4 Environmental Setting

The environmental setting of the Site has been documented in previous investigations including the initial Chlor-Alkali plant RI and FS (ENSR, 1994a and 1994b), the subsequent FS for the Chlor-Alkali site (Aspect, 2004a), the Phase II Environmental Assessment for the 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 Physical Conditions

The Site is relatively flat, with land surface elevations generally ranging from 14 to 16 feet above mean lower low water (MLLW). Figure 4-1 is a topographic elevation contour map for the Site area, generated from LiDAR (light detection and ranging) data obtained from the Puget Sound LiDAR Consortium. 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. Currently, most of the Site is covered by pavement with some remaining buildings from the Mill and Chlor-Alkali plants.

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 ASB north of the Whatcom Waterway, under the terms of the Port's National Permit Discharge Elimination System (NPDES) permit for that facility. The ASB has been permitted since it was constructed in the late 1970s when the Pulp Mill was in full operation. The discharge is sampled and analyzed in accordance with the NPDES permit requirements. The City conveys stormwater collected from other areas of Bellingham through the Site, beneath Laurel Street, to its outfall to the waterway. As described above, the City's Laurel Street stormwater system and outfall does not convey any stormwater from the Site. The Port is currently evaluating the condition of the existing stormwater system on the Site and how the system may be changed as property redevelopment occurs in the future.

The Intergovernmental Panel on Climate Change (IPCC) (2007) estimates that the global average sea level will rise between 0.6 and 2 feet in the next century. Puget Sound is likely to experience sea level rise similar to this global average (University of Washington Climate Impacts Group and Ecology, 2008). In the Waterfront District EIS documents, a potential sea level rise in Bellingham Bay of 2.4 feet by 2100 was considered a reasonable estimate. To account for future sea level rise, current plans for redevelopment of the upland Site area incorporate placing fill to raise grades by several feet.

4.2 Geology and Hydrogeology

This section describes the geologic conditions underlying the Site and the occurrence and movement of groundwater within the geologic units.

4.2.1 Geology

Geologic units beneath the Site include a variety of unconsolidated materials overlying a northward-sloping bedrock surface, as described below.

4.2.1.1 Unconsolidated Units

The Site is built on land formed by filling a tidal flat area of the Whatcom Creek Delta. Filling was 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 20 feet across the Site and primarily consists of silty sand or sandy silt with occasional gravel and organic material (e.g., wood). Prior to filling, historical structures in the Site area were often pile-supported, and abundant wood pilings remain in place within areas of the fill.

Underlying the fill is a 10- to 40-foot-thick sequence of native beach and intertidal deposits. These include approximately 2 to 15 feet of native tidal flat material consisting predominantly of organic-rich silty sand and silt over approximately 10 to 25 feet of marine beach deposits consisting of predominantly medium sand. The marine beach deposits overlie a Glaciomarine Drift (GMD, aka Bellingham Drift), a medium stiff to stiff gray clay generally acting as a low-permeability aquitard unit. The GMD appears to increase in thickness from zero near Cornwall Avenue immediately south of the Site to more than 75 feet along the Whatcom Waterway to the north, as illustrated on Site-wide Cross Section A-A’ running north-south along Laurel Street (Figure 4-2). The location of Cross Section A-A’ is shown on Figure 4-1.

Collectively, the wedge of unconsolidated materials thickens from zero along the topographic bluff south of the Site to greater than 135 feet at the Site’s northern boundary along the Whatcom Waterway. Because of the great depth of bedrock below most of the Site, none of the explorations completed for environmental investigation of the Site have encountered it. The bedrock was encountered in geotechnical borings completed in the area of the railroad grade south of the Site (GeoEngineers, 2007), and borings BB-1, BB-2, and BB-3 from that study are depicted on Figure 4-2. The bedrock surface elevation depicted on Figure 4-2 is taken from a bedrock elevation contour map, developed by W.D. Purnell and Associates, using data from numerous deep geotechnical borings; the contour map is reproduced on Figure 4-3.

4.2.1.2 Bedrock

The unconsolidated units pinch out to the east and south of the Site to bedrock of the Chuckanut formation consisting of sandstone, shale, conglomerate, and coal. The Chuckanut formation was deposited in a river floodplain environment and is described as a coal-bearing sandstone with interbedded conglomerate and thin mudstone lenses (Carroll, 1980). The Chuckanut sandstone typically has little or no primary porosity and groundwater movement is through fractures. Based on information presented on Figure 4-

3, bedrock occurs beneath the Site at less than 30 feet below ground surface (bgs) in portions of the Pulp and Tissue Mill area on the east, to greater than 135 feet bgs in portions of the Chlor-Alkali area on the west.

4.2.2 Hydrogeology

Across much of the Site, the three hydrogeologic units of primary interest 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. Beneath the Lower Sand is a fourth unit, an older GMD unit comprised of stiff silt/clay unit with silty sand layers. In the northeastern portion of the Site (e.g., within Bunker C Tank subarea), the Tidal Flat Aquitard is apparently absent, such that Fill overlies the GMD. The GMD in this area was observed between depths of about 25 to 30 feet and the 75-foot maximum depth of exploration.

The Fill Unit contains a shallow water table aquifer, whereas, where the Tidal Flat Aquitard is present, the Lower Sand Unit is a confined aquifer, which is hydraulically separated from the Fill Unit aquifer by the intervening Tidal Flat Aquitard. Fill Unit and Lower Sand Unit groundwater beneath the Site ultimately discharges to the marine environment of Whatcom Waterway or Bellingham Bay. Additional detail on the Fill Unit, Tidal Flat Aquitard, and Lower Sand is provided below.

4.2.2.1 Fill Unit

Soils within approximately 15 to 20 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, overlying 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, the Fill Unit water table occurred at depths typically ranging from 3 to 6 feet bgs across most of the Pulp and 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 south to greater than 9 feet bgs near the Log Pond on the north.

Fill Unit Groundwater Flow Directions and Gradients

Fill Unit groundwater beneath the Site ultimately discharges to the Whatcom Waterway or Bellingham Bay. Dry season (September 2009) and wet season (April 2010) water table elevation contours for the Fill Unit, and interpreted groundwater flow directions, are depicted on Figures 4-4 and 4-5, respectively. In general, groundwater under the Pulp and Tissue Mill and Chlor-Alkali areas flows north to the Whatcom Waterway, and groundwater beneath the Bellingham Shipping Terminal flows west to Bellingham Bay. Table A-1 in Appendix A presents the two rounds of Site-wide water level data, and well construction information for the monitoring wells from which data were collected.

Three groundwater highs within the Fill Unit aquifer are observed in both the dry and wet seasons. Two occur within the area of the 1974 dredge fill near the Log Pond. One occurs in the area of wells CF-MW02 and EMW-20S in the former chip storage area. These two wells occur on the western flank of a paved topographic high (see Figure 4-1) with depressions near each well that pool water for much of the year. It is likely that there is recharge occurring in these pooled areas through cracks in the pavement, creating a water table mound approximately 2 to 3 feet above surrounding water table elevations. A second water table mound occurs within the footprint of the former Wastewater Settling Basin, a portion of which is unpaved thus allowing focused recharge. Finally, there is a water table mound centered along the Stormwater Swale on the south end of the Site, between the former Chlor-Alkali plant and the BNSF railroad tracks. Groundwater flow diverges from the groundwater mounds. In all cases, the groundwater mounds appear more pronounced in the wet season data.

Review of groundwater elevations from both the dry and wet seasons indicates the Laurel Street storm drain locally influences groundwater in the Fill Unit (see Figures 4-4 and 4-5). The area of influence away from the drain appears localized, perhaps on the order of 150 feet on either side. Though the pipe has been slip-lined by the City, some groundwater infiltration into it could potentially occur if there is a gap in the slip lining. In addition, the drain trench backfill outside the pipe may be sufficiently permeable to provide a preferential groundwater flow pathway. ENSR (1994a) also documented the Laurel Street drain line as a conduit for groundwater flow.

Groundwater elevations during the wet season indicate that the Cornwall Street storm drain may also influence groundwater flow directions near the southwest corner of the Site, as indicated by the gradient between wells AMW-03 and CP-MW09. This interpretation is based on the Spring 2010 water level data (Figure 4-5), since additional wells were added in that area at that time. Groundwater chemistry data also confirm a southward groundwater flowpath toward the Cornwall Street drain line in that area, as described in Section 7.1.

Groundwater flow directions in the Fill Unit may also 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 three-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 4-4). ENSR (1994a) hypothesized that the north-south trending portions of the former bulkhead structure may create groundwater divides within the Fill Unit, especially between the 1974 dredge fill area and the Bellingham Shipping terminal. With the benefit of the more robust monitoring network now available, the current water level data indicate that the buried bulkhead structures may impede, but do not prevent, groundwater flow.

TIDAL STUDIES

A 96-hour tidal study involving continuous water level monitoring was conducted on ten Fill Unit wells from October 19 to 22, 2009, a period of high tidal fluctuations in Bellingham Bay. The results of the study indicate that nearshore wells (CP-MWA3, CP-MWC3, and AA-MW01) exhibited some degree of tidal influence (1.2, 2.3, and 1.5 feet of fluctuation, respectively). However, the wells further inland (EMW-10S, CP-MWA1, CF-MW02, AA-MW04, CP-MWC1, and CP-MW03) show no discernible tidal influence on groundwater levels. Well Law-1 also exhibited little apparent tidal influence, despite being located immediately adjacent to the Log Pond shoreline. This well is screened within dike material placed to contain the dredge filling conducted in 1974, and appears to be of lower permeability than most of the Fill Unit. Other wells did show minor water level fluctuations over the period of monitoring that were not attributable to tidal influence.

The tidal study results were generally consistent with results from ENSR's (1994a) tidal study, which concluded that Fill Unit groundwater beneath the Chlor-Alkali area was not appreciably influenced by tidal fluctuations. However, that study did observe small tidal fluctuations (0.25 foot) in well Law-1, while the tidal response was less apparent in the current data. Data collected during the Phase II Environmental Site Assessment for the Pulp and Tissue Mill area also indicates that Fill Unit groundwater adjacent to the waterway does respond minimally to tidal fluctuations (Aspect, 2004b).

Figure 4-6 summarizes the tidal study data from October 2009 and subsequent monitoring described below. The data on Figure 4-6 include the mean (tidally averaged) groundwater elevation, calculated using the method of Serfes (1991), and the maximum groundwater level fluctuation measured during the monitoring period. Groundwater fluctuations that do not appear to be attributable to tidal response are flagged with an "x". The tidal study water level data for each well are tabulated and presented graphically in Appendix B.

Two subsequent 72-hour tidal studies were conducted in April and May 2010. Four new Fill Unit monitoring wells (CP-MW07, CP-MW08, CP-MW09, and CP-MW-12) were installed in March and a tidal study was conducted in them from April 17 through 19, 2010, to further assess groundwater flow directions in the southwestern portion of the Site, near the Cornwall storm drain line. From May 11 through 13, 2010, monitoring was conducted in Fill Unit wells along transects within two areas of the Site: CP-MWB1, CP-MWB2, and CP-MWB3 in the Chlor-Alkali area; and AA-MW04, FH-MW01, and AA-MW01 within the former Acid Plant area. In addition, newly installed well CP-MW10, located just east of Law-1, was monitored to provide confirmation of tidal study results from Law-1. The results of the supplemental tidal studies were consistent with observations from previous investigations. Only nearshore wells (CP-MW07, CP-MW12, and CP-MWB3) exhibited a significant tidal response, and interior wells, including well CP-MW10 located adjacent to the Log Pond, showed very little tidal response.

In February 2011, an additional 72-hour tidal study was performed in the Law-1 area, using wells Law-1 and new wells L1-MW02 and L1-MW06, to better define groundwater flow directions adjacent to the shoreline (Aspect, 2011b).

HORIZONTAL HYDRAULIC GRADIENTS

Fill Unit hydraulic gradients for Fall 2009 and Spring 2010 were calculated based on interpreted Site-wide groundwater elevation contours for each measurement period (Figures 4-4 and 4-5). The Fill Unit hydraulic gradients and directions, and their seasonal ranges, for defined subareas of the Site (described in Section 6), based on groundwater elevation contour mapping are summarized as follows (also see Table 4-1):

- Bunker C Tank area: ranged from 0.012 ft/ft north (N) in the Fall to 0.015 ft/ft N in the Spring;

- Acid Plant area: ranged from 0.009 ft/ft N in the Fall to 0.011 ft/ft N in the Spring;
- Million Gallon Tanks area: ranged from 0.005 ft/ft northeast (NE) in the Fall to 0.010 ft/ft north-northeast (NNE) in the Spring;
- Confined Nearshore Fill area: ranged from 0.008 ft/ft N in the Fall to 0.009 ft/ft N in the Spring; and
- Chlor-Alkali plant area: ranged from 0.007 ft/ft northwest (NW) in the Fall to 0.008 ft/ft NW in the Spring.

In general, the hydraulic gradient is somewhat higher (steeper) during the wet season.

The tidal study data collected in both Fall 2009 and Spring 2010 were also used to calculate the mean (tidally averaged) hydraulic gradient in areas of the Site. This was done by calculating the mean water level over a 72-hour tidal cycle (using the Serfes [1991] method) for well pairs aligned generally downgradient, and calculating the gradient from those mean water levels. The gradients calculated from the tidally averaged data are as follows (also see Table 4-1):

- Acid Plant area: ranged from 0.006 ft/ft N in the Fall to 0.010 ft/ft N in the Spring, based on the well pair AA-MW01 and AA-MW04.
- Confined Nearshore Fill area: 0.009 ft/ft north-northwest (NNW) in the Fall, based on the well pair EMW-10S and CF-MW02.
- Chlor-Alkali plant area: In Fall, ranged from 0.0034 to 0.0036 ft/ft, toward the west-northwest (WNW), based on the well pairs CP-MWC3 and CP-MWC1, and CP-MWA3 and CP-MWA1, respectively. In Spring, ranged from 0.0036 ft/ft to the WNW to 0.008 ft/ft to the W based on the well pairs CP-MW09 and CP-MW12, and CP-MWB3 and CP-MWB1, respectively.

Although tidal influence in the Fill Unit is small except near the shoreline, the tidally averaged hydraulic gradient estimates are considered more reliable than those calculated from the groundwater elevation contours maps, which represent a “snapshot” water table condition spanning 2 to 3 hours rather than the average condition throughout an entire tidal cycle.

GROUNDWATER FLOW IN LAW-1 AREA

In February 2011, continuous water level data were collected in the Law-1 area over a 72-hour period in wells Law-1, L1-MW02, and L1-MW06 to refine understanding of whether there may be a preferred groundwater flow path to the northwest, around the west end of the low permeability soil berm containing the 1974 dredge fill, which mutes tidal fluctuations in groundwater within and behind it. If a greater tidal response were observed in well L1-MW06, in the Salt Pad area west of the berm, compared to Law-1 in the berm, it would suggest that Log Pond surface water is in more direct hydraulic continuity with groundwater in the Salt Pad area than with groundwater behind the soil berm; this would suggest a local preferred groundwater flow pathway to the Log Pond around the west of the berm (via the L1-MW06 location).

However, the new tidal monitoring data confirm only subtle tidal response in each of the three wells, and a smaller response (tidal efficiency of 1.5 percent) at L1-MW06 located closest to the tide than in either Law-1 or L1-MW02 (tidal efficiencies of 3.4 and 4.1 percent respectively). The data suggest that the existing north-south bulkhead, behind which L1-MW06 is positioned, provides a greater restriction to groundwater interaction with Log Pond surface water than does the soil berm.

Well L1-MW02 had a higher groundwater elevation throughout the tidal cycle than either Law-1 or L1-MW06, indicating a gradient in both directions. However, the collective tidal monitoring data and contoured groundwater elevations for the area suggest that groundwater across the Law-1 area discharges primarily to the Log Pond via its southern shoreline, through the soil berm.

That said, the December 2010 groundwater quality data for the Law-1 area (Section 7.2.2) suggest temporary westward movement of impacted groundwater from source material within the 1974 dredge fill area to the L1-MW02 location. The former Wastewater Settling Basin is an unpaved area and thus an area of concentrated groundwater recharge within the otherwise-paved Site; the groundwater elevation data indicate a groundwater mound beneath the former Basin, away from which groundwater flows radially. We expect that larger seasonal recharge events temporarily increase the size of the groundwater mound, pushing groundwater within the 1974 dredge fill farther to the west (e.g., to L1-MW02). As a recharge event subsides, the mound shrinks. The western flow component likely ebbs and flows with changing recharge, resulting in the observed temporal groundwater quality changes at L1-MW02 and Law-1/L1-MW01. While there is localized flow toward the west, the water level data indicate that the net groundwater flow in the Law-1 area is predominantly toward the north-northeast with discharge to the Log Pond through the soil berm, as outlined above.

Fill Unit Aquifer Properties

Horizontal hydraulic conductivity (K) was estimated for the Fill Unit aquifer by performing slug testing on select wells, evaluating the tidal study data using the stage ratio and time lag methods of Ferris (1963), and conducting a pumping test to support interim action design.

SLUG TESTING

Slug tests were performed on the nine transect wells in the Chlor-Alkali plant area: CP-MWC3, CP-MWB3, CP-MWA3, CP-MWC2, CP-MWB2, CP-MWA2, CP-MWC1, CP-MWB1, and CP-MWA1. A minimum of two falling head and two rising head tests were performed on each well, and a minimum of two tests were analyzed for each well using the Bouwer and Rice (1976 and 1989) methods.

The results of the slug test analyses indicate a geometric mean K of the transect wells of 9×10^{-4} cm/sec with a range exceeding three orders of magnitude (8×10^{-6} to 2×10^{-2} cm/sec). The geometric mean K of the wells slug tested by ENSR (1994a) is 2×10^{-4} cm/sec, with a range covering four orders of magnitude (7×10^{-7} to 2×10^{-2} cm/sec). The wide range of values observed indicates a wide range of fill materials comprising the Fill Unit aquifer. The geometric mean K from slug testing of the Fill Unit wells is 3×10^{-4} cm/sec, which is a typical value for slightly silty to silty sand. The Fill Unit slug test K estimates, including results from ENSR (1994a), are presented in Table 4-2. The slug test data from individual wells tested during the RI are presented in Appendix B.

TIDAL STUDY

The stage ratio and time lag methods of Ferris (1963) were also evaluated to estimate K values from the tidal study data. While the slug testing method tests a small volume of aquifer immediately adjacent to the wellbore and thus provides point estimate for aquifer K, the Ferris (1963) methods are intended to provide a K estimate representing the entire Fill Unit aquifer between the well and the area of discharge to the Whatcom Waterway and Bellingham Bay. In general, the K estimates based on tidal study data were an order of magnitude higher than those based on slug tests for Fill Unit wells with both sets of data (CP-MWA3, CP-MWB3, and CP-MWC3). The Ferris methods were developed for confined aquifer conditions but can be applied for unconfined aquifers if the observed tidal fluctuation in the aquifer is relatively small compared to the aquifer thickness, and the observation well is far enough from the submarine outcrop to avoid vertical flow (Millham and Howes, 1995). Erskine (1991) also observed that aquifers with a large storage coefficient (i.e., unconfined aquifers) can be problematic when estimating K values based on the Ferris methods. The Fill Unit is an unconfined aquifer with a correspondingly larger storage coefficient (specific yield associated with gravity drainage of pore space) and relatively thin saturated thickness, such that tidal fluctuations in shoreline wells can represent a substantial fraction of saturated thickness. Given this information and the discrepancies in K estimates obtained from slug test data versus tidal study data, the Fill Unit K estimates based on the slug tests are considered more reliable than those from the tidal study.

Table 4-2 presents the geometric mean K and standard deviation for the Fill Unit based on the collective data from slug testing of 25 Fill Unit monitoring wells. The geometric mean from the 25 wells covering the Site is considered a reasonable best estimate K for the Fill Unit. Recognizing that the composition of the Fill Unit varies across the Site, K estimates from specific wells can be used if evaluating groundwater flow conditions for specific areas of the Site.

PUMPING TEST

In June-July 2011, a dewatering test well (BC-DW1) was drilled and hydraulically tested to estimate hydraulic parameters of the Fill Unit, supporting design of an excavation dewatering system for Bunker C Tank interim action area. The well was pumped at a rate of approximately 4.9 gpm for 24 hours; water levels were monitored in the pumping well and in nearby monitoring wells BC-MW01 (located 112 feet north of BC-DW1), BC-MW02 (located 166 feet north), and BC-MW04 (located 146 feet north-northwest).

Analysis of the constant-rate pumping test data produced an estimated transmissivity of about 140 ft^2/day for the Fill Unit, or combined Fill Unit-Lower Sand (Tidal Flat Aquitard absent). The saturated thickness of the sand unit above the GMD was about 19 feet at the time of testing, indicating an estimated hydraulic conductivity of about 7.4 ft/day (3×10^{-3} cm/sec). Given that no drawdown was observed in the monitoring wells, storage properties of the Fill unit could not be estimated from the test.

Storage coefficient of the unconfined Fill Unit aquifer (i.e., aquifer specific yield) has not been measured, but, compared to aquifer K, it is constrained within a narrow range (between approximately 0.05 and 0.25) based on literature values for sandy aquifers. Likewise, effective porosity of the Fill Unit is estimated to fall within a narrow range of approximately 0.20 to 0.30 based on literature values. We assume 0.25 as a best estimate effective porosity for the Fill Unit.

Appendix B includes a memorandum detailing the well BC-DW1 pumping test methods, data, and Fill Unit hydraulic parameters based on analysis of the data.

Groundwater Velocities in Fill Unit

Fill Unit horizontal average linear (seepage) velocities (magnitude and direction) and their seasonal ranges, for different areas of the Site, are based on the best estimate horizontal hydraulic gradients, effective porosity, and K. The seepage velocity is calculated using Darcy's Law of the form: $v = K * I / n_e$, where:

- v = seepage velocity (feet/year);
- K = hydraulic conductivity (feet/year);
- I = horizontal gradient (feet/foot); and
- n_e = effective porosity (dimensionless).

The seepage velocity estimates for specific subareas of the Site are summarized below (see also Table 4-3):

- Bunker C Tank area: ranged from 150 ft/year N in the Fall to 190 ft/year N in the Spring.
- Acid Plant area: ranged from 8 ft/year N in the Fall to 14 ft/year N in the Spring.
- Million Gallon Tanks area: ranged from 50 ft/year NE in the Fall to 100 ft/year NNE in the Spring.
- Confined Nearshore Fill area: ranged from 8 ft/year N in the Fall to 9 ft/year N in the Spring.
- Chlor-Alkali plant area: ranged from 13 ft/year NW in the Fall to 30 ft/ft NW in the Spring.

This information indicates there is seasonal variation in Fill Unit groundwater velocities, associated with gradient changes, but they vary by less than a factor of 3 throughout the year.

Groundwater Flux in Fill Unit

Using the hydraulic gradient and K estimates, a range of volumetric groundwater fluxes can also be estimated for the Fill Unit. The volumetric flux is also referred to as specific discharge or Darcy velocity and has units of volume per time. The specific discharge is calculated using Darcy's Law of the form: $q = 7.48 * K * I * A$, where:

- q = specific discharge (gallons/square foot/year);
- K = hydraulic conductivity (feet/year);
- I = horizontal gradient (feet/foot);
- A = aquifer cross sectional area (square feet); and

- 7.48 gallons/cubic foot, units conversion.

In this case, we estimate a unit-specific discharge (flux) of groundwater across 1 square foot of cross-sectional aquifer area perpendicular to the direction of flow (i.e., gallons of water flowing through a square foot of aquifer per year). This unit flux can then be applied to estimate total volumetric flux for specific areas of the Site, considering the saturated thickness and width of aquifer (cross-sectional area) for the specific subarea of interest.

The unit flux estimates for specific subareas of the Site are summarized below (Table 4-3):

- Bunker C Tank area: ranged from 280 to 350 gallons/square foot/year (Fall and Spring, respectively).
- Acid Plant area: ranged from 14 to 26 gallons/square foot/year (Fall and Spring, respectively).
- Million Gallon Tanks area: ranged from 90 to 190 gallons/square foot/year (Fall and Spring, respectively).
- Confined Nearshore Fill area: ranged from 16 to 18 gallons/square foot/year (Fall and Spring, respectively).
- Chlor-Alkali plant area: ranged from 24 to 56 gallons/square foot/year (Fall and Spring, respectively).

4.2.2.2 Tidal Flat Aquitard

A native tidal flat deposit underlying the Fill Unit across much of the Site is comprised of stratified, low permeability silt and silty sand, which acts as an aquitard impeding vertical movement of groundwater between the overlying Fill Unit and the underlying Lower Sand Unit. The Tidal Flat Aquitard (Aquitard) thickness beneath the Site varies from a few feet to as much as 20 feet. However, the Aquitard is comprised of interbedded silt and silty sand, immediately beneath a Fill Unit largely comprised of slightly silty to silty sand, so clearly delineating one unit from the other based on soil samples in the field can be challenging.

In the Bunker C Tank area, the Tidal Flat Aquitard is absent. The Fill Unit, containing an unconfined aquifer, overlies the older GMD, which is clayey silt extending to the 75-foot depth of exploration in this area.

Geotechnical laboratory testing of three Site samples of the Aquitard material indicates a relatively low vertical hydraulic conductivity, in the range of 2×10^{-6} to 4×10^{-6} cm/sec (Appendix D in ENSR, 1994a).

Vertical Gradients across Aquitard

Based on water level data collected in Fall 2009 and Spring 2010, groundwater levels are typically 1 to 6 feet higher in the Fill Unit than in the Lower Sand Unit, confirming the effectiveness of the Aquitard as a hydraulic barrier between the upper and lower aquifer units (Table 4-1). These water level data are consistent with those measured in ENSR (1994a).

Differences in water level (head) between the Fill Unit and Lower Sand Unit, and thus downward gradients across the intervening Aquitard, are measured at four pairs of Fill Unit and Lower Sand Unit wells located close to each other:

- EMW-5S/EMW-28D, located near the northern side of the Cell Building, within the Chlor-Alkali plant area;
- EMW-8S/EMW-29D, located near the Log Pond shoreline within the Confined Nearshore Fill area;
- CP-MW03/CP-MW05, located within the footprint of the former Wastewater Settling Basin, in the Confined Nearshore Fill area; and
- CP-MW06/CP-MW04, located near the former 72 Catch Basin, within the Chlor-Alkali plant area.

The smallest head difference between Fill Unit and Lower Sand Unit wells is measured near the Log Pod shoreline (wells EWM-8S and EMW-29D), ranging from approximately 1 to 3 feet in the Spring and Fall, respectively. For the other three well pairs, groundwater levels in the Fill Unit were approximately 4 to 6 feet higher than in the Lower Sand Unit. Slightly greater head differences (higher vertical gradients) are observed in the Spring than in the Fall, which is indicative of the Fill Unit responding more quickly than the Lower Sand Unit to seasonal recharge.

The data indicate a downward vertical gradient ranging between approximately 0.4 to 3 feet/foot across the aquitard. The vertical gradient measurements for the Site are presented in Table 4-1. The vertical gradient estimates are based on a relatively thin (2 to 4 feet thick) Aquitard unit as interpreted from borings CP-MW04 and CP-MW05. ENSR (1994a) interpreted a thicker Aquitard unit (approximately 15 feet). Assuming a 15-foot-thick Aquitard, the downward vertical gradient would be on the order of 0.06 to 0.4 feet/foot across the Aquitard. The vertical gradient across the Aquitard is much larger than the horizontal hydraulic gradient in either the Fill Unit or Lower Sand Unit aquifers, above and below it, respectively. This is expected given the Aquitard's relatively lower vertical K.

Assuming an Aquitard vertical hydraulic conductivity of 3×10^{-6} cm/sec based on lab testing described above, the measured vertical gradients, interpreted Aquitard thickness range (2 to 20 feet), and an assumed effective porosity of 0.2, the estimated seepage velocity downward across the Aquitard ranges from 0.7 to 47 feet/year (Table 4-3). Again, the large head difference maintained between the upper and lower aquifers confirms the Aquitard's effectiveness in hydraulically separating the two aquifer units.

4.2.2.3 Lower Sand Unit

A marine sand unit referred to as the Lower Sand was deposited on top of the GMD. Where the Tidal Flat Aquitard is present across most of the Site, it separates the Lower Sand from the Fill Unit. The Lower Sand Unit is thinnest to the south, adjacent to the bluff south of the Site, and thickens toward the north (see Figure 4-2).

Lower Sand Unit Groundwater Flow Directions and Gradients

Based on the Fall 2009 and Spring 2010 water level data, groundwater in the Lower Sand Unit flows generally northwest, toward the Whatcom Waterway and Bellingham Bay.

This is based on water levels measured in four wells (CP-MW03, CP-MW04, EMW-28D, and EMW-29D). The Fall 2009 groundwater flow direction and gradient was determined based on the mean groundwater elevation over 72 hours of a tidal study (see below). The Fall data indicate groundwater flow to the northwest, while the interpreted Spring 2010 groundwater flow direction was more northerly. This is consistent with the interpretation in ENSR (1994a), which was based on three Lower Sand Unit wells (EMW-28D, EMW-29D, and EMW-30D). ENSR (1994a) continuously monitored groundwater levels from August 23-26, 1993, and identified a north-northwest flow direction, depending on the tide; they did not evaluate the groundwater flow direction during wet season conditions.

TIDAL STUDY

A 96-hour tidal study was conducted on four wells screened in the Lower Sand Unit from October 19 to 22, 2009. The results of the study indicate that the groundwater in the four wells (CP-MW04, CP-MW05, EMW-28D, and EMW-29D) exhibited a clear tidal influence – more prominent than observed in Fill Unit wells – as expected for a confined aquifer. Well EMW-30D is no longer accessible, so was not included. The wells nearest the shoreline, EMW-29D and CP-MW05, showed the largest tidal fluctuations of about 2.3 and 1.7 feet, respectively. Wells EMW-28D and CP-MW04, located further inland, exhibited less tidal fluctuation (0.6 and 0.5 foot, respectively).

The tidal response observed in the Lower Sand Unit was generally consistent with the ENSR (1994a) tidal study. In that study, wells EMW-30D and EMW-28D had tidal fluctuations of approximately 3.8 and 0.8 foot, respectively. Well EMW-29D was not monitored in that study.

HORIZONTAL UNIT HYDRAULIC GRADIENTS

Lower Sand hydraulic gradients for Fall 2009 and Spring 2010 were calculated based on groundwater levels from the four accessible Lower Sand Unit wells – CP-MW05, CP-MW04, EMW-28D, and EMW-29D. Using fall 2009 tidal study data, the Serfes (1991) method was used to calculate the mean (tidally averaged) water levels for each of the four wells, and thus calculate a mean hydraulic gradient of 0.0018 ft/ft to the northwest. The Lower Sand Unit hydraulic gradient was calculated as 0.0016 ft/ft based on contouring spot groundwater level measurements from Spring 2010 (Table 4-1).

Lower Sand Unit Aquifer Properties

Hydraulic conductivity (K) was estimated for the Lower Sand Unit by performing slug testing on select wells, evaluating the tidal study data using the stage ratio and time lag methods of Ferris (1963), and conducting a pumping test to support interim action design.

SLUG TESTING

Slug tests were performed on the two new deep wells in the Caustic Plume Subarea: CP-MW04 and CP-MW05. A minimum of two rising head tests were performed on each well for reproducibility, and analyzed using the Bouwer-Rice (1976 and 1989) method of analysis. The slug test data from CP-MW04 and CP-MW05 are presented in Appendix B.

The Lower Sand Unit K estimated from slug tests for CP-MW04 and CP-MW05 were very close, 3×10^{-3} and 2×10^{-3} cm/sec, respectively (Table 4-2). ENSR's (1994a) slug testing of Lower Sand Unit wells EMW-28D, EMW-29D, and EMW-30D estimated hydraulic conductivities covering a somewhat wider range (7×10^{-4} to 5×10^{-3} cm/sec).

The relatively narrow range of K – within one order of magnitude – indicates a generally more uniform lithology than the Fill Unit. The Lower Sand Unit slug test K estimates are presented in Table 4-2.

TIDAL STUDY

Lower Sand Unit K values were also estimated from the tidal study data using the stage ratio and time lag methods of Ferris (1963). The Lower Sand Unit is a confined aquifer with corresponding low storage coefficient, which are the aquifer conditions for which the Ferris (1963) methods for K estimation are most applicable. In general, the K values calculated from the tidal study data were one or two orders of magnitude lower than the slug test estimates for a given well (Table 4-2). A likely explanation for this is that the tidal data-based K estimate represents a composite of the entire Lower Sand Unit aquifer between the well and the area of discharge to the Whatcom Waterway and Bellingham Bay. The submarine outcrop of Lower Sand Unit is covered by a veneer of fine-grained recent sediment, which is expected to be of substantially lower K than the Lower Sand Unit. The lower K sediment layer influences the inland tidal response within the Lower Sand Unit, and is thus reflected in the tidal study-based K estimates. Conversely, a slug test measures the aquifer response immediately adjacent to the well, so its resulting K estimates are not affected by aquifer lithology changes or boundaries at distance from the well.

PUMPING TEST

In June-July 2011, a dewatering test well (CP-DW1) was drilled and hydraulically tested to estimate hydraulic parameters of the Lower Sand, supporting design of a Lower Sand depressurization dewatering system for Caustic Plume interim action area. The well was pumped at a rate of approximately 5.9 gpm for 24 hours; water levels were monitored in the pumping well and in nearby monitoring wells CP-MW04 (located about 50 feet west) and EMW-28D (located about 270 feet east).

Analysis of the constant-rate pumping test data from the pumping well produced an estimated transmissivity of about 30 ft^2/day for the Lower Sand. Analysis of data from monitoring well CP-MW04 produced an estimated transmissivity of about 175 ft^2/day for the Lower Sand. The saturated thickness of Lower Sand in this area is uncertain, but assuming a thickness on the order of 50 feet, and the range of transmissivity estimates, results in a range of estimated hydraulic conductivity of about 0.6 to 7.0 ft/day (2×10^{-4} to 2×10^{-3} cm/sec). The higher T and K estimates derived from the monitoring well data are considered best estimates. Using data from the monitoring well, an aquifer storage coefficient of 0.008 is estimated for the Lower Sand.

Appendix B includes a memorandum detailing the CP-DW1 pumping test methods, data, and Lower Sand hydraulic parameters based on analysis of the data.

Groundwater Velocities in Lower Sand Unit

The estimated horizontal linear (seepage) velocity in the Lower Sand Unit aquifer is approximately 15 feet per year NW in the Fall and 13 feet per year N in the Spring based on the estimated horizontal hydraulic gradients described above, an assumed effective porosity of 0.25, and aquifer K of 2×10^{-3} cm/sec calculated from the pumping test data as presented above (Table 4-3).

Groundwater Flux in Lower Sand Unit

Volumetric groundwater fluxes can be estimated for the Lower Sand Unit using the same methodology as applied for the Fill Unit (described above). Assuming a best estimate K of 2 x 10^{-3}cm/sec (2,100 feet/year), and hydraulic gradient range of 0.0016 to 0.0018 feet/foot, we estimate unit groundwater fluxes for the Lower Sand ranging from 25 to 28 gallons/square foot/year (Table 4-3).

4.3 Site-Wide Water Balance

Water level data collected from 55 Fill Unit Aquifer wells covering the entire Site and measured on both September 28, 2009, and March 30, 2010, indicate an average water level change over that 6-month period was +1.40 feet (range of -0.4 to +3.0 feet; Table A-1 in Appendix A). Assuming a porosity of 0.25 for the Fill Unit Aquifer, the average measured groundwater rise observed converts to +0.35 foot of water over the Site. While the degree of water level change is not uniform across the Site, the 55 Fill Unit wells provide a reasonable coverage of the Site, such that the measured groundwater rise represents a reasonable estimate of groundwater recharge to the Fill Unit Site-wide occurring during that time period. Additional precipitation and recharge continued to occur after March.

Precipitation records from the Western Regional Climate Center (WRCC) Bellingham 3 SSW station located approximately 2 miles west of the Site indicate 25 inches (2.07 feet) of precipitation occurred during the 6-month period between water level measurements (October 2009 through March 2010). Therefore, the estimated groundwater recharge (0.35 foot) represents approximately 17 percent of precipitation (2.07 feet) falling on the Site during that time period. Because the Site is mostly covered by impervious surface, the remaining portion of precipitation (83 percent) is likely almost entirely runoff to the Site stormwater system (conveyed to the ASB), with a small percentage consumed by evapotranspiration (ET).

This methodology assumes a short lag time between precipitation and recharge, which is a reasonable assumption for shallow unconfined aquifers. However, a water balance assuming a 1- or 2-month lag between precipitation and recharge (e.g., September 2009 – February 2010 precipitation for a 1-month lag, and August 2009 – January 2010 precipitation for a 2-month lag) both yield essentially the same results (18 percent recharge).

Water balance calculations can also be set up by estimating runoff assuming certain percentages of impervious and pervious surfaces for a site, and assigning runoff coefficients for each. Assumptions can also be made to estimate ET. These methods are typically employed to calculate for the largest unknown factor in the water balance – groundwater recharge. In this case, groundwater recharge at the Site can be estimated directly using measured water level data from the extensive groundwater level network, thus methods to estimate runoff and ET would likely yield a more uncertain estimate of recharge.

4.4 Natural Resources

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. Bellingham Bay is used by several species of salmon (chum, coho, chinook), trout (cutthroat, steelhead, bull), and groundfish, as well as marine invertebrates including clams, geoduck, oysters, shrimp, and crab. A variety of marine mammals (e.g., seals, sea lions, whales, and porpoise) and waterfowl (e.g., gulls, brant, and ducks) also use Bellingham Bay and the Whatcom Waterway.

4.4.1 Exclusion from Terrestrial Ecological Risk Evaluation

The Site qualifies for an exclusion from conducting a terrestrial ecological evaluation (TEE) in accordance with WAC 173-340-7491(1)(b). That exclusion specifies that no further TEE is required if "All soil contaminated with hazardous substances is, or will be, covered by buildings, paved roads, pavement, or other physical barriers that will prevent plants or wildlife from being exposed to the soil contamination. To qualify for this exclusion, an institutional control shall be required by the department under WAC 173-340-440. An exclusion based on planned future land use shall include a completion date for such development that is acceptable to the department."

Under the current Site use, most Site soil, contaminated or not, is covered by pavement or buildings that provide an effective physical barrier that prevents plants or wildlife from being exposed to underlying soil contamination where present. An exception to this is the former Wastewater Settling Basin at the western end of the Confined Nearshore Fill area, which is not paved or otherwise covered.

Under the Port's planned future land use, the entire property encompassing the Site will be filled with several feet of clean fill, over which new structures, roads, and pavements would be built. New greenscape areas would be new fill placed over the existing fill. The Port will execute an institutional control (environmental covenant(s)), in accordance with WAC 173-340-440, requiring the development and maintenance of future areas of soil cover, pavement, and/or structures to provide a long-term effective physical barrier to residual contaminated soil after the cleanup action is implemented. These cleanup elements will be incorporated into the Site Feasibility Study and Cleanup Action Plan as appropriate.

4.5 Historical and Cultural Resources

Cultural resource (historic and archaeological) conditions at the Site are summarized in Section 3.11 of the January 2008 Draft Environmental Impact Statement (DEIS) for the New Whatcom Project, and are presented in detail in Appendix M of that document (Blumen and Associates, 2008a). The DEIS synthesized a pair of detailed assessments conducted to support the redevelopment planning: (1) an investigation of historic Site structures provided in the December 2007 Historic Property Resources Technical Report prepared by Artifacts Consulting Inc., and (2) an investigation of archaeological resources provided in the December 2007 Cultural Resource Assessment prepared by Northwest Archaeological Associates. The latter assessment included coordination with the Lummi Nation and Nooksack Tribe to identify potential issues and availability of existing information. The Port's Supplemental DEIS released in October 2008 concurred with the description of Site cultural resources presented in the DEIS (Blumen and Associates, 2008b).

None of the Site structures present at the time of the historic resources assessment were listed on the National Register of Historic Places, the Washington Heritage Register, or the Bellingham Local Landmark Registry. None of the RI activities had an impact on any of the existing structures at the Site.

Although no archaeological resources have been recorded on the Site, it is located within an archaeologically sensitive area of former tidal flats adjacent to the mouth of Whatcom Creek and to the bluffs to the south. The ancestors of the Lummi Nation inhabited and used the area, and appear to have established seasonal fishing encampments near the creek mouth. Prior to the filling and development of the Site area, the Bellingham Bay shoreline was located generally along the bottom of the bluffs south of the Site. Based on the pre-development conditions, Figure 4-7 (reproduced from Northwest Archaeological Associates' report, included as Appendix M to Blumen and Associates [2008a]) graphically depicts the expected probabilities (high, medium, low) for the presence of Native American archaeological materials beneath the Site and surrounding areas. Areas near the former shoreline, south of the Site and along its southeast corner, have greatest probability, with progressively lower probability moving north and northwest away from the bluffs. Therefore, there is a moderate probability for artifacts being present on the former tidal flat surface (top of Tidal Flat Aquitard) buried beneath fill across most of the eastern two-thirds of the Site, with higher probability along the trace of the former Whatcom Creek which is interpreted to have traversed the east-central portion of the Site. The northwestern portion of the Site, including parts of the Chlor-Alkali plant and Confined Nearshore Fill areas, has a low probability for encountering archeological artifacts.

The RI/FS Work Plan Addendum (Aspect, 2010a) described procedures intended to address potential presence of cultural resources while conducting RI/FS data collection activities. Additional procedures will be required as engineering, design, and permitting processes as Site cleanup and redevelopment proceed.

4.6 Land Uses

Land within the Site is currently owned by both public and private entities, and is generally zoned for industrial uses based on historic operations at the Site. The existing land uses and zoning designations within the Site will be transitioned to industrial and mixed use designations as part of an ongoing planning effort that is being performed under an interlocal agreement by the Port and City. The following sections describe the current property ownership and land use designations within the Site, and present a summary of the ongoing land use planning efforts between the Port and City. The anticipated future land use information presented below represent generalized plans that are being incorporated into the RI/FS to ensure that remedial alternatives in the FS take into account future land use within the Site, as appropriate. Specific design decisions will be made on a project by project basis.

4.6.1 Historical and Current Land Use

Historical land uses at the Site primarily consisted of mixed industrial operations dating back to the early 1900s. Past operations were primarily related to pulp, paper, and chemical processing, sawmill operations, and wood storage and disposal. Marine-based shipping and transport operations were conducted from the Bellingham Shipping Terminal at the west end of the Site. In 1999, GP's Chlor-Alkali plant operations ceased and Pulp and Tissue Mill operations were terminated shortly thereafter in 2000. In

January 2005, the Port purchased the property from GP in anticipation of future cleanup and redevelopment activities in coordination with the City and community planning.

The Site property is currently zoned as industrial/waterfront mixed-use. The current property ownership is presented in Figure 1-2. The majority of the Site is owned by the Port and is largely unused and contains abandoned buildings and chemical processing structures that were used for past industrial operations. Other current land uses at the Site consist of the Encogen Cogeneration Plant along the south side of the Site, which is owned and operated by Puget Sound Energy (PSE) and produces electric power and steam. The BNSF property extends across the eastern and southern perimeter of the Site and contains the BNSF railroad. To the west of the Site, shipping and storage operations are managed by the Port at the Shipping Terminal. Portions of the Shipping Terminal seaward of the inner harbor line are State-owned and managed by the Department of Natural Resources.

4.6.2 Future Anticipated Land Use

Future anticipated land uses and use designations at the Site are currently being designed as part of an ongoing planning effort (Bellingham Waterfront District) that is being performed under an interlocal agreement between the Port and the City. Planning details are included in *The Waterfront District Draft Sub-Area Plan (Port/City, 2012)*. The planning is being coordinated between the Port and the City, and is anticipated to result in a rezoning of the Site to include a mix of industrial, commercial, and institutional designations as shown in Figure 4-8.

The Waterfront District redevelopment will require coordination with remedial activities at the Site to accommodate planned land use and improvements to existing infrastructure within and adjacent to the Site. The improvements include improving and developing new and existing roads, rights-of-way, and stormwater conveyance and treatment systems. Parks, open space, and habitat restoration opportunities are identified throughout the Site and include habitat restoration opportunities adjacent to the Whatcom Waterway and developing a new public park and trail system along the waterfront.

The *Draft Environmental Impact Statement* (DEIS) for the Waterfront District redevelopment was drafted in January 2008 for the Port, and has since been revised to include a *Supplemental DEIS* in October 2008, an *EIS Addendum* in February 2010 (Blumen and Associates, 2008a; 2008b; and 2010), and a subsequent Addendum to the final EIS in December 2012 (EA Engineering, 2012). These documents were prepared under the SEPA to coordinate redevelopment activities consistent with the cleanup, address potential impacts resulting from the proposed redevelopment alternatives, and discuss the need for imposing cleanup-related institutional controls within the context of redevelopment. Institutional controls would be implemented at specific contaminated areas of the Site as needed to prohibit or limit activities that could potentially interfere with the long-term integrity of cleanup actions at the Site. The institutional controls would be established as part of cleanup activities at the Site, and their long-term implementation would be defined in a Compliance Monitoring Plan to be prepared in coordination with the Cleanup Action Plan per the Compliance Monitoring Requirements of MTCA (WAC 173-340-410).

In addition, separate SEPA environmental review for the GP West Site cleanup action will be conducted prior to finalizing the Site cleanup decision.

Table 4-1 Hydraulic Gradient Estimates for Fill Unit, Lower Sand Unit, and Tidal Flat Aquitard

GP West Site RI/FS

Fill Unit and Lower Sand Unit Aquifers

Area	Data Source for Gradient	Season	Horizontal Gradient in ft/ft	Direction (Mill North)
Fill Unit				
Bunker C	Groundwater Elevation Contours	Fall	0.012	N
		Spring	0.015	N
Acid Plant	GW Contours	Fall	0.009	N
		Spring	0.011	N
	Tidal Study wells AA-MW01 and AA-MW04	Fall	0.006	N
		Spring	0.010	N
Million Gallon Tanks	Groundwater Elevation Contours	Fall	0.005	NE
		Spring	0.010	NNE
Nearshore Confined Fill	Groundwater Elevation Contours	Fall	0.008	N
		Spring	0.009	N
	Tidal Study wells EMW-10S and CF-MW02	Fall	0.009	N
Caustic Plume	Groundwater Elevation Contours	Fall	0.007	NW
		Spring	0.008	NW
	Tidal Study wells CP-MWC1 and CP-MWC3	Fall	0.0034	WNW
	Tidal Study wells CP-MWA1 and CP-MWA3	Fall	0.0036	WNW
	Tidal Study wells CP-MW09 and CP-MW12	Spring	0.0036	WNW
	Tidal Study wells CP-MWB1 and CP-MWB3	Spring	0.008	W
Lower Sand	Tidal Study wells CP-MW04, 05, EMW-28D, 29D	Fall	0.0018	NW
	Spot Measurements CP-MW04, 05, EMW-28D, 29D	Spring	0.0016	N

Tidal Flat Aquitard

Area	Data Source for Gradient	Season	Vertical Gradient in ft/ft	Direction
Nearshore Confined Fill	Spot Measurements CP-MW03, CP-MW05	Fall	2.9	Downward
	Spot Measurements CP-MW03, CP-MW05	Spring	3.0	Downward
	Spot Measurements EMW-8S, EMW-29D	Fall	1.3	Downward
	Spot Measurements EMW-8S, EMW-29D	Spring	0.4	Downward
Caustic Plume	Spot Measurements CP-MW06, CP-MW04	Fall	1.3	Downward
	Spot Measurements CP-MW06, CP-MW04	Spring	1.3	Downward
	Spot Measurements EMW-5S, EMW-28D	Fall	1.1	Downward
	Spot Measurements EMW-5S, EMW-28D	Spring	1.2	Downward

Table 4-2 - Hydraulic Conductivity Estimates from Slug Tests and Tidal Studies, Fill Unit and Lower Sand Unit

GP West Site RI/FS

	Estimated Aquifer Hydraulic Conductivity (K) in cm/sec							
	RI Data Collection					Based on Pre-RI Slug Test Data Collection (ENSR, 1994a)	Geometric Mean by Well (tidal data)	Geometric Mean by Well (slug test data)
	Based on Slug Test Data		Based on Tidal Study Data					
	Test 1	Test 2	Stage Ratio Method	Max Peak Lag	Min Peak Lag			
Fill Unit								
CP-MWA1	8E-05	3E-05						5E-05
CP-MWA2	7E-04	5E-04						6E-04
CP-MWA3	4E-03	2E-03						3E-03
CP-MWB1	8E-04	7E-04						7E-04
CP-MWB2	2E-03	2E-03						2E-03
CP-MWB3	6E-03	6E-03						6E-03
CP-MWC1	4E-04	2E-04						3E-04
CP-MWC2	7E-04	5E-04						6E-04
CP-MWC3	2E-03	4E-03						3E-03
EMW-10S						2E-05		2E-05
EMW-11S						7E-07		7E-07
EMW-12S						1E-03		1E-03
EMW-13S						5E-03		5E-03
EMW-1S						5E-04		5E-04
EMW-2S						8E-06		8E-06
EMW-4S						2E-02		2E-02
EMW-5S						3E-04		3E-04
EMW-6S						6E-03		6E-03
EMW-7S						4E-05		4E-05
EMW-8S						6E-06		6E-06
EMW-9S						5E-05		5E-05
LAW-1						3E-04		3E-04
LAW-4						2E-05		2E-05
LAW-5						1E-03		1E-03
LAW-6						1E-03		1E-03
Fill Unit Geometric Mean - Slug Tests								**3E-04**
Lower Sand								
CP-MW04	2E-03	2E-03	3E-05	6E-04	3E-04		2E-04	2E-03
CP-MW05	4E-03	4E-03	2E-05	2E-04	1E-04		7E-05	4E-03
EMW-29D			5E-06	4E-05	3E-05	8E-04	2E-05	8E-04
EMW-28D			2E-05	3E-04	1E-04	5E-03	9E-05	5E-03
EMW-30D						4E-03		4E-03
Lower Sand Geometric Mean - All Data								**5E-04**

Note: Refer to text regarding data usability (slug test vs. tidal study) for the two aquifers, and discussion of hydraulic conductivity estimates from pumping tests.

Table 4-3 Groundwater Velocity Estimates for Fill Unit, Lower Sand, and Tidal Flat Aquitard

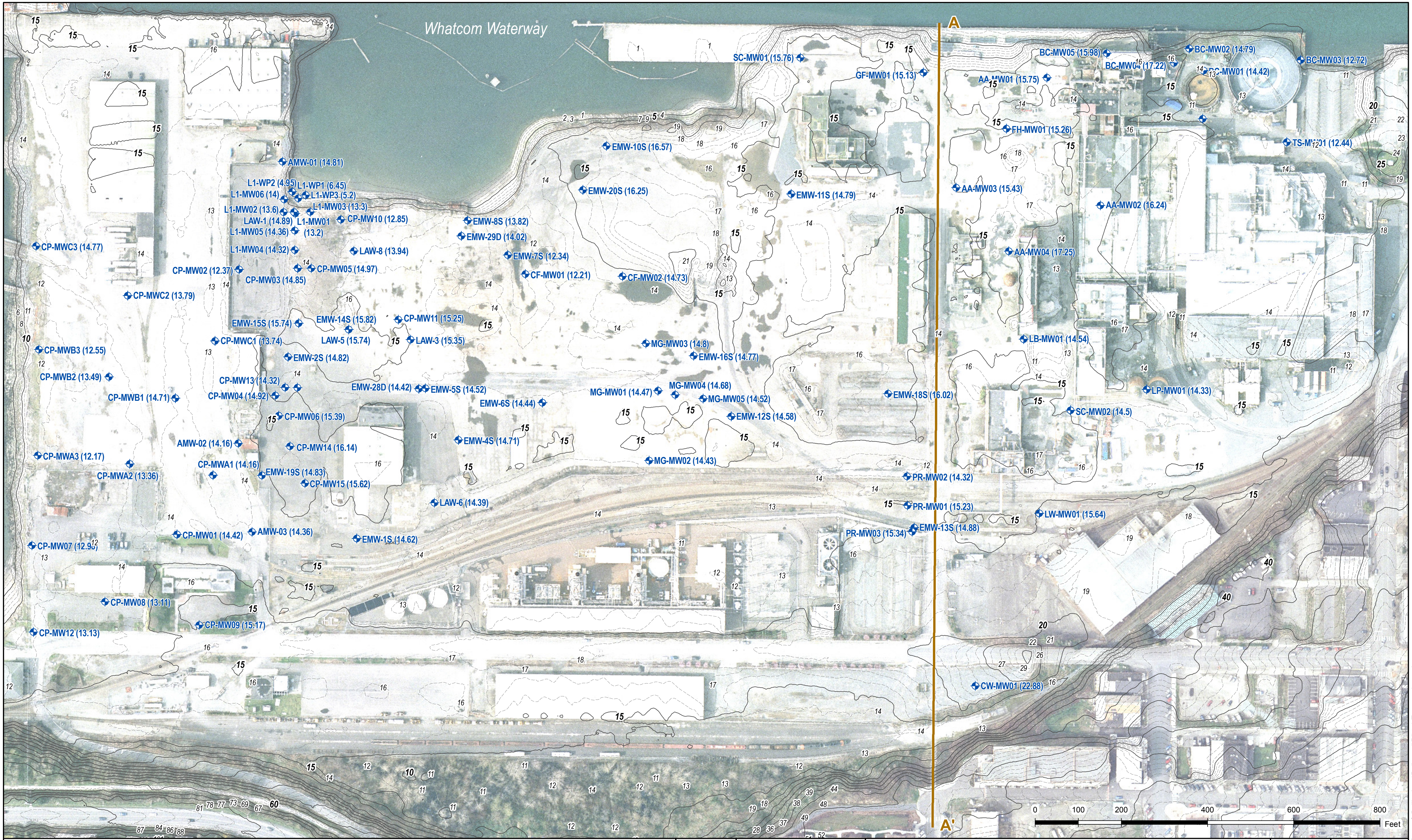
GP West Site RI/FS

Fill Unit and Lower Sand Unit Aquifers

Area	Data Source for Gradient	Season	Horizontal Gradient in ft/ft	Direction (Mill)	Effective Porosity	Data Source	Hydraulic Conductivity in cm/sec	Horizontal Seepage Velocity in ft/year	Horizontal Groundwater Flux in gal/ft^2-yr
Fill Unit									
Bunker C	Groundwater Elevation Contours	Fall	0.012	N	0.25	Pumping test data from BC-DW1	3.E-03	150	280
		Spring	0.015	N	0.25		3.E-03	190	350
Acid Plant	Groundwater Elevation Contours	Fall	0.009	N	0.25	Geometric Mean of Fill Unit Wells not in the Caustic Plume	3.E-04	11	21
		Spring	0.011	N	0.25		3.E-04	14	26
	Tidal Study wells AA-MW01 and AA-MW04	Fall	0.006	N	0.25		3.E-04	8	14
		Spring	0.010	N	0.25		3.E-04	13	23
Million Gallon Tanks	Groundwater Elevation Contours	Fall	0.005	NE	0.25	Geometric Mean of EMW -6S, -12S	2.E-03	50	90
		Spring	0.010	NNE	0.25		2.E-03	100	190
Nearshore Confined Fill	Groundwater Elevation Contours	Fall	0.008	N	0.25	Geo. Mean of EMW-4S through -10S, and Law-1, -4, -5, -6	3.E-04	8	16
		Spring	0.009	N	0.25		3.E-04	9	18
	Tidal Study wells EMW-10S and CF-MW02	Fall	0.009	N	0.25		3.E-04	9	18
Caustic Plume	Groundwater Elevation Contours	Fall	0.007	NW	0.25	Geometric Mean of Caustic Plume Well Slug Tests	9.E-04	26	49
		Spring	0.008	NW	0.25		9.E-04	30	56
	Tidal Study wells CP-MWC1 and CP-MWC3	Fall	0.003	WNW	0.25		9.E-04	13	24
	Tidal Study wells CP-MWA1 and CP-MWA3	Fall	0.004	WNW	0.25		9.E-04	13	25
	Tidal Study wells CP-MW09 and CP-MW12	Spring	0.004	WNW	0.25		9.E-04	13	25
	Tidal Study wells CP-MWB1 and CP-MWB3	Spring	0.008	W	0.25		9.E-04	30	56
Lower Sand									
Caustic Plume	Tidal Study wells CP-MW04, 05, EMW-28D, 29D	Fall	0.0018	NW	0.25	Pumping Test Data from CP-DW1	2.E-03	15	28
	Spot Measurements CP-MW04, 05, EMW-28D, 29D	Spring	0.0016	N	0.25		2.E-03	13	25

Tidal Flat Aquitard

Area	Data Source for Gradient	Season	Vertical Gradient in ft/ft	Direction	Effective Porosity	Hydraulic Conductivity Source	Vertical Hydraulic Conductivity in cm/sec	Vertical Seepage Velocity in ft/year
Nearshore Confined Fill	Spot Measurements CP-MW03, CP-MW05	Fall	2.9	Downward	0.2	ENSR 1994a	3.E-06	45
	Spot Measurements CP-MW03, CP-MW05	Spring	3.0	Downward	0.2	ENSR 1994a	3.E-06	47
	Spot Measurements EMW-8S, EMW-29D	Fall	1.3	Downward	0.2	ENSR 1994a	3.E-06	21
	Spot Measurements EMW-8S, EMW-29D	Spring	0.4	Downward	0.2	ENSR 1994a	3.E-06	7
Caustic Plume	Spot Measurements CP-MW06, CP-MW04	Fall	1.3	Downward	0.2	ENSR 1994a	3.E-06	19
	Spot Measurements CP-MW06, CP-MW04	Spring	1.3	Downward	0.2	ENSR 1994a	3.E-06	20
	Spot Measurements EMW-5S, EMW-28D	Fall	1.1	Downward	0.2	ENSR 1994a	3.E-06	17
	Spot Measurements EMW-5S, EMW-28D	Spring	1.2	Downward	0.2	ENSR 1994a	3.E-06	19
General Range	Maximum vertical head difference (Spot Measurements CP-MW03, CP-MW05), assumed 2-ft thickness	Spring	3.0	Downward	0.2	ENSR 1994a	3.E-06	47
	Maximum vertical head difference (Spot Measurements CP-MW03, CP-MW05), assumed 20-ft thickness	Spring	0.3	Downward	0.2	ENSR 1994a	3.E-06	5
	Minimum vertical head difference (Spot Measurements EMW-8S, EMW-29D), assumed 2-ft thickness	Spring	0.4	Downward	0.2	ENSR 1994a	3.E-06	7
	Maximum vertical head difference (Spot Measurements EMW-8S, EMW-29D), assumed 20-ft thickness	Spring	0.04	Downward	0.2	ENSR 1994a	3.E-06	0.7



CP-MW03 (14.85) Well Location (Surveyed Top of Casing Elevation in Feet)

Site-Wide Cross Section A-A'

LiDAR-Derived Five-Foot Elevation Contours*

LiDAR-Derived One-Foot Elevation Contours*

* *LiDAR data are from the 2006 USGS North Puget Sound LiDAR survey (as made available through the Puget Sound LiDAR Consortium). Elevations have been converted from the NAVD88 vertical datum to the site vertical datum, Mean Lower Low Water (MLLW), by subtracting 0.48 ft.*

MILL NORTH — TRUE NORTH — 45°

Aspect CONSULTING

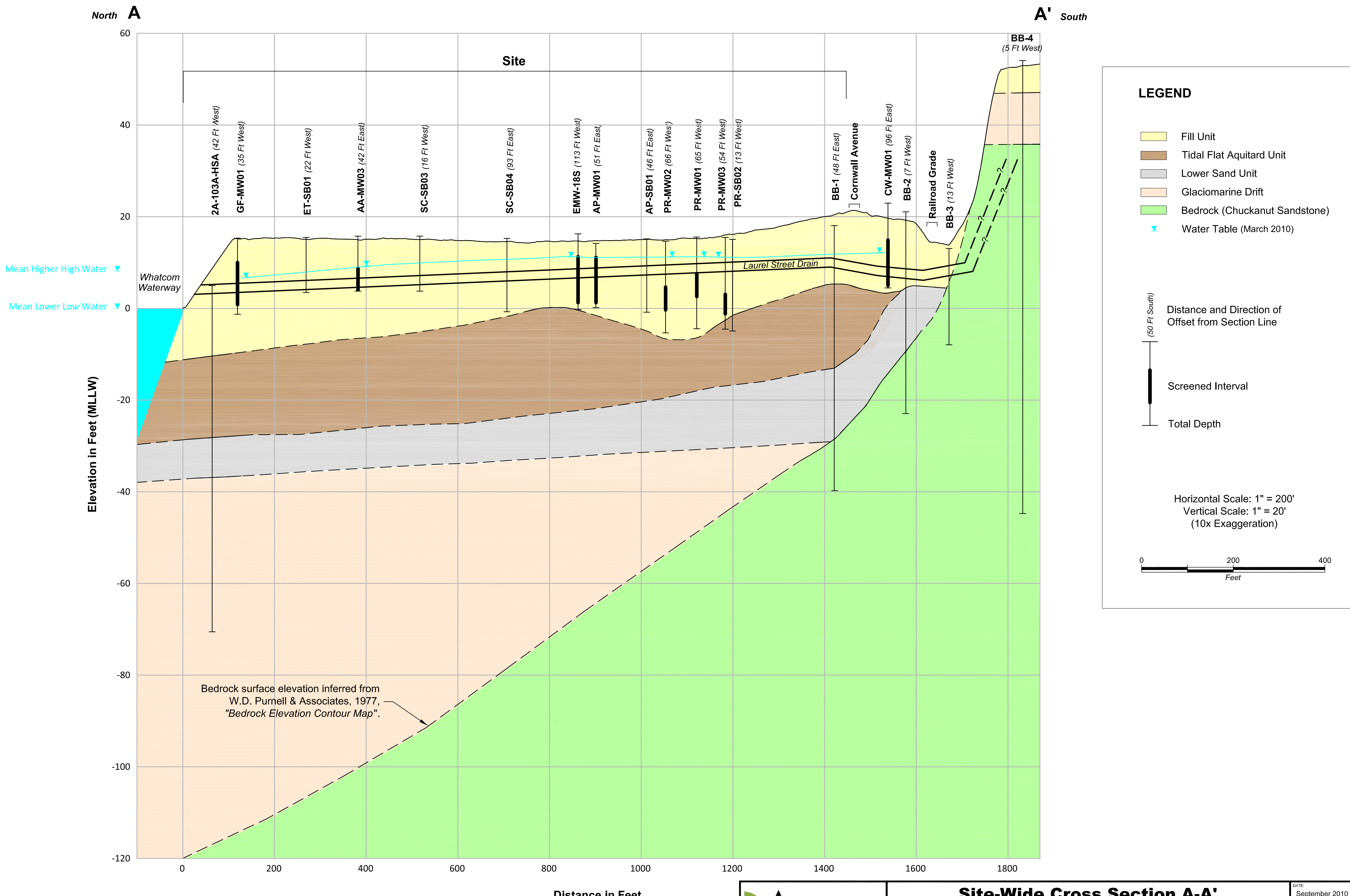
Topographic Elevation Contour Map

GP West Site RI/FS

Bellingham, WA

DATE: Apr 2011	PROJECT NO. 070188
DESIGNED BY: SJG	
DRAWN BY: PPW	FIGURE NO. 4-1
REVISED BY: PPW	

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-1 Topography.mxd



Aspect CONSULTING

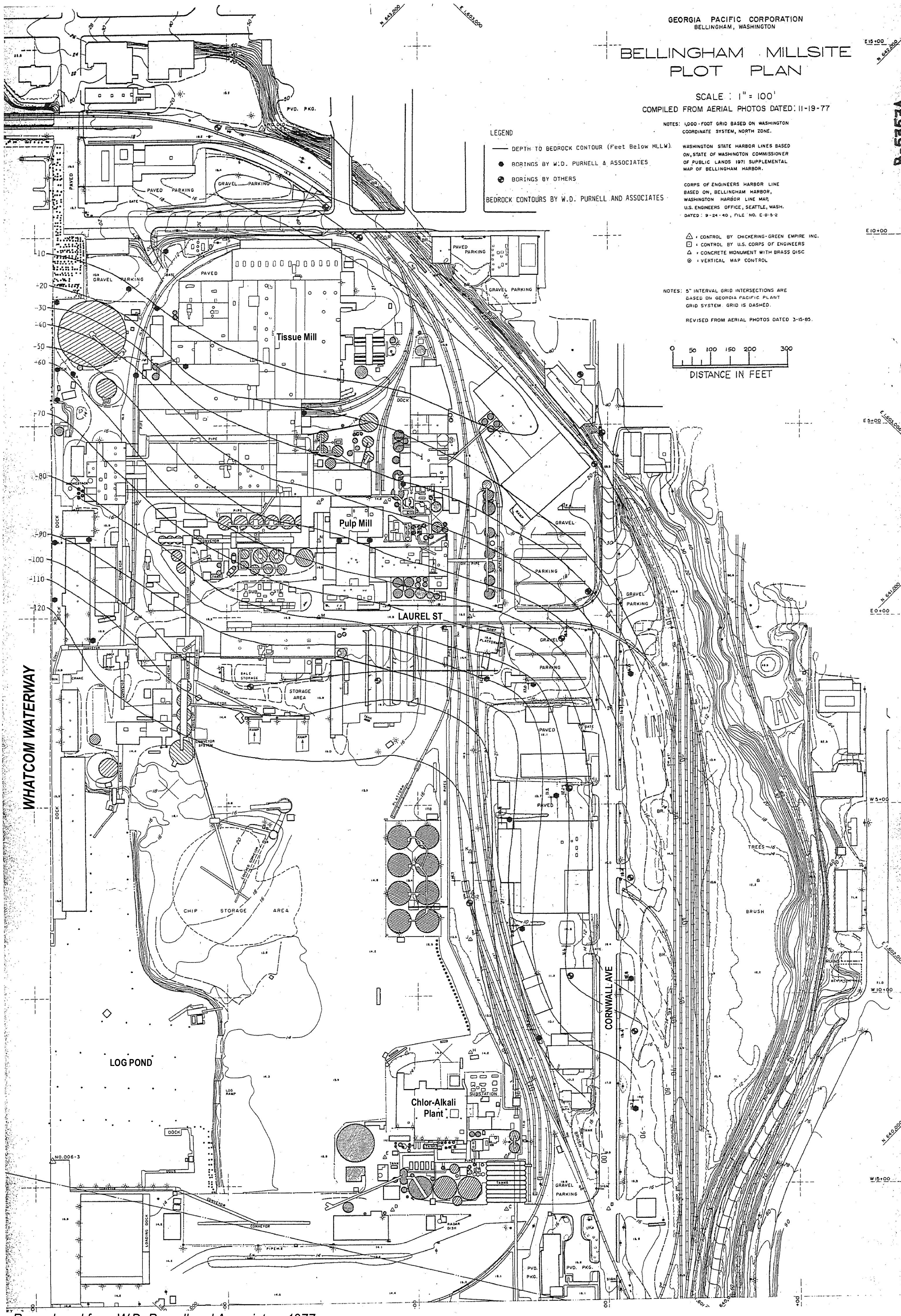
Site-Wide Cross Section A-A'

GP West Site RI/FS
Bellingham, Washington

DATE: September 2010	PROJECT NO. 070188
DESIGNED BY: MV	
DRAWN BY: SCC	FIGURE NO. 4-2
REVISED BY: SCC	

Q:\Port of Bellingham\070188 Former GP Mill Property\2010-03 Cross Sections\070188-A.dwg Section A-A' 11x17

Sep 27, 2010 1:51pm scudd



Reproduced from W.D. Purnell and Associates, 1977

TRUE NORTH
45°
MILL NORTH

Aspect CONSULTING

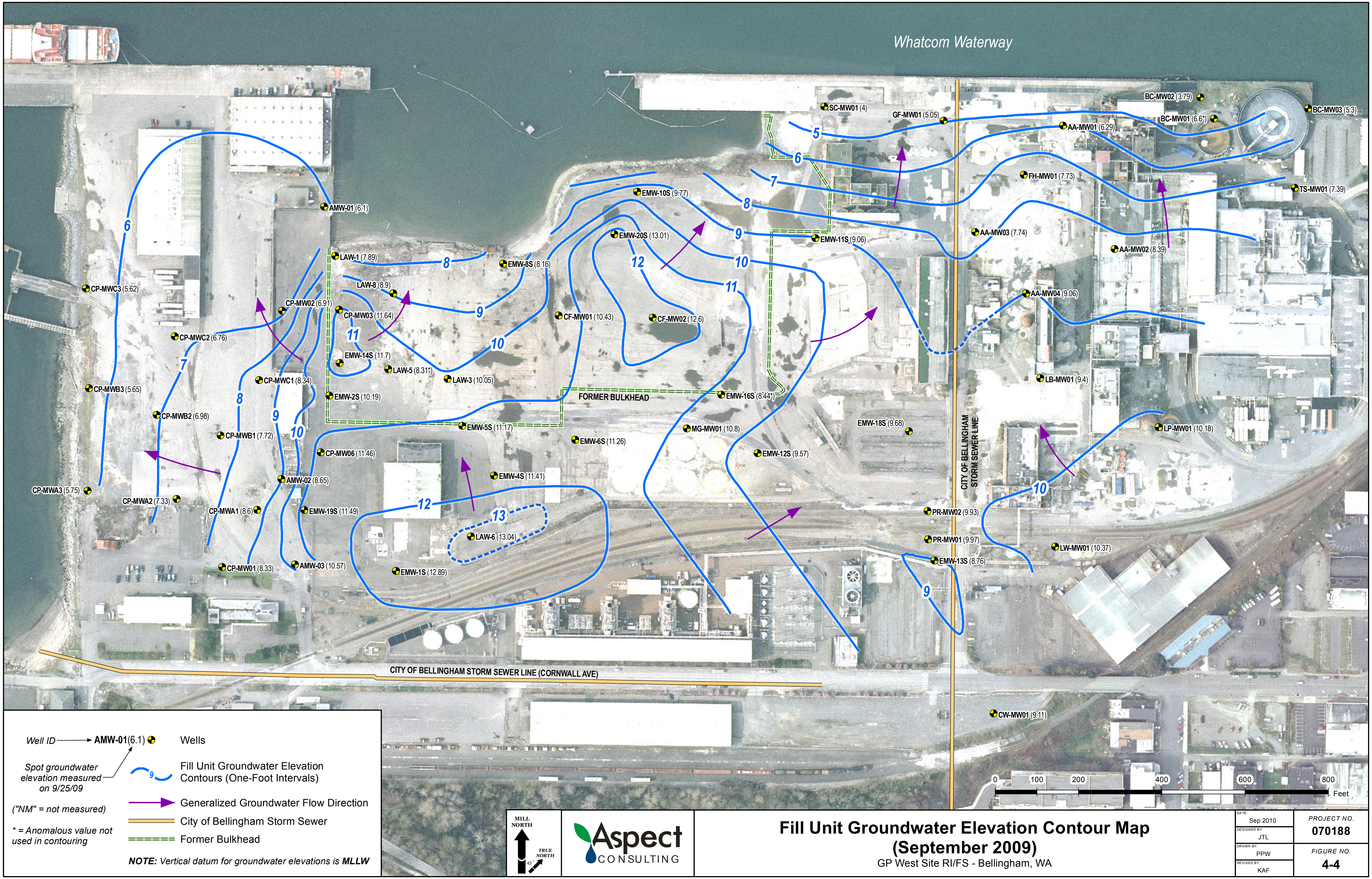
Bedrock Elevation Contour Map

GP West Site RI/FS

Bellingham, WA

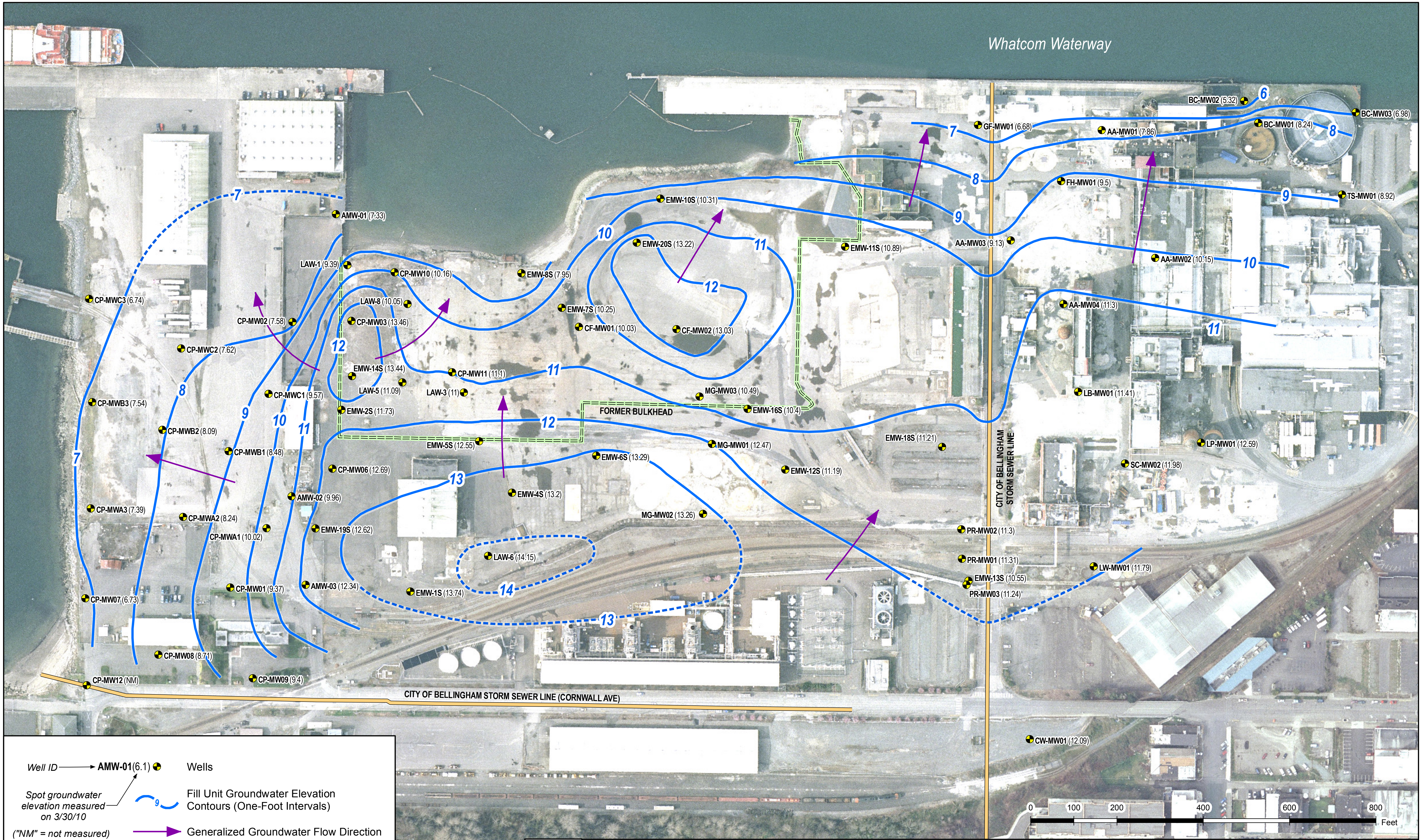
DATE: Sep 2010	PROJECT NO. 070188	
DESIGNED BY: WDP-77		
DRAWN BY: ---	FIGURE NO. 4-3	
REVISED BY: ---		

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-3 Bedrock Contours.mxd



Fill Unit Groundwater Elevation Contour Map (September 2009)

GP West Site RI/FS - Bellingham, WA



Well ID → **AMW-01**(6.1) Wells

Spot groundwater elevation measured on 3/30/10

("NM" = not measured)

Fill Unit Groundwater Elevation Contours (One-Foot Intervals)

Generalized Groundwater Flow Direction

City of Bellingham Storm Sewer

Former Bulkhead

NOTE: *Vertical datum for groundwater elevations is* ***MLLW***

MILL NORTH / TRUE NORTH 45°

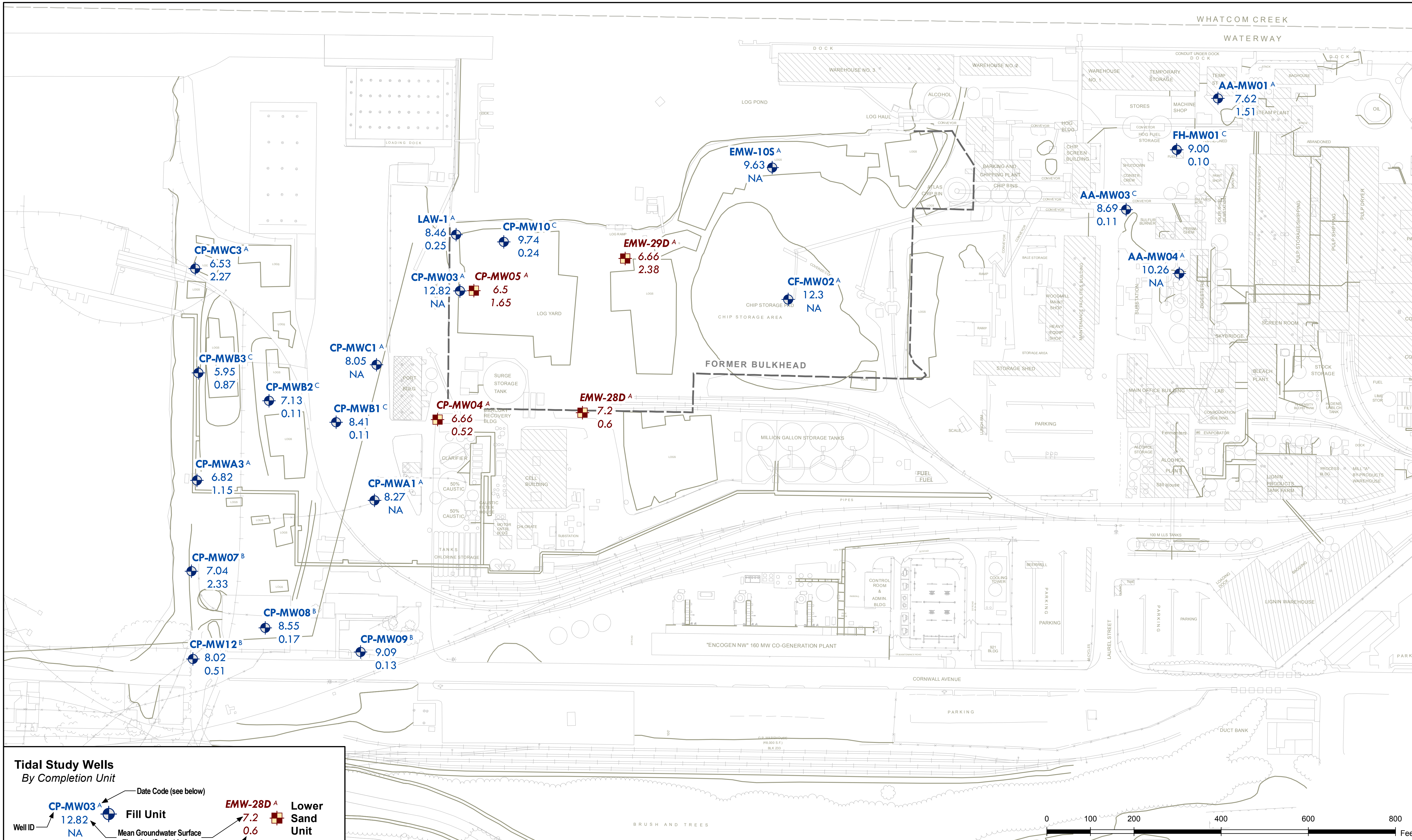
Aspect CONSULTING

Fill Unit Groundwater Elevation Contour Map (March 2010)

GP West Site RI/FS - Bellingham, WA

DATE: Sep 2010	PROJECT NO. 070188
DESIGNED BY: JTL	
DRAWN BY: PPW	FIGURE NO. 4-5
REVISED BY: KAF	

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-5 March_2010_GW_Elev_Contours.mxd



Tidal Study Wells
By Completion Unit

CP-MW03 A — Fill Unit: Well ID; Date Code (see below); 12.82 = Mean Groundwater Surface Elevation (Serfes) in feet; NA = Maximum tidally-influenced groundwater level fluctuation in feet. ("NA" = No tidal influence observed in groundwater level)

EMW-28D A — Lower Sand Unit: 7.2; 0.6

Date Codes: A: October, 2008 || B: April, 2010 || C: May, 2010

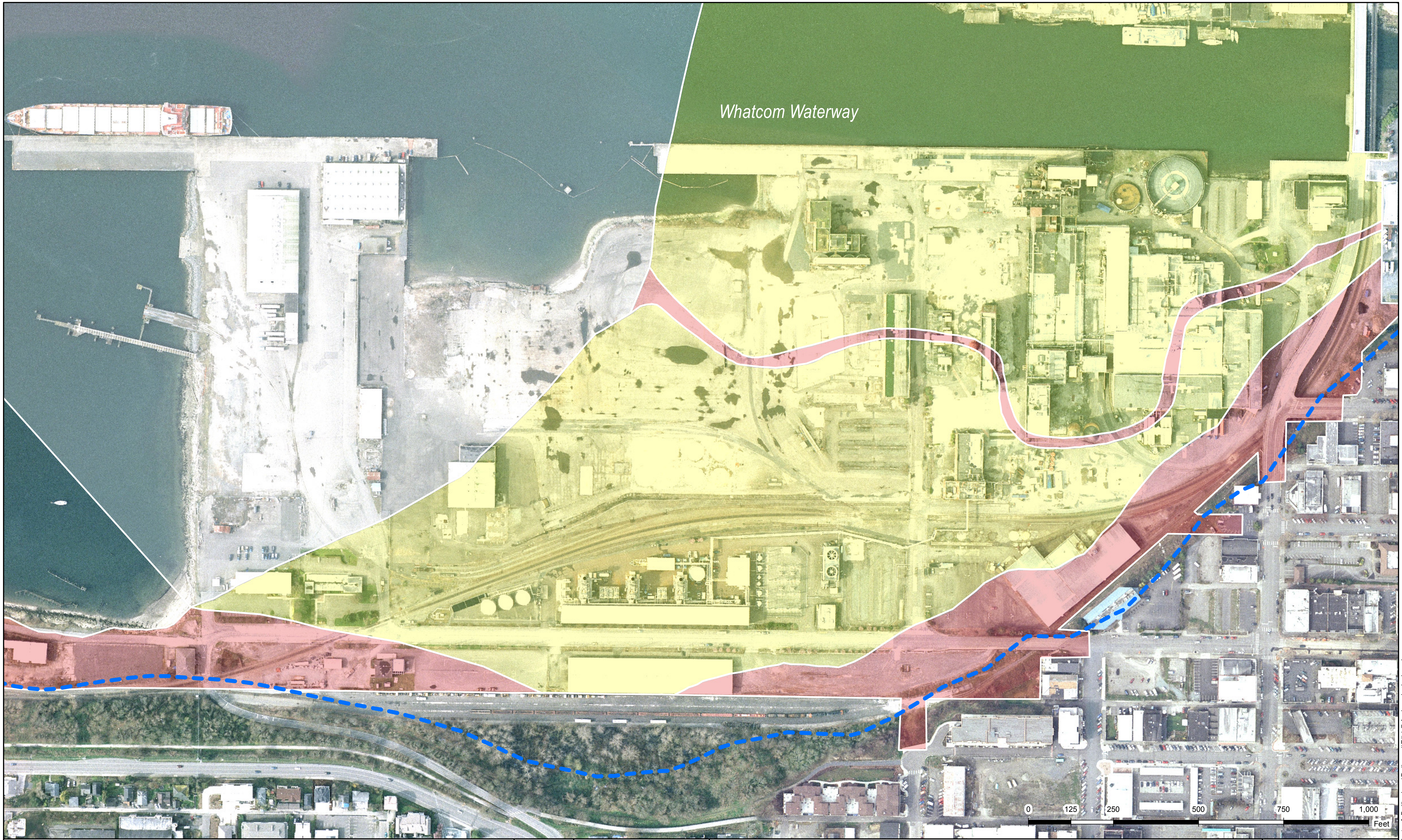
Tidal Study Data Collected During RI

GP West Site RI/FS
Bellingham, WA

Aspect CONSULTING

DATE: Sep 2010
DESIGNED BY: JWC
DRAWN BY: PPW
REVISED BY: PPW
PROJECT NO. 070188
FIGURE NO. 4-6

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-6 TidalStudyData.mxd



Native American Material Probability Zones:

- High
- Medium
- Low

1887 Shoreline

Archaeological zones and 1887 shoreline reproduced from Figure 13 in NW Archaeological Associates (2007), which is Appendix M to Port of Bellingham (2008)

MILL NORTH

TRUE NORTH

45°

Aspect CONSULTING

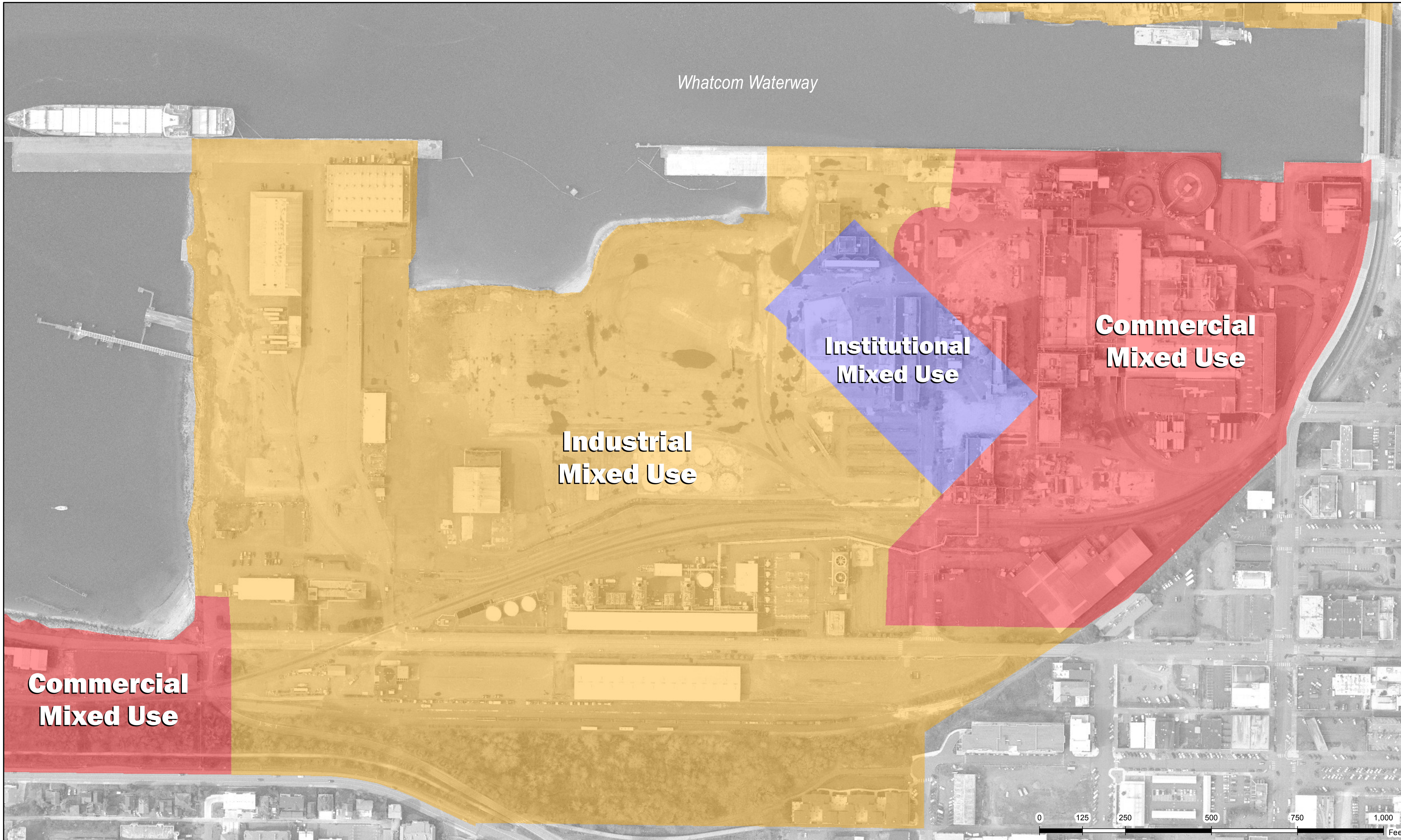
Archaeological Probability Zones

(from NW Archaeological Associates, 2007)

GP West Site RI/FS - Bellingham, WA

DATE: Sep 2010	PROJECT NO. 070188
DESIGNED BY: PPW	
DRAWN BY: PPW	FIGURE NO. 4-7
REVISED BY: PPW	

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-7 Archaeological.mxd



Aspect CONSULTING

Planned Land Use Areas for Site
(from Waterfront District Sub-Area Plan - 2012 DRAFT)
GP West Site RI/FS - Bellingham, WA

DATE: Dec 2012	PROJECT NO. 070188
DESIGNED BY: PPW	
DRAWN BY: PPW	FIGURE NO. 4-8
REVISED BY: PPW	

Path: T:\projects_8\Port_of_Bellingham\Delivered\RI\4-8 Planned Land Use.mxd