excessive production of sand and silt) will not be used for the RI/FS data collection. Those wells will be targeted for decommissioning in accordance with Chapter 173-160 WAC and, if warranted for the purposes of completing the site RI/FS, replacement. The condition of the protective monuments for all of the existing monitoring wells was evaluated by Aspect during a site reconnaissance in October 2008. A licensed driller will be contracted to replace any damaged monuments on usable wells.

Groundwater Level Monitoring

One round of concurrent groundwater level measurements will be made from all existing usable wells. Depth-to-groundwater measurements will be conducted in the wells using an electric well sounder, graduated to 0.01 foot. An oil-water interface probe will be used to measure water levels and evaluate the presence of floating free-phase product in wells in the Million Gallon Tanks and Bunker C Tank areas.

Groundwater Sampling

Groundwater samples will be collected with a peristaltic pump and pre-cleaned, dedicated downhole fluoropolymer (Teflon) tubing attached to a length of pre-cleaned styrene/ ethylene/ butylenes silicone (SEBS) tubing, following low-flow sampling techniques to minimize suspended solids in the samples. This tubing is required for sample collection for the low-level mercury analysis (EPA Method 1669) so will be used for all sampling.

Prior to sample collection, the static water level in the well will be measured. The well will then be purged at flow rates less than 0.5 liter per minute, and the field parameters temperature, pH, electrical conductance, dissolved oxygen, and oxidation-reduction potential (Eh) will be monitored using a YSI meter and flow-through cell, or equivalent. These field parameters will be recorded at 2 to 4 minute intervals throughout well purging until they stabilize. Stabilization is defined as three successive readings where the parameter values vary by less than 10% (or 0.5 mg/L dissolved oxygen if the readings are below 1 mg/L). However, no more than three well casing volumes will be purged prior to groundwater sample collection.

Once purging is complete, the groundwater samples will be collected using the same low flow rate. Samples will be collected by directly filling laboratory supplied pre-cleaned containers from the pump discharge tubing. Samples for dissolved metals analyses will be filtered using an in-line 0.45 μm filter; at least one liter of water will be purged through the filter prior to sample collection. To reduce the likelihood of trace metals contamination, field sampling methods for collection of metals samples will generally follow the protocol established in EPA Method 1669, Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels. In addition to the procedures described above, clean, non-talc disposable gloves will be used to handle the sampling apparatus, samples, and blanks for samples collected for low-levels metals analyses.

Sampling quality assurance and quality control mechanisms are outlined in detail in the QAPP, provided in Appendix D of the RI Work Plan.

Slug Testing

Slug tests will be performed on select wells to estimate the hydraulic conductivity of aquifer materials. The test method involves quickly displacing a volume of water within a well and measuring water level recovery rate. Analytical methods are used to estimate hydraulic conductivity of the soil from the recorded water level data.

A slug test can consist of a “slug-in” or falling head test, where the water level in the well is rapidly raised, or a “slug-out” or rising head test, where the water level in the well is rapidly lowered. A minimum of two slug tests will be performed at each well to be tested. An electric well sounder will be used to determine the depth from the top of the casing to the water table. The depth to water measurement will be compared to the well construction log to determine if the well screen is fully saturated. Rising and falling head tests will be performed in wells where the screen section is fully saturated. Only rising head tests will be conducted in wells with partially saturated screens.

Slug tests will be performed using a solid PVC slug rod to perturb the water level in the well. A pressure transducer and data logger will be used to measure and record displacement and recovery of the water in the well. For a falling head test, the slug rod will be rapidly lowered into the well and water levels monitored until they approach the pre-test measured water level. For a rising head test the slug rod will be lowered into the well and the water level allowed to re-equilibrate. The slug rod will then be rapidly removed and water levels will be monitored until they approach the pre-test measured water level.

Tidal Study Instrumentation

Each well to be monitored in the tidal study will be equipped with a downhole pressure transducer/data logger to allow automated collection of water level data at 5-minute intervals. A data logger will also be placed in the Whatcom Waterway to directly record tidal fluctuations. A barometric pressure data logger will also be installed on site to allow water level data to be corrected for changes in atmospheric pressure throughout the study. Data loggers will be suspended securely to avoid movement during the test, and will be set to measure synchronously at the same time (within a minute).

During installation of the data loggers, a manual depth-to-water measurement will be collected in each well approximately when the data logger takes its first reading, and again at the end of the test prior to removing the logger. The depth-to-water measurements (below surveyed top of well casing) provide groundwater elevations which will be used to convert the data logger readings into groundwater elevations.

Exploration Surveying

All sampling locations for the project will be initially located in the field with hand-held GPS, and recorded again once completed ("as built") using GPS. All new and usable existing monitoring well locations will also be surveyed by a licensed surveyor relative to a common horizontal and vertical datum being used for the Whatcom Waterway cleanup work. Monitoring well top-of-casing elevations will be surveyed to the nearest 0.01 foot, and horizontal coordinates to the nearest 0.1 foot, or better. Measurements will be taken at the "notched" or "marked" spot at the top edge of the open PVC casing. Where not yet marked, the highest point on the casing will be surveyed and marked.

Field Quality Control Procedures

The following sections define procedures for field activities to ensure the quality of measurements and the integrity of samples collected. The procedures focus on soil and groundwater sampling; detailed procedures and Quality Control (QC) measures for soil vapor sampling and analysis are presented in Attachment C-2.

Field Measurements

The calibration and general maintenance of the instruments will be the responsibility of the Aspect Field Manager. All calibration procedures and measurements will be made in accordance with manufacturers' specifications. Field instruments will be checked and calibrated before their use on site, and batteries will be charged and checked daily. It is expected that field measurements will include the following:

- Electrical specific conductance (EC);
- Temperature;
- pH;
- Dissolved oxygen (DO); and
- Oxidation reduction potential (ORP).

Field Equipment

The following equipment will be used in the field to collect samples and take measurements:

Direct-Push Geo-Probe. Subsurface soil samples will be collected with direct-push Geo-probe samplers. Disposable plastic liners will be used to recover soil samples. Upon retrieval, the liners will be cut into desired sections and the recovered soil transferred into a stainless steel bow for homogenization, and then dispensed into sample containers.

Hand Auger. Surface soil samples will be collected using a hand auger sampling equipment transferred to a stainless steel bowl for homogenization before placed into the sample container for each sample.

Stainless Steel Spoons and Bowls. Soil samples will be collected directly using decontaminated, stainless steel spoons and homogenized in a stainless-steel bowl before being placed into sample containers. Pre-cleaned, stainless-steel sampling equipment may be brought to the site for use.

Global Positioning System (GPS) Unit. A hand-held GPS unit will be used to measure the position of the sampling locations. The GPS unit will be capable of measuring to sub-meter accuracy and coordinates will be established in the WGS84 or equivalent coordinate system.

Electric Well Sounder. The well sounder will be used to measure water levels within the groundwater borings prior to collecting grab groundwater samples. The well sounder will be decontaminated before use at each location, using techniques specified in Section 3.4. The measurements will be recorded in the field logbook.

Water Quality Meter. A water quality meter will be used to measure the temperature, pH, oxidation-reduction potential, turbidity and specific conductivity of each groundwater sample. The results will be recorded in the field log book.

Peristaltic Pump. A peristaltic pump will be used to evacuate groundwater from the soil borings when collecting the grab groundwater samples.

Pump Tubing. ¼ inch Teflon lined polyethylene tubing will be used to draw water from the monitoring wells using a peristaltic pump. In addition, silicone tubing will be used around the peristaltic pump head. New dedicated polyethylene and silicone tubing will be used at each groundwater sampling location.

Filters. 0.45 µm membranes will be used to filter the groundwater samples collected for dissolved mercury and metals analyses.

Digital Camera. A digital camera will be used to photograph the field investigation activities.

Field Instrument/Equipment Calibration

Calibration of equipment and instrumentation ensures that accurate and reliable measurements are obtained. All instruments and equipment used on the investigation are calibrated and adjusted to operate within manufacturers' specifications and with a frequency stipulated by the maintenance schedule or by analytical methods.

Groundwater samples will not be collected until the water quality parameters achieve the required stability, as described in the groundwater sampling section.

All field instrument calibration and maintenance documentation will be maintained in an active field logbook. Logbook entries regarding the status of field instruments will contain, but will not necessarily be limited to, the following information:

- Date and time of calibration
- Name of person conducting calibration
- Type of equipment being used or serviced and identification (make and model)
- Reference standard used for calibration (such as pH of buffer solutions)
- Calibration and/or maintenance procedure used
- Adjustments made based on calibration results
- Other pertinent information (e.g., operational problems such as drift in readings)

Equipment Decontamination

Decontamination will be performed on all non-dedicated sampling equipment that may contact potentially contaminated water or soil. This includes hand augers, WLIs, and stainless steel bows and spoons. Clean nitrile gloves or powder-less surgical gloves are to be worn during decontamination.

An equipment decontamination station will be centrally located on site. Each piece of non-dedicated sampling equipment will be decontaminated between uses at each sampling location. The decontamination procedures are:

- Disassemble equipment (if appropriate);
- Wash equipment in an Alconox (or equivalent) and water solution using a brush or clean cloth to ensure removal of all contaminants;
- Rinse equipment in fresh tap water;
- Rinse again with de-ionized water; and
- Dry equipment with paper towel and place in clean plastic, if appropriate.

The effectiveness of these decontamination procedures will be verified by equipment rinsate samples. Decontamination wastewater will be collected and stored in 55-gallon drums and disposed of in accordance with the Investigation Driven Waste (IDW) Plan.

Sample Handling and Custody Requirements

Field Documentation

While conducting field work, the field representative will document pertinent observations and events on field forms specific to each activity (e.g., boring log form, groundwater sampling form etc.) and/or in a field notebook, and, when warranted, provide photographic documentation of specific sampling efforts. Field notes will include a description of each field activity, sample descriptions, and associated details such as the date, time, and field conditions.

Sample Labeling and Nomenclature

Sample labels will be filled out using indelible ink to indicate the sample number, date, preservative added, if any, and any pertinent comments. Soil samples will be designated by exploration location number and sample depth interval, and groundwater samples will be designated by exploration location number and date of sample collection. For example, exploration BC-MW02 is a planned soil boring that is to be completed as a monitoring well. A soil sample collected from a depth of 3 to 4 feet from this exploration would be labeled BC-MW02-3-4. A groundwater sample collected from this well on September 30, 2009 would be labeled BC-MW02-093009.

Sample Handling

Upon collection, samples will be placed upright in a cooler. Ice will be placed in each cooler to meet sample preservation requirements. Inert cushioning material will be placed in the remaining space of the cooler to limit movement of the sample containers. If the sample coolers are being shipped, not hand carried by Aspect personnel, the chain of custody (COC) form will be placed in waterproof bag taped to the inside lid of the cooler for shipment.

Upon sample receipt, the laboratory will fill out a cooler receipt form to document sample delivery conditions. A designated sample custodian will accept custody of the shipped samples and will verify that the chain of custody form matches the samples received. The laboratory will notify as soon as possible the Aspect project manager of any issues noted with the sample shipment or custody.

Sample Custody

After collection, samples will be maintained in Aspect's custody until formally transferred to the analytical laboratory. For purposes of this work, custody of the samples will be defined as follows.

- In plain view of the field representatives;
- Inside a cooler that is in plain view of the field representative; or
- Inside any locked space such as a cooler, locker, car, or truck to which the field representative has the only immediately available key(s).

A COC record provided by the laboratory will be initiated at the time of sampling for all samples collected. The record will be signed by the field representative and others who subsequently take custody of the sample. Couriers or other professional shipping representatives are not required to sign the COC form; however, shipping receipts will be collected and maintained as a part of custody documentation in project files. A copy of the COC form with appropriate signatures will be kept by Aspect’s project manager.

Decontamination and Investigative-Derived Waste

All non-disposable sampling equipment (stainless steel spoons and bowls) will be decontaminated before collection of each sample. The decontamination sequence consists of a scrub with a detergent (Alconox) solution, followed by tap water (potable) rinse, and finished with thorough spraying with deionized or distilled water. Decontamination water will be combined in labeled 55-gallon drums for proper management.

Soil cuttings from borings and disposable personal protective equipment (PPE) will be placed in labeled 55-gallon drums pending the analytical results from each boring to determine appropriate disposal. The drums will be temporarily consolidated in the on-site mercury cell building, profiled based on available analytical data, and disposed of appropriately at a permitted off-site disposal facility.

Water generated during decontamination and monitoring well development and sampling will be containerized at the wellhead and transferred to the Port’s aerated stabilization basin for permitted treatment and discharge.

ATTACHMENT C-1

Aspect consulting
earth+water

BORING LOG

SHEET ______ OF ______

LOCATION OF BORING	PROJECT NO.	BORING NO.
	PROJECT NAME	
SKETCH OF LOCATION	DRILLING METHOD:	
	LOGGED BY:	
	DRILLER:	
	SAMPLING METHOD:	
	HAMMER WEIGHT/SAMPLER DIAMETER	

					START	FINISH
OBSERVATION WELL INSTALL YES ____ NO ____						
WATER LEVEL					TIME	TIME
TIME						
DATE					DATE	DATE
CASING DEPTH						

DATUM

GRADE ELEV.

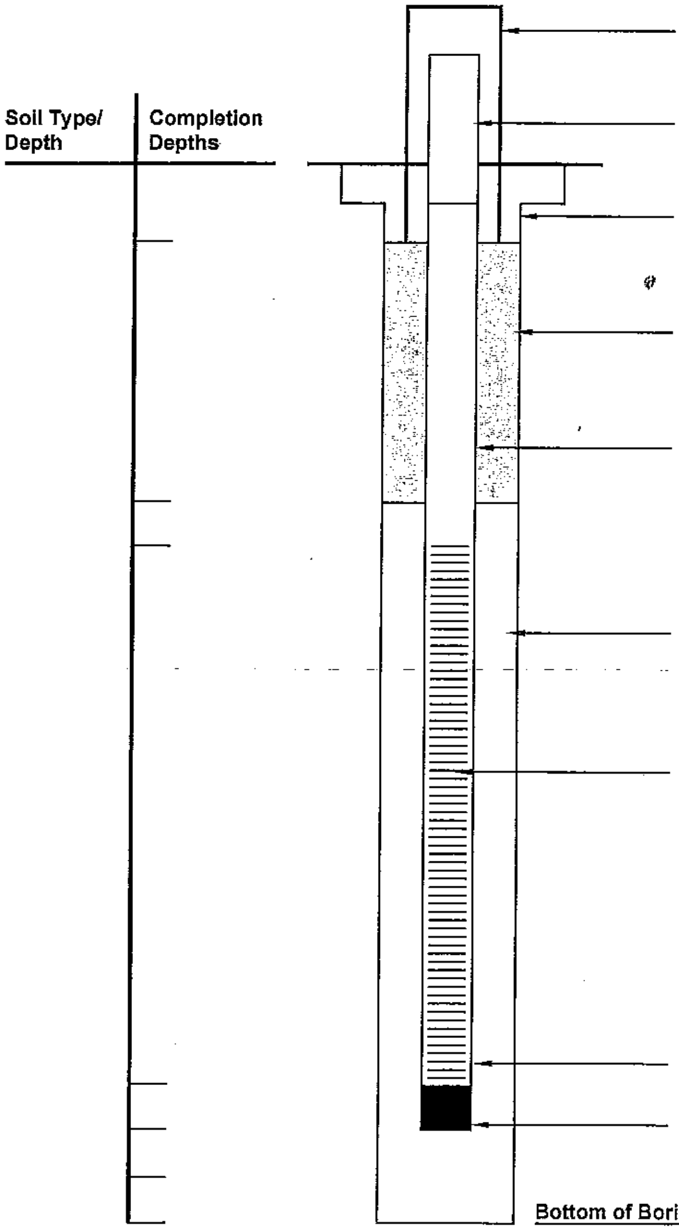
SURFACE CONDITION

SIZE (%)									
GRAVEL	SAND (SIZE RANGE)	FINES	SAMPLE NO. / SAMPLE TYPE	SAMPLE DEPTH	INCHES DRIVEN / INCHES RECV'D	DEPTH IN FEET	PENETRATION RESISTANCE	USCS SUMMARY	DESCRIPTION: Density, moisture, color, minor, MAJOR CONSTITUENT. NON-SOIL SUBSTANCES: Odor, staining, sheen, scrap, slag, etc. DRILL ACTION
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			
						1			
						2			
						3			
						4			
						5			
						6			
						7			
						8			
						9			
						0			

As-Built Well Completion Diagram

Project Number:	Boring/Monitoring Well Number: Sheet: of:
Project:	Location:
Elevation:	Drilling Contractor:
Drilling Method and Equipment Used:	Logged By:
Water Levels:	Completion Start: Finish:

Ecology Well ID ______________



Monument Type/Height ______________

Well Cap Type ______________

Surface Seal Material ______________

Seal Material ______________
(list NSF/ANSI certification)

Well Casing ID ______________

Type of Casing ______________

Type of Connection ______________

Filter Pack/Size ______________

Filter Pack Interval ______________

Well Screen ID ______________

Type of Screen ______________

Slot Size ______________

Screen Interval ______________

Centralizers ______________

Diameter of Borehole ______________

Sump ______________

Bottom of Boring ______________

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a limited liability company

Materials Used:	Screen:
Sand:	Bentonite:
Blank:	Monument:
Concrete:	Other:

Q:_ACAD Standards\Standard Details\Well Diagram.dwg

Columbia Analytical Services

800.695.7222
www.caslab.com

Client:

CHAIN of CUSTODY

Page ___ of ___

Project:

Method of Shipment

Project Manager

Telephone No.

Fax No.

Special Detection Limit/Reporting

			Matrix				**Prsv.**																		
Sample I.D.	Lab Sample No.	No. of Containers	Soil	Water	Air	Other	Yes	No	Sampling Date	Sampling Time															Turn Around Time (working days)

MARKS

Sample Received Intact: Yes No

Temperature received: Ice No ice

Relinq. by sampler (Sign & Print Name)	Date Time	Received by (Sign & Print Name)	
Relinquished by	Date Time	Received by	
Relinquished by	Date Time	Received by	
Relinquished by	Date Time	Received by laboratory	Date Time

Lab Work No.

ATTACHMENT C-2

FRONTIER GEOSCIENCES INC.
pioneering environmental solutions

U.S. EPA Method 30B
Laboratory Performance Demonstration Study

__Hg Reference Method:__

**Total Vapor Phase Mercury Emission Measurements via
Solid Sorbent Trap Method**

__Laboratory Method:__

**Wet Acid Digestion Followed by Analysis via
Principles of US EPA Method 1631**

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Table of Contents

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1 Overview

What is US EPA Method 30B?

US EPA Method 30B is a procedure for measuring total vapor phase mercury (Hg) emissions from coal-fired combustion sources. This method uses sorbent trap sampling and an extractive or thermal analytical technique. The EPA has drafted Method 30B as a reference method for Relative Accuracy Test Audits (RATAs) of vapor phase Hg Continuous Emission Monitoring Systems (CEMS) and sorbent trap monitoring systems installed at coal-fired boilers. Method 30B is also appropriate for Hg emissions testing at such boilers.

What is required for a laboratory to support US EPA Method 30B?

The EPA requires several performance tests in order to characterize and verify the performance of a labs' intended analytical system and associated sampling and analytical procedures. These tests assess the accuracy of both the sample collection and performance of the sorbent trap digestion and analytical procedures. In addition, they define the minimum amount of Hg (as the sample collection target) that can be reliably quantified. Please refer to the method for details regarding these tests. The tests required by EPA Method 30B are:

(a) Analytical Matrix Interference Test;
(b) Determination of Minimum Sample Mass;
(c) Hg^0 and $HgCl_2$ Analytical Bias Test;
(d) Determination of Nominal Sample Volume;
(e) Field Recovery Test.

What techniques does Frontier Geosciences use in the application of US EPA Method 30B?

FGS utilizes a specially designed, custom-built, dry sorbent trap to collect mercury from gas streams. The trap collects all available vapor phase mercury (elemental and oxidized forms) when inserted into a gas stream with a metered amount of gas pulled through it. These traps are often referred to as FSTM (Fluegas Sorbent Total Mercury) traps.

Mercury concentrations are determined on a mass basis (ug/m^3) and then combined with gas flow data (m^3/min) to calculate the continuous mass rate of total vapor phase mercury. The analysis of sorbent traps for US EPA Method 30B is performance based and therefore the analytical method used is required to demonstrate both accuracy and precision. Frontier Geosciences (FGS) provides several different approaches for the measurement of Hg captured on sorbent traps. However, Frontier has found that the method FGS developed and has been using for the past 16 years is the most superior approach for this application in terms of detection limit, precision and accuracy. This method is a wet acid extraction to remove Hg from the sorbent trap, followed by analysis/measurement of the mercury using the principles of US EPA Method 1631 (FGS SOP-069), a compliance analytical method promulgated in 1997. Frontier designed and perfected the principles used in US EPA Method 1631 in 1991, and later co-authored EPA 1631 and served as the US EPA Reference Laboratory for the method validation.

What is the purpose of this report?

This report summarizes the results from each of the performance tests and verifies that Frontier Geosciences, Inc. is able to provide reliable results for our clients.

A copy of Method 30B (http://www.epa.gov/ttn/emc/promgate/Meth30B.pdf, current as of September 2008) is included in Appendix A. Certificates of analysis for all spiking standards used for this validation study are in Appendix B. In addition, a QA/QC report supporting Frontier's sorbent trap material is included in Appendix C. Raw data packages for any data referenced in this document are available upon request by contacting the FGS QA Office at 206-622-6960.

2 Executive Summary

Following is a brief overview of the outcome of each test required by Method 30B. For details about each study and how it was performed, please refer to the test-specific sections of this document.

Analytical Matrix Interference Test (Section 3):
Pass – all dilutions are within 5% of each other. Recoveries range from 92.7% to 95.1%. No dilution of the digested sample is required. Frontier's default analytical dilution of 100x is suitable for US EPA Method 30B analysis.

Determination of Minimum Sample Mass (Section 4):
FGS has determined a minimum sample mass of 2 ng for 6 mm sorbent traps, and 4 ng for 10 mm sorbent traps.

Hg^0 and $HgCl_2$ Analytical Bias Test (Section 5):
Pass – Hg^0 and $HgCl^2$ spikes ranging from 2.2 ng to 738.8 ng analyzed in triplicate recovered between 90% and 110% for the upper and lower bounds of loading for the sorbent material.

Determination of Target Sample Volume (Section 6):
This is a client-specified parameter and not part of the validation study. However, Frontier recommends the target sample volume be sufficient to load several times the minimum sample mass onto the trap.

Determination of Sample Run Time (Section 7):
This is a client-specified parameter and not part of the validation study. The minimum sample time for conducting relative accuracy test audits of mercury monitoring systems is 30 minutes.

Field Recovery Test (Section 8):
This is a client-specified parameter and not part of the validation study. Having a spike at the same level as the expected mercury load maximizes the probability of a successful RATA.

3 Analytical Matrix Interference (AMI) Test (EPA Method 30B, section 8.2.1)

3.1 EPA Method 30B Requirement

The AMI test is required for use of wet digestion, which Frontier uses for sample preparation. The purpose of this test is to verify the presence or absence of known and potential analytical matrix interferences, and to determine the minimum dilution necessary to mitigate matrix effects on the sample digestate solutions (EPA Method 30B, section 8.2.1). The concentrations of the spiked digests must be within ±5 percent of the digestate-free solution. The result of the AMI test is used to establish the minimum sample mass needed for the analytical bias test and to determine the nominal sample volume for a test run (EPA Method 30B, section 8.2.1).

3.2 Frontier Geosciences AMI Test Procedure

The following is intended to describe how FGS performed the analytical matrix interference test to satisfy the provisions of Method 30B: For this test, blank traps were digested via FGS standard operating digestion procedure for this matrix; a hot digestion with concentrated acids followed by dilution with dilute bromine monochloride (FGS SOP-009). These digestions were used to create seven different dilutions. Each dilution represented a different ratio of digestate to diluent (see chart below) and was spiked with 80 ng of Hg, using the same standard source used to calibrate the Hg analyzer (FGS ID 0800526). All seven dilutions were analyzed at an aliquot size of 1 mL. Based on analysis of many samples for a variety of different clients, FGS established that the maximum aliquot size for analysis of this digest is 1 mL. FGS uses a manual analysis technique; therefore, sub-aliquots of sample are placed into approximately 100 mL of pre-purged reagent water. This effectively dilutes the sample matrix by 100X (minimum dilution) based on the internally specified maximum sample aliquot of 1 mL.

Analytical Matrix Interference Test Results			
THg11-080819-1, F808098, 8H19009			
Instrument sensitivity: 95.4% - 93.8% (ICV, CCVs %Recovery)			
Dilution Ratio (Digestate:Diluent)	Spike Amount (ng)	Aliquot Size (mL)	Recovery*
9.98:10	80	1	95.1%
1:2	80	1	94.2%
1:5	80	1	94.8%
1:10	80	1	93.0%
1:20	80	1	94.8%
1:100	80	1	94.2%
0:10	80	1	92.7%

*AMI recoveries match the instrument sensitivity at the time the samples were analyzed.

3.3 Conclusions

All dilution levels tested within 5% of the control sample. Method 30B stipulates that if a digest ratio of >9:10 recovers within 5% of the control sample, no dilution of digested samples is required. Frontier's analytical minimum dilution necessary is generally 100X, based on a maximum aliquot size of 1 mL of digestate diluted to 100 mL in the purge vessel at the time of analysis. A NELAC (National Environmental Laboratory Accreditation Conference) compliant MDL study for total Hg in water and total Hg in the sorbent trap matrix also addresses matrix interference concerns (see Determination of Minimum Sample Mass).

4 Determination of Minimum Sample Mass (EPA Method 30B, section 8.2.2)

4.1 EPA Method 30B Requirement

This test evaluates instrument sensitivity and linearity and determines the minimum mass of Hg that must be collected per sample. This information is necessary to effectively perform the analytical bias test, to estimate target sample volumes/sample times for test runs, and to ensure the quality of the measurements (EPA Method 30B, section 8.2.2).

The calculation for the minimum sample mass, whose components will be detailed further in the next section, is as follows:

Minimum Sample Mass	=	[2 * Lowest Analytical Calibration Value]	*	[Sample Digest Size]	*	[Minimum Dilution Necessary (as calculated in AMI test)]

4.2 Frontier Geosciences Determination of Minimum Sample Mass Procedure

The following is intended to describe how FGS performed the determination of minimum sample mass test to satisfy the provisions of Method 30B. For this test, two of the variables of the minimum sample mass equation, sample digest size and minimum dilution necessary, are already determined. Only determining the lowest analytical calibration value is necessary to calculate the minimum sample mass. This value is dependent upon the Method Detection Limit (MDL) for the sorbent trap matrix. NELAC compliant MDL and Practical Quantitation Limit (PQL) studies for total Hg in water and total Hg in sorbent traps were performed. Per Method 30B, data was not corrected by preparation blanks.

Method 30B states that the lowest point in the analytical calibration curve must be at least five times the MDL. The MDL is determined according to EPA 40 CFR Part 136, Section B. A copy of this method is included at the end of this document in Appendix D and the calculations are outlined in the MDL/PQL study tables in Appendix E. Ten replicates (nine degrees of freedom) were run of a sample that was spiked between three and ten times the expected MDL. The standard deviation (σ) was taken from the resulting data and the MDL is calculated as follows: MDL=2.821 * σ. This value should not be interpreted as the method reporting limit.

The Practical Quantitation Limit (PQL) is the reporting limit for the method and the control limit of the method for the specified analyte (2003 NELAC regulation 5.5.5.2.2.1.h.3). The PQL is determined by running ten replicate samples with a concentration that will produce a recovery of 70-130%. When possible the same samples used for the MDL study are used to generate this data.

Performing MDL/PQL studies, as described above, for Frontier's sorbent traps yields the following MDLs/PQLs:

6 mm trap (20 mL digest): MDL: 0.172 ng/trap PQL: 1 ng/trap	10 mm trap (40 mL digest): MDL: 0.317 ng/trap PQL: 2 ng/trap

To calculate the recommended lowest calibration point, the MDL value must be converted from ng/trap to ng/L. Converting from ng/trap to ng/L gives the following values, assuming an operational maximum sample aliquot of 1 mL and a 100 mL purge vessel size:

6 mm trap (20 mL digest) MDL:

(0.172 ng/trap) * (1 trap/20 mL) = 0.0086 ng/mL = 0.0086 ng in analytical purge vessel

0.0086 ng / 0.1 L (purge vessel volume) = 0.086 ng/L

10 mm trap (40 mL digest) MDL:

(0.317 ng/trap) * (1 trap/40 mL) = 0.0079 ng/mL = 0.0079 ng in analytical purge vessel

0.0079 ng / 0.1 L (purge vessel volume) = 0.079 ng/L

The recommended lowest calibration value based on these MDLs would be 0.43 ng/L for 6 mm traps and 0.40 ng/L for 10 mm traps. Frontier's lowest calibration point is 0.5 ng/L, which falls between five to ten times the MDL for both trap sizes and thus meets 30B requirements.

4.3 Conclusions

Minimum sample mass, as stated above, equals:

Minimum Sample Mass	=	[2 * Lowest Analytical Calibration Value]	*	[Sample Digest Size]	*	[Minimum Dilution Necessary (as calculated in AMI test)]

Following this equation and based on the 100X minimum dilution from the AMI test, Frontier calculates a minimum sample mass of 2 ng for a digest with a final volume of 20 mL. This final volume applies to 6 mm low-flow sorbent traps (0.2-1.0 L/minute).

6 mm traps:

(2 x 0.5ng/L)*(0.02L)*(100) = 2 ng

A trap digested to a final volume of 40 mL has a minimum sample mass of 4 ng. This final volume applies to 10 mm high-flow sorbent traps (0.2-5.0 L/minute).

10 mm traps:

(2 x 0.5ng/L)*(0.04L)*(100) = 4 ng

It is important to note that regardless of trap size, the type of sorbent material used is the same. Also regardless of trap size, the ratio of sorbent trap material and reagents used in the wet digestion is the same.

5 Hg^0 and $HgCl_2$ Analytical Bias Test (EPA Method 30B, section 8.2.3)

5.1 EPA Method 30B Requirement

The laboratory is required to demonstrate the ability to recover and accurately quantify Hg^0 and $HgCl_2$ from the sorbent media. The analytical bias test is performed at a minimum of two distinct sorbent trap Hg loadings that will: 1) represent the lower and upper bound of sample Hg loadings for application of the analytical technique to field samples; and (2) be used for data validation (EPA Method 30B, section 8.2.3). Spikes are to be analyzed in triplicate and the average of the recoveries must be within 90-110% for each spike concentration.

5.2 Frontier Geosciences Analytical Bias Test Procedure

The following is intended to describe how FGS performed the analytical bias test to satisfy the provisions of Method 30B: Frontier spiked sorbent traps with Hg^0 (FGS IDs 0800524, 0800531, 0800533, 0800534) and sorbent trap digests with HgCl2 (FGS IDs 0800772, 0800770). Traps were spiked in triplicate at each concentration level listed in the following table.

Analytical Bias Test Results

Hg^0: THg26002-080905-1, F809131, 8I19003 and

THg13-080910-1, F809130, 8I11002

$HgCl_2$: THg17-080916-1, F809129, 8I19004

Standard	Spiking Level (ng/trap)	Mean % Recovery of 3 reps	% Relative Std. Deviation (RSD) of 3 reps
$HgCl_2$	2.2	97.0	0.5
$HgCl_2$	738.8*	94.5	0.8
Hg^0	2.0	100.3	4.4
Hg^0	17.0	96.3	1.4
Hg^0	50.0	95.6	0.7
Hg^0	145	93.1	3.2
Hg^0	1,000	104.5	3.9

*Due to the 0.1 mL maximum spiking aliquot dictated by Method 30B and the concentration of the $HgCl_2$ standards available, 738.8 ng was the closest reachable mass to 1000 ng.

5.3 Conclusions

All recoveries for Hg^0 and $HgCl_2$ spikes are within the 90-110% recovery requirement of Method 30B for the upper and lower bounds of mercury loading. In the future Frontier will likely continue this study to expand the loading range, as previous data indicate that much higher spiking levels recover within the 90-110% range.

6 Determination of Target Sample Volume (EPA Method 30B, section 8.2.4)

The target sample volume is an estimate of the sample volume needed to ensure that valid emissions data are collected (EPA Method 30B, section 8.2.4). The client will specify this volume, however Frontier can aid in a recommendation. The sampling volume is dependent upon the minimum sample mass and estimated concentration of mercury in the stack gas. For example, with a target sample mass of 30 ng and an expected stack gas concentration of 2 $\mu g/m^3$ (ng/L), the target sample volume would be:

(30 ng) / (2 ng/L) = 15 L

Target sample volume equals the target sample mass in ng divided by the expected stack gas concentration in ng/L.

7 Determination of Sample Run Time (EPA Method 30B, section 8.2.5)

Sample run time will be a function of minimum sample mass, target sample volume and nominal equipment sample flow rate (EPA Method 30B, section 8.2.5). The client will specify the sample run time, however FGS can aid in a recommendation. Method 30B states that the minimum sample run time for conducting RATAs is 30 minutes and for emissions testing is one hour.

Sampling time in minutes equals the target sample volume in liters divided by the sampling rate in liters per minute. For example, if the target sample volume is 15 L and the sampling rate is 0.5 L/min, then the sample run time would be 30 minutes:

(15 L) / (0.5 L/min) = 30 min

8 Field Recovery Test (EPA Method 30B, section 8.2.6)

The field recovery test provides a program-specific verification of the performance of the combined sampling and analytical approach (EPA Method 30B, section 8.2.6). The client determines this test. FGS will send a spiked trap paired with a non-spiked trap. The mass of the mercury spike must be 50 to 150 percent of the expected mass to be collected on the unspiked trap and each spike must recover at 85% to 115% of the expected value. For example, in the case of an expected stack concentration of 2 µg/m^3 (ng/L), a target sample rate of 0.5 L/min and a sample run time of 30 minutes, the field recovery test spiking level should be 50-150% of 30 ng:

(0.5 L/min)*(30 min)*(2 ng/L) = 30 ng
(30 ng)*(0.5) = 15 ng
(30ng)*(1.5) = 45ng

In this case, a spike in the range of 15 ng to 45 ng would be acceptable. However, choosing a spike at the same level as the expected mercury load on the traps minimizes the risk that sampling and analytical variability lead to a failing field recovery sample.

9 Sample Handling, Preservation, Storage, Transport

In addition to Method 30B requirements, a sample holding time study was performed in 2003 to assess potential impacts of time on spiking. Sorbent trap spikes recovered well (97.8%-103.5%) up to 16-weeks after spiking. The results are summarized below.

Sample ID	Spike (ng/trap)	A-traps (ng/trap)	B-traps (ng/trap)	Spike Recovered	B-Trap Breakthrough	Comments
#7 (2 week hold)	10000	10307	0.89	103.1%	0.009%	Average Spike recovery
#8 (2 week hold)	10000	10347	1.13	103.5%	0.011%	102.0%
#9 (4 week hold)	10000	10307	0.63	103.1%	0.006%	
#10 (4 week hold)	10000	10226	0.93	102.3%	0.009%	Avg. B-Trap Breakthrough
#11 (8 week hold)	10000	10347	0.85	103.5%	0.008%	0.009%
#12 (8 week hold)	10000	10185	1.07	101.9%	0.011%	
#13 (16 week hold)	10000	10063	0.71	100.6%	0.007%	
#14 (16 week hold)	10000	9780	0.95	97.8%	0.010%	

10 Appendices

10.1 Appendix A: EPA Method 30B

10.2 Appendix B: Certificates of Analysis for Standards Used

10.3 Appendix C: Sorbent Trap Quality Assurance Document

10.4 Appendix D: EPA 40 CFR, Appendix B, Part 136

10.5 Appendix E: MDL/PQL Study Tables

APPENDIX D

Quality Assurance Project Plan

Introduction

This Quality Assurance Project Plan (QAPP) identifies quality control (QC) procedures and criteria required to ensure that data collected in this RI/FS are of known quality and acceptable to achieve project objectives. Specific protocols and criteria are also set forth in this QAPP for data quality evaluation, upon the completion of data collection, to determine the level of completeness and usability of the data. It is the responsibility of all project personnel performing or overseeing this sampling and analysis activity to adhere to the requirements of the Sampling and Analysis Plan (SAP) and this QAPP.

Project Management

Project Organization and Responsibilities

The project consultant team consists of representatives from Aspect Consulting, LLC (Aspect), Pyron Environmental, Inc. (Pyron), Columbia Analytical Services, Inc. (CAS), and Frontier Geosciences, Inc. (Frontier). Specific individuals on the consultant team and their roles on this project are summarized below.

Aspect Project Manager – Steve Germiat. The Aspect project manager is responsible for the successful completion of all aspects of this project, including day-to-day management, production of plans and reports, field operations oversight, liaison with the Port of Bellingham and regulatory agencies, and coordination with the project team members. The Aspect project manager is also responsible for resolution of non-conformance issues, is the lead author on project plans and reports, and will provide regular, up-to-date progress reports and other requested project information to the Port project manager.

Aspect Field Manager – Jay Chennault The Field Manager is responsible for implementing the sampling program outlined in this plan, including collecting samples that are representative of site conditions and ensuring that they are handled properly prior to transfer of custody to the project laboratory. The field manager will manage procurement of necessary field supplies, assure that all monitoring equipment is operational and calibrated in accordance with the specifications provided herein, and act as the Site Health and Safety Officer.

Pyron Project Chemist – Mingta Lin. The project chemist is responsible for developing data quality objectives, selecting analytical methods, coordinating with the analytical laboratory, overseeing laboratory performance, and approving QA/QC procedures. The project chemist is also responsible for reviewing and validating the analytical data reports received from the project laboratories.

CAS Laboratory Project Manager – Jeff Christian. The laboratory project manager is responsible for ensuring that all laboratory analytical work for soil and water media is performed in full compliance with project requirements, and acting as a liaison with Aspect project manager, field manager, and project chemist to fulfill project needs on the laboratory work.

Frontier Laboratory Project Manager – Robert Brunette. Frontier is responsible for performing the sampling and analysis of soil vapor samples for total mercury. The Frontier project manager is responsible for overseeing and implementing the soil vapors sampling activities, ensuring that all laboratory analytical work is performed in full compliance with project requirements, and acting as a liaison with Aspect project manager, field manager, and project chemist to fulfill project needs on the soil vapor sampling and analysis.

Project Schedule

Specific tasks and the schedule for the project are detailed in Section 2 in the RI/FS Work Plan (Work Plan).

Data Quality Objectives

Soil and groundwater samples are to be collected from six of the seven Site subareas identified in Section 6.3 of the Work Plan to fill in data gaps based on previous studies conducted on the Site. Additional data collection is not planned for the Stormwater Swale subarea. Data will also be collected at three miscellaneous areas of isolated soil or groundwater contamination identified at the Site. Data, in whole, are to be used for the evaluation of remedial action alternatives in the FS or, if appropriate, interim cleanup actions.

Data quality objectives (DQOs), which derive data collection rationales, sampling and analysis designs, and sample collection procedures are presented in the Work Plan and SAP. The sampling and analysis scheme for this RI/FS is summarized in Table D-1.

Quality Control for Laboratory Procedures

At a minimum, the laboratories should be accredited by the State of Washington for all analytical procedures applied to the analyses of any project samples and by the National Environmental Laboratory Accreditation Program (NELAP) for a comprehensive analytical laboratory accreditation. The laboratories are responsible for ensuring that all procedures performed for this project comply with all requirements specified in the accreditation programs, laboratory quality assurance (QA) manual, individual analytical methods, and this QAPP.

The following sections identify laboratories performing sampling (soil vapor only) and analyses of samples for this RI/FS, analytical methods, and general requirements for data reporting, instrument calibration, and instrument preventive maintenance.

Analytical Laboratory

The chemical analyses of soil and groundwater samples will be performed by Columbia Analytical Services, Inc. (CAS) in Kelso Washington; and dioxins/furans analyses will be performed by CAS in Houston, Texas. The laboratory PM and contact information are as follows:

Laboratory Project Manager - Jeff Christian
Columbia Analytical Services, Inc.
1317 South 13th Avenue
Kelso, Washington 98626
Tel: (360) 577-7222
e-mail: jchristian@caslab.com

The soil vapor sampling and analysis for mercury will be performed by Frontier Geosciences, Inc. in Seattle, Washington. The laboratory project manager and the contact information are as follows:

Laboratory Project Manager – Robert Brunette
Frontier Geosciences, Inc.
414 Pontius Avenue, North
Seattle, WA 98109
Tel: (206) 957-1461
Fax: (206) 622-6870
e-mail: BobB@frontiergeosciences.com

Analytical Methods

Analytical methodologies applied to the analyses of all project samples are in accordance with the following documents:

- USEPA SW Methods - *USEPA Test Methods for Evaluating Solid Waste, Physical/Chemical Methods*, SW-846, Third Edition, December 1996.
- *USEPA Method 1631, Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry,* Office of Water, U.S. Environmental Protection Agency, August 2002, EPA-821-R-02-019.
- *USEPA Methods for Chemical Analysis of Water and Wastes,* EPA-600/4-79-020, March 1983 and updates.
- *Standard Methods for the Examination of Water and Wastewater,* American Public Health Association, 20th Edition, 1995.
- Ecology (Washington State Department of). 1997. *Analytical Methods for Petroleum Hydrocarbons.* Publication No. ECY 97-602. June 1997.

As summarized in Table D-1, groundwater samples will be analyzed for volatile organic compounds (VOCs), polycyclic aromatic hydrocarbons (PAHs), diesel and oil range total petroleum hydrocarbons (TPHs), dissolved metals (arsenic, cadmium, chromium, copper, lead, mercury, nickel, and zinc), major cations (calcium, iron, magnesium, manganese, potassium, and sodium), anions (bromide, chloride, fluoride, nitrate, nitrite, and sulfate), hexavalent chromium (Cr[VI]), sulfide, alkalinity, total suspended solids, and total dissolved solids. Soil samples will be analyzed for PAHs, metals (same as water samples), Cr (VI), pH, and TPHs. Specific target analytes for each sample are detailed in the SAP.

Method Detection Limits

Method detection limit (MDL) is the minimum concentration of a substance that can be measured and reported with 99 percent confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte. MDLs are determined through a MDL study following the requirements in 40 CFR 136, Appendix II.

Method Reporting Limits

Method Reporting Limit (MRL) represents the value for which the laboratory has demonstrated the ability to reliably quantitate target analytes within a prescribed performance criteria for the method performed. Operationally, it is equivalent to the concentration of the lowest calibration standard (at a minimum) in the initial calibration curve. Sample-specific MRLs for an individual sample should be adjusted according to the percent moisture (for dry-weight-basis sample result reporting), sample/extract volume used for the analysis, sample matrix effects (if any), and dilutions.

All laboratory analytical results should be evaluated and reported to the MDLs; concentrations reported below the MRL but above the MDL and qualified “J” (“B” for metals) as estimated. All soil analytical results should be reported on a dry-weight basis.

Instrument Calibration and Maintenance

The procedures for maintenance and calibration used by the analytical laboratory are included in their laboratory QA plans and analytical methods. The laboratory selected for this investigation has demonstrated its ability to analyze investigation samples within holding time by having well-maintained instruments and adequate backup instrumentation.

All laboratory calibration standards must be traceable to the NIST or other primary standards. Methods and intervals of calibration are based on the type of equipment, stability characteristics, required accuracy, intended use, and environmental conditions.

Maintenance is conducted by trained technicians, using service manuals or through service agreements with qualified maintenance contractors. Instruments and equipment that are identified to be out of calibration or malfunctioning are removed from operation until they are recalibrated or repaired. In addition, backup for instruments/equipment and critical spare parts are maintained to quickly correct malfunctions.

Calibration and maintenance schedules and records are maintained for the laboratory’s instruments and field equipment. Both equipment and equipment records are located in a controlled-access facility when not in use. This is done to minimize equipment damage, theft, and tampering that may jeopardize field or laboratory measurements, and ultimately, data quality.

Field and Laboratory Quality Control Samples

QC samples are controlled samples introduced into the analysis stream, and the results are used to assess the accuracy and precision associated with the collected data. The types of QC samples, frequency, and evaluation criteria are described in this section. Collection frequency for field and QC samples are summarized in Table D-1.

Field QC Samples

Field QC is accomplished through the analysis of controlled samples that are introduced to the laboratory from the field. Field duplicates, and temperature blanks will be collected and submitted to the investigation laboratory to provide a means of assessing the quality of data resulting from the field sampling program.

Field (Ambient) Blank

Field blanks are collected by pouring the de-ionized (D.I.) water used for field procedures (*e.g.,* equipment decontamination) into pre-cleaned sample containers following the same procedures for collecting regular field samples. The blank is then processed, analyzed, and reported as regular field samples. Field blank results are used to evaluate the impurities, if any, associated with the rinse water and the ambient condition on the sampling site.

Equipment Rinsate Blank

Equipment rinsate blanks are collected to determine the potential of cross-contamination introduced by sampling equipment between samples. D.I. water is used to rinse through the cleaned sampling equipment and collected into adequate sample containers. The blank is then processed, analyzed, and reported as regular field samples. Equipment rinsate blanks will only be collected for reusable equipment; dedicated or disposable equipment will not be monitored with equipment rinsate blanks.

Filtration Blank

Filtration blanks are used to monitor whether target contaminants are introduced during the sample filtration processes. Selected groundwater samples will be filtered in the field for dissolved metals analyses. One filtration blank will be prepared per preparation batch by filtering analytical-grade D.I. water in the same manner as that applied to the field samples. The blank is then processed, analyzed, and reported as regular field samples.

Trip Blank

Trip blank samples will be used to monitor any possible cross-contamination occurs during the transport of VOCs and samples. Trip blank samples are prepared by the laboratory using organic-free reagent-grade water into a VOA vial prior to the collection of field samples. Two vials per trip blank sample are placed with and accompanying the VOCs samples through the entire transporting process. Trip blank samples will be prepared and analyzed only for VOCs (by EPA Method 8260B).

Field Duplicates

Field duplicate samples are used to check for sampling and analysis reproducibility. Field duplicate samples will be collected at a frequency of 10 percent of the field samples for every matrix and analytical method.

Laboratory QC Samples

Analytical procedures conducted by the laboratories should meet all requirements specified in the analytical methods or approved laboratory standard operating procedures (SOPs), *e.g.*, instrument performance check, initial calibration, calibration check, blanks, surrogate spikes, internal standards, and/or labeled compound spikes.

In addition to the method-mandated QC analyses, the laboratories are required to perform and report matrix spike (MS) and MS duplicate (MSD) analyses on selected project samples, in order to evaluate the sample-specific effects on the analytical methodologies. As specified in Table D-1, additional volumes will be collected for selected samples for MS/MSD analyses. For inorganic parameters (e.g., anions, TDS), laboratory duplicate analyses can be performed in lieu of MSD.

Data Quality Indicators

The quality and usability of data collected in this investigation will be determined, based on the outcomes of data verification and validation, and expressed as data quality indicators (DQIs) - precision, accuracy (bias), representativeness, comparability, completeness, and sensitivity. Table D-3 presents a summary of QC samples and parameters corresponding to each of the DQIs. The definitions of the DQIs are presented as follows:

Precision

Precision is defined as the degree of agreement between or among independent, similar, or repeated measures. Precision is expressed in terms of analytical variability. For this investigation, analytical variability will be measured as the RPD or coefficient of variation between analytical laboratory duplicates and between the MS and MSD analyses. Monitoring variability will be measured by analysis of blind field duplicate samples. Precision will be calculated as the RPD as follows:

$$RPD\ (\%) = 100 \times \frac{|S - D|}{(S + D)/2}$$

where:

S = analyte concentration in a sample

D = analyte concentration in a duplicate sample

The resultant RPD will be compared with criteria established by this QAPP, and deviations from these criteria will be reported. If the QAPP criteria are not met, the laboratory will supply a justification of why the limits were exceeded and implement the appropriate corrective actions. The RPD will be evaluated during data review and validation. The data reviewer will note deviations from the specified limits and will comment on the effect of the deviations on reported data.

Accuracy

Accuracy is the amount of agreement between a measured value and the true value. It will be measured as the percent recoveries of MS and MSD, organic surrogate compounds, and the LCS. Additional potential bias will be assessed using calibration standards and blank samples (e.g., method blanks).

In cases where accuracy is determined from spiked samples, accuracy will be expressed as the percent recovery. The closer these values are to 100, the more accurate the data. Surrogate recovery will be calculated as follows:

$$\text{Recovery}\,(\%) = \frac{MC}{SC} \times 100$$

where:

SC = spiked concentration
MC = measured concentration

MS percent recovery will be calculated as follows:

$$\text{Recovery}\,(\%) = \frac{MC - USC}{SC} \times 100$$

where:

SC = spiked concentration
MC = measured concentration
USC = unspiked sample concentration

The resultant percent recoveries will be compared with criteria established by this QAPP, and deviations from these criteria will be reported. If the objective criteria are not met, the laboratory will supply a justification of why the limits were exceeded and implement the appropriate corrective actions. Percent recoveries will be evaluated during data review and validation, and the data reviewer will comment on the effect of the deviations on the reported data.

Representativeness

Representativeness is the degree to which sample results represent the system under study. This component is generally considered during the design phase of a program. This program will use the results of all analyses to evaluate the data in terms of its intended use. Site sampling locations for this investigation are placed using a biased approach to maximize the likelihood of locating and identifying site contamination. Areas of apparent contamination have been selected to be representative of potential impacts from past activities. Representativeness will also be determined by evaluating hold time, sample preservation, and blank contamination. Samples with expired hold times, improper preservation, or contamination may not be representative.

Comparability

Comparability is the degree to which data from one study can be compared with data from historical studies at the site, other similar studies, reference values (such as background), and reference materials. This goal will be achieved through the use of standard techniques to collect samples, USEPA-approved methods to analyze samples, and consistent units to report analytical results. Data comparability also depends on data quality. Data of unknown quality cannot be compared.

Completeness

Completeness will be calculated as follows:

$$Completeness\ (\%) = \frac{V}{P} \times 100$$

where:

V = number of valid measurements
P = number of planned measurements

Valid and invalid data (i.e., data qualified with the R flag [rejected]) will be identified during data validation.

Sensitivity

Sensitivity will be determined by reviewing MRLs. MRLs will be set low enough to allow meaningful comparisons with screening criteria to the extent possible, taking into account matrix effects. The laboratory will be directed to report compounds detected above the MDL and positively identified below the MRL as detected estimated (J flag).

Data Quality Control Criteria

Specific data quality control criteria are established in this QAPP to ensure the project DQOs are met during the course of data collection, and to set forth criteria to assess the data quality and usability. The data QC criteria are derived from the analytical laboratory’s in-house performance-based statistics, developed according to the NELAP and USEPA requirements. Data quality control criteria are summarized in Tables D-4 and D-5 for soil and water samples, respectively.

Data Validation and Data Usability Assessment

The data collection process will be reviewed to verify that the data have been collected consistently with the program design and this plan. The Aspect field manager and project chemist will review the progress of the data collection, starting with the monitoring and sampling and the documentation of field activities. Any deviations from the sampling protocol, rationale for the deviations, and expected impact on the program and the collected data will receive particular attention.

The review will follow the sample-handling process from collection to delivery at the analytical laboratory. Proper COC documentation will be evaluated and confirmed. Sample handling within the laboratory, analytical procedures used, QC activities, and subsequent data reporting by the laboratory will be reviewed and evaluated.

Field Data Quality Review

Before using the field data, Aspect project manager will ensure the data integrity by reviewing all field logs, reviewing and checking raw data entries and calculations, and verifying the custody integrity of all samples collected. Corrective actions will be taken when the precision and accuracy results fall outside of the control limits.

Laboratory Internal Review and data reporting

Laboratory Internal Review

The laboratory will review the data internally prior to submitting the data. Specifically, the laboratory will review the data package to ensure the following:

- Sample preparation information is correct and complete;
- Analytical information is complete and was generated within acceptable criteria;
- The appropriate SOPs have been followed;
- QC samples were within established control limits;
- Analytical requirements have been met (e.g., the correct analytical procedures were used); and
- Documentation is complete.

An authorized laboratory employee must sign the data package to indicate the data have been reviewed.

Laboratory Deliverables and Data Verification

All laboratory reports will be reviewed by the project chemist to verify for completeness. Laboratory reports should include the following:

- Cover sheet listing the samples included in the report.
- Narrative comments describing problems encountered in analysis, identification of any analyses not meeting quality control criteria, including holding times, and cautions regarding non-quantitative use or unusable data due to out-of-control-limit QC results.
- Completed COC and cooler receipt forms.
- Methods of extraction, cleanup, and analyses.

- Tabulated results of target analytes identified and quantified, with analyte-specific MDLs/MRLs. All analytes will be reported for each sample as a detected concentration or as not detected above the specific MDLs. The laboratory will also report dilution factors, date of extraction, extraction batch, cleanup procedures used, date of analysis, surrogate percent recoveries, batch run logs, and analytical batch number for each sample, with corresponding sample results. All soil and sediment data are to be reported as dry weight and the percent moisture must be provided.
- Analytical results for QC sample – All spikes (surrogates, internal standards, labeled compounds), laboratory duplicates, initial and continuing calibrations, verifications of standards and laboratory blanks, LCSs, laboratory reference materials, ICP interference check samples, and detection limit check samples.
- Documentation of rationale for the use of method of standard addition, if required.
- Raw data – Instrument printouts (or legible photocopies) identifying date of reported analysis, analyst, parameters analyzed, calibration curves, calibration verifications, second column confirmations, method blanks, any reported sample dilutions, cleanup logs, laboratory duplicates, spikes, control samples, sample spiking levels, preparation/extraction logs, run logs, and chromatograms.
- Mass calibration and mass spectral tuning data for all mass spectrometry analyses.

Data reduction and QC review steps will be documented, signed, and dated by an authorized laboratory representative.

Data Validation and data Usability Assessment

To ensure that project data quality needs are met and data are used to the appropriate extent, three distinctive evaluative steps – data verification, data review/validation, and data quality assessment - will be conducted for this project.

Data Validation

The *Contract Laboratory Program (CLP) National Functional Guidelines for Data Review* (EPA 2002, 2004, & 2007) will be used as the basis for the data review and validation processes. One hundred percent of the laboratory data will be reviewed for compliance with the pre-established project goals and limits defined by the analytical methods (if applicable) and the QC criteria established in this QAPP. A Data Review Report will be prepared for each sample delivery group (SDG) to discuss and present findings of the review. The following data quality parameters will be reviewed during the validation:

Case Narrative. Review the case narrative to verify that any anomalies, deficiencies, or QC problems have been identified. Any corrective actions should also be discussed in the case narrative.

COC and Sample Management. Review the data package to verify that an original copy of this form has been included. Receipt signatures from laboratory personnel should be included on this form.

Holding Time. Verify sample preparation and analysis holding times for compliance with method or project-prescribed holding times.

Analytical Method Compliance. Review sample preparation and instrumental analysis run log to verify that preparation batches and analytical sequence meet method requirements in terms of instrument performance check, calibrations, and QC analysis frequency.

Mass Spectrometry Tuning and Performance Check. Verify the mass spectral tuning data for GC/MS, HRGC/HRMS, and ICP/MS analyses meet the method requirements.

Initial Calibration. Review initial calibration calculations for agreement with summary form results, linearity, and method-specified minimum requirements.

Continuing Calibration. Review continuing calibration results and verify against method-specified requirements.

Method and Instrument Blanks. Review method and instrument blank results for positive detections of target compounds and compare with positive sample detections for possible sample contamination.

Trip, Filtration, Field and Equipment Rinsate Blanks. Review trip, filtration, field, and equipment rinsate blank results for positive detections of target compounds and compare with positive sample detections for possible sample contamination.

Matrix Spike and Matrix Spike Duplicate. Review MS and MSD percent recovery and relative percent difference values for compliance with project-specified limits, appropriate corrective actions, and potential interference from the sample matrix.

Laboratory Control Sample and Standard Reference Material. Review LCS or SRM percent recovery values for compliance with project-specified limits and appropriate corrective actions.

Laboratory Duplicate. Review RPD values for compliance with project-specified limits, appropriate corrective actions, and to verify laboratory precision.

Field Duplicate Sample. Review results for original and field duplicate samples for positive detections (the RPD is calculated for all positive detections and reviewed for agreement).

Internal Standards and Labeled Compounds. Review internal standard and/or labeled compound responses to verify that minimum and maximum method-specified requirements are met and the correct internal standard or labeled compound has been assigned to target compounds.

Project-Required Detection Limits. Review sample-specific detection limits against QAPP criteria for project-specified limit requirements.

Data qualifiers that may be applied to project data based on data validation are listed below:

- U - The analyte was analyzed for but was determined to be non-detect above the reported sample quantitation limit, or the quantitation limit was raised to the concentration found in the sample due to blank contamination.
- J - The analyte was positively identified; the associated numerical value is the approximate concentration of the analyte in the sample.
- N - The analysis indicates the presence of an analyte for which there is presumptive evidence to make a "tentative identification."
- NJ - The analysis indicates the presence of an analyte that has been "tentatively identified" and the associated numerical value represents its approximate concentration.
- UJ - The analyte was not detected above the reported quantitation limit. However, the reported quantitation limit is approximate and may or may not represent the actual limit of quantitation necessary to accurately and precisely measure the analyte in the sample.
- R - The sample results are rejected due to serious deficiencies in the ability to analyze the sample and meet QC criteria. The presence or absence of the analyte cannot be verified.

Data Usability Assessment

A data usability assessment considers whether data meet project DQOs, and evaluate whether data are suitable for making relevant project decisions. The assessment will be conducted by the PC based on the field notes taken during sample collection, the outcome of field data quality review, and the outcome of laboratory data review.

A data usability assessment report will be prepared and incorporated in the QA/QC section of the project report. The assessment report will present and discuss the following:

- A brief description of sampling and analytical procedures applied in collecting and analyzing each type of samples;
- Deviations from any planned sampling procedures or activities;
- Identifying unrepresentative sample(s) through field/laboratory notes or data review;
- Overall precision and accuracy/bias associated with the data;
- Overall measurement performance via evaluation of sensitivity and quantitation limits for each type of analysis;
- Data comparability to results collected from other sampling events at the site;
- Completeness of the sampling and analysis for the entire project; and
- Conclusion and recommendation of the extent for data usage.

Corrective Actions

Any non-conformance with the established QC procedures will be expeditiously identified, corrected, and controlled. Where procedures are not in compliance with the established protocol, corrective actions will be taken immediately. Subsequent work that depends on the nonconforming activity will not be performed until the identified nonconformance is corrected.

In summary, corrective action involves the following steps:

- Discovery of a nonconformance
- Identification of the responsible party
- Determination of root causes
- Planning and scheduling of corrective/preventive action
- Review of the corrective action taken
- Confirmation that the desired results were produced

Field Corrective Action

The FM will review the procedures being implemented in the field for consistency with the established protocols. Sample collection, preservation, labeling, and other procedures will be checked for completeness. Where procedures are not in compliance with the established protocol, the deviations will be field documented and reported to the PM.

Examples of field non-conformances include, but are not limited to, the following:

- Items provided by a subcontractor supplier that do not meet the contractual requirements
- Errors made in following work instruction or improper work instruction
- Unforeseen or unplanned circumstances that result in services that do not meet quality/contractual/technical requirements
- Unapproved or unwarranted deviations from established procedures
- Sample chain-of-custody missing or deficient
- Data falling outside established objective criteria

Corrective actions will be defined by the Aspect field manager and project manager with concurrence with the Port project manager and documented. Problems that require corrective action are documented by the use of a corrective action report. Upon implementation of the corrective action, the field manager will provide the Aspect project manager with a written memo documenting field implementation. The memo will become part of the RI/FS working file.

Laboratory Corrective Action

The laboratory quality assurance officer or his designee will review the data generated to ensure that all samples have been analyzed as specified in this QAPP. The laboratory project manager will deliver the COCs and cooler receipt forms to Aspect project manager and project chemist within 12 hours of sample receipt. PM will be notified immediately if discrepancies occur between the contracted analyses and the analyses listed on the COCs. The laboratory project manager will contact the project chemist to discuss noncompliant data sets within 72 hours of first discovering that any analysis failed to meet the required data quality criteria. If the analyses cannot produce data sets that are within control limits, the Port project manager will be notified. At a minimum, corrective actions are necessary if any of the following occur:

- Initial calibration verification and continuing calibration verification do not meet investigation-specific QC criteria.
- Any changes in the MRL.
- Blanks contain contaminants at concentrations greater than the MRL for any target analyte.
- The QC data are outside the acceptance windows for precision and accuracy.
- Undesirable trends are detected in MS or LCS recoveries.
- Undesirable trends are detected in RPD for MS/MSD or laboratory duplicates.
- The laboratory quality assurance officer detects deficiencies during internal or external audits.

If laboratory personnel identify a non-conformance in analytical methodologies or QC sample results, corrective actions will be implemented immediately. Corrective action procedures will be handled initially at the bench level by the analyst, and follow with protocols specified in the laboratory QA manual.

Corrective action may include, but will not be limited to, the following:

- Recalibrating analytical instruments.
- Reanalyzing suspect samples if holding time criteria permit. The need for reanalysis is dependent on the number of analytes that are out of compliance, the importance of the outlier to the decision making process, and the magnitude of the outlying data.
- Re-sampling and analyzing newly collected samples.
- Evaluating and amending sampling and/or analytical procedures.
- Accepting data with an acknowledged level of uncertainty.
- Evaluating and attempting to identify limitations of the data.

Following the implementation of the required corrective action measures, data still deemed unacceptable, possible follow-up corrective actions will be explored.

Corrective Actions Following Data review

The project chemist will review the laboratory data generated for this investigation to ensure that all project DQOs are met. If any non-conformances in the data have resulted from the field procedures, sample collection procedures, field documentation procedures, or laboratory analytical and documentation procedures, the impact of those non-conformances on the overall project data quality and usability will be assessed.

Appropriate actions, including re-sampling and/or re-analysis of samples may be recommended to the project manager to achieve the ultimate project objectives.

References for Quality Assurance Project Plan

USEPA Method 1669, Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels, Environmental Protection Agency, Office of Water, July 1996.

USEPA Test Methods for Evaluating Solid Waste (SW-846). Third Edition and Revised Update IIIA. Office of Solid Waste and Emergency Response, Washington, D.C., April 1998.

USEPA Analytical Operations/Data Quality Center National Functional Guidelines for Chlorinated Dioxin/Furan Data Review, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, August 2002, EPA 540/R-02/003.

USEPA Method 1631, Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry, Office of Water, U.S. Environmental Protection Agency, August 2002, EPA-821-R-02-019.

USEPA Contract Laboratory Program National Functional Guidelines for Inorganic Data Review, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, October 2004, EPA 540/R-04/004.

USEPA Contract Laboratory Program National Functional Guidelines for Superfund Organic Methods Data Review, Office of Superfund Remediation and Technology Innovation, U.S. Environmental Protection Agency, July 2007, EPA-540-R-07-003.

USEPA Methods for Chemical Analysis of Water and Wastes, EPA-600/4-79-020, March 1983 and updates.

Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 20th Edition, 1995.

Ecology (Washington State Department of), 1997, Analytical Methods for Petroleum Hydrocarbons, Publication No. ECY 97-602, June 1997.

Aspect Consulting, LLC, RI/FS Scoping Plan, Former GP Mill Property, Bellingham, Washington, February 17, 2009.

Table D-1 – Summary of Analytical Schedule

Analytical Parameters	Analytical Methods	Number of Field Samples	Field Duplicate	Trip Blank	Field Blank	Equipment Rinsate Blank	Filtration Blank	MS/MD (MS/DUP)
Groundwater (each sampling event)*								
VOCs	SW846 Method 8260B	1	1	1				1/1
PAHs	SW846 Method 8270-SIM	9	2					1/1
Diesel & Motor Oil Range TPH	Method NWTPH-Dx	9	2					1/1
Dissolved Metals	SW846 Method 6020	16	4				1	2/2
Dissolved Mercury	EPA Method 1631	46	7				1	4/4
Major Cations	SW846 Method 6010B	21	4					2/2
Anions	EPA Method 300.0	21	4					2/2
Hexavalent Chromium	SW846 Method 7196A	21	4					2/2
Total Sulfide	EPA Method 376.2	21	4					2/2
Alkalinity	EPA Method 310.0	21	4					2/2
TSS	SW846 Method 160.3	21	4					2[A]
TDS	SM2540C	21	4					2[A]
Soil								
Dioxins/Furans	SW846 Method 8290	5	1					1/1
PAHs	SW846 Method 8270-SIM	28	2		1	1		2/2
Total Metals	SW846 Method 6010B	3	1		1	1		2/2
Total Mercury by	SW846 Method 7471A	42	4		1	1		2/2
Hexavalent Chromium by	SW846 Methods 3060A/7196A	3	1					1/1
pH by	SW846 Method 9045C	3	1					1[A]
Diesel- and Oil-Range TPH	NWTPH-Dx/SW846 Method 3660 (Silica Gel Cleanup)	2	1					1/1
TCLP/Mercury	SW846 Methods 1131/7470A	2						1/1
Mercury in Soil Vapor	EPA Methods 30B/1631	10	1		1			4[B]

Notes:

*** -** Groundwater will be sampled in two rounds. This list includes all analyses for one round of groundwater sampling.
[A] – Duplicate analysis only
[B] – Traceable spiked trap
VOCs – Volatile organic compounds
PAHs – Polycyclic aromatic hydrocarbons
Dissolved Metals – Arsenic, cadmium, chromium, lead, nickel, mercury, and zinc
Major Cations – Sodium, calcium, magnesium, potassium, iron, and manganese
Anions – Bromide, chloride, fluoride, nitrate, nitrite, and sulfate
TDS – Total dissolved solids
TSS – Total suspended solids
Total Metals – Arsenic, cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc
Dioxins/Furans – Polychlorinated
USEPA SW Methods - *USEPA Test Methods for Evaluating Solid Waste, Physical/Chemical Methods,* SW-846, Third Edition, December 1996.
USEPA Method 1631 – *Method 1631 Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry,* Office of Water, U.S. Environmental Protection Agency, August 2002, EPA-821-R-02-019.
EPA Methods - *USEPA Methods for Chemical Analysis of Water and Wastes,* EPA-600/4-79-020, March 1983 and updates.
SM - *Standard Methods for the Examination of Water and Wastewater*, American Public Health Association, 20th Edition, 1995.
NWTPH - Ecology (Washington State Department of). 1997. *Analytical Methods for Petroleum Hydrocarbons.* Publication No. ECY 97-602. June 1997.

Table D-2 – Sample Container Descriptions

Sample Matrix	**Analytical Parameter**	**Analytical Method**	**Container Description [a]**	**Number of Containers**	**Preservation Requirements**	**Holding Time**
Soil	Dioxins/Furans	SW846 Method 8290	16-oz glass	2	4°C ±2°C	1year for extraction 40 days for analysis
	PAHs	SW846 Method 8270-SIM			4°C ±2°C	14 days for extraction 40 days for analysis
	Total Metals	SW846 Method 6010B			4°C ±2°C	180 days
	Total Mercury	SW846 Method 7471A			4°C ±2°C	28 days
	Hexavalent Chromium	SW846 Methods 3060A/7196A			4°C ±2°C	28 days
	pH	SW846 Method 9045C			4°C ±2°C	14 days
	Diesel & Motor Oil Range TPH	NWTPH-Dx/SW846 Method 3660 (Silica Gel Cleanup)			4°C ±2°C	14 days for extraction 40 days for analysis
	TCLP/Mercury	SW846 Methods 1131/7470A			4°C ±2°C	28 days for TCLP 28 days for analysis
Groundwater	VOCs	SW846 Method 8260B	40-mL VOA Vials	3	4°C ±2°C HCl pH < 2	14 days for analysis
	PAHs	SW846 Method 8270-SIM	1-L Amber Glass	2	4°C ±2°C	7 days for extraction 40 days for analysis
	Diesel & Motor Oil Range TPH	Method NWTPH-Dx	500-mL Amber Glass	2	4°C ±2°C H_2SO_4 pH < 2	7 days for extraction 40 days for analysis
	Dissolved Metals	SW846 Method 6020	1-L HDPE	1	4°C ±2°C HNO_3 pH < 2 (after filtration)	180 days
	Dissolved Mercury	EPA Method 1631	500-mL Polyfluorochloro Coated HDPE	1	4°C ±2°C HNO_3 pH < 2 (after filtration)	28 days
	Major Cations	SW846 Method 6010B	500-mL HDPE	1	4°C ±2°C HNO_3 pH < 2	180 Days
	Anions	EPA Method 300.0	1-L HDPE	1	4°C ±2°C	48 hours for nitrate, nitrite 28 days for others
	Hexavalent Chromium	SW846 Method 7196A	500-mL HDPE	1	4°C ±2°C	24 hours
	Total Sulfide	EPA Method 376.2	500-mL HDPE	1	4°C ±2°C NaOH pH > 9 Zinc Acetate	7 days
	Alkalinity	EPA Method 310.0	500-mL HDPE	1	4°C ±2°C	14 days
	TSS	SW846 Method 160.3	500-mL HDPE	1	4°C ±2°	7 days
	TDS	SM2540C	500-mL HDPE	1	4°C ±2°	7 days

Note: [a] - All glass sample containers will have Teflon-lined lids
HDPE – high-density polyethylene

Table D-2 – Sample Container Descriptions

Sample Matrix	Analytical Parameter	Analytical Method	Container Description [a]	Number of Containers	Preservation Requirements	Holding Time
Soil	Dioxins/Furans	SW846 Method 8290	16-oz glass	2	4°C ±2°C	1year for extraction 40 days for analysis
	PAHs	SW846 Method 8270-SIM			4°C ±2°C	14 days for extraction 40 days for analysis
	Total Metals	SW846 Method 6010B			4°C ±2°C	180 days
	Total Mercury	SW846 Method 7471A			4°C ±2°C	28 days
	Hexavalent Chromium	SW846 Methods 3060A/7196A			4°C ±2°C	28 days
	pH	SW846 Method 9045C			4°C ±2°C	14 days
	Diesel & Motor Oil Range TPH	NWTPH-Dx/SW846 Method 3660 (Silica Gel Cleanup)			4°C ±2°C	14 days for extraction 40 days for analysis
	TCLP/Mercury	SW846 Methods 1131/7470A			4°C ±2°C	28 days for TCLP 28 days for analysis
Groundwater	VOCs	SW846 Method 8260B	40-mL VOA Vials	3	4°C ±2°C HCl pH < 2	14 days for analysis
	PAHs	SW846 Method 8270-SIM	1-L Amber Glass	2	4°C ±2°C	7 days for extraction 40 days for analysis
	Diesel & Motor Oil Range TPH	Method NWTPH-Dx	500-mL Amber Glass	2	4°C ±2°C H_2SO_4 pH < 2	7 days for extraction 40 days for analysis
	Dissolved Metals	SW846 Method 6020	1-L HDPE	1	4°C ±2°C HNO_3 pH < 2 (after filtration)	180 days
	Dissolved Mercury	EPA Method 1631	500-mL Polyfluorochloro Coated HDPE	1	4°C ±2°C HNO_3 pH < 2 (after filtration)	28 days
	Major Cations	SW846 Method 6010B	500-mL HDPE	1	4°C ±2°C HNO_3 pH < 2	180 Days
	Anions	EPA Method 300.0	1-L HDPE	1	4°C ±2°C	48 hours for nitrate, nitrite 28 days for others
	Hexavalent Chromium	SW846 Method 7196A	500-mL HDPE	1	4°C ±2°C	24 hours
	Total Sulfide	EPA Method 376.2	500-mL HDPE	1	4°C ±2°C NaOH pH > 9 Zinc Acetate	7 days
	Alkalinity	EPA Method 310.0	500-mL HDPE	1	4°C ±2°C	14 days
	TSS	SW846 Method 160.3	500-mL HDPE	1	4°C ±2°	7 days
	TDS	SM2540C	500-mL HDPE	1	4°C ±2°	7 days

Note: [a] - All glass sample containers will have Teflon-lined lids
HDPE – high-density polyethylene

Table D-3 – QC Parameters Corresponding to Data Quality Indicators

Data Quality Indicators	**QC Parameters**
Precision	RPD values of: (1) LCS/LCSD (2) MS/MSD (or Laboratory Duplicate) (3) Field Duplicates
Accuracy	%RPD, %R, %D, or %D_f values of: (1) Initial Calibration and Calibration Verification (2) Surrogate Spikes (3) Internal Standards (4) Labeled Compounds (5) LCS (6) MS Results of: (1) Instrument and Calibration Blank (2) Method (Preparation) Blank (3) Trip Blank (4) Field Blank (5) Equipment Rinsate Blank (6) Filtration Blank
Representativeness	(1) Results of All Blanks (2) Sample Integrity (3) Holding Times (4) Total vs. Dissolved Metals Correlation
Comparability	(1) Sample-specific MRLs (2) Sample Collection Methods (3) Laboratory Analytical Methods
Completeness	(1) Data qualifiers (2) Laboratory deliverables (3) Requested/Reported valid results
Sensitivity	Sample-specific MRLs

Notes:

%RSD – Percent relative standard deviation
%R – Percent recovery
%D – Percent difference
%D_f – Percent drift
LCS – Laboratory control sample
LCSD – Laboratory control sample duplicate
MS – Matrix Spike
MSD – Matrix spike duplicnate
RPD – Relative percent difference

Table D-4 – Precision, Accuracy, and Completeness Control Criteria for Soil (1)

Analyte	Preparation Method(2)	Analytical Method(2)	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% Rec.)	Precision (RPD)	Completeness (%)
Conventional Inorganic Parameters									95
pH	Method	9045C	NA	0.1		90-110	NA	20	
Hexavalent Chromium (mg/kg)	3060A	7196A	0.06	0.5		90-110	80-120	20	
***Metals* (mg/kg)**									95
Arsenic	3050B	6010	5	20		81-123	49-139	30	
Cadmium	3050B	6010	1	1		92-125	58-144	30	
Chromium	3050B	6010	0.7	2		93-123	22-184	30	
Copper	3050B	6010	0.7	2		85-118	51-147	30	
Iron	3050B	6010	0.6	4		64-154	75-125	30	
Lead	3050B	6010	7	20		82-131	49-148	30	
Manganese	3050B	6010	0.07	2		83-130	25-178	30	
Mercury	Method	7471A	0.006	0.02		75-118	60-123	30	
Nickel	3050B	6010	3	4		92-123	74-126	30	
Zinc	3050B	6010	0.9	2		88-126	32-168	30	
Total Petroleum Hydrocarbons (mg/kg)									95
Diesel Range TPH	Method	NWTPH-Dx	1.2	25		75-124	40-175	40	
o-Terphenyl (Surr.)	Method	NWTPH-Dx			50-150				
Polycyclic Aromatic Hydrocarbons (µg/kg)									95
2-Methylnaphthalene	3541	8270-SIM	0.39	5.0		41-113	21-120	40	
Acenaphthene	3541	8270-SIM	0.23	5.0		47-113	25-123	40	
Acenaphthylene	3541	8270-SIM	0.24	5.0		46-115	33-115	40	
Anthracene	3541	8270-SIM	0.47	5.0		53-116	23-134	40	
Benz(a)anthracene	3541	8270-SIM	0.48	5.0		58-111	18-140	40	
Benzo(a)pyrene	3541	8270-SIM	0.14	5.0		57-119	11-146	40	
Benzo(b)fluoranthene	3541	8270-SIM	0.25	5.0		53-125	15-144	40	
Benzo(g,h,i)perylene	3541	8270-SIM	0.64	5.0		43-122	13-135	40	

Table D-4 – Precision, Accuracy, and Completeness Control Criteria for Soil (1)

Analyte	Preparation Method[2]	Analytical Method[2]	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% Rec.)	Precision (RPD)	Completeness (%)
Benzo(k)fluoranthene	3541	8270-SIM	0.15	5.0		54-123	21-131	40	
Chrysene	3541	8270-SIM	0.25	5.0		53-122	14-147	40	
Dibenz(a,h)anthracene	3541	8270-SIM	0.28	5.0		37-126	14-133	40	
Dibenzofuran	3541	8270-SIM	0.59	5.0		44-116	26-119	40	
Fluoranthene	3541	8270-SIM	0.61	5.0		54-120	12-150	40	
Fluorene	3541	8270-SIM	0.5	5.0		49-115	15-138	40	
Indeno(1,2,3-cd)pyrene	3541	8270-SIM	0.16	5.0		43-119	11-132	40	
Naphthalene	3541	8270-SIM	0.37	5.0		47-103	24-111	40	
Phenanthrene	3541	8270-SIM	0.75	5.0		52-111	15-138	40	
Pyrene	3541	8270-SIM	0.37	5.0		53-120	12-152	40	
Fluoranthene-d10 (Surr.)	3541	8270-SIM			10-141	NA	NA	NA	
Fluorene-d10 (Surr.)	3541	8270-SIM			10-126	NA	NA	NA	
Terphenyl-d14 (Surr.)	3541	8270-SIM			25-139	NA	NA	NA	
Dioxins/Furans (ng/kg)									95
2,3,7,8-TCDD	3541	8290	0.051	1.0		87-135	87-126	25	
1,2,3,7,8-PeCDD	3541	8290	0.050	2.5		88-135	88-124	25	
1,2,3,4,7,8-HxCDD	3541	8290	0.049	2.5		81-138	81-138	25	
1,2,3,6,7,8-HxCDD	3541	8290	0.048	2.5		82-136	82-136	25	
1,2,3,7,8,9-HxCDD	3541	8290	0.048	2.5		77-135	77-135	25	
1,2,3,4,6,7,8-HpCDD	3541	8290	0.059	2.5		93-144	93-144	25	
OCDD	3541	8290	0.164	5.0		93-162	93-162	25	
2,3,7,8-TCDF	3541	8290	0.048	1.0		82-141	82-141	25	
1,2,3,7,8-PeCDF	3541	8290	0.038	2.5		92-139	92-139	25	
2,3,4,7,8-PeCDF	3541	8290	0.036	2.5		74-145	74-145	25	
1,2,3,4,7,8-HxCDF	3541	8290	0.041	2.5		86-142	86-142	25	
1,2,3,6,7,8-HxCDF	3541	8290	0.041	2.5		88-162	88-162	25	

Table D-4 – Precision, Accuracy, and Completeness Control Criteria for Soil (1)

Analyte	Preparation Method(2)	Analytical Method(2)	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% Rec.)	Precision (RPD)	Completeness (%)
Conventional Inorganic Parameters									95
pH	Method	9045C	NA	0.1		90-110	NA	20	
Hexavalent Chromium (mg/kg)	3060A	7196A	0.06	0.5		90-110	80-120	20	
***Metals* (mg/kg)**									95
Arsenic	3050B	6010	5	20		81-123	49-139	30	
Cadmium	3050B	6010	1	1		92-125	58-144	30	
Chromium	3050B	6010	0.7	2		93-123	22-184	30	
Copper	3050B	6010	0.7	2		85-118	51-147	30	
Iron	3050B	6010	0.6	4		64-154	75-125	30	
Lead	3050B	6010	7	20		82-131	49-148	30	
Manganese	3050B	6010	0.07	2		83-130	25-178	30	
Mercury	Method	7471A	0.006	0.02		75-118	60-123	30	
Nickel	3050B	6010	3	4		92-123	74-126	30	
Zinc	3050B	6010	0.9	2		88-126	32-168	30	
Total Petroleum Hydrocarbons (mg/kg)									95
Diesel Range TPH	Method	NWTPH-Dx	1.2	25		75-124	40-175	40	
o-Terphenyl (Surr.)	Method	NWTPH-Dx			50-150				
Polycyclic Aromatic Hydrocarbons (µg/kg)									95
2-Methylnaphthalene	3541	8270-SIM	0.39	5.0		41-113	21-120	40	
Acenaphthene	3541	8270-SIM	0.23	5.0		47-113	25-123	40	
Acenaphthylene	3541	8270-SIM	0.24	5.0		46-115	33-115	40	
Anthracene	3541	8270-SIM	0.47	5.0		53-116	23-134	40	
Benz(a)anthracene	3541	8270-SIM	0.48	5.0		58-111	18-140	40	
Benzo(a)pyrene	3541	8270-SIM	0.14	5.0		57-119	11-146	40	
Benzo(b)fluoranthene	3541	8270-SIM	0.25	5.0		53-125	15-144	40	
Benzo(g,h,i)perylene	3541	8270-SIM	0.64	5.0		43-122	13-135	40	

Table D-5 – Precision, Accuracy, and Completeness Control Criteria for Water(1)

Analyte	Preparation Method(2)	Analytical Method(2)	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% R)	Precision (RPD)	Completeness (%)
Conventional Inorganic Parameters (mg/L)									95
Bromide	EPA 300.0	EPA 300.0	0.2	1		90-110	80-120	20	
Chloride	EPA 300.0	EPA 300.0	0.009	0.2		90-110	80-120	20	
Fluoride	EPA 300.0	EPA 300.0	0.006	0.2		90-110	80-120	20	
Nitrate	EPA 300.0	EPA 300.0	0.003	0.1		90-110	80-120	20	
Nitrite	EPA 300.0	EPA 300.0	0.003	0.1		90-110	80-120	20	
Sulfate	EPA 300.0	EPA 300.0	0.007	0.2		90-110	80-120	20	
Hexavalent Chromium	7196A	7196A	0.03	0.05		90-110	80-120	20	
Total Sulfide	EPA 376.2	EPA 376.2	0.004	0.05		90-110	80-120	20	
Alkalinity	EPA 310.0	EPA 310.0	1	2		90-110	NA	20	
TSS	160.3	160.3	NA	0.1		90-110	NA	20	
TDS	SM2540C	SM2540C	NA	0.1		90-110	NA	20	
***Metals* (µg/L)**									95
Arsenic	3020A	6020	0.07	0.5		88-110	68-128	20	
Cadmium	3020A	6020	0.02	0.02		90-109	82-114	20	
Chromium	3020A	6020	0.2	0.2		87-114	62-121	20	
Copper	3020A	6020	0.07	0.1		87-114	52-129	20	
Lead	3020A	6020	0.02	0.05		90-110	72-116	20	
Nickel	3020A	6020	0.05	0.2		87-114	66-121	20	
Zinc	3020A	6020	0.2	0.5		87-116	57-126	20	
Mercury	EPA 1631	EPA 1631	0.06	1		77-123	71-125	24	
Calcium	3010A	6010	10	50		94-111	75-125	20	
Iron	3010A	6010	3	20		94-113	58-142	20	
Magnesium	3010A	6010	0.5	20		91-112	75-125	20	
Manganese	3010A	6010	2	5		95-112	82-122	20	

Table D-5 – Precision, Accuracy, and Completeness Control Criteria for Water[(1)]

Analyte	Preparation Method[(2)]	Analytical Method[(2)]	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% R)	Precision (RPD)	Completeness (%)
Potassium	3010A	6010	1000	2000		89-117	75-125	20	
Sodium	3010A	6010	60	100		92-116	75-125	20	
Total Petroleum Hydrocarbons (µg/L)									95
Diesel Range TPH	Method	NWTPH-Dx	11	100		75-124	40-175	30	
o-Terphenyl (Surr.)	Method	NWTPH-Dx			50-150				
Volatile Organic Compounds (µg/L)									95
1,1,1,2-Tetrachloroethane	5030B	8260B	0.111	0.5		76-121	72-128	30	
1,1,1-Trichloroethane (TCA)	5030B	8260B	0.116	0.5		65-130	63-137	30	
1,1,2,2-Tetrachloroethane	5030B	8260B	0.138	0.5		68-119	63-126	30	
1,1,2-Trichloroethane	5030B	8260B	0.138	0.5		78-118	75-123	30	
1,1-Dichloroethane	5030B	8260B	0.101	0.5		74-119	68-129	30	
1,2,3-Trichloropropane	5030B	8260B	0.24	0.5		73-117	68-121	30	
1,2-Dichloroethane (EDC)	5030B	8260B	0.114	0.5		67-125	62-129	30	
cis-1,2-Dichloroethene	5030B	8260B	0.116	0.5		78-121	69-134	30	
1,2-Dichloropropane	5030B	8260B	0.174	0.5		73-116	69-124	30	
1,2-Dibromoethane (EDB)	5030B	8260B	0.0981	2		75-117	71-121	30	
2-Butanone (MEK)	5030B	8260B	2.3	20		64-131	61-134	30	
2-Chloroethyl Vinyl Ether	5030B	8260B	0.333	5		10-174	10-170	30	
2-Hexanone	5030B	8260B	3.96	20		49-133	41-142	30	
4-Methyl-2-pentanone (MIBK)	5030B	8260B	2.7	20		57-132	52-135	30	
Acetone	5030B	8260B	4.08	20		57-133	51-137	30	
Acrolein	5030B	8260B	6.66	20		10-191	10-179	30	
Acrylonitrile	5030B	8260B	0.531	5		44-143	60-133	30	
Benzene	5030B	8260B	0.175	0.5		74-116	71-126	30	
Bromobenzene	5030B	8260B	0.172	2		77-107	73-113	30	

Table D-5 – Precision, Accuracy, and Completeness Control Criteria for Water[1]

Analyte	Preparation Method[2]	Analytical Method[2]	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% R)	Precision (RPD)	Completeness (%)
Bromochloromethane	5030B	8260B	0.164	0.5		76-119	72-125	30	
Bromodichloromethane	5030B	8260B	0.109	0.5		76-130	71-135	30	
Bromoform	5030B	8260B	0.279	0.5		65-133	61-137	30	
Bromomethane	5030B	8260B	0.217	0.5		32-153	28-161	30	
Carbon Disulfide	5030B	8260B	0.159	0.5		66-134	60-151	30	
Carbon Tetrachloride	5030B	8260B	0.139	0.5		66-139	63-149	30	
Chlorobenzene	5030B	8260B	0.134	0.5		81-112	74-122	30	
Dibromochloromethane	5030B	8260B	0.104	0.5		76-125	72-130	30	
Chloroethane	5030B	8260B	0.226	0.5		66-134	62-145	30	
Chloroform	5030B	8260B	0.136	0.5		73-117	69-123	30	
Chloromethane	5030B	8260B	0.136	0.5		41-141	40-148	30	
cis-1,3-Dichloropropene	5030B	8260B	0.11	0.5		66-127	60-131	30	
Dibromomethane	5030B	8260B	0.119	0.5		73-118	68-121	30	
Dichlorodifluoromethane	5030B	8260B	0.4	0.5		24-160	24-168	30	
Ethylbenzene	5030B	8260B	0.375	5		77-119	74-130	30	
Iodomethane	5030B	8260B	0.105	2		22-167	34-163	30	
Isopropylbenzene	5030B	8260B	0.193	2		66-107	62-117	30	
Methylene Chloride	5030B	8260B	0.0943	0.5		68-141	69-141	30	
Styrene	5030B	8260B	0.597	10		80-125	67-138	30	
trans-1,4-Dichloro-2-butene	5030B	8260B	0.131	0.5		42-170	61-165	30	
Trichlorofluoromethane	5030B	8260B	0.663	5		54-133	55-137	30	
Vinyl Acetate	5030B	8260B	0.136	0.5		10-196	35-172	30	
Ethyl Methacrylate	5030B	8260B	0.13	0.5		41-155	71-156	30	
m,p-Xylenes	5030B	8260B	0.219	0.5		76-123	72-134	30	
o-Xylene	5030B	8260B	0.102	0.5		75-118	72-126	30	

Table D-5 – Precision, Accuracy, and Completeness Control Criteria for Water(1)

Analyte	Preparation Method(2)	Analytical Method(2)	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% R)	Precision (RPD)	Completeness (%)
Methyl tert-Butyl Ether	5030B	8260B	0.197	0.5		48-128	43-131	30	
Tetrachloroethene (PCE)	5030B	8260B	0.126	0.5		72-117	62-133	30	
Toluene	5030B	8260B	0.108	0.5		71-117	68-125	30	
trans-1,2-Dichloroethene	5030B	8260B	0.143	0.5		73-118	70-128	30	
trans-1,3-Dichloropropene	5030B	8260B	0.0894	0.5		51-127	45-132	30	
Trichloroethene (TCE)	5030B	8260B	0.133	0.5		73-117	61-130	30	
Vinyl Chloride	5030B	8260B	0.042	0.5		60-139	55-153	30	
1,2-Dichloroethane-D4 (Surr.)	5030B	8260B			49-142	NA	NA	NA	
4-Bromofluorobenzene (Surr.)	5030B	8260B			73-118	NA	NA	NA	
Dibromofluoromethane (Surr.)	5030B	8260B			82-125	NA	NA	NA	
Toluene-D8 (Surr.)	5030B	8260B			87-120	NA	NA	NA	
Polycyclic Aromatic Hydrocarbons (µg/L)									95
2-Methylnaphthalene	3520C	8270-SIM	0.0027	0.01		42-117	33-122	30	
Acenaphthene	3520C	8270-SIM	0.002	0.01		56-119	46-126	30	
Acenaphthylene	3520C	8270-SIM	0.0018	0.01		55-123	41-136	30	
Anthracene	3520C	8270-SIM	0.0011	0.01		47-122	42-131	30	
Benz(a)anthracene	3520C	8270-SIM	0.0021	0.01		60-124	39-136	30	
Benzo(a)pyrene	3520C	8270-SIM	0.0016	0.01		42-136	24-145	30	
Benzo(b)fluoranthene	3520C	8270-SIM	0.002	0.01		61-135	26-149	30	
Benzo(g,h,i)perylene	3520C	8270-SIM	0.0037	0.01		47-132	18-140	30	
Benzo(k)fluoranthene	3520C	8270-SIM	0.0014	0.01		59-132	25-149	30	
Chrysene	3520C	8270-SIM	0.0013	0.01		63-128	42-136	30	
Dibenz(a,h)anthracene	3520C	8270-SIM	0.0017	0.01		41-137	14-146	30	
Dibenzofuran	3520C	8270-SIM	0.0071	0.01		51-122	36-134	30	
Fluoranthene	3520C	8270-SIM	0.0024	0.01		63-132	50-137	30	

Table D-5 – Precision, Accuracy, and Completeness Control Criteria for Water[(1)]

Analyte	Preparation Method[(2)]	Analytical Method[(2)]	Laboratory MDL	Laboratory MRL	Surrogate Spike (% R)	LCS (% R)	Matrix Spike (% R)	Precision (RPD)	Completeness (%)
Fluorene	3520C	8270-SIM	0.0026	0.01		58-124	48-130	30	
Indeno(1,2,3-cd)pyrene	3520C	8270-SIM	0.0021	0.01		44-131	16-143	30	
Naphthalene	3520C	8270-SIM	0.0032	0.01		49-113	40-124	30	
Phenanthrene	3520C	8270-SIM	0.0032	0.01		60-123	55-127	30	
Pyrene	3520C	8270-SIM	0.0023	0.01		60-131	48-136	30	
Fluoranthene-d10 (Surr.)	3520C	8270-SIM			49-131	NA	NA	NA	
Fluorene-d10 (Surr.)	3520C	8270-SIM			49-123	NA	NA	NA	
Terphenyl-d14 (Surr.)	3520C	8270-SIM			37-140	NA	NA	NA	

Notes:

(1) - Listed surrogate spike, precision, and accuracy control limits are based on in-house performance statistics of Columbia Analytical Services, Inc.-Kelso, Washington. The values are subject to change as the laboratory is updating the control limits per EPA requirements.

(2) - All preparation and analytical methods were based on USEPA Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846, Third Edition, December 1996, unless otherwise noted.

NWTPH-Dx - Analytical Methods for Petroleum Hydrocarbons, ECY 97-602, Washington State Department of Ecology, June 1997.

EPA Methods - *USEPA Methods for Chemical Analysis of Water and Wastes,* EPA–600/4-79-020, March 1983 Revision.

SM – Standard Methods for the Examination of Water and Wastewater, American Public Health Association, 20th Edition, 1995.

USEPA Method 163*1 – Method 1631 Revision E: Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry,* Office of Water, U.S. Environmental Protection Agency, August 2002, EPA-821-R-02-019.

LCS – Laboratory control sample.
MDL – Method detection limit.
MRL – Method reporting limit.
MS – Matrix spike.
%R - Percent recovery
mg/L – milligram per liter
µg/L - microgram per liter
ng/L - nenogram per liter
NA - Not applicable
RPD - Relative precent difference
SIM - Selective ion monitoring

APPENDIX E

Annotated Outline for RI/FS Documents

Annotated Outline for
RI/FS Documents

Overview: The annotated outline presented below has been developed to assist with the preparation of Remedial Investigation / Feasibility Study (RI/FS) reports as required under project specific Agreed Orders. The format is based on Model Toxics Control Act (MTCA) regulatory requirements listed in WAC 173-340-350 (which are not explicit to document format) and on the format used in the Whatcom Waterway 2006 Supplemental RI/FS. In addition, the disproportionate cost analysis example included in Attachment A to this outline is excerpted from Exhibit B of the Whatcom Waterway 2007 Consent Decree. Both of these Whatcom Waterway documents can be found at
http://www.ecy.wa.gov/programs/tcp/sites/whatcom/ww.htm
Because the specifics of each site are different, deviations from this standard outline may be warranted, but these should be discussed with the Ecology site manager prior to using an alternative structure. This will help minimize the potential for delays during the RI/FS review and finalization process.

Some of the sections listed below are optional, depending on the needs of the site. Section numbering should be adjusted as appropriate.

1. Introduction
a. Site Description and Background
b. Document Organization

2. Project Background
a. Site History
b. Objectives of the RI/FS
c. Relationship of RI/FS to Other Documents (if applicable)

Site history should provide a concise summary of site discovery, identified sources, previous studies and/or cleanup actions as applicable. For MTCA Interim Cleanup Actions, 2-a should discuss the timing and nature of the cleanup action as well as its performance based upon the results of compliance monitoring.

Use 2-c to discuss how the RI/FS relates to other applicable environmental documents. These could include RI/FS or cleanup work at adjacent/nearby sites, or could include separate SEPA documents relating to the cleanup action. This section should provide context, with any detailed analysis addressed in subsequent portions of the document (see Section 15).

3. Optional Section: RI Methods

RI investigation methods can either be included in the RI document as a section, or they can be attached as an appendix to the document. Placing them as an appendix is generally preferred to enhance readability of the final document. However, this should be decided on a case-by-case basis by the PLP and the Ecology site manager. Quality assurance should be addressed as part of the methods section.

4. **Environmental Setting**
   a. **Physical Conditions**
   b. **Geology and Hydrogeology (include for upland sites)**
   c. **Natural Resources**
   d. **Historical and Cultural Resources**
   e. **Land and Navigation Uses (as applicable)**

Use 4-a to describe bathymetry, topography, surface water and circulation patterns (where applicable), sea level rise, and other physical characteristics of the site.

For upland sites, geology and hydrogeology (4-b) will typically be broken out into separate subsections. For sediment sites, they may be addressed under 4-a, depending on the level of detail required.

Section 4-c will typically be more detailed for sediment sites, to comply with requirements of SMS and address factors that may influence site unit designations. For upland sites this section will typically be used to assess the need for an ecological assessment as part of cleanup levels development.

Use 4-d to generally describe any landmarks or evidence of historic, archaeological, scientific, or cultural importance known or suspected to be on or near the site.

In 4-e, describe land ownership, zoning, current and expected land uses. For sediments, include a discussion of current and anticipated navigation uses including mooring, storage, and boat launch or access uses.

5. **Site Screening Levels**
   a. **Exposure Pathways and Receptors**
   b. **Screening Levels (by media and/or receptor)**

Present (using subsections as necessary) potentially applicable screening levels for each media if available. This will typically include summary tables documenting the criteria that will be used to evaluate the contaminant data for the site in subsequent sections. For contaminants or media for which screening levels do not exist, derivation of site specific screening levels will likely be necessary as identified in rule as "case by case".

6. Nature and Extent of Contamination

a. Constituents of Concern

b. Nature & Extent – Describe by Media (Use subsections as appropriate)

Example 1: Surface Sediment, Subsurface Sediment, Surface Water
Example 2: Soil Impacts, Groundwater Impacts, Surface Water, Soil Vapor, etc.

In Section 6-a, the constituents of concern (contaminants that may represent MTCA "indicator hazardous substances") should be introduced based on exceedances of screening levels, which may include both chemical or biological impact data correlated with the associated chemical data. Where these screening levels are later modified significantly through risk assessment or other cleanup levels development (e.g., screening against SQS, with some sites ultimately using the CSL; or screening of groundwater against surface water criteria, with later development of location-specific cleanup levels for the site), this section should reference the different considerations applicable.

Section 6-b should provide a description of the type, concentration and extent of contamination. All data used to define the nature and extent of contamination should be presented. The data should be discussed by media, using additional subsections as appropriate. Sources should be discussed where known. Areas of co-mingled or off-site source contamination relevant to the project should be discussed as applicable.

7. Optional Section – Risk Assessment

For some sites a risk assessment (human health or ecological) may be required. If required, these should be summarized or included in this section. Where documentation associated with these studies is extensive, they may be attached as appendices or incorporated by reference with sufficient description to familiarize the reader with their key findings.

8. Contaminant Fate & Transport

a. Source Control

b. Attenuation/Transport Processes – (Organize as Applicable)

The RI needs to include a statement about whether the original source has been controlled. If the source has not been controlled, then this must be considered as part of the Feasibility Study (e.g., removal of buried tank) and potentially as part of coordinated actions under other authorities (e.g., surface water quality work under separate CSO control programs). For sediment sites, applicable subsections may include analyses of other potential sources of contamination (stormwater & industrial discharges, and adjacent contaminated sites), sediment deposition, sediment disturbance, and sediment transport properties. For upland *sites, potential groundwater or vapor transport, or potential anthropogenic soil/groundwater disturbances should be discussed. For sites with both a sediment and upland component, the RI must identify soil and groundwater contaminant concentrations that provide compliance with sediment screening levels If extensive modeling or transport studies are conducted, these may require separate sections, or this section may be used to summarize work attached as appendices or provided as a separate document.*

9. Optional Section – Pre-Design or Engineering Testing (Include when Applicable)

In some cases, extensive pre-design testing may be collected to support the feasibility study process, or provide information needed for site-specific decision-making. For example, treatability testing used to support technology screening could be described in this section.

10. Conceptual Site Model

a. **Contaminants & Sources**
b. **Nature & Extent of Contamination**
c. **Fate & Transport Processes**
d. **Exposure Pathways and Receptors**
e. **RI Conclusions**

The Conceptual Site Model should include one or more graphics illustrating the four elements (10-a through 10-d above). These graphics should be concise and are intended to help communicate the conclusions of the RI study to the public and to project stakeholders.

RI conclusions should state whether data gaps necessary for an RI/FS have been filled, and should differentiate between RI/FS data gaps and pre-design data gaps relevant to subsequent project phases.

For 2-volume RI/FS documents, terminate the RI at this point and include a References Cited section. Provide a transition section in the second volume to introduce the FS (Introduction, recap of Conceptual Site Model etc.). For single-volume RI/FS documents, continue with Section 11.

11. Cleanup Requirements

a. **Site Cleanup Levels**
b. **Remedial Action Objectives**
c. **Potentially Applicable Laws**

Site cleanup levels should be defined, along with potentially applicable points of compliance in Section 11-a. Where alternative points of compliance are proposed, the rationale for consideration of these must be provided. Ecology will approve final cleanup levels and points of compliance as part of the Cleanup Action Plan for the site.

Remedial action objectives should be provided in 11-b. These are intended to be simple statements of what the remedy needs to accomplish in order to address issues defined in the Conceptual Site Model. The RAOs are communication tools that help the reader assess what needs to be accomplished. RAOs are not evaluation criteria under MTCA regulations.

ARARs should be presented using tables as appropriate.

12. Optional Section -- Site Units (if applicable)

Describe for Each Site Unit

- *Physical Factors*
- *Land Use and Navigation*
- *Natural Resources*
- *Contaminant Distribution*

Some sites may not require definition of site units. However, larger upland site and most sediment sites will require site unit definition. Site unit definition should be discussed with your Ecology site manager during initial development of the feasibility study.

13. Screening of Remedial Technologies

This section should be used to introduce potential technologies that were considered prior to development of the remedial alternatives. While not explicitly required by MTCA, this section is important to communicate the completeness of the evaluation conducted. Technologies should be described along with potential site-specific limitations. They should then be screened for effectiveness, implementability and cost. A table should be provided summarizing technologies retained for use in developing remedial alternatives.

14. Description of Remedial Alternatives

Develop and describe a reasonable number of cleanup alternatives for the upland portion of the site as well as a separate set of cleanup alternatives for the sediment portion of the site (where applicable). The number of alternatives considered will vary from site to site. Describe for each alternative

- *Actions*
- *Costs and Schedule*
- *Other Considerations (e.g. Habitat, Land Use and/or Navigation)*

All alternatives evaluated must be capable of achieving MTCA threshold criteria. Alternatives that do not should not be considered, unless there are no alternatives considered capable of achieving such cleanup levels.

This section should not evaluate the alternatives. This should be a description, with appropriate tables and figures. Alternatives should be described apples-to-apples, with the subsequent section addressing significant differences between the alternatives and their appropriateness under MTCA regulatory criteria. Cost estimates for each alternative should contain the same line items (i.e. one alternative may include excavation with no capping and the other no excavation and all capping-both should have excavation and capping line items).

Other Considerations should be identified through a review of a blank SEPA checklist. Where such review identifies issues that could affect the evaluation of alternatives, concise factual information on these issues should be presented.

Where a MTCA interim cleanup action has previously been implemented, the remedial alternatives should contain a concise summary of the interim action and a statement about the performance of the interim action based upon the results of compliance monitoring. Any impact each alternative may have upon the previously conducted interim action should also be described.

15. Detailed Evaluation of Alternatives

- **a. MTCA (and SMS) Evaluation Criteria**
  - **i. MTCA Threshold Requirements**
  - **ii. Other MTCA Requirements**
  - **iii. MTCA Disproportionate Cost Analysis**
  - **iv. SMS Evaluation Criteria (Sediment sites only)**
- **b. Evaluation of Alternatives**
- **c. MTCA Disproportionate Cost Analysis (see Attachment A)**
  - **i. Comparative Evaluation of Alternatives**
  - **ii. MTCA Disproportionate Cost Analysis**

This section should begin with a presentation of the regulatory criteria under MTCA (and SMS for sediment sites) used to evaluate the remedial alternatives.

The alternatives evaluation should include appropriate summary tables summarizing the evaluation against the MTCA criteria. The evaluation criteria and process is specified in MTCA. However, the number of alternatives, the specific format of the analysis, and the specific factors considered in evaluating alternatives (i.e., what factors contribute to overall protectiveness rating for an alternative) will vary from site to site and need to be discussed with the Ecology site manager. See Attachment A for detailed DCA information and an example DCA.

SMS criteria are similar to MTCA criteria and are mostly covered in the MTCA analysis with the exception of environmental impacts and net environmental effects. While these are not explicit criterion under MTCA, Ecology expects integration/coordination of MTCA and SEPA in accordance with Policy 130A. As a result, review of a blank SEPA checklist is to be performed at various steps leading up to the completion of an RI/FS. If such review ultimately results in a SEPA *determination of significance, a draft EIS must be prepared and issued concurrent with (or integrated into) the draft RI/FS. In this situation both the RI/FS and the EIS are used by Ecology to select a remedy. If through such review a SEPA determination of non-significance appears likely then the "Other Considerations" section in number 14 above is used to identify environmental impacts that could appreciably affect the evaluation of alternatives. The detailed alternatives analysis in this section would then include an evaluation of Net Environmental Effects as a criterion.*

16. Optional – Coordination with Other Environmental Documents

This section should be used where necessary to discuss environmental reviews conducted under separate documents (e.g., SEPA EIS), to discuss coordination with other cleanup sites, or coordination with other source control or land use activities. This section is provided for information only.

17. Summary and Conclusions

a. Description of the Preferred Alternative
b. Basis for Alternative Identification
c. Implementation of Site Cleanup

The preferred alternative should be identified, along with a short summary of how it was identified and how it will be implemented. This section should recognize the role of subsequent documents (e.g., Cleanup Action Plan, project engineering design, project permits) in finalizing cleanup decisions and project design details.

18. References Cited

19. Tables

20. Figures

Separate figures should be prepared for each impacted media. Separate figures should be prepared for each COC. All data being used to delineate the nature and extent of contamination should be depicted on figures with analytical results. Based upon the complexity of the graphics consider color to help differentiate information.

21. Appendices