2. Affected Environment

How did WSDOT collect the information about soils and geology?

The geology and soils analysts used published maps and reports, existing geotechnical information, boring logs, and a field reconnaissance survey to determine the topography, surficial soils, regional and site geology, soil characteristics, and geologic hazards within the study area. The geology and soils study area is indicated by the conceptual layouts in Exhibit 1. Geologic conditions in the Grays Harbor area and Commencement Bay area are also described to provide a regional context.

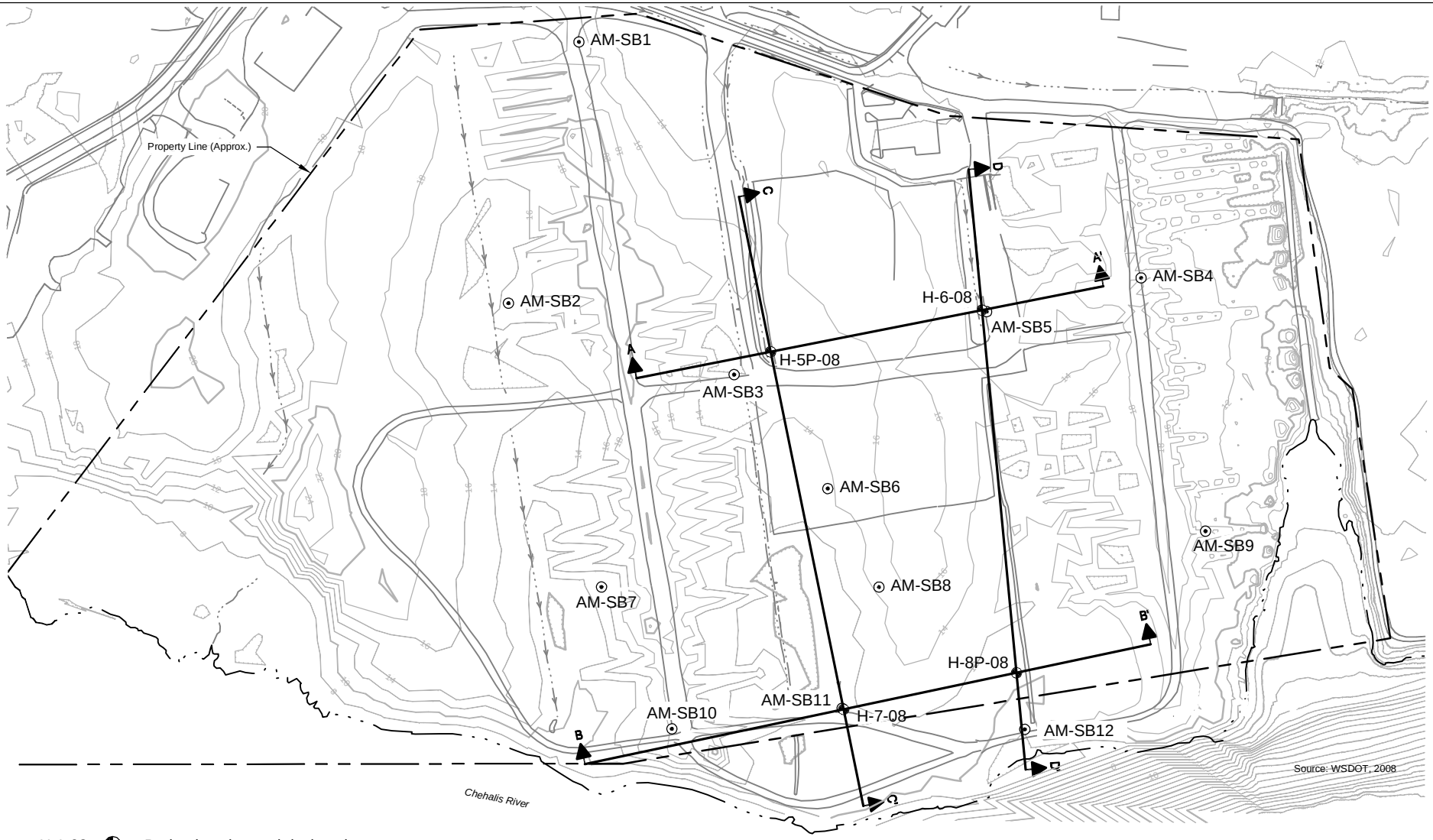
The analysts defined geologic units and soil characteristics within the study area using geotechnical information available at publicly available sources and Web sites listed in Section 5. This information includes maps and reports published by governmental agencies as obtained from the Internet and from the CH2M HILL library in Bellevue, Washington. These sources consist of the following:

- Published maps, including topographic, geologic, and geologic hazard area maps
- Geotechnical reports containing summaries of existing geological conditions, site plans, boring logs, cross sections of subsurface soil profiles, geotechnical recommendations, and soil index testing results
- Drillers' well logs, including soil and groundwater information
- Environmental impact statements, assessments, and reports pertinent to the study area

WSDOT geotechnical archives provided data from about 50 borings, 30 cone penetration tests (CPTs), and 30 test pits (Exhibits 2 and 3) within the study area, including soil types and consistency. The information from these data includes visual descriptions of the soil, results from standard penetration tests, and engineering classifications of the soil.

The geology and soils analysts also reviewed 47 Washington State Department of Ecology (Ecology) well logs for borings and wells up to 170 feet deep within the study area. The well logs provide general soil descriptions based on observation, depths where groundwater was encountered, and groundwater well construction details.

The analysts identified the potential for geologic hazards in the Grays Harbor study area and the CTC site by reviewing hazard and critical area maps published by the City of Hoquiam, City of Tacoma, United States Geological Survey (USGS), and Washington State Department of Natural Resources (WDNR), and by interpreting the available geotechnical information.



H-1-08 Boring location and designation

ALY-SB1 GeoProbe™ approximate location and designation

10 Elevation contour

A A' Geologic cross section location and designation

Source: Landau (2009).

N 0 200 400 Feet

Exhibit 2. **Existing Subsurface Exploration Locations for Anderson & Middleton Alternative**

Pontoon Construction Project

Washington State Department of Transportation

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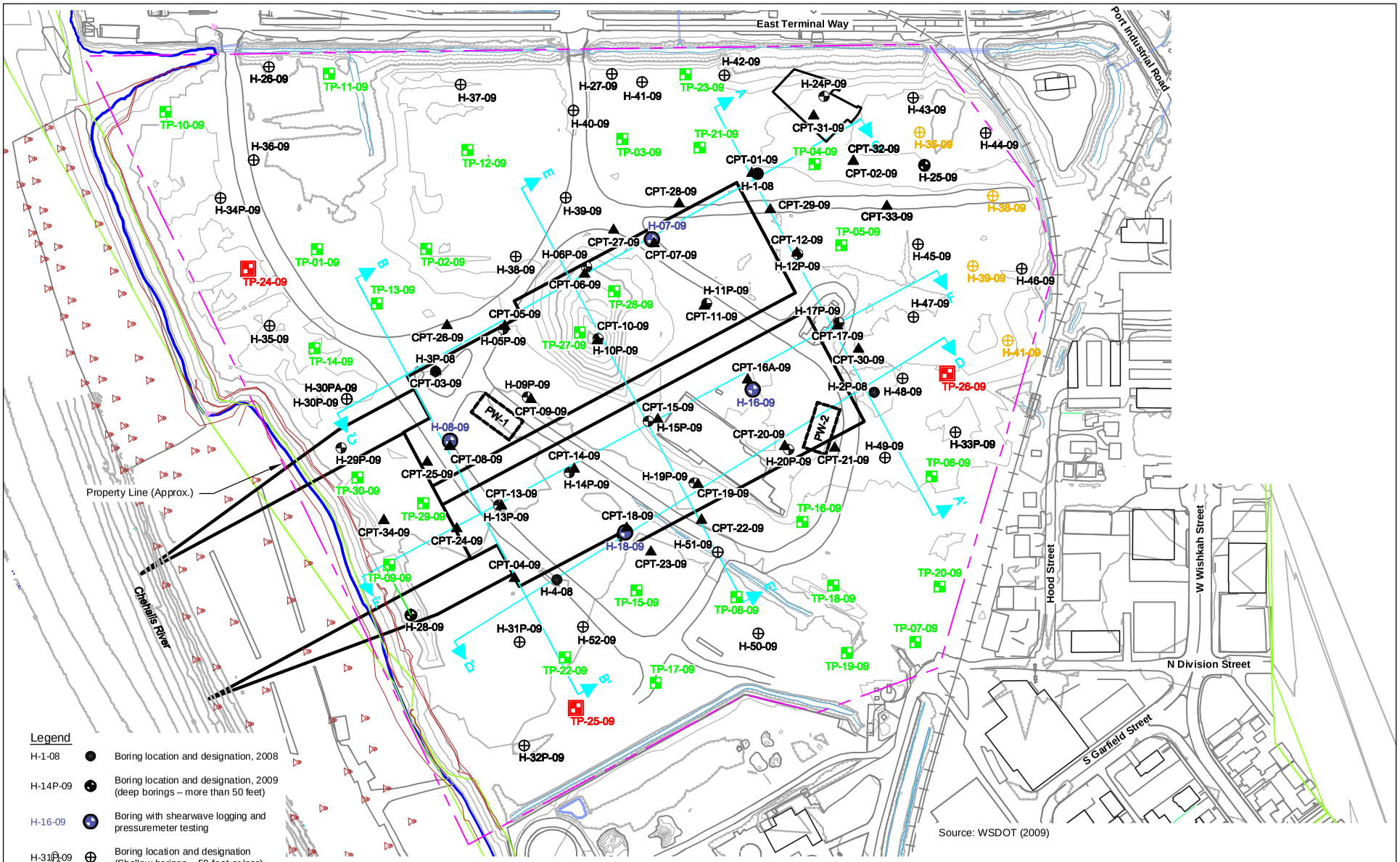

Legend

H-1-08	Boring location and designation, 2008
H-14P-09	Boring location and designation, 2009 (deep borings – more than 50 feet)
H-16-09	Boring with shearwave logging and pressuremeter testing
H-31P-09	Boring location and designation (Shallow borings – 50 feet or less)
	Denotes piezometer installation
CPT-18-09	CPT location and designation
TP-21-09	Test pit location and designation
TP-26-09	Test pit with infiltration testing location and designation
PW-2	Pump test location and designation (pumping and observation wells)
	Pile (existing)

Notes

1. Explorations by others are not shown on this plan. Refer to Appendix G of the RFP.
2. For Test Pit TP-20, refer to Appendix A, of the GDR.
3. Black and white reproduction of this color original may reduce its effectiveness and lead to incorrect interpretation.

N

0 200 400 Feet

Exhibit 3. **Existing Subsurface Exploration Locations for Aberdeen Log Yard Alternative**

Pontoon Construction Project

Washington State Department of Transportation

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What are the existing geology and soil characteristics of the project vicinity?

This section describes the topography, geology, soils, groundwater, and potential aggregate sources for each project site. Because the two Grays Harbor build alternatives are relatively close to each other, their geologic conditions are similar.

Regional Topography

The regional topography of the Grays Harbor study area consists of a broad, shallow bay that drains five rivers. The Grays Harbor area is relatively flat with gentle slopes to the north. The regional topography of the CTC site consists of a series of north-south trending ridges separated by deep troughs. The troughs are now occupied by rivers, streams, lakes, and marine waterways. Exhibit 4 shows the regional topography of both the Grays Harbor study area and the CTC site.

Local Topography

CTC Facility

The CTC facility is located in an industrial area. The natural topography at the site has been altered to facilitate the operation of the CTC facility. The site is flat except for a small casting basin and launch channel that is located below-grade.

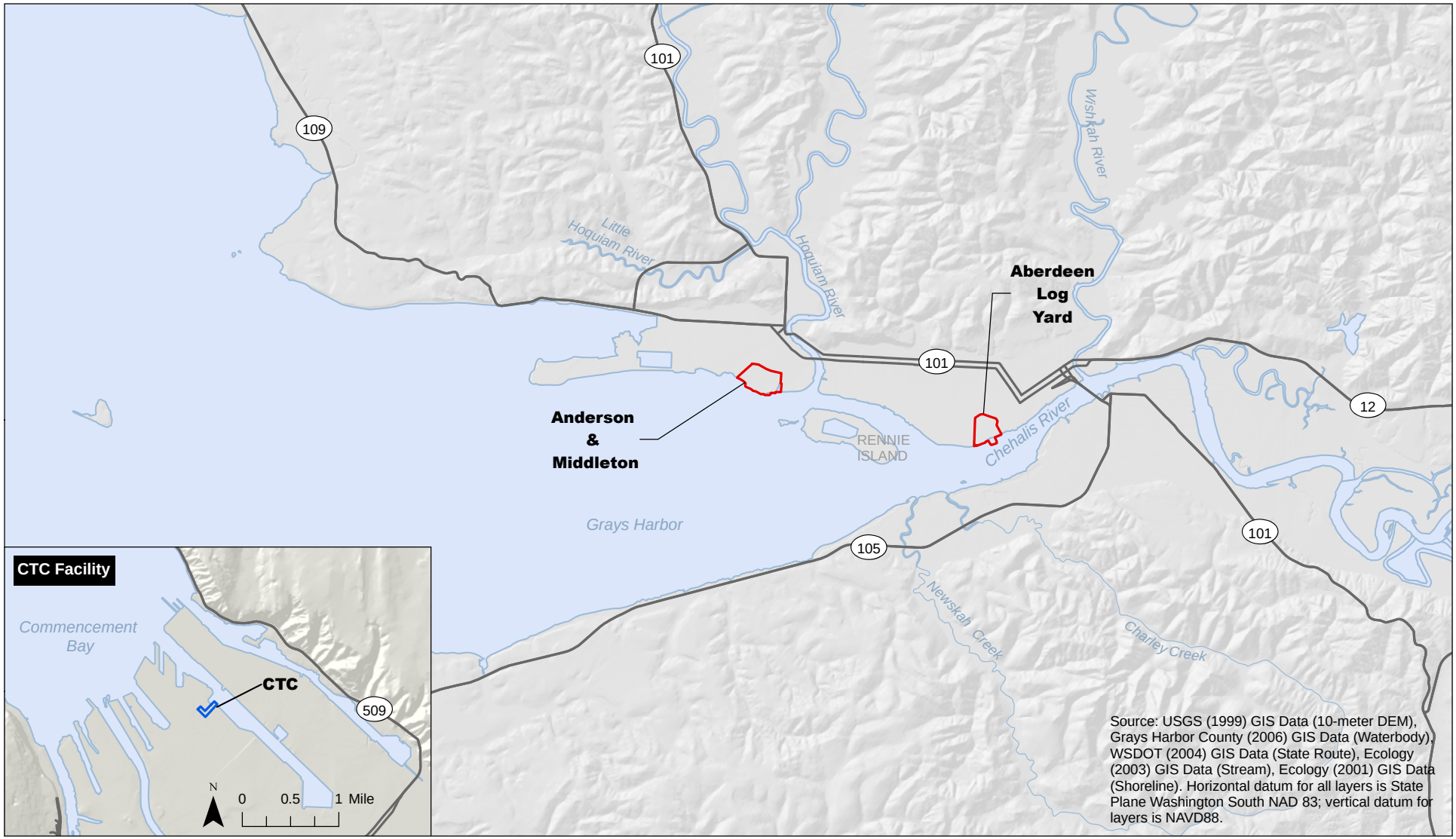
Anderson & Middleton Alternative

The Anderson & Middleton site (Exhibit 2) is relatively flat. Average surface elevations range from about +10 feet mean lower low water (MLLW) to +16 feet MLLW, with the western and southern portions of the site sloping down toward the shore. The topography of this site has been modified by river sediment deposition subsequent to the original glacial shaping, along with artificial filling during the 1960s and subsequent modification of the area for development (Landau 2009a).

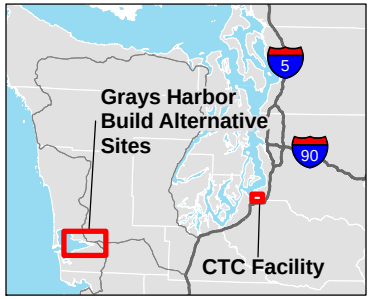
> What is mean lower low water?
>
> Mean lower low water is a tidal datum that refers to the mean of the lower of the daily low waters over a long period of time.

Aberdeen Log Yard Alternative

Surface elevations at the Aberdeen Log Yard site (Exhibit 3) range from +4 feet MLLW near the shoreline to approximately +15 feet MLLW, with stockpiles as high as +30 feet MLLW. In the mid-1800s, the shoreline was located north of the present-day site, and the entire site was tidal mudflats. Filling likely occurred from north to south. By 1966, the majority of the site was filled except for the southeast corner. Sometime between 1974 and 1984, the southeast corner was filled. This site was formerly occupied by a mill and other various buildings and was primarily used for log storage and minor lumber mill operations (Landau 2009b).



Source: USGS (1999) GIS Data (10-meter DEM), Grays Harbor County (2006) GIS Data (Waterbody), WSDOT (2004) GIS Data (State Route), Ecology (2003) GIS Data (Stream), Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.



Build Alternative Site

CTC facility limits

N 0 0.5 1 2 Miles

Exhibit 4. **Regional Topography**

Pontoon Construction Project

Washington State Department of Transportation

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Geology

Regional Geology

The CTC facility site is in the south-central portion of the Puget Lowland. The geology in this area is a result of multiple glaciations that occurred over the last 2 million to 10,000 years.

The last glaciation is believed to have filled the regional lowland area with ice up to 1 mile thick above the existing soil deposits; the weight of the ice resulted in compaction of the soil into a very dense consistency. After the last glaciation, the soil surface was modified by erosional and depositional processes such as stream incision and deposition.

The geology of the Grays Harbor region was formed by multiple glaciations and soil deposition from the Hoquiam and Chehalis rivers. Glaciations occurred from 2 million to 10,000 years ago, a period referred to by geologists as the Pleistocene Epoch. The land was modified during each advance and retreat of the glaciers during the Pleistocene from erosion and deposition of soils. The repeated glaciations left a thick deposit of unconsolidated soil in the region, including the study area. These glacial soil deposits overlie bedrock. Since the most recent glacial retreat from about 13,000 to 10,000 years ago, the Hoquiam and Chehalis rivers have continued to alter the land by depositing thick layers of loose, unconsolidated soils over the glacial deposits and bedrock.

> What is consolidated soil?
>
> A consolidated soil is a soil that has been compressed by geologic processes. An unconsolidated soil is an uncompressed soft soil that is prone to settlement.

CTC Facility

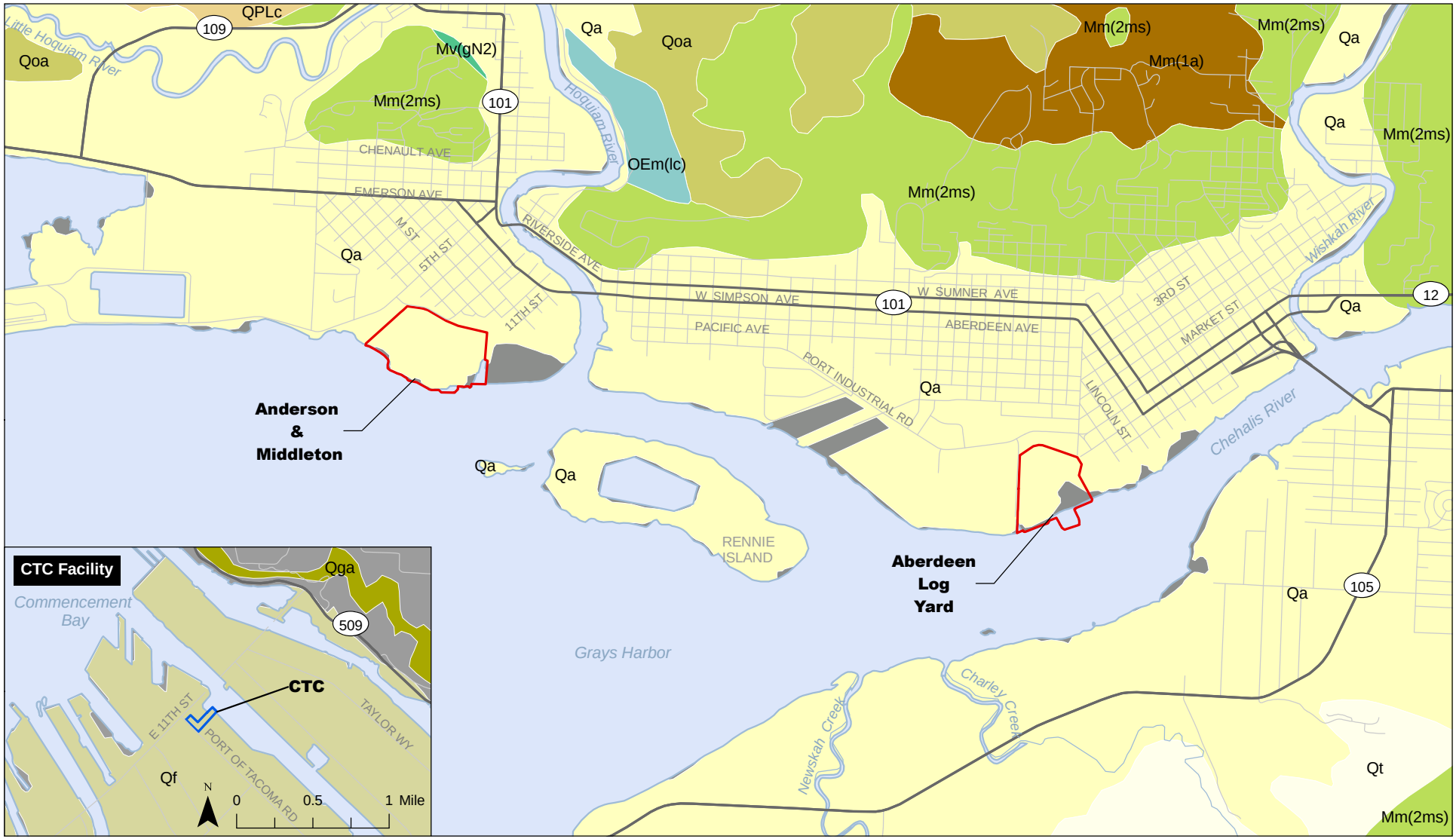
The CTC facility is mapped as being underlain by fill (Logan 1987) as shown in Exhibit 5. The CTC Facility Soils section, below, provides a further description of soil units at the CTC facility.

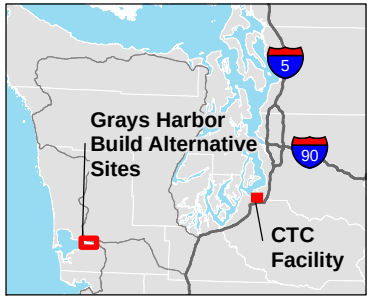
Grays Harbor Build Alternatives

The study area is mapped as being underlain by alluvium (Logan 1987), as shown in Exhibit 5. According to available geotechnical reports, fill was placed in both of the Grays Harbor alternative sites, with varying amounts of wood waste in the upper 15 feet.

> What is alluvium?
>
> Alluvium refers to sediments or soils deposited by a river or stream. Alluvium can contain silt, clay, sand, and/or gravel.

Available geotechnical reports on the Grays Harbor alternative sites indicate that fill soils overlie alluvium. These loose and soft soil deposits are underlain by denser material consisting of outwash from receding glaciers (recessional outwash). Within the alternative sites, these dense glacial deposits are typically encountered at approximately 110 feet below the surface at the Aberdeen Log Yard site and between 145 to 160 feet below the surface at the Anderson & Middleton site.





Tacoma geologic units

- Qf — Fill
- Qga — Advanced outwash deposits

Grays Harbor geologic units

- Mm(1a) — Marine sedimentary rocks
- Mm(2ms) — Marine sedimentary rocks
- Mv(gN2) — Basalt flows (GrandeRondeBasalt, upper flows of norm.mag.pol.)
- OEm(lc) — Marine sedimentary rocks
- QPLc — Continental sedimentary deposits or rocks
- Qa — Alluvium
- Qoa — Alluvium, older
- Qt — Terraced deposits

- No data available
- Build Alternative Site
- CTC facility limits

N 0 2,000 4,000 Feet

Source: WDNR (2005) GIS Data (Geology), Grays Harbor County (2006) GIS Data (Waterbody and Street), WSDOT (2004) GIS Data (State Route), and Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.

Exhibit 5. **Surficial Geology**

Pontoon Construction Project

Washington State Department of Transportation

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Exhibit 6 describes geologic units underlying the Grays Harbor alternative sites. Surficial and subsurface soils are discussed in greater detail below. Exhibit 7 summarizes typical engineering properties and hazard susceptibilities of the geologic units that are potentially within the Grays Harbor alternative boundaries.

EXHIBIT 6
Summary of Geologic Units Underlying the Grays Harbor Build Alternative Sites

Geologic Unit	Description	Density/Hardness
Artificial Fill and Dredge Deposits	Sand and silt with wood waste and other materials, placed as a direct result of human activity.	Very soft to stiff or very loose to dense
Alluvium	Mostly silt and sand deposited in streambeds and fans; occasionally contains gravel.	Loose to dense or soft to stiff
Recessional Outwash	Layered pebble, cobble, and boulder gravel deposited in meltwater streams and their deltas	Dense to very dense

Source: Logan (1987).

EXHIBIT 7
Summary of Typical Engineering Properties and Hazard Susceptibility of Geologic Units Underlying the Grays Harbor Build Alternative Sites

Geologic Unit	Strength	Permeability	Liquefaction Potential[a]
Fill/Dredged Deposits	Potentially low	Variable	Potentially high
Alluvium	Potentially low	Variable	Potentially high
Recessional Outwash	High[b]	High	Low

[a] Liquefaction depends in part on density of the material and the groundwater table elevation. These ratings assume a shallow groundwater condition.

[b] High strength unless cut vertically below the water table, then potentially low to medium strength.

Note: The terms low, medium, and high were determined on the basis of professional opinion from experience with the soil types. Hazard susceptibility was determined on the basis of criteria in City of Hoquiam Municipal Codes 10.09.080 and professional opinion.

Soils

Surficial soils have been mapped by the National Resources Conservation Service (NRCS).

CTC Facility

The surficial soils at the CTC facility are mapped as “made land,” classified as soils that have been modified through dredging, grading, or industrialization. Exhibit 8 shows the surficial soils at the CTC facility. The subsurface soils at the CTC facility are fill underlain by a loose to medium dense sand to silty sand (Hart-Crowser and Port of Tacoma, date unknown).

Tacoma soils

- Ma — 0 to 25% slopes, made land
- Ph — 0 to 3% slopes, Puyallup fine sandy loam
- Pk — 0 to 3% slopes, Puyallup loam
- Rd — 25 to 60% slopes, rough broken land
- Su — 0 to 3% slopes, sultan loam
- Ta — 0 to 3% slopes,Tacoma muck
- Td — 0 to 1% slopes, tidal marsh

Grays Harbor soils

- 36 — 1 to 8% slopes, Elochoman silt loam
- 37 — 8 to 30% slopes, Elochoman silt loam
- 39 — Fluvaquents, tidal
- 46 — 8 to 30% slopes, Hoquiam silt loam
- 47 — 30 to 65% slopes, Hoquiam silt loam
- 58 — 65 to 90 % slopes, Katula very cobbly loam
- 104 — Ocosta silty clay loam
- 125 — Pits, quarries
- 121 — Rennie silty clay loam
- 134 — 0 to 8% slopes,Skamo silt loam
- 147 — Udorthents, level
- 163 — 8 to 30% slopes, Zenker silt loam
- 164 — 30 to 65% slopes, Zenker silt loam
- 165 — 65 to 90% slopes, Zenker silt loam

- No data available
- Build Alternative Site
- CTC facility limits

Source: USDA (1939, 2007) GIS Data (Soil), Grays Harbor County (2006) GIS Data (Waterbody and Street), and WSDOT (2004) GIS Data (State Route), Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.

Exhibit 8. **Surficial Soils**

Pontoon Construction Project

Washington State Department of Transportation

Grays Harbor Build Alternatives

The soils mapped for the Grays Harbor alternative sites are sandy and loamy river dredgings. Nearby surficial soils as mapped by NRCS are alluviums and silty clay loam which may be encountered at the build alternative sites. Exhibits 8 and 9 provide information about the surficial soil units at the Grays Harbor sites.

EXHIBIT 9
Summary of Surficial Soil Units

Surficial Soil (NRCS Map Symbol)	Geologic Unit/Parent Material	Percent Slopes	Profile (Depth in Inches)	Depth to Water Table (Depth in Inches)
Udorthents, level (147)	Sandy and loamy river dredgings	0 – 2	0 to 6: Sandy loam 6 to 60: Sandy loam	24 to 72 inches
Fluvaquents, tidal (39)[1]	Alluvium	0 – 1	0 to 6: Very fine sand 6 to 60: Stratified sand to silty clay	0
Ocasta (104)[1]	Silty clay loam	0 – 1	0 to 12: Silty clay loam 12 to 20: Clay, silty clay 20 to 60: Clay	12 to 72 inches

Source: NRCS (2008).
[1]Surficial soils nearby build alternative sites that may be encountered.

The characteristics of soils underlying the Grays Harbor study area determine to a large extent the methods of design and construction that would be used to build the casting basin facility. Soils also affect long-term operational issues that must be considered for the project. The main documents reviewed by the analysts to determine subsurface soils of the study area were preliminary analyses prepared by Landau Associates (2006; 2007a, b; 2009a, b, c, d, e). The analysts relied heavily on these documents for statements regarding liquefaction susceptibility, with the understanding that these may be revised during design as more detailed methods of analysis are used. Much of the information from the Landau reports is information gathered at the Industrial Development District #1 (IDD #1) site in Grays Harbor. The soil unit information collected at IDD #1 is generally applicable to the Anderson & Middleton and Aberdeen Log Yard sites because the proximity of the three sites means that most of their soil units are similar.

In general, the Landau Associates reports describe the soils underlying the Grays Harbor study area as an upper layer of fill underlain by alluvium, which is underlain by glacial soils consisting of recessional outwash. These soils are divided into soil units at each build alternative. These units are described below. Exhibit 10 compares the soil units at each Grays Harbor alternative site.

EXHIBIT 10
Comparison of Subsurface Soil Units at Grays Harbor Build Alternative Sites

Soil	Anderson & Middleton Alternative	Aberdeen Log Yard Alternative
Soil Unit 1: Fill and Silt	Fill: The upper fill unit encountered varies in thickness from 10 to 15 feet. Soil Unit 1: Includes fill and wood from previous filling overlying native massive silt. In general, the native silt consists of high-plasticity, medium-stiff silt with sand, clay, and organics. Soil Unit 1 (fill plus silt) varies in thickness from about 10 to 15 feet.	Fill: The fill unit varies in thickness up to 15 feet. The fill ranges from silt to sand with heavy amounts of wood debris. Soil Unit 1: Varies in thickness up to 36 feet. Primarily alluvial silt with varying amounts of sand.
Soil Unit 2: Sand and Silt	Borings show this unit primarily consists of Soil Unit 2B. However, borings on the south side contain more silt, thereby suggesting a transition to Soil Unit 2A, which might be located between these test holes and the shoreline. The boundary between Soil Units 2A and 2B on the site is unknown.	The silt of this unit is slightly laminated to massive with lenses of organics and sand. Sand was encountered mainly in middle and lower portions of the soil unit. The lower portion of Unit 2 gradually transitions into sand and gravel (Unit 4).
Soil Unit 3: Silt	Consists of medium to high-plasticity silt. The thickness is relatively uniform throughout the site. A seam of silty sand exists near the top of this unit.	Not encountered.
Soil Unit 4: Very Sandy Gravel	Top of sand and gravel layer varies from about elevation –130 to –140 feet MLLW.	Top of sand and gravel layer near elevation of –90 to -104 feet MLLW.
Soil Unit 5: Siltstone	Not encountered	Soft and highly weathered sandy siltstone. Encountered at a depth of 200 feet below the ground at approximately 187 feet MLLW.

MLLW = mean lower low water

Source: Landau (2009a, e).

Anderson & Middleton

Fill and Soil Unit 1—Silt

The upper subsurface soil unit (Fill and Soil Unit 1) includes fill from previous site filling overlying native, massive to slightly laminated silt with variable sand content. Field inspectors observed that the fill consisted predominantly of very loose to medium dense silty sand to sandy silt with wood waste, extending to depths ranging from 6 to 9 feet below ground surface. The thickness of the fill varies across the site. Field inspectors smelled hydrogen sulfide odor while excavating test pits nearby the Anderson & Middleton site.

Methane gas was also present in many of these test pits. The hydrogen sulfide odor and presence of methane is likely caused by decomposed wood waste found in this upper soil unit. Some of the fill at each site is susceptible to liquefaction. In general, the native silt consists of

What is plasticity?

Plasticity is a measure of a soil's ability to be reshaped and hold shape. Generally speaking, plasticity refers to the "stickiness" of the soil. Plasticity is one of many parameters that influence the soil's potential to liquefy during an earthquake.

high-plasticity, medium-stiff silt with variable content of sand, clay, and organics. The silt of Soil Unit 1 is not susceptible to liquefaction, but some of the sand layers within Soil Unit 1 are susceptible to liquefaction.

Soil Unit 2—Sand and Silt

Soil Unit 2 primarily consists of layered deposits of silt and sand varying in depth from approximately 30 to 65 feet below ground surface at the Anderson & Middleton site. Soil Unit 2 is further divided into Soil Units 2A and 2B, as described in the following paragraphs.

Soil Unit 2A was encountered adjacent to the Chehalis River just east of the Anderson & Middleton site boundaries, and should be expected along the southern portion of the Anderson & Middleton site as well. Soil Unit 2B was predominantly encountered at the Anderson & Middleton site.

Soil Unit 2A predominantly consists of silt with sand layers. The silt in Soil Unit 2A is generally of medium plasticity and varies in consistency from medium stiff to stiff. The sand layers within Soil Unit 2A consist of loose to medium dense, silty to very silty, fine to medium sand. Based on its plasticity, most of the silt in Soil Unit 2A is not susceptible to liquefaction; however, the sand layers within Soil Unit 2A are susceptible to liquefaction. Soil Unit 2B predominantly consists of sand with silt to silty sand with thin layers of silt. Field inspectors observed that the sand was loose to medium dense. The consistency of silt within Soil Unit 2B is medium stiff. Most of the soil in this unit is susceptible to liquefaction.

Soil Unit 3—Silt

Soil Unit 3 consists of slightly layered to massive silt with lenses of abundant organics (material derived from plant and animal life) and sand. The depth of this unit varies from approximately 65 to 150 feet below ground surface at the Anderson & Middleton site and from approximately 70 to 110 feet below ground surface at the Aberdeen Log Yard site. The unit is very compressible, and the abundant organic content tends to make stress-independent, or secondary, settlement continue for many years after excavation or fill. Soil Unit 3 was encountered beneath Soil Unit 2 across the entire site at the Anderson & Middleton site and beneath the northwest and southeast corners of the proposed facilities at the Aberdeen Log Yard site. The silt varies in consistency from medium stiff to very stiff. A 5- to 10-foot layer of silty sand to sandy silt was also observed within Soil Unit 3. This layer was stiff to very stiff and medium dense in consistency/density. Soil Unit 3 is not susceptible to liquefaction.

Soil Unit 4—Sand and Gravel

Soil Unit 4 consists of very sandy gravel with silt. Decomposed wood was encountered in a boring near the Anderson & Middleton site but was not encountered in any test holes at the Anderson & Middleton site. However, the possibility of decomposed wood in this soil unit should be considered. The sandy gravel is generally dense to very dense with some medium dense layers. Soil Unit 4 is not susceptible to liquefaction.

Aberdeen Log Yard

Fill and Soil Unit 1—Silt

The fill at the Aberdeen Log Yard site consists of a variety of soil types, from silt and sand mixtures to sandy gravel with varying quantities of cobbles, small boulders, and debris. The fill was encountered at the ground surface extending to the top of Soil Unit 1 (silt) at elevations about 0 to 6 feet MLLW. Large quantities of wood debris are found in the fill layer. Other limited quantities of debris, including concrete, steel banding, railroad ties, creosoted wood, brick, and steel and plastic pipes, were encountered.

Soil Unit 1 primarily consists of alluvial silt with varying amounts of sand varying in thickness from approximately 28 to 36 feet. The silt in this layer typically has a higher plasticity than in Soil Unit 2, with fewer laminations and sand interbeds. Wood fragments were encountered so logs and other wood debris are likely to be present within this unit.

The Aberdeen Log Yard site contains a significant amount of wood debris and wood waste, so the presence of methane gas and hydrogen sulfide odor should be expected.

Some of the fill at each site is susceptible to liquefaction. In general, the native silt consists of high-plasticity, medium-stiff silt with variable content of sand, clay, and organics. The silt of Soil Unit 1 is not susceptible to liquefaction, but some of the sand layers within Soil Unit 1 are susceptible to liquefaction.

Soil Unit 2—Sand and Silt

Soil Unit 2 primarily consists of layered deposits of silt and sand varying in depth from approximately 45 to 115 feet below ground surface. The lower portion of Unit 2 gradually transitions into the sand and gravel layer below. The silt in this unit is slightly laminated to massive with lenses of organics and thin interbeds of sand. The sand interbeds are thicker in the middle and lower portions of this unit. The sand in Unit 2, encountered mainly in the middle and lower portions of the soil unit, varies from a silty sand to sand with limited silt content. Wood fragments were encountered during field explorations so logs are likely to present.

Standard penetration tests (SPTs) performed in the silt of this unit show a consistency of very soft to medium stiff, but laboratory and other field tests indicate a consistency of medium stiff to very stiff. The silt is expected to have a high sensitivity. The sand layers relative density based on SPTs vary from very loose to dense.

Due to the sand content and high water table, this unit should be considered susceptible to liquefaction.

Soil Unit 3—Silt

Soil Unit 3 was not encountered at the Aberdeen Log Yard site.

Soil Unit 4—Sand and Gravel

Soil Unit 4 consists of very sandy gravel with silt. The upper portion of this unit grades transitionally from the alluvial deposits of Unit 2. The contact between Unit 2 and 3 is based upon higher SPT values and increasing gravel content. The sandy gravel is generally dense to very dense with some medium dense layers. Soil Unit 4 is not susceptible to liquefaction.

Soil Unit 5—Siltstone

Siltstone was encountered in one boring approximately 200 feet below the ground surface. The siltstone appears to be soft and highly weathered sandy siltstone.

Exhibit 11 provides a generalized subsurface profile comparing the two Grays Harbor alternative sites. The profile shows the interpretation of analysts from Landau Associates and WSDOT of subsurface conditions based on borings that were drilled in these sites. Soil Unit 5 at the Aberdeen Log Yard is not shown in Exhibit 11 due to the depth of the layer.

Groundwater

CTC Facility

The analysis found no groundwater information for the CTC site, but groundwater near the site typically is shallow, normally within the upper 12 feet (Port of Tacoma 2008). The groundwater elevation is expected to fluctuate with the tide.

Grays Harbor Build Alternatives

The Grays Harbor study area is located in the lower Chehalis River basin at the mouth of the Hoquiam and Chehalis rivers. Sand and gravel alluvium in the Chehalis River valley yields large quantities of water. Some wells tapping the alluvium of the Chehalis River valley are capable of producing up to 300 gallons per minute (gpm).

There are two distinct aquifers within the alluvium: the upper aquifer extends to a depth of approximately 100 feet, and the lower aquifer is present below the 100-foot depth. The lower aquifer yields large quantities of water—between 200 gpm and 3,000 gpm (Eddy 1966). The following subsections discuss the location of the groundwater at each build alternative site.

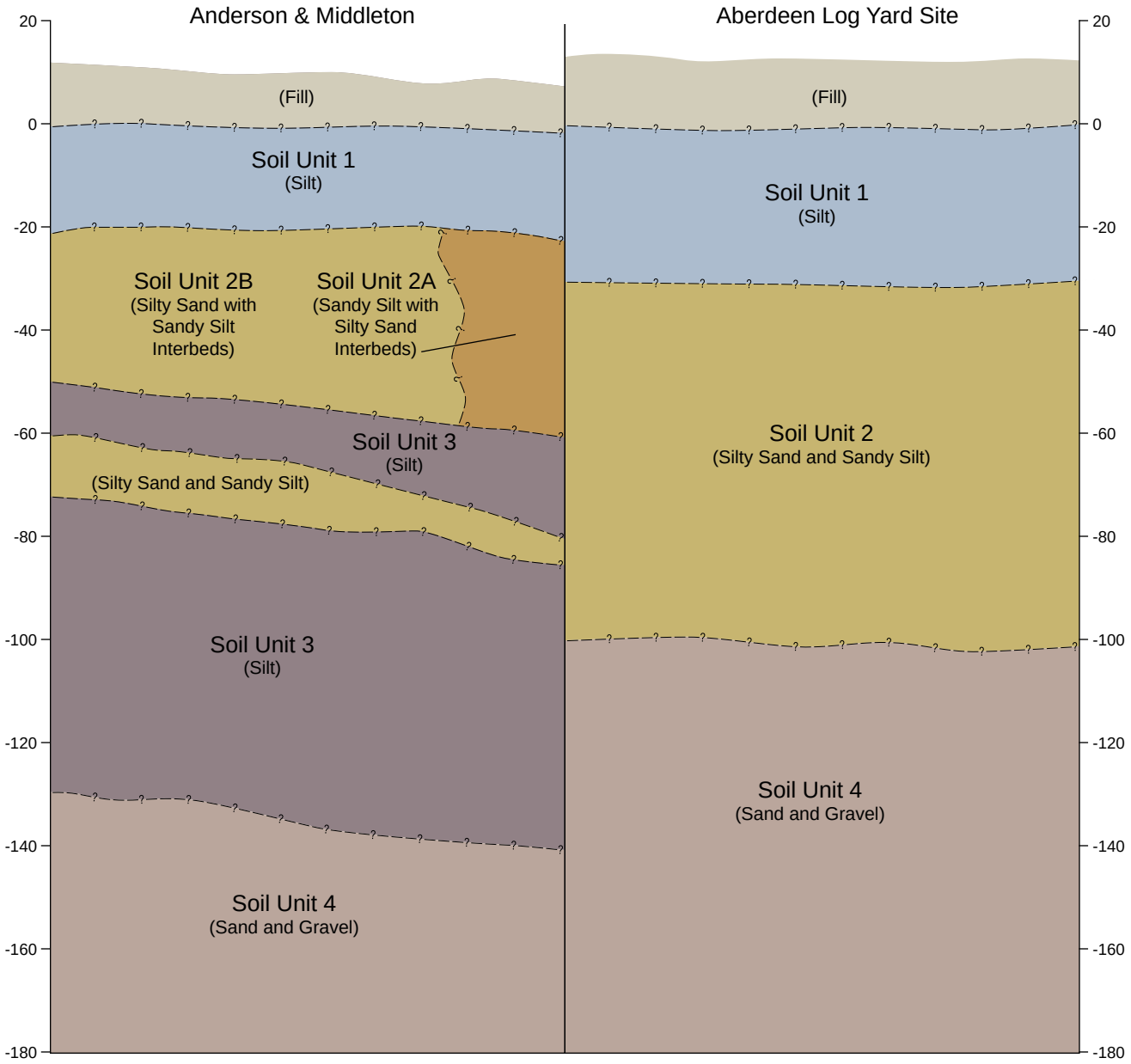
> What is an aquifer?
>
> An aquifer is a water-bearing layer of soil or rock that yields groundwater to wells or springs.

Anderson & Middleton Alternative

Groundwater at the Anderson & Middleton Alternative site is typically between 5 and 7 feet below ground. The groundwater level is likely influenced to some extent by the tide.

Aberdeen Log Yard Alternative

Groundwater at the Aberdeen Log Yard Alternative site is typically between 5 and 10 feet below ground. The groundwater level is likely influenced to some extent by the tide. Surface water infiltration through the upper fill layer is most likely high due to the broken angular rock on the surface and to the high amount of wood waste in the upper soils.



Adapted from Landau (2009)

Estimated Soil Unit Depths

Exhibit 11. **General Subsurface Profiles for Grays Harbor Sites**

Pontoon Construction Project

Washington State Department of Transportation

Aggregate Sources

CTC Facility

No construction activities for the development of the CTC site would occur, so no aggregate will be imported or exported from the site.

> What is aggregate?
>
> Aggregate consists primarily of sand and gravel. It is often used during construction as fill underneath structures or behind retaining walls.

Grays Harbor Build Alternatives

Most of the soil types within the Grays Harbor alternative sites would not be good sources of aggregate because of the high fines (fine-grained soil) content and wet conditions. Soils with high fines content are more difficult to work with during construction because they are moisture-sensitive, thus making them difficult to compact.

The aggregate quantity requirement for the Grays Harbor build alternatives would be about 450,000 cubic yards and 550,000 cubic yards for the Anderson & Middleton and Aberdeen Log Yard sites, respectively. Imported aggregate would be required as backfill for the casting basin walls and drains and to repair the existing rock berm at the Anderson & Middleton site

by increasing the height and armoring the toe (no shoreline armoring would be required at the Aberdeen Log Yard site). Imported aggregate would also be needed for lining the launch channel, for construction of pontoons, and potentially for access road subgrade and as fill for structures. Aggregate would be brought to the alternative sites from other locations in western Washington by truck, train, or barge.

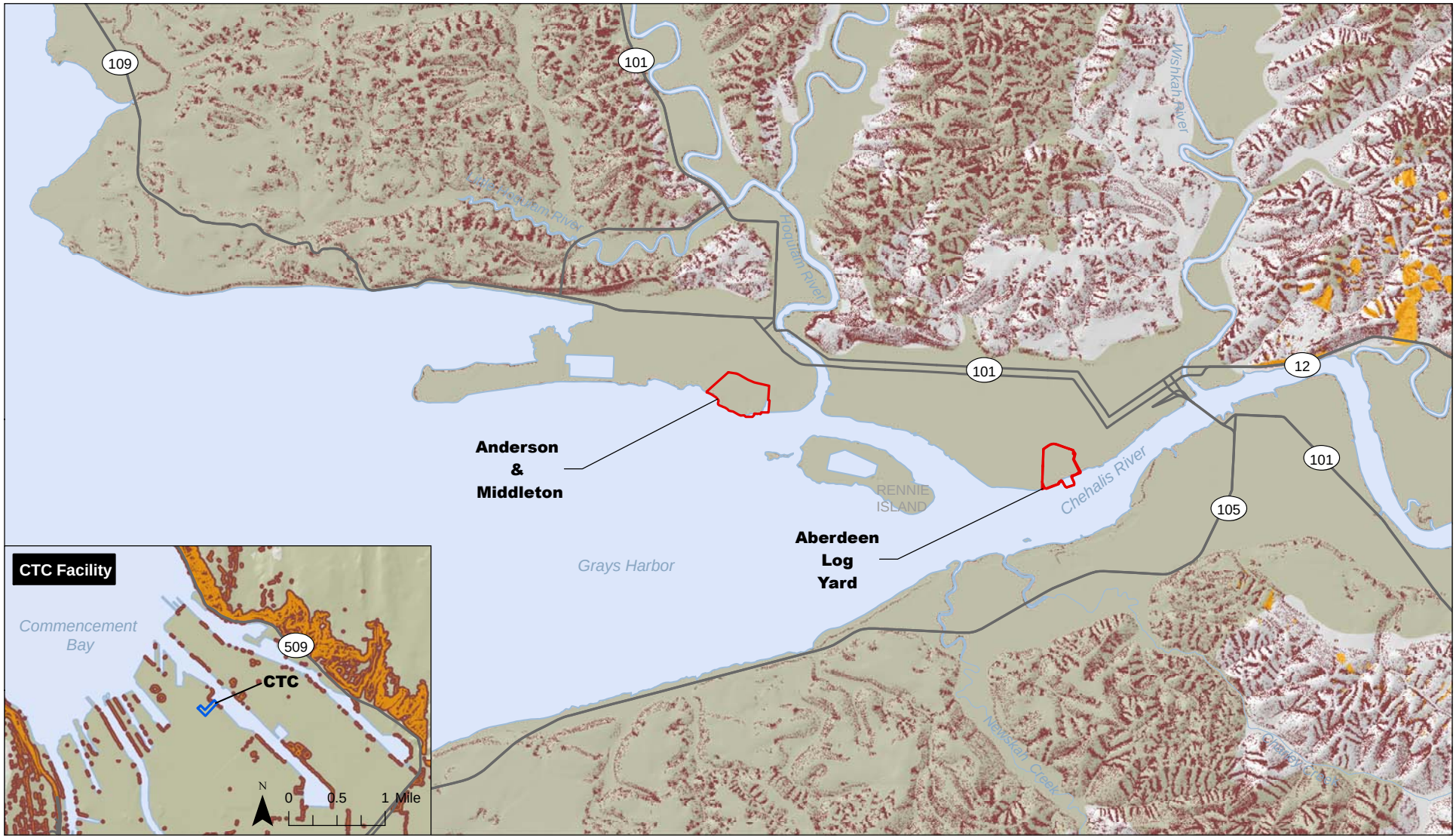
Do the existing geology and soil conditions pose any geologic hazards?

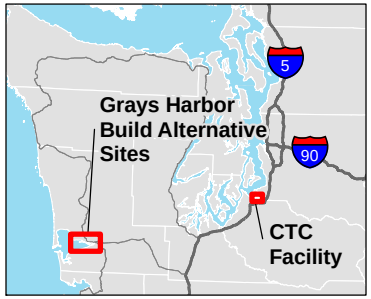
Geologic hazards in the study areas are shown in Exhibits 12 through 15 and described below. These hazards consist of seismic hazards and settlement or soft ground hazards.

Seismic Hazards

Seismic hazard areas are subject to severe risk of damage as a result of earthquake-induced ground shaking, slope failure, settlement, soil liquefaction, or surface faulting. The primary seismic hazards shown in western Washington and county maps involve ground-shaking hazards, liquefaction hazards, faulting hazards, and tsunami inundation or seiche hazard. The following subsection summarizes the regional ground-shaking hazard. Subsequent subsections give details for each of the project sites regarding ground shaking and the other seismic hazards.

> What is a seiche?
>
> A seiche is wave that swings back and forth in an enclosed body of water such as a lake or bay. A seiche can last from a few minutes to a few hours and is often caused by earthquakes.





Slope instability

Landslide hazard

Liquefaction

Build Alternative Site

CTC facility limits

Source: USGS (1999) GIS Data (10-meter DEM), WDNR (2000) GIS Data (Slope Instability), (2004) GIS Data (Liquefaction and Landslide Hazard), City of Tacoma (2006) GIS Data (Steep Slope), GeoEngineers (2003) GIS Data (Landslide Hazards) Pierce County (2004) GIS Data (Liquefaction Hazard), and Grays Harbor County (2006) GIS Data (Waterbody), Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.

N 0 0.5 1 2 Miles

Exhibit 12. **Geologic Hazard Areas**

Pontoon Construction Project

Washington State Department of Transportation

Hood Canal Fault zone (fault no.552)

Puget Sound

Hood Canal

520

Seattle Fault zone (fault no.570)

5

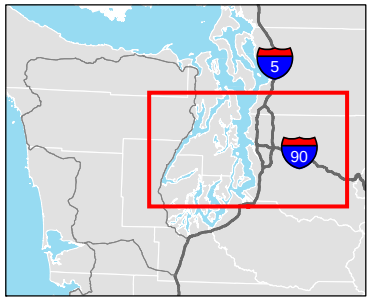
90

Tacoma Fault zone (fault no.581)

CTC Facility

5

Source:USGS (1999) GIS Data (10-meter DEM), USGS (2004) GIS Data (Fault), WSDOT (2004) GIS Data (State Route) and Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.



Fault

Note: Mapped sources of magnitude greater than 6 Earthquakes during the Quaternary (past 1,600,000 years).

N

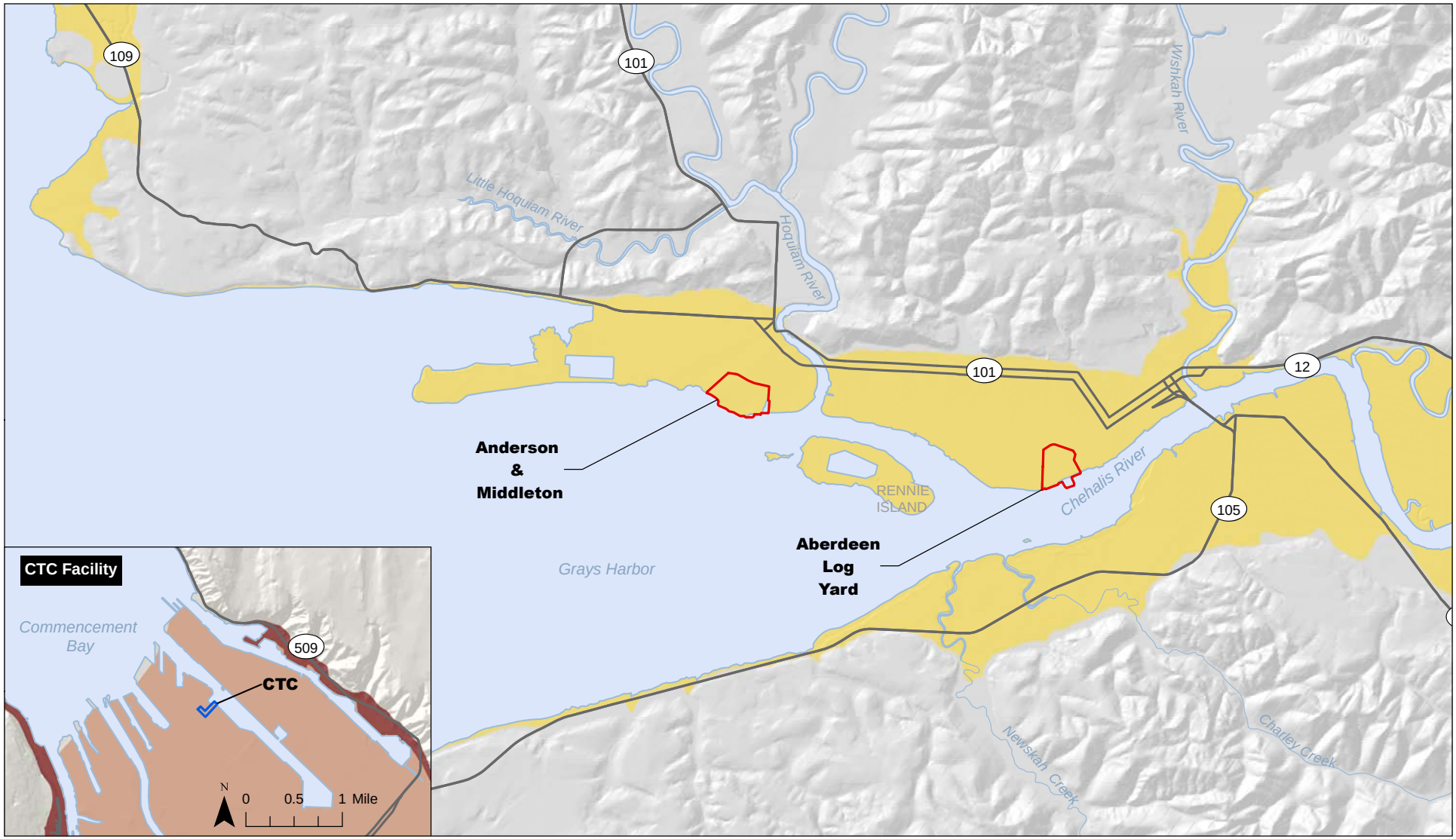
0 5 10 Miles

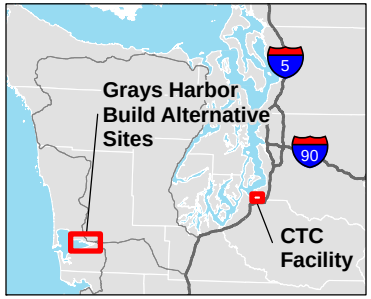
Exhibit 13. **Fault Zones Near CTC Site**

Pontoon Construction Project

Washington State Department of Transportation

\\SIMBA\PROJ\PARAMETRIX\180171\GIS\MAPFILES\PONTOON\GEOLOGYSOILS\PON_TM_GEOL_CTCFAULT.MXD PON_TM_GEOL_EX13_CTCFAULT.PDF 11/3/2009





- Tacoma Case I volcanic inundation level (500- to 1,000-year frequency)
- Tacoma Case II volcanic inundation level (100- to 500-year frequency)
- Grays Harbor tsunami inundation limits
- Build Alternative Site
- CTC facility limits

Source: USGS (1999) GIS Data (10-meter DEM), Pierce County (2006) GIS Data (Volcanic Hazard), Grays Harbor County (2006) GIS Data (Waterbody), Grays Harbor County (2007) GIS Data (Tsunami) and Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.

N 0 0.5 1 2 Miles

Exhibit 14. **Inundation Limits**

Pontoon Construction Project

Washington State Department of Transportation

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Unnamed Fault zone near Aloha (Class B) (fault no.586)

Unnamed Fault zone near Langley Hill (fault no.587)

101

115

Unnamed Fault zone near Langley Hill (fault no.587)

Build Alternative Sites

Grays Harbor Fault zone (fault no.589)

Saddle Hill Fault zone (fault. no 588)

12

Grays Harbor

105

Unnamed Faults near mouth of Willapa Bay (fault no.590)

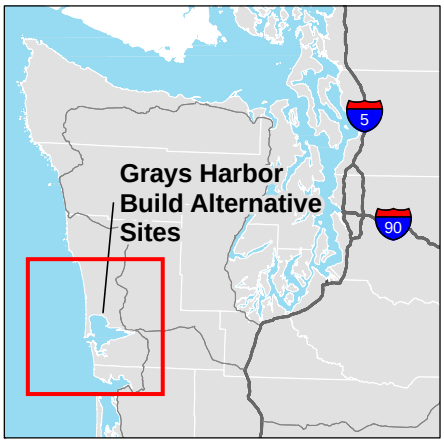
101

Unnamed Fault zone offshore Cape Shoalwater (fault no.591)

Unnamed Fault zone offshore Cape Shoalwater (fault no.592)

Pacific Ocean

Unnamed Faults near mouth of Willapa Bay (fault no.590)



Fault

Note: Mapped sources of magnitude greater than 6 Earthquakes during the Quaternary (past 1,600,000 years).

Source: USGS (1999) GIS Data (30-meter DEM), USGS (2004) GIS Data (Fault), WSDOT (2004) GIS Data (State Route) and Ecology (2001) GIS Data (Shoreline). Horizontal datum for all layers is State Plane Washington South NAD 83; vertical datum for layers is NAVD88.

N

0 2.5 5 Miles

Exhibit 15. **Fault Zones in Grays Harbor**

Pontoon Construction Project

Washington State Department of Transportation

Regional Ground-Shaking Hazard

The potential for future earthquake-related ground shaking is relatively high in the study areas. Earthquakes in western Washington can result from any one of three sources illustrated in Exhibit 16:

- Cascadia subduction zone off the coast of Washington
- Deep subcrustal zone approximately 20 to 40 miles below the surface
- Shallow crustal faults

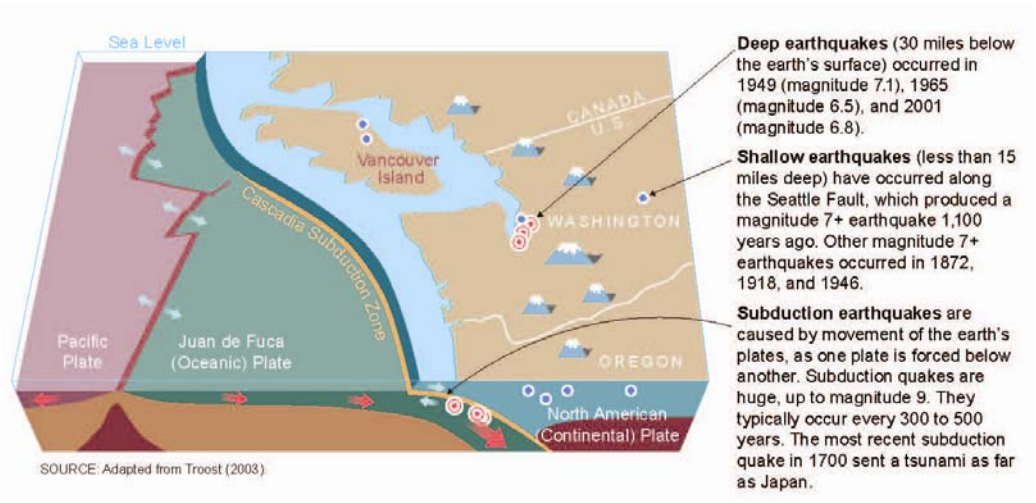


EXHIBIT 16. Potential Seismic Source Zones in the Pacific Northwest

An earthquake with one of these source mechanisms could result in large vibratory ground motions at the study areas. The most recent large earthquakes in the region include the1949 magnitude 7.1 Olympia earthquake, the 1965 magnitude 6.5 Sea-Tac earthquake, and the 2001 6.8 magnitude Nisqually earthquake. All of these recent large earthquakes are examples of movement within the deep subcrustal zone. Ground shaking is the primary cause of earthquake damage to structures and property in Washington. Liquefaction, faulting, and tsunami inundation are direct results to geology and soils from earthquake related ground-shaking hazards.

CTC Facility

The CTC facility is prone to seismic hazards similar to those at the Grays Harbor build alternative sites (see below), including ground shaking, liquefaction, fault hazards, and inundation. The nearest fault to this site is within approximately 15 miles (the Tacoma Fault Zone). The Seattle Fault Zone is within approximately 20 miles of the site (see Exhibit 13).

Exhibit 12 shows geologic hazards at the CTC facility. This site is underlain by a soil unit of sand that is susceptible to liquefaction (Hart-Crowser and Port of Tacoma, date unknown). The CTC facility's foundation consists of 14-inch-diameter piles that are bearing into a dense soil unit. The facility was not designed to mitigate seismic hazards and would be expected to

incur damage during a large earthquake. The site is also susceptible to inundation from mudflows or debris flows caused by a volcanic eruption of Mount Rainier (see Exhibit 14). The use of this site would not alter the geologic hazards in the study area. In the case of a large earthquake or volcanic eruption, facility damage should be expected.

Grays Harbor Build Alternatives

The different types of seismic hazards in the Grays Harbor study area are described in the following paragraphs.

Ground-Shaking Hazard

Direct results on geology and soils from ground shaking include liquefaction, faulting, and tsunami inundation, as discussed in the following paragraphs. Structural damage often occurs in the event of an earthquake as the motion of the ground-shaking interacts with the structure. Ground-shaking hazard effects on structures are typically minimized or avoided in the design of the structure. WSDOT would design the facility for life safety in the event of an earthquake.

Liquefaction Hazard

Soil liquefaction and the accompanying settlement, lateral spreading, or floatation of buried vaults and pipes can occur where areas are underlain by cohesion-less soils (for example, fine-grained sand, silt, or sandy silt) of low density, usually in association with a shallow groundwater table, that lose substantial strength during earthquakes. The fills and alluvium that underlie each Grays Harbor alternative site are loose and saturated and therefore are potentially susceptible to liquefaction during earthquake shaking. The alternative sites are mapped by WDNR as being in a liquefaction-prone area (see Exhibit 12).

> What is lateral spreading?
>
> Lateral spreading consists of lateral movement of level or near-level ground associated with liquefaction of soil during an earthquake.

Landau Associates performed a liquefaction and lateral spreading potential study (Landau 2007a) at the IDD #1 property bordering the Anderson & Middleton site on the east. Both IDD #1 and the Anderson & Middleton site are underlain by Soil Unit 2B, so the results can reasonably be applied to this soil unit at the Anderson & Middleton site. These results indicate that Soil Unit 2B consists primarily of soils that are susceptible to liquefaction. Soil Units 1 and 2A consist of relatively high-plasticity silt that is not susceptible to liquefaction. Some granular layers of Soil Units 1 and 2A, however, are susceptible to liquefaction. Soil Units 3 and 4 are deeper than 80 feet, below which liquefaction is not typically considered (WSDOT 2008).

At the Aberdeen Log Yard site, the upper soils (Soil Units 1 and 2) are potentially liquefiable with the potential for lateral spreading. Current studies are underway to determine the extent of liquefaction and lateral spreading at the Aberdeen Log Yard.

Faulting Hazard

A faulting hazard is the possibility of a surface rupture caused by fault movement within a project site. There are six fault zones located within 20 miles of the Grays Harbor build alternative sites, the closest being about 10 miles from the sites (Exhibit 15). These faults,

which are considered active by USGS, are referred to by USGS as the unnamed fault zone near Aloha (Fault No. 586), the unnamed fault zone near Langley Hill (Fault No. 587), the Saddle Hill fault zone (Fault No. 588), the Grays Harbor fault zone (Fault No. 589), the unnamed fault zone offshore Cape Shoalwater (Fault No. 591 and 592), and unnamed faults near mouth of Willapa Bay Fault No. 590) (USGS 2008). A low hazard of surface rupture is anticipated based on the distance (more than 10 miles) of the study area from the mapped faults. Unmapped faults may exist in the area that could potentially present a risk to the alternative.

Tsunami Inundation or Seiche Hazard

The Grays Harbor build alternative sites are identified as being in a tsunami inundation zone, as shown in Exhibit 14. A tsunami that enters shallower areas of water, such as Grays Harbor, can increase in height and cause great loss of life and property as it come ashore. Tsunamis present a severe threat to the coastal areas of Hoquiam and Aberdeen; however, the risk of seiches or tsunami inundation is generally thought to be low, given the low annual frequency of large earthquakes off the west coast of Washington (on the Cascadia fault zone), in Japan, or in Alaska. There would also likely be enough warning to evacuate these facilities if a large tsunami from a distant source were forecasted. Nevertheless, a potential for these hazards does exist.

Settlement or Soft Ground Hazards

Areas underlain by soft or loose compressible sediments can experience ground settlement during and sometimes after construction. Structures and buried utilities may settle unevenly (differential settlement) and become damaged unless they are supported on piles or the ground is improved. These soft soils could also require the use of special construction procedures during placement of fills. If these procedures are not used, bearing or slope failures could occur when fill heights exceed certain limits. Generally, areas mapped as seismic hazards associated with liquefaction also coincide with areas of settlement hazard.

Soft soils and settlement are not a geologic hazard at the CTC facility. However, settlement is a potential issue at Anderson & Middleton and Aberdeen Log Yard Alternative sites. At the Aberdeen Log Yard, buried logs and old piling could protrude through the fill when settlement occurs (similar conditions at Anderson & Middleton site should be expected but would not be as extreme). The potential for differential settlement is significant as well. The effects of settlement are anticipated to be a significant issue primarily within the potential Grays Harbor sites, but have some potential, if unmitigated, to affect offsite facilities. WSDOT feels that there are solutions to keep offsite settlement within limits that will not damage adjacent facilities. Studies to evaluate the likely risks are ongoing. The nearby wastewater treatment plant structures and buried utilities could be damaged if the compressible sediments are disturbed by dewatering or construction vibrations.