TACOMA HARBOR, WA FEASIBILITY STUDY PIERCE COUNTY, WASHINGTON

APPENDIX B - ENGINEERING

April 2022





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1. Physical Environment

Tacoma Harbors' location is on the southwest region of Commencement Bay on the lowlands formed by the Puyallup River's delta. High bluffs dominate the bay's shoreline on the northeast and southwest. Depths in Commencement Bay range from 560 feet at the entrance to 100 feet as you approach the Blair Waterway. Tacoma Harbor's waterways location is in a glacial-scoured trough which is occupied by the Puyallup River. The trough is filled with alluvial and marine deposits laid down during the building of the Puyallup delta. Materials vary in gradation from silts and clays to coarse sand. Layers of organic silt and peat are found scattered throughout the deposit.

The Tacoma Harbor Federal navigation project includes the Hylebos, Blair, and Thea Foss (also known as city) waterways, all with varying authorized depths (Table B-1). Figure B-1 Tacoma Harbor — Authorized Federal Navigation Project shows the currently authorized navigation channels for each reach, as described in Table B-1; Port of Tacoma currently maintains the Sitcum Waterway. The Federal navigation project includes 7.75 miles of channel. The current Tacoma Harbor Feasibility Study is investigating channel deepening and widening the Blair Waterway.

Table B-1 Existing Tacoma Harbor Federal Navigation Project - Channel Reach and Stationing

| Channel reach | Authorized depth (feet, MLLW) | Channel Station | Within Project | |
|------------------|-------------------------------------|-------------------|----------------|--|
| Hylebos Waterway | -30 | 0+00 to 165+14.7 | No | |
| Blair Waterway | -51 | 0+00 to 139+99.94 | Yes | |
| City Waterway | -29,-22,-19 | 0+00 to 82+20 | No | |



Figure B-1 Tacoma Harbor – Authorized Federal Navigation Project

1.1 Climatology

The average annual precipitation over the Tacoma area is 39 inches and is relatively low compared to the adjacent areas where moisture-laden air masses are forced up the sides of the Cascade and Olympic Mountains, creating over 100 inches of precipitation per year. Over 75% of the annual precipitation occurs in the four-month period from October to March. The weather in the Tacoma area is temperate, with mean low and high temperatures of 33° F and 76° F, respectively.

1.2 Streamflow characteristics

The Puyallup River Basin is shown in Figure B-2. It drains approximately 1,000 square miles of western-central Washington originating on the glaciers of Mount Rainier in the Cascade mountain range and flowing in a northwesterly direction to Commencement Bay on Puget Sound. Elevations vary from sea level at Tacoma to an elevation of 14,411 feet at the summit of Mount Rainier. The upper portion of the Basin is characterized by steep, mountainous terrain, while the lower portion is characterized by broad floodplains and low gradient stream channels.

The Basin is diverse and is comprised of three glacially fed rivers, the Puyallup River and its tributaries, the White River, and the Carbon River. Each of these major river systems originates on the northern slopes of Mount Rainier and join together upstream of the city of Tacoma (the third-largest city in the state of Washington) before draining into Puget Sound.

- The Puyallup River drains the northwest slope of Mount Rainier and flows northwest for approximately 50 miles before discharging into Commencement Bay in the city of Tacoma, Washington. Clear Creek (RM 2.7) and Clarks Creek (RM 5.8) are tributaries to the lower Puyallup River).
- The White River drains the northeastern slope of Mount Rainier and flows in a generally northwest direction for about 50 miles before turning southward and entering the Puyallup River from the north at RM 10.3. The White River is the largest tributary to the Puyallup River. Mud Mountain Dam (MMD), a Federally authorized (Corps of Engineers) flood control project, is located at RM 29.6 on the White River.
- The Carbon River originates on the north face of Mount Rainier at the Carbon Glacier and enters the Puyallup River at RM 17.3. South Prairie Creek at RM 5.8 is a major tributary to the Carbon River.

According to United States Geological Survey (USGS) gage 12101500 at the Puyallup River, the average daily flow is around 3,332 cubic feet per second (cfs). However, as recently as of January 2009, flooding caused by heavy rainfall combined with warmer temperatures and a rapidly melting snowpack resulted in recorded peak flows at the gage of 48,200 cfs.

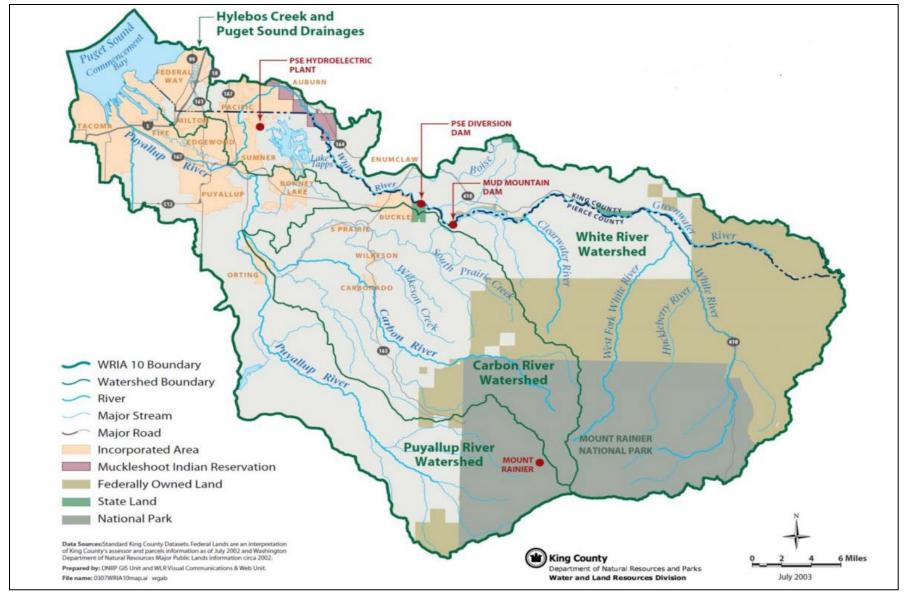


Figure B-2 White/Carbon/Puyallup River Basin

1.3 Tides

Tides in Tacoma Harbor have the diurnal inequality typical of the U.S. West Coast. Tidal ranges for Tacoma are listed in Table B- 2, as related to our Mean Lower Low Water (MLLW) datum, determined from tidal epoch spanning 1983 to 2001. The mean diurnal tidal range for Tacoma published by the National Ocean Survey is 8.06 feet. The great diurnal tidal range for Tacoma is 11.77 feet. Observed water levels are primarily a function of astronomical tide influences. However, anomalies from the predicted astronomical tide occur due to factors including changes in atmospheric pressure, wind setup, wave set-up, and river discharge.

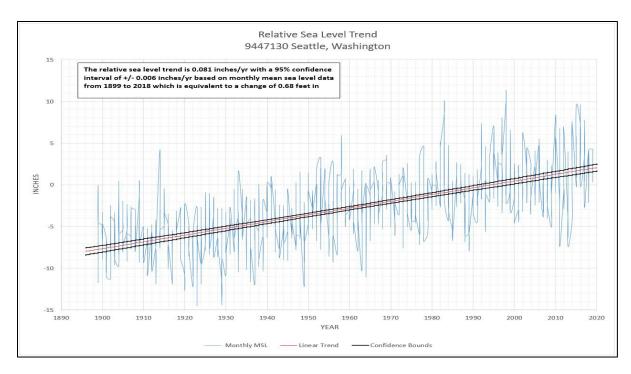
Table B- 2 Tide range as related to MLLW datum at Tacoma, WA, NOS Station 9446484

| Datum | Water Level |
|---|-------------|
| Highest Observed Water Level | 14.87 |
| Mean Higher-High Water (MHHW) | 11.78 |
| Mean High Water (MHW) | 10.90 |
| Mean Tide Level (MTL) | 6.87 |
| Mean Low Water (MLW) | 2.84 |
| North American Vertical Datum 88 (NAVD88) | 2.39 |
| Mean Lower Low Water (MLLW) | 0.00 |
| Lowest Observed Water Level | -4.73 |

1.4 Sea Level Change

Sea level change is an uncertainty, potentially increasing the frequency of extreme water levels. Planning guidance in the form of a USACE Engineering Regulation (ER), USACE ER 1100-2-8162 (USACE 2013), incorporates new information, including projections by the Intergovernmental Panel on Climate Change and National Research Council (IPCC 2007, NRC 2012). The ER requires that projects are evaluated to determine how sensitive they are to various scenarios of future sea-level change (SLC). Since predictions of future SLC have uncertainty, the risks associated with three SLC scenarios are analyzed. These scenarios are termed low, intermediate, and high and correspond to different rates of global sea level acceleration. Historically, this global (eustatic) sea level rise rate has been approximately 0.067 inches (in) per year.

Locally, SLC varies geographically as it is the difference between the global SLC (0.067 in/year according to IPCC 2007) and local vertical land movement (VLM). The accuracy of local mean sea level rates is a function of the period of record of the water level time series. ER 1100-2-8162 recommends that a National Oceanic and Atmospheric Administration (NOAA) water level station should be used with a period of record of at least 40 years. The historical sea level change observed in Seattle since 1899 is shown in Figure B-3 and Table B-3; it is the closest gage to our project site for which the necessary period of record is available and presents low, intermediate, and high scenarios. At 50 years, the predicted sea level rise at the project ranges from 0.57 to 3.25 feet.



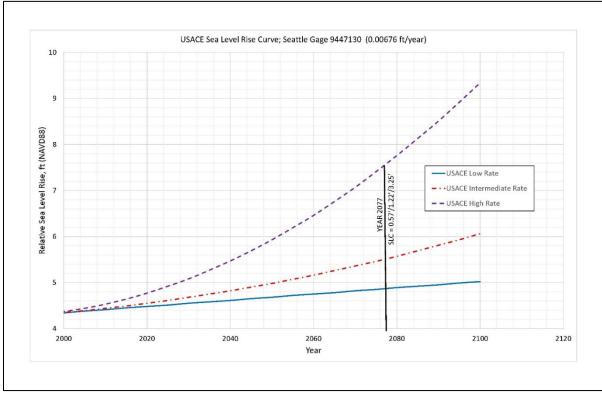


Figure B-3 Sea level change rate projections in Seattle, WA (from NOAA/NOS CO-OPS)

Table B-3 Predicted sea level change (in feet) at Seattle, WA per ER 1100-2-8162

| Year | Low | Int | High | Year | Low | Int | High |
|------|------|------|------|------|------|------|------|
| 1992 | 0 | 0 | 0 | 2077 | 0.57 | 1.22 | 3.25 |
| 2027 | 0.24 | 0.35 | 0.69 | 2080 | 0.6 | 1.28 | 3.47 |
| 2030 | 0.26 | 0.39 | 0.79 | 2085 | 0.63 | 1.4 | 3.84 |
| 2035 | 0.29 | 0.46 | 0.98 | 2090 | 0.66 | 1.52 | 4.22 |
| 2040 | 0.32 | 0.53 | 1.18 | 2095 | 0.7 | 1.64 | 4.63 |
| 2045 | 0.36 | 0.61 | 1.4 | 2100 | 0.73 | 1.77 | 5.05 |
| 2050 | 0.39 | 0.69 | 1.64 | 2105 | 0.76 | 1.9 | 5.5 |
| 2055 | 0.43 | 0.78 | 1.9 | 2110 | 0.8 | 2.04 | 5.96 |
| 2060 | 0.46 | 0.87 | 2.17 | 2115 | 0.83 | 2.18 | 6.44 |
| 2065 | 0.49 | 0.97 | 2.47 | 2120 | 0.87 | 2.32 | 6.94 |
| 2070 | 0.53 | 1.07 | 2.78 | 2125 | 0.9 | 2.47 | 7.46 |
| 2075 | 0.56 | 1.17 | 3.12 | 2127 | 0.91 | 2.53 | 7.67 |

1.5 Currents

Figures B-4 through B-7 display velocity magnitude (color contours) and direction (vectors) during four tidal stages (peak ebb, peak flood, low water slack, and high water slack) as predicted by the Coastal Modeling System (CMS-FLOW) hydrodynamic model during average flow conditions (*Dredged Material Management Program: Dispersive Disposal Site Fate and Transport Analysis for Puget Sound, Washington, September 2012*). CMS modeling software is a 2-dimensional modeling tool that averages velocity through the water column and outputs a single value for each computational cell. High and low water slack refers to the point at which the tidal flow is about to reverse direction, a point at which there is minimal movement in either direction. In general, currents in each waterway are less than 0.5 knots (0.25 meters per second) during all tidal phases. The currents are stronger at the mouth of the Puyallup River and the Hylebos Waterway during ebb tides (Figure B-4). In the Blair Waterway, the current direction is oriented parallel to the waterway orientation. Peak current velocities range from 0.1 knots (0.05 m/s) at the mouth near Husky Terminal to 0 knots (0.01 m/s) at the head of the waterway near Pierce County Terminals.

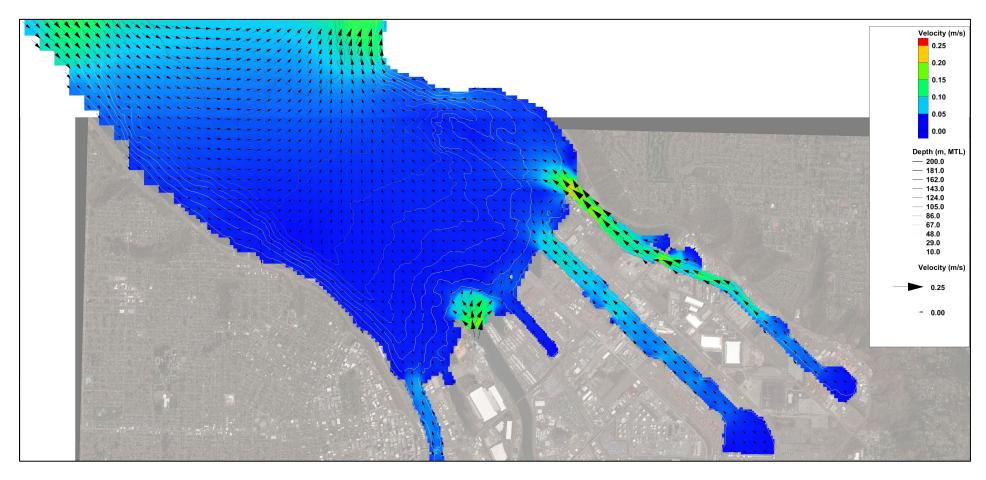


Figure B-4 CMS-FLOW depth averaged current velocities during <u>peak ebb</u> tidal phase

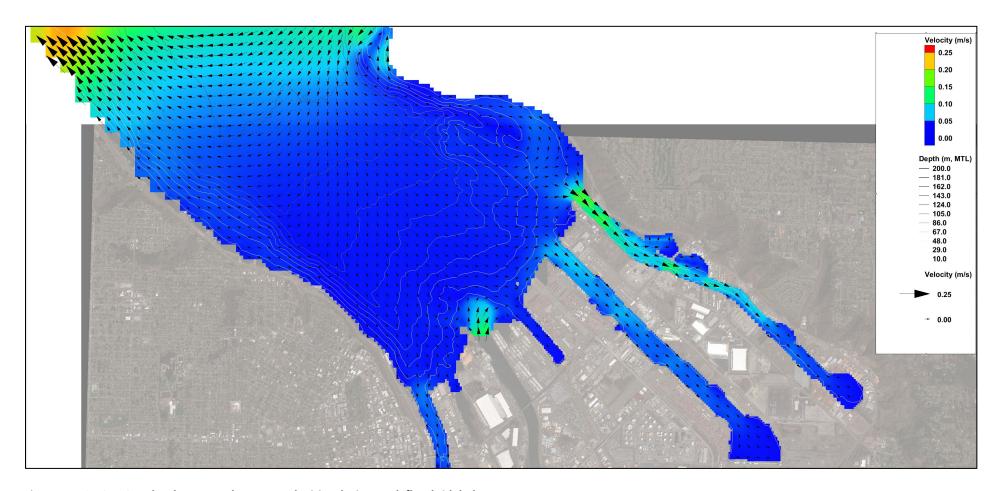


Figure B-5 CMS-FLOW depth averaged current velocities during peak flood tidal phase

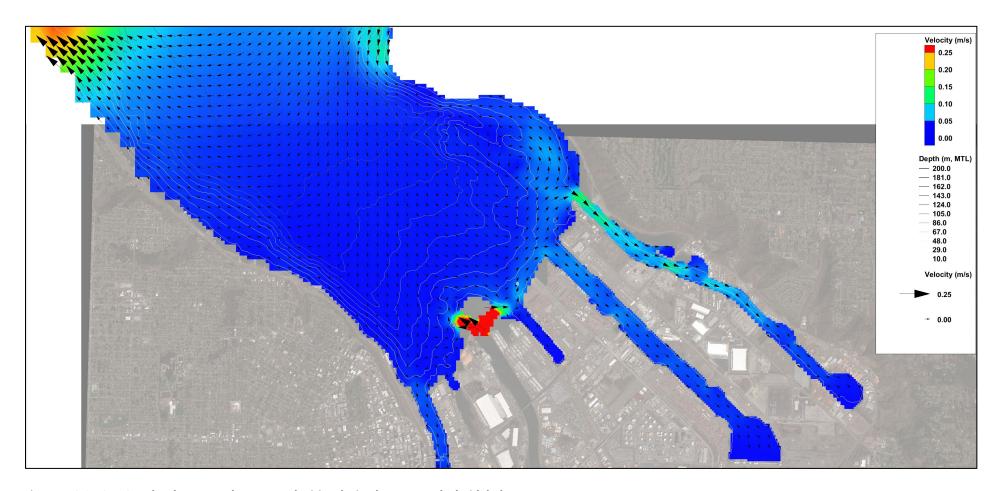


Figure B-6 CMS-FLOW depth averaged current velocities during low water slack tidal phase

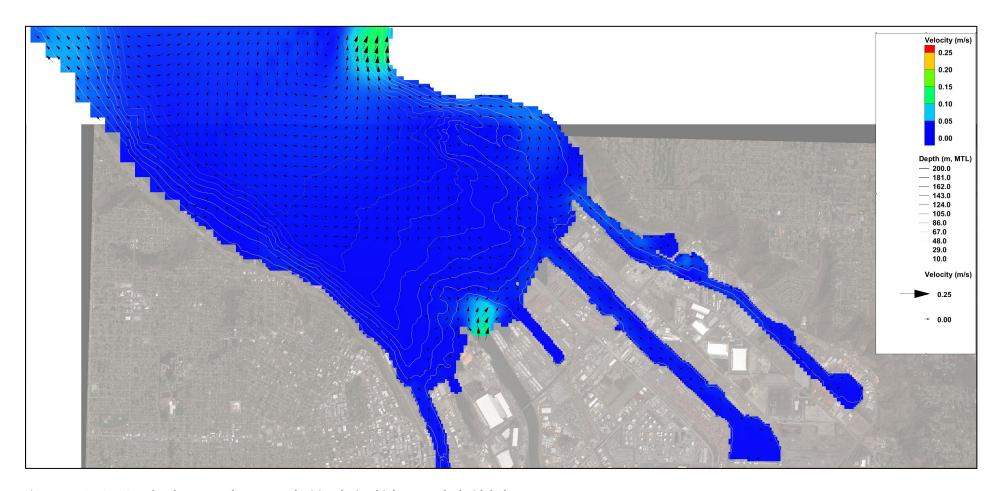


Figure B-7 CMS-FLOW depth averaged current velocities during high water slack tidal phase

1.6 Winds

The seasonal cycle of winds over the northeast Pacific Ocean is largely determined by the circulation of the North Pacific high pressure area and the Aleutian low pressure area, which drives the jet stream over the North Pacific. During the summer months, the high reaches its greatest development. In July, the center of highest pressure is located near latitude 35° N., longitude 150° W. During this period, the Aleutian low is almost nonexistent. This pressure distribution causes predominantly northwest and north winds over the coastal and near offshore areas of Oregon and Washington. The high weakens with the approach of the winter season and by November is usually little more than a weak belt of high pressure lying between the Aleutian low and the equatorial belt of low pressure. These traveling depressions moving eastward cause considerable day-to-day variation in pressure, particularly in the area north of latitude 40° N.

As shown in Figure B-8, in Tacoma, the prevailing wind direction is out of the southeast and northwest. However, the strongest wind speeds originate mainly from the south and southwest directions and have recorded speeds exceeding 20 knots.

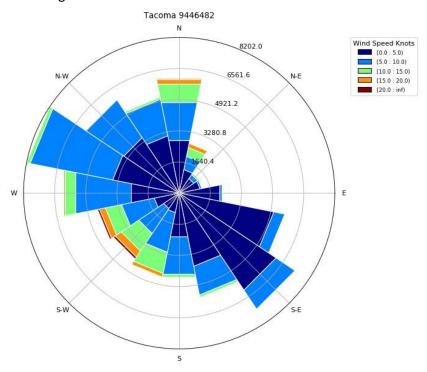


Figure B-8 Wind Rose of 2-minute average wind speeds (Tacoma, WA).

1.7 Waves

Waves in Puget Sound are fetch limited with the strongest winds out of the south and southwest (Figure B-8). However, due to the orientation of Commencement Bay, there is limited fetch in the southerly directions. Therefore the largest wind generated waves occur out of the northwest through Dalco Pass (Figure B-9), with waves near the Entrance to the Blair Waterway typically less than 0.6 m (2 feet) in height (Figure B-10).

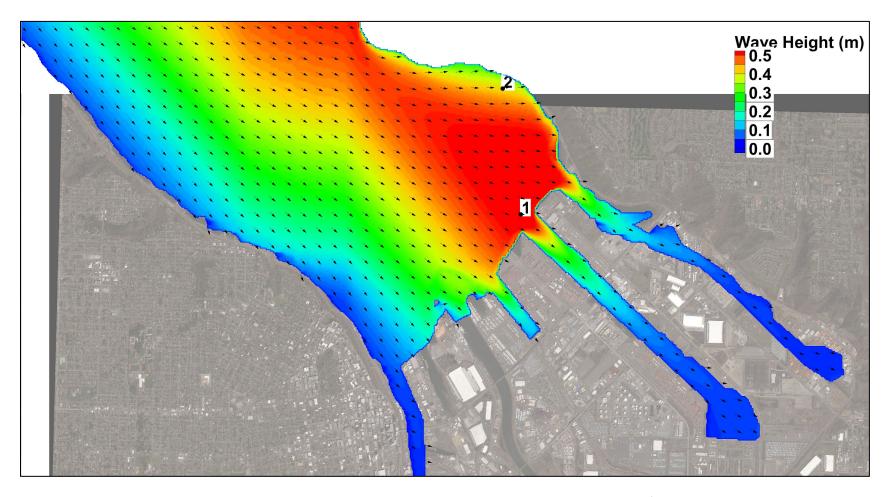


Figure B-9 CMS-WAVE modeled wave height for incident wind speed of 20 knots (10 m/s), Dir = 292.5°

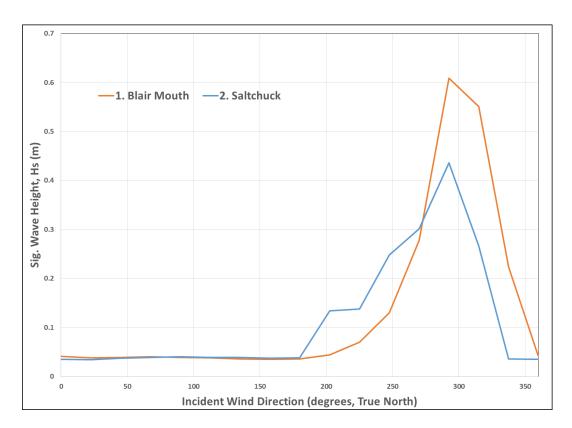


Figure B-10 CMS-WAVE computed wave height at the entrance to the Blair Waterway for a 20 knot wind event at various incident directions.

1.8 Sedimentation

An annual average sediment load on the Puyallup River is estimated at 980,000 tons per year (Czuba et al. 2011). However, the seasonal and yearly variation can be quite large with much larger sediment loads in the winter months. The majority of sedimentation affecting the Tacoma Harbor project occurs in the Puyallup River. However, most of the coarser grained material of the delta deposits into extremely deep water of Commencement Bay. This confines the extents of the alluvial fan from prograding out laterally a large distance. Finer grain material in suspension is transported throughout the harbor however due to the relatively weak currents very little sediment deposits in the Blair Waterway.

Analysis of historic condition surveys from 2010 to 2018 indicates sedimentation to be approximately 1,200 cubic yards (CY) per year in the Blair Waterway (Figure B-11). These surveys were selected based on the fact that they provided the best coverage/resolution combination of all available surveys. The region showing greatest shoaling (cool colors) occurs at the entrance of the Blair Waterway near Husky and TOTE terminals, where suspended sediments and sediment displaced by vessel propeller wash settles. The analysis shows areas of significant scour (hot colors) near the berthing areas and the centerline of the Federal navigation channel as a result of vessel propeller wash. Figure B- 12 shows the current depth conditions for Blair Waterway.

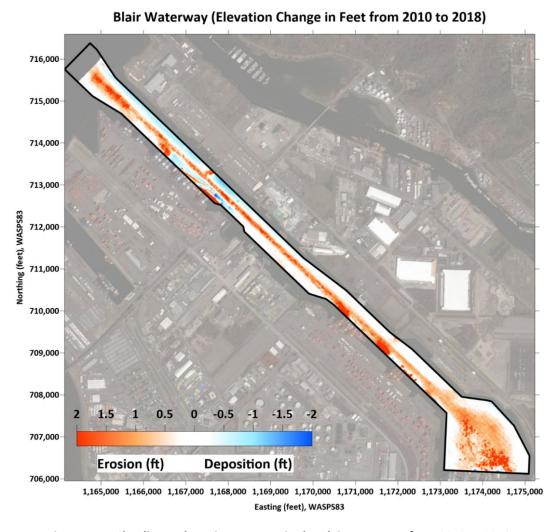


Figure B- 11 Shoaling and erosion patterns in the Blair Waterway from 2010 to 2018

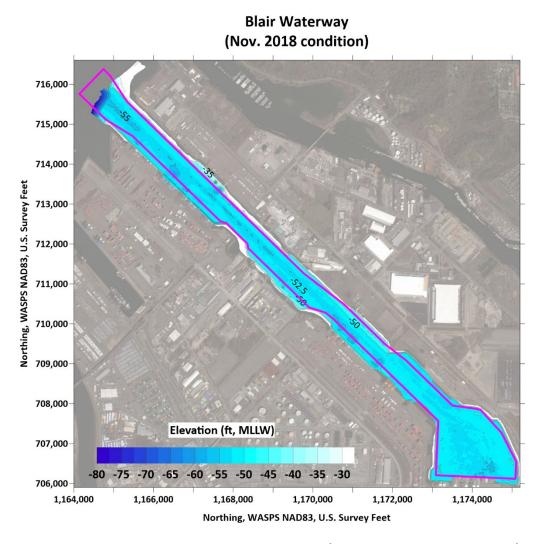


Figure B- 12 Current bathymetry in the Blair Waterway (November 2018 condition survey)

1.9 Geotechnical Considerations

1.9.1 Geology

The project is located on the historic Puyallup River delta. The downstream reaches of the Puyallup River have been channelized at the mouth with multiple training structures confining the deposition of new sediments to a localized area. The Hylebos, Blair, Sitcum, and City Waterways are manmade channels dredged into the delta for the purpose of navigation. The Puyallup River and its tributaries drain the west slopes of Mount Rainer. The upper reaches of the river traverse basaltic andesite flows and volcanic epiclastic and pyroclastic deposits. Large debris flows initiated by glacial outbursts, storms and subglacial eruptions have carried poorly sorted material down to the lower flanks of the volcano, including the lower Puyallup River valley (Dragovich et al, 1994; Swanson et al., 1992). Most recently about 5,700 years ago the Osceola Mudflow deposited large volumes of sediment in the Puyallup River valley and established the configuration of the current delta (Figure B-13). The mudflow deposits contain abundant clays of possible hydrothermal origin (Vallance and Scott, 1997).

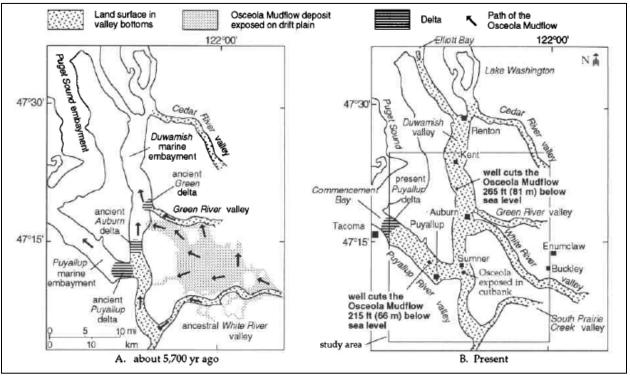


Figure B-13 Pre and Post Osceola Mudflow delta configuration (from Dragovich et al. 1994)

1.9.2 Subsurface Exploration

Subsurface vibracore borings were collected in February 2019 in the Blair Waterway (Anchor QEA 2019) to advise the likely suitability of the sediments for open water placement. In total 25 samples were collected throughout the waterway (Table B-4) (Figure B- 14). Samples contained a majority of sand sized particles with the remaining fraction consisting of silts and clays. Some gravels were encountered, however, represented less than 3% of the sample on average.

Samples identified as native have a higher percentage of sand and lower percentage of fines than the non-native and unidentified material, consistent with the expected characteristics of the native material. Data from laboratory testing by Applied Geotechnology, Inc., in spring 1991 prior to the last deepening event determined shear strengths of the silts to range from 1100 to 2300 pounds per square foot (PSF). The angle of internal friction of the sands ranges from 34 degrees to 37 degrees. Densities throughout the channel range from loose/soft to medium dense with depth (USACE 1999).

New subsurface samples will be conducted in the Pre-Construction Engineering and Design phase (PED) to ensure the dredge area is sufficiently characterized. A strategic risk-based decision was made to delay collection of new subsurface cores for this project to the PED phase as Dredged Material Management Program (DMMP) rules only allow subsurface cores to be utilized to characterize material for open water disposal suitability for 3 to 7 years following collection. The earliest potential construction year for this project is estimated at 2027 which would negate any new subsurface cores collected in the feasibility stage for use during the construction phase.

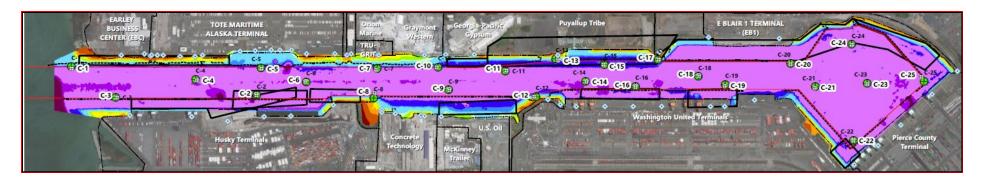


Figure B- 14 Vibracore samples collected in the Blair Waterway in February 2019 for suitability characterization (USACE 2019)

Table B-4 Vibracore sampling data

| Station | х | Υ | Mudline Elevation ft, MLLW | Native Horizon Elevation ft, MLLW |
|---------|-----------|----------|----------------------------------|-----------------------------------|
| C-1 | 1165157.4 | 715708.8 | -49.9 | -53.1 |
| | 1105157.4 | /13/06.6 | -49.9 | -33.1 |
| C-2 | 1166970.1 | 713363.2 | -51.4 | -52.9 |
| C-3 | 1165354.3 | 714876 | -52.5 | Undetermined |
| C-4 | 1166455.2 | 714192.3 | -53.7 | -53.7 |
| C-5 | 1167320 | 713610.6 | -51.5 | -52.2 |
| C-6 | 1167677.8 | 712979.4 | -53.9 | -53.9 |
| C-7 | 1168617.2 | 712335.3 | -50.4 | -51.3 |
| C-8 | 1168345.9 | 712082.2 | -52 | Undetermined |
| C-9 | 1169230.3 | 711295.5 | -53 | -53 |
| C-10 | 1169339.5 | 711694.4 | -49 | -54.6 |
| C-11 | 1170100.3 | 710890.6 | -51.6 | -53.3 |
| C-12 | 1170124.7 | 710281.3 | -22.7 | Undetermined |
| C-13 | 1170797.6 | 710436.2 | -39 | Undetermined |

| Station | Х | Υ | Mudline Elevation | Native Horizon Elevation |
|---------|-----------|----------|----------------------|-----------------------------|
| | | | ft, MLLW | ft, MLLW |
| C-14 | 1170888.7 | 709878.9 | -52.6 | -56.6 |
| C-15 | 1171275.8 | 709886.8 | -45.6 | Undetermined |
| C-16 | 1171390.8 | 709280.6 | -50.6 | -52.6 |
| C-17 | 1171960.3 | 709337.6 | -21.7 | Undetermined |
| C-18 | 1172236.9 | 708704.3 | -52.2 | -53.1 |
| C-19 | 1172424.4 | 708310 | -52.4 | -52.4 |
| C-20 | 1173409.8 | 707832.4 | -51.3 | -51.3 |
| C-21 | 1173431.1 | 707291.8 | -53.7 | -53.7 |
| C-22 | 1173278.7 | 706259.8 | -51 | -51 |
| C-23 | 1174069.4 | 706752.9 | -53.7 | -53.7 |
| C-24 | 1174329.1 | 707378.1 | -51.1 | -51.9 |
| C-25 | 1174764.8 | 706243 | -51.4 | -54.2 |

2 **Project History**

The Blair Waterway (originally named the Wapato Waterway) was originally constructed by local interests between in the 1920's to 1940's. The Rivers and Harbor Act of 1935 authorized a Federal project for Operations and maintenance for a channel 700 feet wide and 30 feet deep. In 1949 the Wapato Waterway was renamed the Port Industrial Waterway, and in 1952, the Port extended a 250 foot wide by 30 foot deep (-30 feet MLLW) (hereafter expressed as -X MLLW; which indicates the number of feet below MLLW) channel to Lincoln Avenue.

In 1953, the USACE investigated the feasibility of extending and improving the waterway to Lincoln Avenue. The study was favorable and recommended authorization of a channel 250 feet wide and 800 feet long by 30 feet deep, except for a 150-foot-wide restriction at the East 11th Street Bridge. The project was authorized in 1954 and construction was completed in 1956.

In 1955, the USACE initiated a study to extend the Port Industrial waterway beyond Lincoln Avenue. This project was authorized by the Flood Control Act of 1962. Construction was completed in 1969 to deepen the federal channel to -35 feet MLLW, extending the waterway by approximately 3900 feet at a width of 300 feet, and adding a Turning Basin 1200 feet wide beyond the end of the channel, and revising the widths of the existing channel to 600 feet between East 1st Street and Lincoln Avenue, and reducing the width to 650 feet seaward of East 11th Street. ...

Renamed the Blair Waterway in 1969, the Blair Waterway extends 2.6 miles and serves seven marine terminal facilities located on Port owned land, as well as several shipping and industrial facilities on private lands.

In 1979, further revisions to the Blair waterway were recommended by USACE, and a modified version of this proposal was authorized by Congress in 1979, and 1986. The channel was deepened to -45 feet MLLW, and widened to 520 feet except in the vicinity of the East 11th Street Bridge, where it was 300 feet wide, and 260 feet wide between Lincoln Avenue and the 1200 feet turning basin.

During the period 1993-1995, the entire navigation channel and certain berth areas were dredged as part of the Sitcum Waterway Remediation Project. This project was performed by the Port pursuant to a federal Consent Decree under the Environmental Protection Agency's (EPA) Superfund cleanup authorities (Comprehensive Environmental Response, Compensation, and Liability Act of 1980, or CERCLA). Contaminated sediments were removed from the project area and capped in the Milwaukee Waterway nearshore confined disposal site. The dredging conducted as part of this project deepened the waterway to approximately -48 feet MLLW from Commencement Bay to station 94+40, and to approximately -45 feet MLLW in the remainder of the waterway including the turning basin.

Several other channel improvement projects have been completed in the Blair Waterway since completion of the dredging conducted as part of the Sitcum Waterway Remediation Project in 1995. Demolition of the East 11th Street Bridge and removal of part of the southwest bridge abutment fill was

completed in March 1998, providing a 355-foot wide channel through this reach with a depth of –48 feet mllw. The Blair Waterway Turning Basin Expansion Project, also completed in March 1998, provided a 1,400 foot turning radius at a depth of –45 feet mllw by dredging and cutback of the east bank. Both projects included disposal of dredged material at the Commencement Bay Puget Sound Dredge Disposal Analysis (PSDDA) site.

In 1999, the USACE and the Port of Tacoma pursued a Section 107 channel improvement to deepen and widen the Blair waterway so that the federal channel was 520 feet wide from the mouth to the 11th Street Bridge reach, 520 feet from 11th Street to Lincoln Avenue, 330 feet from Lincoln Avenue to the turning basin, and a 1300 foot turning basin. The project was constructed in 2000 and the federally authorized navigation channel was deepened throughout to -51 feet MLLW. This construction generally completed the current configuration of the authorized federal navigation channel in the Blair waterway.

Another notable Superfund action in Blair Waterway included dredging of tributyltin (TBT) contaminated sediments at Pier 4 as part of a Time Critical Removal Action. This action was completed in 2016 under the regulatory authority of the U.S. EPA and included removal of 71,000 cubic yards of contaminated sediment in conjunction with the redevelopment of Pier 4.

3 **Design considerations**

3.1 Vessel Traffic

Data on vessels calling port since 2012 have been compiled from the National Navigation Operation & Management Performance Evaluation & Assessment System database. Vessels transiting the Blair Waterway include containers, tankers, and breakbulk cargo ships. Approximately 4,153 vessels transited the Blair Waterway from January 2012 to December 2017, 2,575 of these being container ships. The largest beam vessels generally called on Washington United Terminals. The largest dimensions to transit the Blair Waterway during these years, which do not necessarily correspond to the same vessel, are as follows: Beam (B) = 160 feet, Length (LOA) = 1,146 feet, Draft (D) = 52.5 feet, Dead weight tonnage (DWT) = 134,869 metric tons.

Table B-5 lists the average and maximum vessel dimension for vessels calling on individual terminals within the waterway. Vessels typically enter the waterway at 3 knots and use 2-3 tug assists depending on the pilot and the conditions. The current operating guidance used by the pilots is to have an underkeel clearance of 10% of the draft.

Table B-5 Blair Waterway (Vessel Statistics 2012-2017)

| DIMENSION ¹ | UNIT HUSK | Y PCT | WUT | Other | All |
|------------------------|-----------|-------|-----|-------|-----|
|------------------------|-----------|-------|-----|-------|-----|

¹ B = Beam Width; D = Operation Draft; DD = Design Draft; DWT = Dead Weight Tonnage; N = Number of Vessels

| Sum of Call Count | Calls | 698 | 801 | 1,232 | 1,422 | 4,153 |
|----------------------|-------------|--------|---------|---------|---------|---------|
| Average Beam (B) | Feet | 119 | 131 | 127 | 89 | 113 |
| Max. Beam (B) | Feet | 132 | 159 | 160 | 144 | 160 |
| Average Draft (D) | Feet | 35 | 37 | 33 | 26 | 32 |
| Max. Draft (D) | Feet | 46 | 50 | 48 | 43 | 50 |
| Average Length (LOA) | Feet | 824 | 938 | 997 | 578 | 811 |
| Max. Length (LOA) | Feet | 998 | 1,099 | 1,146 | 1,101 | 1,146 |
| Median (DWT) | Metric tons | 58,248 | 68,098 | 82,213 | 23,120 | 56,221 |
| Max (DWT) | Metric tons | 85,626 | 134,869 | 124,092 | 115,940 | 134,869 |

3.2 Design Vessel

Vessels are progressively getting larger and future vessel fleet forecasts continue show this trend. Trade between the U.S. West Coast and Asia is not constrained by beam restrictions imposed by the Panama Canal thus could hypothetically could receive wider beam vessels. Carriers such as CMA CGM, Evergreen and Hyundai Merchant Marine, all of which are expected to operate increased size vessels, call on the Port of Tacoma regularly. On the Blair Waterway, these vessels will dock at Husky and Washington United Terminals. As such, cranes have been upgraded in Husky Terminal to have an outreach capacity of 210 feet (or 24 container wide vessels). Washington United Terminals are set up with 2 cranes having a 24 container outreach while the remaining 4 have an 18 box outreach. The forecasted maximum vessel is a Generation IV E-Class container ship with a capacity of up to 15,000 twenty-foot equivalent units (TEU), or approximately 157,000 dead weight tons (DWT). The *Emma Maersk* represents a typical vessel in this fleet. Design dimensions considered for this study are presented below:

- Beam (B) = 184 feet
- Length (L) = 1,302 feet
- Draft (D) 52.5 feet

3.3 Channel Design

The currently authorized Blair Waterway navigation channel is approximately 13,530 feet in length. Width varies along the waterway and starts at 520 feet decreasing to 330 feet at its narrowest before increasing again to 1,682 at the turning Basin. USACE Engineering Manual for deep draft navigation projects, EM 1110-2-1613, suggests a design channel width range of two to six (2.0 to 6.0) times the design beam width for one-way ship traffic for a canal type channel with negligible currents (USACE 2006). Thus, according to guidance, the navigation channel would require a minimum width of 2.0*(184 feet) = 368 feet and an arbitrary design width of two and a half (2.5) times the design beam width was adopted as a starting point. The proposed channel makes use of the existing authorized channel as much as possible which meets width criteria at the entrance and was modified to achieve the dimensions wherever it does not. A feasibility level ship simulation study was conducted in April 2019 by ERDC-CHL in Vicksburg, MS to

determine the adequacy of the proposed design. The exercise resulted in the finalized footprint for the Federal navigation channel shown in Figure B-15.

For this feasibility study, channel depth requirements were exclusively based on vessel draft as per current Puget Sound Pilots document "General Guidelines for Vessels Transiting Restricted Waterways or Ports". A channel depth of [vessel draft] + [ten percent of the vessel draft] was adopted over the entire design for a total of 52.5' + 0.10*52.5' = 58'. Calculations were made to determine trim, squat, and tidal effects, as defined below, on transiting vessels and the channel depth found to be adequate. A 2' overdepth allowance was considered for volume calculations, to account for the imprecise nature of the dredging operation.

<u>Design Draft</u>. The design vessel for Blair Waterway has a loaded draft of 52.5 feet.

<u>Minimum safe clearance</u>. A minimum of two additional feet in depth is required under the keel after all other requirements for depth have been met. This is needed to avoid damage to ships propellers from sunken timbers and debris, to avoid fouling of pumps and condensers by bottom material, reduce propeller wash effects, provide allowance for spot shoals, and offset poor steerage effects caused by underkeel clearance close to the seabed.

<u>Trim.</u> The difference between the vessel draft at midship and the bow or stern is termed trim. It is often complex and expensive to keep a ship at even keel and a nose down vessel does not maneuver well, so a vessel is often loaded to keep the stern lower than the bow.

<u>Squat.</u> A moving ship causes a drawdown of the water surface causing the vessel to ride lower relative to a fixed datum. Squat is dependent upon many variables including vessel speed through the water, water depth, and vessel to channel blockage ratio. Vessel speed in the Waterways is generally limited to less than 4 knots. Computation using the empirical formula (Eryuzulu et al 1994) indicate squat would be approximately 0.5 feet in Blair Waterway.

<u>Tidal effects.</u> The reference datum, 0.0 foot, for the project area is mean lower low water (MLLW). A tidal analysis shows that on the average, over a period of one year, the tide is below the reference 4% of the time. Similarly, the tide is below the elevation -2.0 feet MLLW, approximately 0.1% of the year. The economic analysis (Appendix A) takes into account both the design and sailing draft of each vessel class and the availability of tide when each vessel calls using NOAA tide stations that are included in the HarborSym model. The transiting costs are based on the calls at each project depth and by evaluating how the calls would differ under each scenario. "Riding the tide" is a common practice in multiple ports and the Corps economic analysis takes that into account to determine if an additional foot of channel depth is more efficient than allowing a certain number of vessels to wait for the tide when their sailing draft requires it. The underkeel clearance requirement used in the analysis is based on existing practices for the current fleet. Those practices, along with pilot interviews, were used to estimate the additional underkeel clearance required for vessels larger than the current fleet that are anticipated to call during the period of analysis. The recommended plan is based on taking into account the reduction in total

transiting costs, which includes any delays for tide, for the forecasted fleet during the period of analysis and the total project cost for each alternative.

Turning Basin Design

The Federal channel turning Basin at the head of the Blair Waterway was last designed for a 2nd generation Post-Panamax containership with a length in excess of 900 feet (USACE 1999). Since then the Port of Tacoma dredged the areas outside the Federal channel to a consistent -51 MLLW to accommodate larger vessels. However, with the new design vessel the extents of the Federal channel will need to be expanded. EM 1110-2-1613 recommends a turning basin size should provide a minimum turning diameter of a t least 1.2 times length of the design ship where prevailing currents are 0.5 knot of less. This results in a turning basin diameter of 1,600 feet. This turning basin size was evaluated in the 2019 feasibility-level ship simulation. However, during the simulation the Puget Sound Pilots indicated this size turning basin was insufficient as the result created areas of varying depth that may be perceived as usable. The recommendation was to extend the eastern side of the turning Basin approximately 350 feet to avoid this problem. The final turning basin design incorporated these recommendations.

3.4 Berthing Areas

The berthing areas along the Blair Waterway have been increased to accommodate the new design vessel and the channel offset as necessary to avoid overlap between berths and navigation channel. The local sponsor will be responsible for all O&M related dredging in the berthing areas including to be commensurate with the Federal Channel.

In the April 2019 ship simulation study, multiple scenarios were modeled to evaluate different transit configurations of the design vessel as well as berthed vessel configurations. Inbound transits were considered into Husky Terminals, Washington United Terminals and Pierce County Terminals. Outbound transits were considered from the same locations in a variety of configurations including backing out stern first into Commencement Bay. Alternately ships docked at Washington United Terminals utilized the turning Basin to turn the ship around and head out bow first. Puget Sound Pilots conducting the simulation confirmed this is not uncommon, especially when faced with foggy, low visibility conditions. Winds were simulated from the prevailing southwest direction as well as from the north with speeds ranging to a maximum of 30 knots. Design vessels were berthed at Husky, Washington United, and Pierce County terminals sans the destination berth. All other waterway berths, East Blair, East Blair 1 and Tote Maritime had their respective vessels docked to simulate as complicated a transit as possible.

The pilots employed three tugs at all times in different configuration. In order to narrow the swept path of the vessel while passing berthed vessels, a T-squared tug package, (2-50 ton tugs) on the stern of the inbound vessel and (1-75 ton tug) on the bow quarter was tried on several runs. The scenario was tested for multiple environmental wind conditions (15 knot south, 15 knot south-southwest, 15 knot northwest, and 25 knot northwest winds).

3.5 Utilities

Various utilities cross beneath the Blair Waterway near the former 11th Street bridge. These have all been relocated to depths below the maximum expected dredging depths associated with this project. A communication cable, two power cables (15kV and 115 kV), and water line all cross the channel below - 90 MLLW. Additionally, a sanitary sewer crosses near Lincoln Street. This sewer was relocated to a depth of -80 MLLW in the early 1990s prior to the last deepening construction.

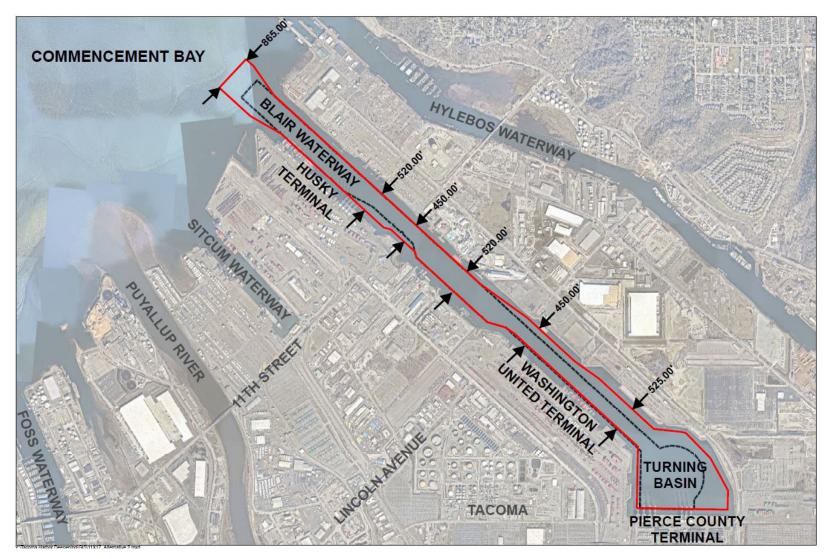


Figure B- 15 Tacoma Harbor Navigation Improvement Project – Channel Design and Berthing Area (Proposed channel shown in red, existing channel in black)

3.6 Slope stability

Preliminary modelling indicates that the recommended sideslope for the Federal channel is 1 vertical on 2 horizontal or greater/shallower. The berthing areas are maintained by the Port of Tacoma commensurate to the Federal channel depth. In order to ensure sideslope stability, the Port has constructed bulkheads to support the wharf and local service facilities.

Additional sideslope stabilization may be necessary along the following stationing presented below:

- STA 44+00.00 to STA 48+00.00
- STA 74+50.00 to STA 82+00.00
- STA 94+50.00 to STA 97+50.00
- STA 118+00.00 to STA 125+50.00

Figure B- 16 shows the potential locations where sideslope stabilization may be necessary along the Blair Waterway. Sideslope improvements have been appropriately factored into the cost risk schedule. Sideslope stability requirements will be further analyzed and addressed in PED phase when ship simulation confirms the final channel alignment and width.

3.6.1 Methodology

The submerged side slopes in the Blair Waterway were evaluated to determine potential impacts to their stability as a result of the proposed deepening and widening of the channel. Assumptions for this analysis included: the existing waterway footprint would not be expanded, existing slopes without wharfs are stable since the last dredge in 2001, and previous geotechnical investigations would be used to characterize soil layers for analysis. Areas for analysis were identified by projecting a 2H:1V slope from the proposed dredged channel toe (-58 feet with 2 feet of overdepth/overdredge) landward to the point at which it daylights at the upland surface. This exercise revealed four locations (Figure 16) where such an assumed slope would either require an expansion of the existing waterway footprint, or where steeper slopes would be necessary to fit within the existing waterway.

Bathymetry data from 2018 indicated that the existing submerged slopes in these locations were approximately 2H:1V, or shallower. Modeling conducted by USACE H&H indicated that 1.5H:1V side slopes would allow the proposed dredged channel to "fit" within the Blair Waterway footprint.

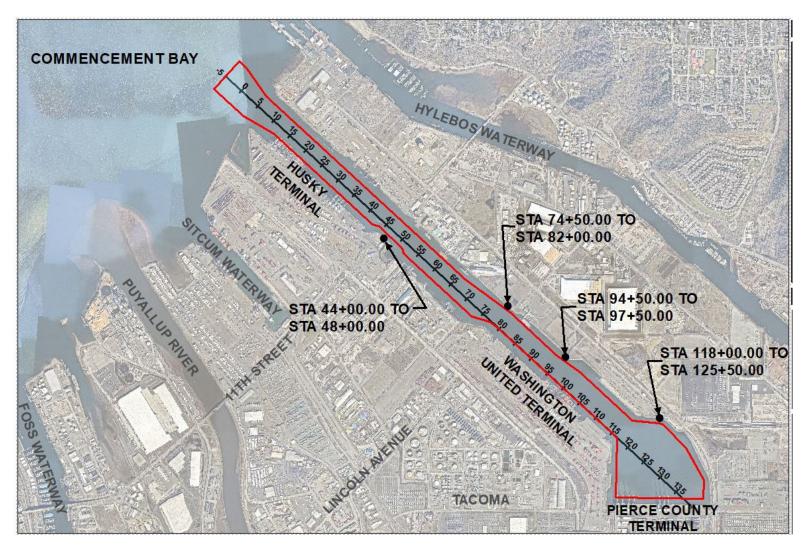


Figure B- 16 Areas of potential slope stabilization

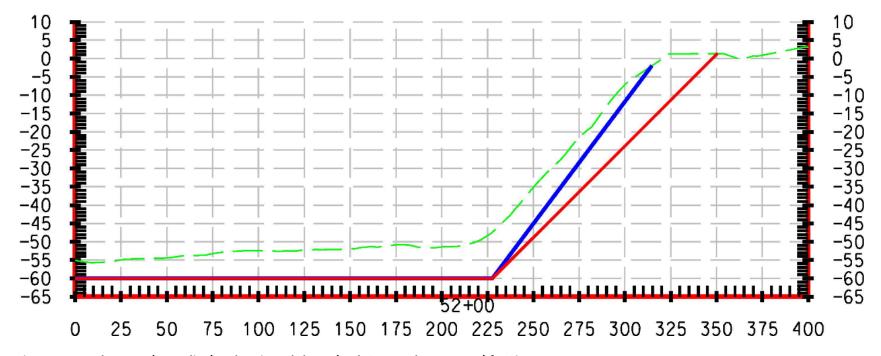


Figure B-17 Bathymetry (green line) and projected slopes (Red=2H:1V, Blue=1.5H:1V) for Site 1

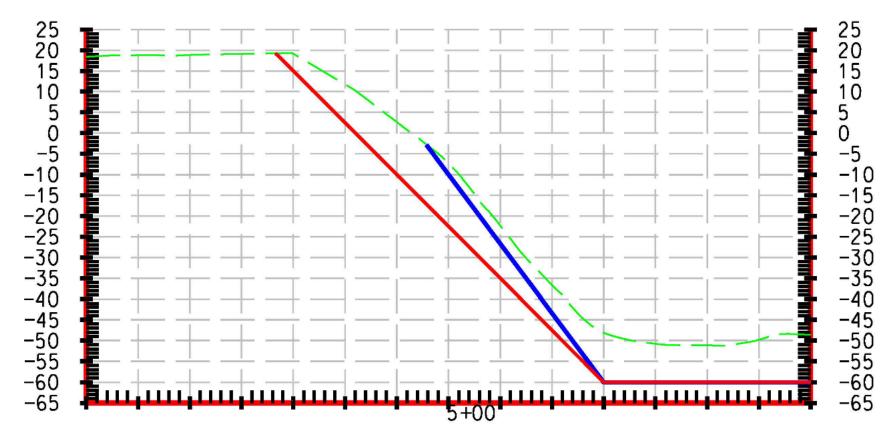


Figure B-18 Bathymetry (green line) and projected slopes (Red=2H:1V, Blue =1.5H:1V) for Site 4

Slope stability analysis was conducted for two of the four sites: Site 1 (STA 44+00 to 48+00) and Site 4 (STA 118+00 to 125+50), where previous geotechnical boring data was identified.

3.6.2 Analysis

The GEOSTUDIO 2019 SLOPE/W program was utilized to model slope stability. The default analysis type, Spencer's, was run for all scenarios using half-sine Side Function and Piezometric Line pore water pressure conditions. Soil layers for each location were informed by previous geotechnical borings performed by others. The piezometric line is assumed/hypothetical to allow a preliminary assessment of the slopes at 1.5H:1V slope and a 60 foot depth. Modelling assumed 64 lbs. per cubic foot for salt water. Modelling drawdown for tidal influence will be completed in the engineering phase of the project. Additionally, a comparison of the existing condition with seismic pseudo static existing/dredged will be performed to inform acceptable limits for slope failures.

Table B-6 Location, material properties, and source

| Location | Material | Density | Cohesion | Friction Angle | Source |
|------------------------|---|---------|----------|-------------------|--------------|
| STA 44+00- 48+00 | ML | 100 | 300 | 30 | Hartcrowser |
| STA 44+00- 48+00 | SP-SM | 110 | 0 | 33 | Hartcrowser |
| STA 118- 125+50 | Dense silty SAND | 125 | 0 | 34 | GeoEngineers |
| STA 118- 125+50 | Loose to med dense SAND | 120 | 0 | 31 | GeoEngineers |
| STA 118- 125+50 | Medium dense to dense SAND w/silt | 125 | 0 | 34 | GeoEngineers |
| STA 118- 125+50 | Soft SILT | 110 | 0 | 24 | GeoEngineers |

Geotechnical Engineering Services [Blair Waterway Widening/ Kaiser Site Development, Port of Tacoma, Washington, 2004 by Geo Engineers (Annex 7). Port of Tacoma Pier 4 Phase 2 Reconfiguration Tacoma, Washington, 2015 by HartCrowser (Annex 6)].

Three scenarios were run for STA 44+00 to 48+00: existing conditions >2H:1V (not shown), 2H:1V dredged, and 2H:1V dredged, pseudo-static (Figure B-17and Figure B-18). The existing condition model was used to verify the validity of the inputs based upon the assumption that the existing condition is stable. The existing condition model was not used to validate STA 118+00 to 125+50 because the 2H:1V slope model is steeper than the existing slope, based upon recent bathymetry data. The slopes were evaluated for 1.5:1V dredged, and 1.5:1V dredged, pseudo-static (Figure B-17 and Figure B-18). Modelling for pseudo static utilized seismic conditions noted in stability modeling by others (see Annex 6 and 7). According to EM 1110-2-1902 Engineering and Design - Slope Stability, "typical minimum acceptable values of factor of safety are about 1.3 for end of construction and multistage loading, 1.5 for normal long-term loading conditions." PGA for pseudostatic analysis = 0.18g. (Note: Stationing for figures is correct, ignore site reference.)

3.6.3 Results

Table B-7 Location, condition, and factor of safety.

| Location | Condition | FS (Factor of Safety) | |
|-----------------|------------------------|-----------------------|--|
| STA 44+00-48+00 | 2H:1V Dredged | 1.31 | |
| STA 44+00-48+00 | 2H:1V Dredged, Pseudo- | 0.72 | |
| | Static | | |
| STA 118-125+50 | Existing Conditions | 1.48 | |
| | | | |
| STA 118-125+50 | 1.5H:1V Dredged | 0.81 | |
| STA 118-125+50 | 1.5H:1V Dredged | 0.39 | |
| | Pseudo-Static | | |

Previous wharf and pier projects have relied upon driven piles and stone columns to improve slope stability, especially to meet seismic design standards. Driven piles, stone columns, or secant pile walls could be used for the final design at these locations; however, less robust designs may be determined as acceptable after further analysis during the engineering phase of this study. No alternatives have been evaluated during the feasibility stage of this project.

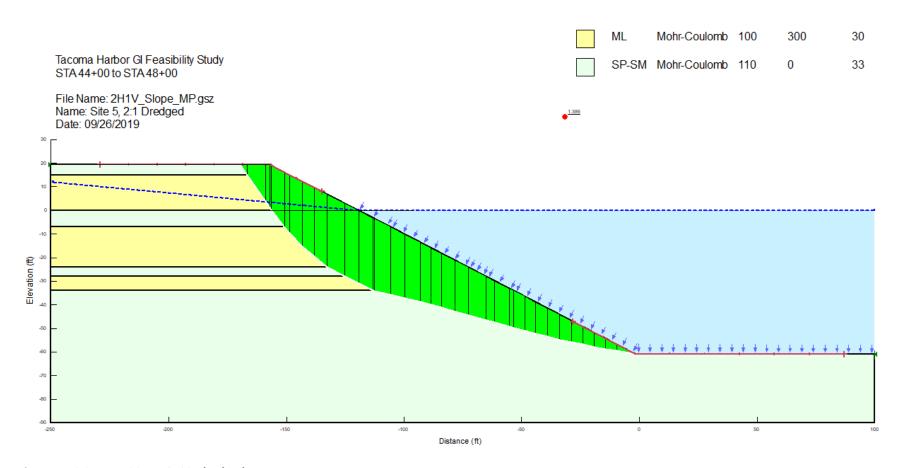


Figure B-19 STA 44+00 to 48+00, dredged.

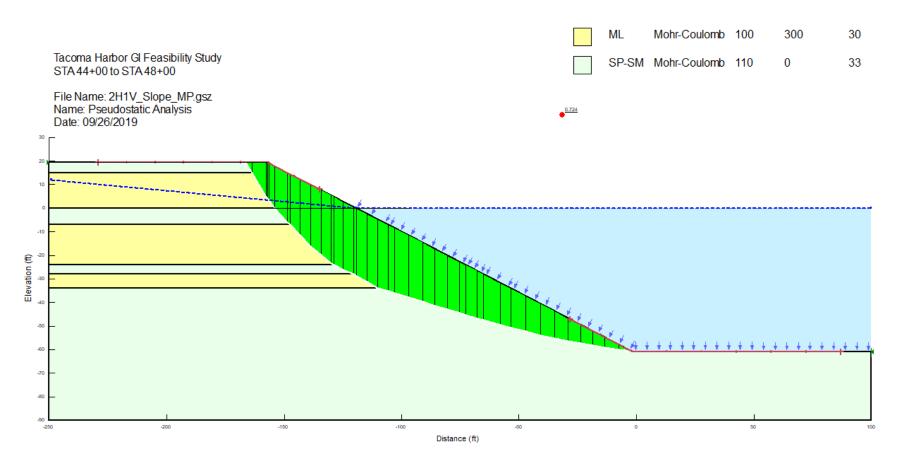


Figure B-20 5: STA 44+00 to 48+00, pseudo-static.

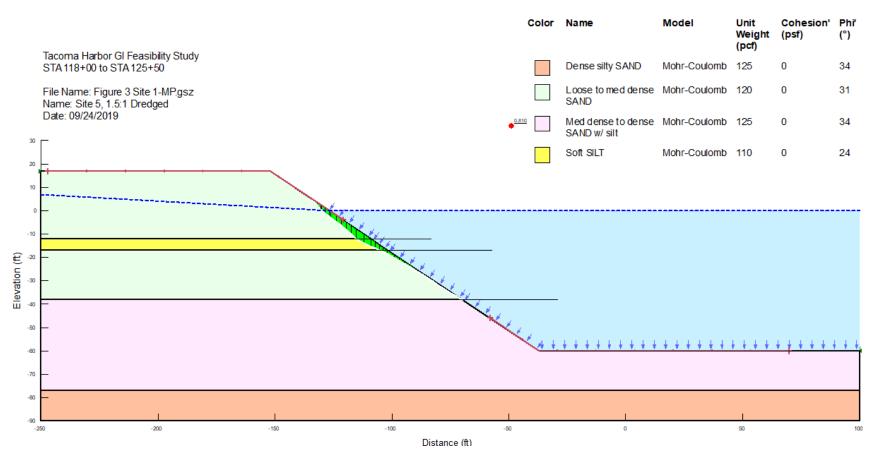


Figure B- 21 STA 118+00 to 125+50, dredged.

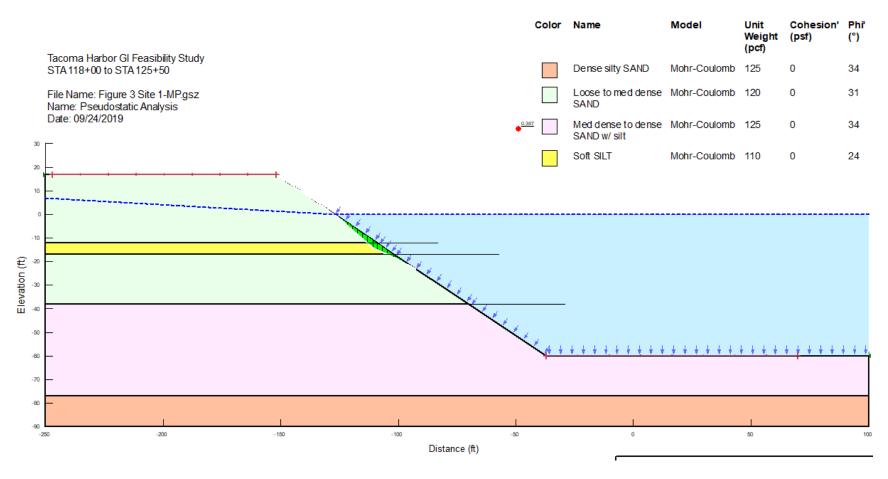


Figure B- 22 STA 118+00 to 125+50, pseudo-static

3.7 Dredging and placement of dredged materials

Three alternatives are considered in the Feasibility Report.

- Alternative 1: No Action maintain current project depth of -51 MLLW
- Alternative 2: Blair Waterway Deepening Deepen project depth to -58 MLLW in entire waterway.
- Alternative 2a: Blair Waterway Deepening through Husky Terminal Deepen project depth to -58 MLLW up to the Husky Terminal
- Alternative 2b: National Economic Development (NED), Deepen project depth to -57 MLLW in entire waterway.

The maximum allowable dredging depth for each alternative includes 2 feet tolerance beyond the project depth to account for inaccuracies during dredging operations. For each alternative, it is assumed the channel would be dredged to its project depth plus 2 feet overdepth and to its full width. The suitability of dredged material in the Blair Waterway has been characterized by Anchor QEA, LLC (USACE, 2019d) at the behest of the Port of Tacoma.

3.7.1 Dredged material quantities

For economic development analysis, the channel was sub-divided into three (3) reaches: 1) Husky (Sta-5+00.00 to Sta 41+85.18), 2) WUT (Washington United Terminals; Sta 41+85.18 to Sta 108+40.43) and 3) Turning Basin (Sta 108+40.43 to Sta 137+24.11) (Figure B-23). A contingency of 10% is added to the neatline volume to account for additional sedimentation between the survey and project implementation. Quantities were computed through surface to surface calculations in MicroStation InRoads. A Digital terrain model (DTM) was developed from XYZ triplet data set surveyed by the Navigation Section Hydrosurvey Unit and data provided by the Port of Tacoma. The waterways were surveyed using a Reson 712 Multibeam, 140° swath, 400 kHz transducer in HYPACK, Inc. HYSWEEP® software. Tidal corrections were performed using RTK. Delaney triangulation was used to create the DTM surface. The "Generate Sloped Surface" command in InRoads is used to project the channel sideslopes of 1 vertical on 2 horizontal (1:2) from the channel bottom up to the point of intersection with the condition survey DTM. Assumptions and methodology for computing dredged material volumes are described in more detail in (USACE 2019). Tables B-8 and B-9 list dredged volumes to obtain the project depth plus 2-feet of overdepth allowance for Alternative 2b. Table B-10 and Table B-11 list dredged volumes to obtain the project depth plus 2-feet of overdepth allowance for Alternative 2a and by extension for Alternative 2. Suitability of dredged material for open water placement was estimated from chemical analysis of sediment cores collected in February 2019 and discussed in DMMP Advisory Determination dated June 25, 2019 (USACE 2019d) available in the Annex to this document. A full sediment characterization will be performed in PED to formally characterize dredged material per the requirements of the DMMP User's Manual (DMMP 2018)

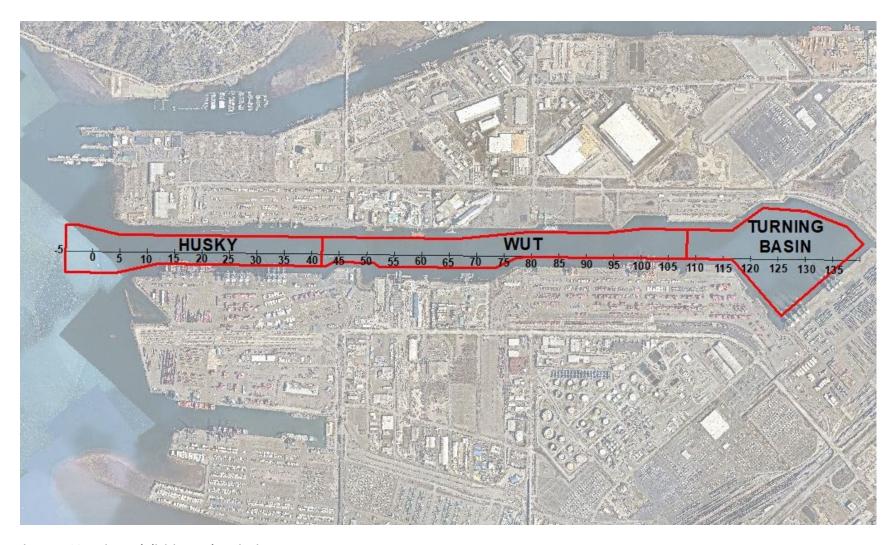


Figure B- 23 Project subdivision and stationing.

Table B-8 Required total dredging for recommended channel depth for NED alternative, dredge depth = -57' MLLW

| Channel Reach | Stationing | Volume |
|----------------|------------------------|-----------|
| Blair Waterway | - | CY |
| HUSKY | -5+00.00 TO 41+85.18 | 674,000 |
| WUT | 41+85.18 TO 108+40.43 | 1,183,000 |
| TURNING BASIN | 108+40.43 TO 137+24.11 | 947,000 |
| Total | | 2,804,000 |

Table B- 9 Volume breakdown by material and suitability for NED alternative, dredge depth = -57' MLLW

| Channel Reach | Native Material | Non-Native Material | Suitable for In- Water Disposal | Un-suitable for In- Water Disposal |
|----------------|--------------------|------------------------|------------------------------------|---------------------------------------|
| Blair Waterway | CY | CY | CY | CY |
| HUSKY | 550,000 | 123,000 | 600,000 | 74,000 |
| WUT | 823,000 | 360,000 | 934,000 | 249,000 |
| TURNING BASIN | 858,000 | 90,000 | 878,000 | 69,000 |
| Total | 2,231,000 | 573,000 | 2,412,000 | 392,000 |

Table B-10 Quantity breakdown by material and suitability for Maximum Expansion alternative including Husky Alternative; dredge depth = -58', MLLW².

| Channel Reach | Native Material | Non-Native Material | Suitable for In- Water Disposal | Un-suitable for In- Water Disposal |
|----------------|--------------------|------------------------|------------------------------------|---------------------------------------|
| Blair Waterway | CY | CY | CY | CY |
| HUSKY | 658,000 | 122,000 | 697,000 | 83,000 |
| WUT | 980,000 | 359,000 | 1,074,000 | 265,000 |
| TURNING BASIN | 1,003,000 | 89,000 | 1,012,000 | 80,000 |
| Total | 2,641,000 | 570,000 | 2,783,000 | 428,000 |

Table B-11 Required total dredging for recommended channel depth for Maximum Expansion Alternative, including Husky Alternative; dredge depth = -58′, MLLW³.

| Channel Reach | Stationing | Volume |
|----------------|------------------------|-----------|
| Blair Waterway | STA | CY |
| HUSKY | -5+00.00 TO 41+85.18 | 780,000 |
| WUT | 41+85.18 TO 108+40.43 | 1,339,000 |
| TURNING BASIN | 108+40.43 TO 137+24.11 | 1,092,000 |
| Total | | 3,211,000 |

³ Neatline volumes include 2-feet of overdepth and a 10% contingency to account for shoaling prior to implementation

3.7.2 Dredging schedule and production

It is assumed that one clamshell and two bottom dump scow barges will be utilized to meet a four-year completion schedule. Historical deepening dredging production during the 1999-2000 Blair Waterway cutback project averaged 8,000 cubic yards per day (Project # 20-520031, Port of Tacoma). The environmental dredging window in the project area is 16 August to 15 February. Based on the production rate, the Blair Waterway would take four dredge seasons to complete.

The February 2019 subsurface sampling established a native/non-native horizon, and dredged material open water placement suitability percentages were assigned. Native material is expected to be more densely compacted than non-native material. Denser native material is expected to result in lower production than O&M dredging. This will affect dredge production rates and, ultimately, schedule and cost. In order to comply with regulations requiring emissions to be kept below 100 TPY, construction has been scheduled for 4 years as per section 3.5 of the main report.

3.7.3 Placement of dredged materials

Three possible placement options were evaluated. Placement of dredged material suitable for open water disposal will be hauled by a bottom dump barge approximately 2.6 nautical miles northwest of the project area to the DMMP open-water disposal site in Commencement Bay (Figure B- 24). Beneficial Use of dredged material is also an alternative and is explained further in sub-section 3.7.3.2. Material that is neither suitable for beneficial reuse nor open-water disposal will be taken to an upland disposal facility, as discussed in sub-section 3.7.3.3.

3.7.3.1 Commencement Bay DMMP disposal site

The DMMP open-water disposal site has been identified as the Federal standard for placement of dredged material for this project. The disposal site is managed through the Dredged Material Management Program, which consists of the U.S. Army Corps of Engineers, U.S. Environmental Protection Agency - Region 10, Washington State Department of Natural Resources, and Washington State Department of Ecology (DMMP 2018). The disposal site is at a water depth of 540 to 560 feet, and the disposal zone is a 1,800 foot diameter circle (Figure B- 25). Following various waterway improvement projects conducted by the Port of Tacoma, approximately 8 million CY has been placed in the site between 1995 and 2007. A northwest drift of material has been observed outside of the disposal site (USACE, 2009). It is anticipated that the DMMP agencies will require stricter operational controls during this project to ensure material stays within the disposal site boundaries. This may require temporary shifts in the target zone, altering the heading of the scow prior to placement, and possibly controlling the timing of the disposal to avoid peak ebb currents.

3.7.3.2 *Open water disposal site capacity*

The Corps' Engineering Regulation ER 1105-2-100 mandates that all Corps Districts develop a Dredged Material Management Plan for all Federal harbor projects where there is an indication of insufficient placement capacity to accommodate maintenance dredging for the next 20 years. The largest volume of material will be required during construction. The Commencement Bay Site has sufficient capacity to

accommodate this project. Site capacity was recently reevaluated for an additional as per Puget Sound Dredged Disposal Analysis methodology (USACE 2009). The evaluation found the site adequate for placement of up to an additional 15 MCY of material. The MDFATE numerical model was employed to predict the geometry of the placed mound while CMS-M2D determined currents would not be strong enough to initiate bed load transport. There will not be significant O&M dredging in the Blair Waterway following construction given low sedimentation rates. O&M dredging on the Blair Waterway is currently not required. However, it is anticipated that some O&M dredging will be needed over the 50-year project life to maintain the authorized depth. O&M dredging is anticipated two times, at years 25 and 50, following construction. A maximum volume of 60,000 cubic yards of O&M dredging over the next 50 years is estimated.

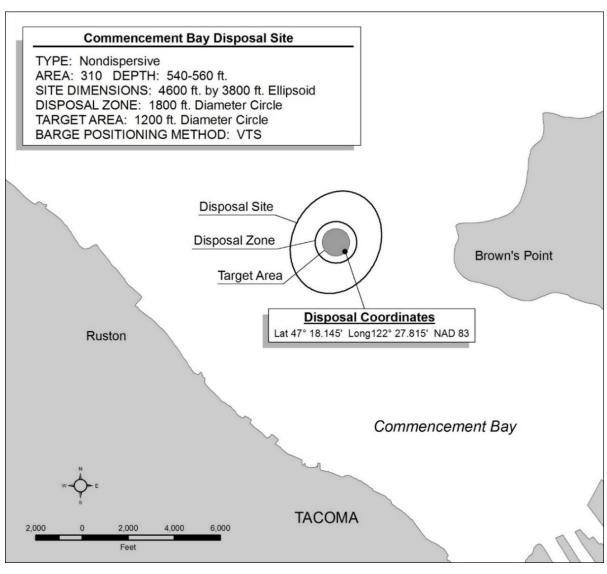


Figure B- 24 Commencement Bay PSDDA open water disposal site; north of the Tacoma Harbor project.

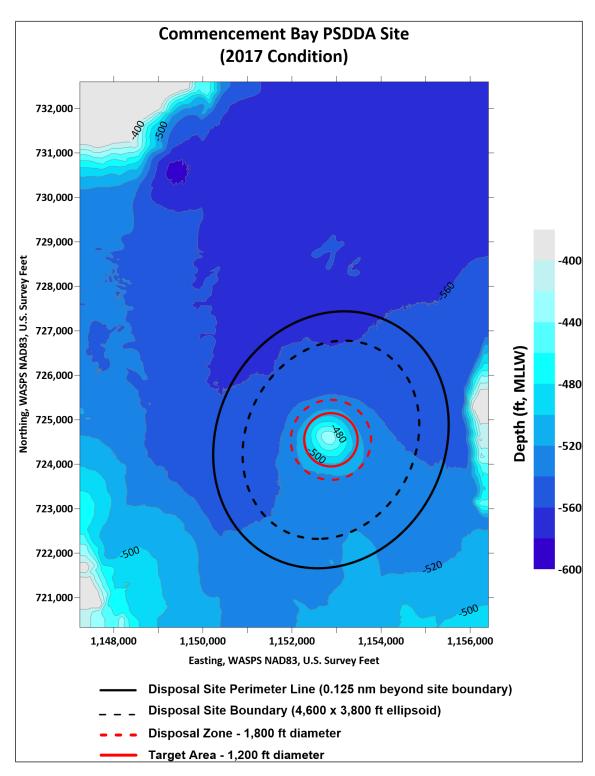


Figure B- 25 Commencement Bay PSDDA open water disposal site depths and boundaries.

3.7.3.3 Beneficial Use of dredged material.

The Saltchuk nearshore placement site located on the northeastern side of Commencement Bay about 0.9 nautical miles from the entrance to Blair Waterway and is being considered as a site for beneficial use. The most basic alternative would place dredged material from the -20 MLLW contour offshore to create a broad flat bench (Figure B- 26). The range in volume for dredged material placement is estimated as 0.85 million CY to 1.85 million CY for additional lifts and island creation (Figure B- 27). The basic alternative could potentially utilize the same equipment while not significantly increasing the cost compared to placement at the Commencement Bay PSDDA open water site. For placement of dredged material shallower than -20 MLLW, additional equipment such as flat deck barges and a barge mounted excavator would be required to place and shape the material. This would increase placement cost beyond the Federal standard and would need to be pursued by the project sponsor as a locally preferred plan or independent from the Federally cost shared project.

3.7.3.4 Upland disposal considerations

Pierce County LRI is the assumed upland disposal facility. Upland disposal is required for all sediments which do not meet the chemical criteria required for open water disposal (DMMP 2018). The LRI Landfill is a privately owned mixed municipal solid waste landfill located in Graham, Washington with a 168-acre footprint and an approximate capacity of 29.2MCY.

The required dredging volumes were computed in MicroStation InRoads by generating Digital Terrain Model (DTM) surfaces representing both finished channel dredged bottom and native/non-native material horizon. Suitability was then determined by applying the respective percentage to the calculated volumes based on the area ratio of the segment under consideration versus the total area of the subdivision. The disposal requirements for Blair Waterway for the Base and NED plan, assuming full Saltchuk disposal capacity is used (including island creation), is summarized in Table B-12.

Table B-12 Required disposal volumes for Maximum Expansion and NED alternative.

| | NED (full) | Max Expansion (to HUSKY) | Max Expansion (full) |
|-------------------------------|---------------|--------------------------|----------------------|
| | -57 MLLW | -58 MLLW | -58 MLLW |
| Open Water PSDDA Site | 562,000 | 0 | 933,000 |
| Beneficial Use at Saltchuk | 1,850,000 | 697,000 | 1,850,000 |
| Upland (Unsuitable) | 392,000 | 83,000 | 428,000 |
| TOTAL | 2,804,000 | 780,000 | 3,211,000 |

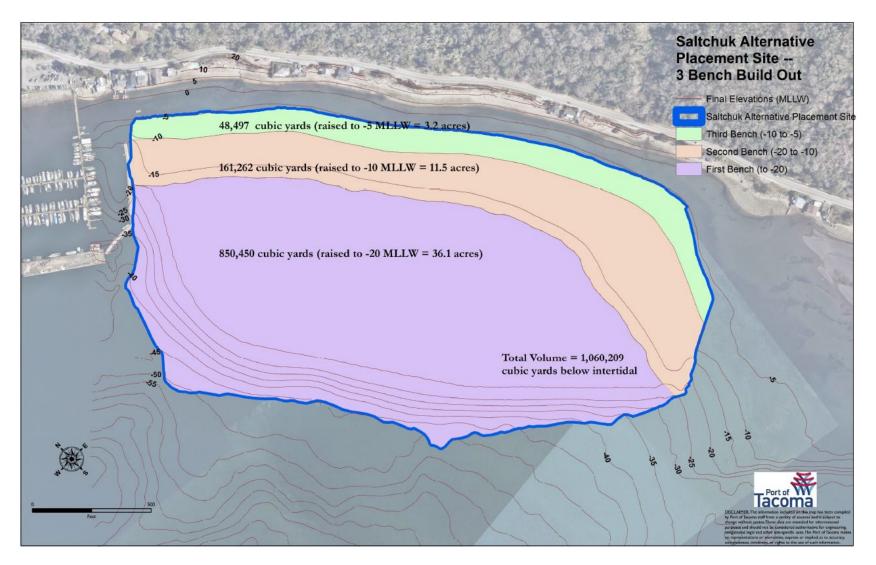


Figure B- 26 Saltchuk Beneficial Use Site Nearshore Placement Alternatives

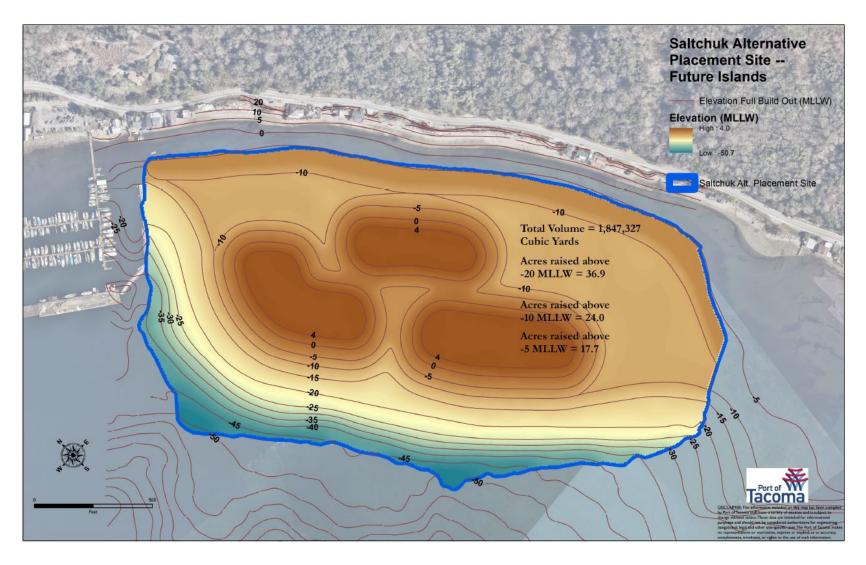


Figure B- 27 Saltchuk Beneficial Use Site anticipated potential habitat improvement features (conducted by the Port of Tacoma).

3.8 Impacts to Salinity from Channel Deepening

Channel deepening may result in a greater excursion of saltwater into systems with freshwater inflow, such as estuaries and rivers. Salinity is not anticipated to be significantly affected in the Blair waterway as it is a manmade channel without any significant freshwater input.

3.9 Impacts to Currents from Channel Deepening

Currents velocities in the Blair Waterway are presently very slow (less than 0.5 knots). The deepening project will not have a significant impact on the magnitude or direction of the velocities in the waterway.

3.10 Impacts from sea level change

There are no bridge clearance concerns associated with the project within the Blair Waterway footprint. The biggest potential risk associated with SLC is inundation to the local service facilities (LSF), including the piers, sea cranes, and utilities serving the berthing areas. Impacts to the LSF are assessed using statistics from historical water levels combined with the predicted SLC scenarios. The 99% annual exceedance probability (AEP; or 1-year return period) of the measured total water level (TWL) at the Seattle tide gauge is added to each SLC scenario. If SLC, coupled with the 99% AEP total water level exceeds the deck height of the terminals on the waterways, it is assumed to be in a condition that would require significant structural modifications. Currently, the lowest deck height is TOTE Maritime's 17.5 feet. Based on projections, this is enough to avoid inundation until at least the year 2095's High SLC scenario (Table B-3 and Table B-13). This indicates there is a low overall risk to the LSF at the project over the 50-year project life cycle.

Table B-13 Deck height of each Terminal in the Blair Waterway and predicted SLC scenarios

| Terminal | Deck Height (feet, | 2077 Low/High + 1-year | 2127 Low/High SLC + 1- | |
|----------|--------------------|------------------------|-------------------------|-------------|
| | MLLW) | TWL ¹ | year TWL ¹ | |
| Husky | 18.0 | | | |
| TOTE | 17.5 | | | |
| WUT | 21.0 | 13.4 / 16.1 | 12 4 / 16 1 12 7 / 20 5 | 12.7 / 20.5 |
| PCT | 22.0 | | 13.7 / 20.5 | |
| EB1 | 21.5 | | | |

¹ 1-year TWL (99% Annual Exceedance Probability) is 12.82 feet MLLW (NOAA 2015);

As discussed in section 3.7.3.3, the beneficial use of the material is being considered for what has been named the Saltchuk nearshore placement site. One of the alternatives considers the construction of three islands that would be placed to an elevation of 4 feet above MLLW. Further hydrodynamic analysis would be necessary to determine the sustainability of such a plan, but as per Corps SLC projections (3.25 feet increase at year 50), only 9 inches of the islands would remain above MLLW at the year 2077.

3.11 Operations and Maintenance

Historically channel deepening and widening projects result in a net increase in O&M dredging requirements. This has been well documented over multiple historic deepening and widening projects (Rosati 2005). The Tacoma Harbor project was dredged beyond its authorized depth of -51 MLLW due to dredge overdepth tolerance allowed during construction. O&M dredging has not been required since the last deepening project. O&M dredging within the navigation channel and side slopes is the responsibility of the Federal government, while O&M dredging of the berthing areas, commensurate to navigation channel depth, is the responsibility of the Port of Tacoma (Figure B- 28).

As of the November 2018 condition survey, only 15,000 CY of material is currently available above the currently authorized depth of -51 MLLW. Average sedimentation in the proposed channel footprint in the Blair waterway still occurs at a rate of 1,200 CY per year (Figure B- 11). As a result, sedimentation will result in the need for O&M dredging at the recommended depth over the project life. Shoaling rates are computed using the empirical method using historical survey data separated by distinct points in time (Vincente and Uva 1984). The empirical formula assumes that the shoaling rate is proportional to the relative bottom elevation in the channel. The proportionality is expressed by

$$\frac{dC}{dt} = K(C_e - C) \tag{1}$$

where C is a variable that represents the different bottom elevations at time t; C_e is a constant that represents the bottom natural equilibrium elevation in the channel, and K is a constant sedimentation coefficient that expresses the proportionality between shoaling rate and bottom elevation. By integrating equation (1), one obtains

$$C_2 = C_1 + (C_e - C_1) \cdot (1 - e^{-K \cdot (t2 - t1)}) \tag{2}$$

where C_1 is the initial depth at time t_1 , and C_2 is the future depth at time t_2 .

The shoaling analysis was completed for each waterway using multibeam surveys from 2010 and 2018, or a time interval of 8 years. The shoaling rates were completed only within the Federal Channel boundaries. For the without project condition, it is computed to require O&M at 25-year intervals to maintain the authorized depth in each waterway. At approximately 1,200 CY/year, the analysis predicts O&M dredging would be approximately 30,000 CY every 25 years

3.12 SLC and Shoaling Impact on Project

As sea levels around the world rise they increase a channels navigable depth countering the effects of shoaling. As sea level rises at a faster rate than shoaling occurs, navigable depths will be maintained longer. The analysis resulted in SLC slightly outpacing shoaling, which translates into the channel increasing in depth in all but the low SLC scenarios. However, the increase in channel depth is minimal and negates the possibility of dredging to a shallower depth while still realizing the navigation benefits.

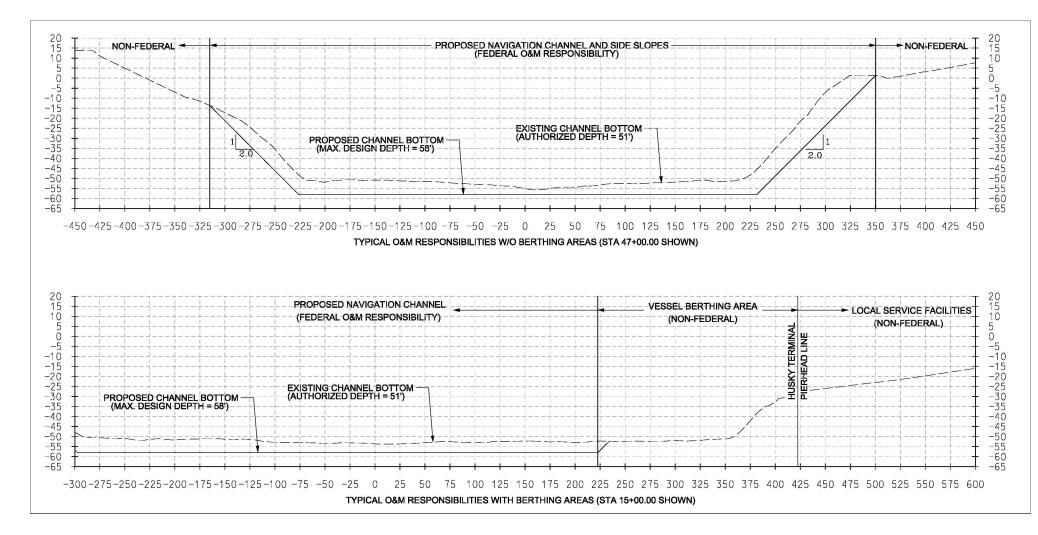


Figure B- 28 O&M dredging showing both Federal and non-Federal responsibilities

4 References

- Anchor QEA. 2019. Dredged Material Characterization Tacoma Harbor Deepening Study. Sediment Characterization Report. April 2019.
- Czuba, J.A., Magirl, C.S., Czuba, C.R., Grossman, E.E., Curran, C.A., Gendaszek, A.S., and Dinicola, R.S. 2011. Sediment load from major rivers into Puget Sound and its adjacent waters. U.S. Geological Survey. Fact Sheet 2011-3083. http://pubs.usgs.gov/fs/2011/3083/pdf/fs20113083.pdf
- Dredged Material Management Program (DMMP). 2018. Dredged Material Evaluation and Disposal Procedures User Manual. December 2018. https://www.nws.usace.army.mil/Missions/Civil-Works/Dredging/User-Manual/.
- Eryuzlu, N. E., Y. L. Cao, and F. D'Agnolo. 1994. Underkeel requirements for large vessels in shallow waterways. 28th International Navigation Congress, PIANC, Paper S11-2, Sevilla, 17-25.
- Intergovernmental Panel on Climate Change. 2007. *Climate Change 2007: The Physical Science Basis, Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (S. Solomon, D. Qin, M. Manning, Z. Chen, M. Marquis, K. B. Averyt, M. Tignor, and H. L. Miller, eds.). Cambridge, United Kingdom, and New York, NY: Cambridge University Press. http://ipcc-wg1.ucar.edu/wg1/wg1-report.html
- National Research Council. 2012. Sea-Level Rise for the Coasts of California, Oregon, and Washington:

 Past, Present, and Future. Committee on Sea Level Rise on California, Oregon, and Washington,

 Board on Earth Sciences and Resources and Ocean Studies Board. Washington, DC: National

 Academy Press.
- PIANC (Permanent International Association of Navigation Congresses). 1995. Approach Channels Preliminary Guidelines. PTC II-30, 1995.
- Puget Sound Pilots (PSP). 2019. General Guidelines for transiting restricted Waterways or Ports. May 2019.
- Rosati, J.D. 2005. Coastal Inlet Navigation Channel Shoaling with Deepening and Widening. U.S. Army Corps of Engineers, Coastal Hydraulics Laboratory. ERDC/CHL CHETN-IV-64. June 2005.
- U.S. Army Corps of Engineers. 1998. ER 1110-2-1403. Studies by Coastal, Hydraulic, and Hydrologic Facilities and Others. 1 January 1998.

- U.S. Army Corps of Engineers. 2003. EM 1110-2-1902. Engineering and Design Slope Stability. 31 October 2003. https://pubs.usace.army.mil/HQ_Public/ENG_Manuals/EM_1110-2-1902.pdf#search=slope.
- U.S. Army Corps of Engineers. 2006. EM 1110-2-1613. Engineering and Design Hydraulic design of deep draft navigation projects. 31 May 2006. http://140.194.76.129/publications/eng-manuals/EM_1110-2-1613_sec/toc.htm
- U.S. Army Corps of Engineers, Seattle District. 2009. Reauthorization of dredged material management program disposal site Commencement Bay, Washington. Supplemental Environmental Impact Statement. August 2009.
- U.S. Army Corps of Engineers. 2013. Incorporating sea level change in Civil Works Programs Engineering Regulation ER No. 1100-2-8162.
- U.S. Army Corps of Engineers, Seattle District. 2019a. Dredging assumptions and volume calculation methods for the Tacoma Harbor Navigation Improvement Project. Memorandum For Record. CENWS-ENH-HC. August, 2019.
- U.S. Army Corps of Engineers, Seattle District. 2019b. O&M dredging volumes and maintenance schedule for channel improvement alternatives at Tacoma Harbor. Memorandum For Record. CENWS-ENH-HC.
- U.S. Army Corps of Engineers, 2019c. Tacoma Harbor Feasibility Ship Simulation Study Report. Engineer Research and Development Center Coastal Hydraulics Laboratory, LR-19-8. 30 July 2019.
- U.S. Army Corps of Engineers, 2019d. DMMP advisory determination regarding the potential suitability of proposed dredged material from the Blair Waterway in Tacoma Harbor for unconfined openwater disposal at the Commencement Bay disposal site or for beneficial use. Memorandum for Record. Prepared by the Dredged Material Management Office. 25 June, 2019.
- Vincente, C.M., and Uva, L.P. 1984. Sedimentation in dredged channels and basins -- prediction of shoaling rates, "Proceedings, 19th International Conference on Coastal Engineering. American Society of Civil Engineers, 1863-1878.

| 5 | Engineering Appendix - Annex | |
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Engineering Appendix Annex

- Volume calculation MFR (USACE 2019a)
- O&M Volumes Calculation MFR (USACE 2019b)
- Tacoma Harbor Feasibility Level Ship Simulation Study Report (USACE 2019c)
- Tacoma Harbor DMMP advisory memo (USACE 2019d)
- Hartcrowser GT Report near Sta 40+00
- GeoEngineers GT report for WUT wharf extension near Sta 100+00 to 110+00

MEMORANDUM FOR RECORD

SUBJECT: Dredging assumptions and volume calculation methods for the Tacoma Harbor Feasibility Study (THFS).

Dredging Alternatives

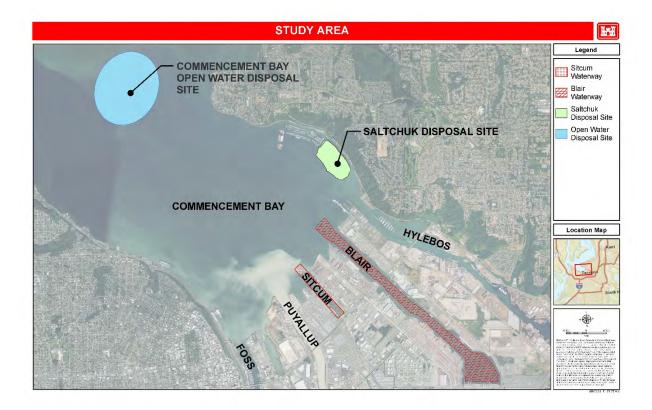
- 1. Dredged material volumes associated with channel improvement will be computed for the channel footprint throughout several depths associated with the economic analysis. A wider approach channel is recommended to improve safety in the waterway. The approach channel width is being widened to be 865 feet and inner reaches vary in width from 450 feet to 520 feet.
- 2. The Blair Waterway extends from project station -5+00 to 25+00 and 0+00 to 10+00. Consistent with the economic analysis, volumes will be broken out according to the major terminals being served by the Blair Waterway as follows:
 - a. Husky Terminals (STA-5+00 to STA 41+85)
 - b. Washington United Terminals (STA 41+85 to STA 108+40)
 - c. Turning Basin and Pierce County Terminals (STA 108+40 to STA 137+24)
- 3. Channel sideslopes are specified as 1 vertical on 2 horizontal (1V:2H) from the channel toe.
- 4. Volumes are computed in one (1) foot increments ranging from -51 to -58 feet Mean Lower low water (MLLW).
- 5. A two (2) foot overdepth tolerance is included in each reported volume to incorporate inaccuracies associated with dredging.
- 6. All volumes are computed in reference to a combination of condition surveys performed by USACE and by the Port of Tacoma during 2018 and 2019.
- 7. A 10% contingency is applied to all volumes to minimize risk associated with shoaling prior to project implementation (Table 1)

Berthing Assumptions

 Project sponsor berthing areas on the Blair Waterway are operated by the Port of Tacoma and assumed to extend the length of the pier for a beam width between the federal channel and the pier head line. O&M dredging in the berthing regions is assumed to be the sponsor's responsibility.

Disposal assumptions

1. Two disposal alternatives are being considered in the study. The primary alternative is Commencement Bay's PSDDA open water disposal site located in the northwestern quadrant of the Bay. Alternative number two is beneficial use of dredged material at Saltchuk location.



- 2. Based on sampling data provided in DMMO's Advisory Memo dated 25 June 2019, a native/non-native horizon .dtm surface was created. Volumes computed above this layer (up to existing conditions survey) are considered to be non-native material (shoaling) and volumes computed below this layer (down to design channel bottom) are considered to be native material.
- 3. All material in channel modifications (Entrance North/South, Mid Channel, TB1 and TB2) is assumed to be native since modifications fall outside of currently authorized dredging boundaries and presumably has never been dredged.
- 4. As per the same memo's sampling data, suitability percentages were assigned for the dredged material as shown below.
 - a. Unsuitable material for In-Water = 100% %Suitable (from table)
 - b. Once calculated, unsuitable volumes for in-water were used for Saltchuk as well.
 - c. As can be seen, %Suitable for Saltchuk differs from in-water for three areas making the total suitable volume slightly less than for in-water disposal.
 - d. This can be interpreted as volume **EXCLUSIVELY** suitable to in-water disposal.

| IN-WATER | | | SALTCHUK | | |
|-------------------|--------------------|-----------|--------------------|--------------------|-----------|
| TERMINAL | AREA | %Suitable | able TERMINAL AREA | | %Suitable |
| | Entrance North | 60 | | Entrance North | 60 |
| Husky | Entrance South | 60 | Huelor | Entrance South | 60 |
| пизку | Husky - non-native | 90 | Husky | Husky - non-native | 85 |
| Husky - native 95 | | | Husky - native | 95 | |
| WUT1 | Mid Channel | 60 | WUT1 | Mid Channel | 60 |

| | TB1 | 60 | | TB1 | 60 |
|---------|-------------------|-----|---------|-------------------|-----|
| | WUT1 - non-native | 60 | | WUT1 - non-native | 40 |
| | WUT1 - native | 95 | | WUT1 - native | 95 |
| | TB1 | 60 | | TB1 | 80 |
| WUT2 | WUT2 - non-native | 100 | WUT2 | WUT2 - non-native | 100 |
| | WUT2 - native | 95 | | WUT2 - native | 95 |
| | TB1 | 80 | | TB1 | 80 |
| | TB2 | 80 | | TB2 | 80 |
| Turning | Turning Basin - | | Turning | Turning Basin - | |
| Basin | Non-native | 100 | Basin | Non-native | 100 |
| | Turning Basin - | | | Turning Basin - | |
| | native | 95 | | native | 95 |

Volume calculation method

- This memorandum describes the methodology utilized to arrive at the volumes reported in the Tacoma Harbor Feasibility Study. All reported volumes represent surface to surface neat line dredge volumes.
- 2. Digital terrain model (DTM) surfaces are created in Bentley® InRoads version 8i software using XYZ triplet ascii data.
- 3. First a polygon representing the bottom of the navigation channel is drawn in MicroStation and assigned a Z elevation using the CivTools command. For the recommended alternative this elevation corresponds to a project elevation of -51', -52', etc. Mean Lower Low Water (MLLW). 2 feet of allowable overdepth tolerance is included to estimate volume dredged associated with dredging inaccuracies. Therefore the neatline elevation will be specified as -51 (+2), -52 (+2),-54 (+2), etc.
- 4. XYZ ascii data of the bathymetric condition hydosurvey combined with uplands data provided by the Port of Tacoma (2019) is imported into InRoads using the "Text Import Wizard" command. The condition survey utilized to compute the volumes was collected 2018 by the U.S. Army Corps of Engineers, Seattle District Hydrosurvey Unit. Sounding data were collected using a Reson 712 Multibeam, 140° swath, 400 kHz transducer in HYPACK, Inc. HYSWEEP® software. Tidal corrections were performed using RTK.
- 5. The XYZ data is loaded as a Random Feature dataset and then triangulated to a DTM surface in InRoads using Delaunay's algorithm. In order to eliminate erroneous interpolation errors a maximum triangle length of 100 feet is specified which deletes any triangles which exceed this length from the DTM.
- 6. The "Generate Sloped Surface" command in InRoads is used to project the channel sideslopes of 1 vertical on 2 horizontal (1:2) from the channel bottom up to the point of intersection with the condition survey DTM. This command creates a new surface which represents the neatline surface required for dredging. An Exterior Boundary is placed around the polygon at the point of intersection between the condition survey DTM and the neatline surface DTM. This effectively clips the neatline surface DTM at the point of intersection and deletes any triangles outside of the Exterior Boundary polygon; this ensures accurate volume calculations in Step 7.

- 7. Finally dredged volumes are computed in InRoads using the "Triangulate Volume" command. Volumes are computed between the neatline surface DTM and the condition survey DTM in each Reach separately using a Fence. The fence effectively bounds the volume computation to a specified area. In this case the area for each reach represents the Exterior Boundary polygon created in Step 6.
- 8. In order to allow for contingencies in the required dredged volume related to shoaling between now and construction a 10% contingency is added to the volumes computed in InRoads in each waterway.

References

Vincente, C.M., and Uva, L.P. 1984. Sedimentation in dredged channels and basins -- prediction of shoaling rates, "*Proceedings, 19th International Conference on Coastal Engineering*. American Society of Civil Engineers, 1863-1878.

Daniel Bernal, P.E. Coastal Engineer

David R. Michalsen, P.E. Coastal Engineer

Table 1-4. Tacoma Harbor – Dredged material volumes for Blair Waterway relative to 2018/2019 condition surveys.

Table 1. Volume breakdown by material and suitability for NED alternative, dredge depth = -57', MLLW¹.

| Channel Reach | Native Material | Non-Native Material | Suitable for In-Water Disposal | Un-suitable for In-Water Disposal |
|----------------|-----------------|---------------------|--------------------------------|-----------------------------------|
| Blair Waterway | CY | CY | CY | CY |
| HUSKY | 550,000 | 123,000 | 600,000 | 74,000 |
| WUT | 823,000 | 360,000 | 934,000 | 249,000 |
| TURNING BASIN | 858,000 | 90,000 | 878,000 | 69,000 |
| Total | 2,231,000 | 573,000 | 2,412,000 | 392,000 |

Table 2. Required total dredging for recommended channel depth for NED alternative, dredge depth = -57', MLLW¹.

| Channel Reach | Stationing | Volume |
|----------------|------------------------|-----------|
| Blair Waterway | - | CY |
| HUSKY | -5+00.00 TO 41+85.18 | 674,000 |
| WUT | 41+85.18 TO 108+40.43 | 1,183,000 |
| TURNING BASIN | 108+40.43 TO 137+24.11 | 947,000 |
| Total | | 2,804,000 |

Table 3. Maximum Expansion alternative including Husky Alternative; dredge depth = -58', MLLW¹.

| Channel Reach | Native Material | Non-Native Material | Suitable for In-Water Disposal | Un-suitable for In-Water Disposal |
|----------------|-----------------|---------------------|--------------------------------|-----------------------------------|
| Blair Waterway | CY | CY | CY | CY |
| HUSKY | 658,000 | 122,000 | 697,000 | 83,000 |
| WUT | 980,000 | 359,000 | 1,074,000 | 265,000 |
| TURNING BASIN | 1,003,000 | 89,000 | 1,012,000 | 80,000 |
| Total | 2,641,000 | 570,000 | 2,783,000 | 428,000 |

Table 4. Maximum Expansion Alternative, including Husky Alternative; dredge depth = -58', MLLW¹.

| Channel Reach | Stationing | Volume |
|----------------|------------------------|-----------|
| Blair Waterway | STA | CY |
| HUSKY | -5+00.00 TO 41+85.18 | 780,000 |
| WUT | 41+85.18 TO 108+40.43 | 1,339,000 |
| TURNING BASIN | 108+40.43 TO 137+24.11 | 1,092,000 |
| Total | | 3,211,000 |

CENWS-ENH-HC 14 August 2019

MEMORANDUM FOR RECORD

SUBJECT: O&M dredging volumes and maintenance schedule for channel improvement alternatives at Tacoma Harbor Blair Waterway

- 1. Channel improvement alternatives are currently being evaluated for the Blair Waterway in Tacoma Harbor. Initial construction dredging volumes have already been developed using the November 2018 survey, however future Operations and Maintenance costs in each waterway have not been evaluated.
- 2. In order to support accurate calculation of project life cycle costs, O&M dredging volumes in the federal channel are required. The local sponsor is responsible for O&M dredging at the berthing areas near each ship terminal, thus only O&M dredging quantities in the federal channel are computed.
- 3. Rosati (2005) provides documentation on comparable deep draft channel improvement projects which demonstrates how channel deepening increases O&M dredging volumes following implementation. Additionally, an empirical equation is provided to estimate the increase in channel shoaling volumes based on data collected at five projects throughout the country. However the relationship does not incorporate site specific information about the rate of sedimentation in the Blair Waterway.
- 4. In order to increase confidence in future O&M dredging demands, the method developed by Vicente and Uve (1984) is selected. This method computes shoaling rates from site specific surveys collected at two time intervals and develops a relationship for shoaling based on time, current channel depth, and channel equilibrium depth. The analysis included here utilizes two multibeam surveys collected in 2010 and 2018 by the USACE Hydrosurvey Unit (Figure 1).
- 5. Figure 2, displays the relationship between shoaling depth (C2-C1) and the initial depth (C1) for each waterway. These figures show how shoaling depth increases with channel depth. A linear regression line was fit to the gridded survey data using the mean depth for each 5-foot depth bin. In general the shoaling depth between surveys ranged from 0.1 to 0.5 feet in approximately 9 years. Note there is an outlier in the data around -58' MLLW which is likely related to elevation change resulting from regrading of the Husky terminal versus shoaling.
- 6. Using the Vicente and Uve (1984) relationship included in the inset of Figure 2, the estimated shoaling depth as a function of time can be computed. Similarly the shoaling volume can be computed by integrating the shoaling depth cells over the entire Waterway.
- 7. O&M dredging is assumed to occur at 25 year intervals to ensure shoaling depth does not impact navigation in the channel while minimizing mobilization costs of a dredge. For each alternative the computed maximum shoaling depth is less than 1.0 feet at year 25. Figure 3, shows the required dredging volumes at years 25 and 50 over the project life cycle for each waterway. For the NED plan of -57' 1' overdepth tolerance (e.g. -58' MLLW), this corresponds to approximately 30,000 cubic yards at year 25 and 50.

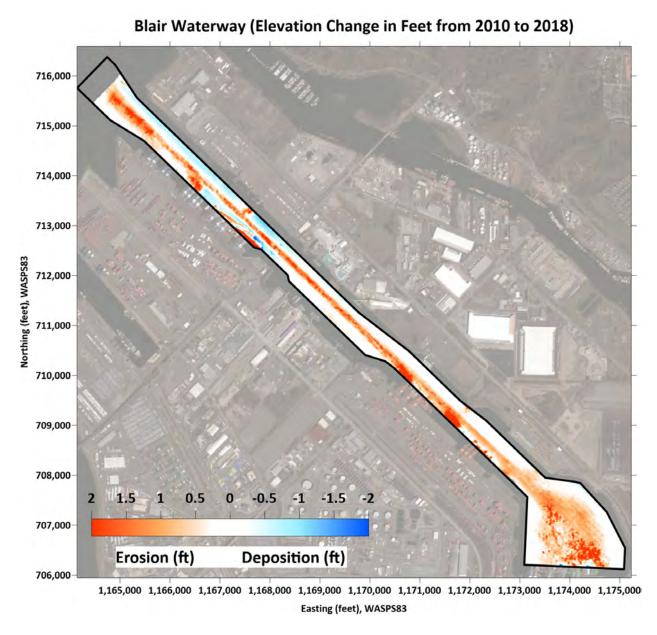


Figure 1. Bed Elevation change in the proposed federal navigation channel from 2010 to 2018

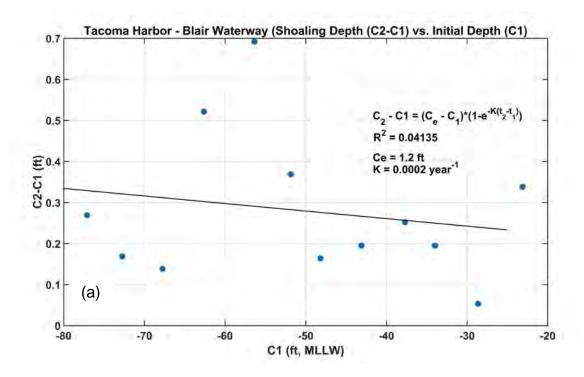


Figure 2. Relationship developed for shoaling depth to initial depth for the Blair Waterway. Survey dates for C1 and C2 represent years t1 = 2010 and t2 = 2018.

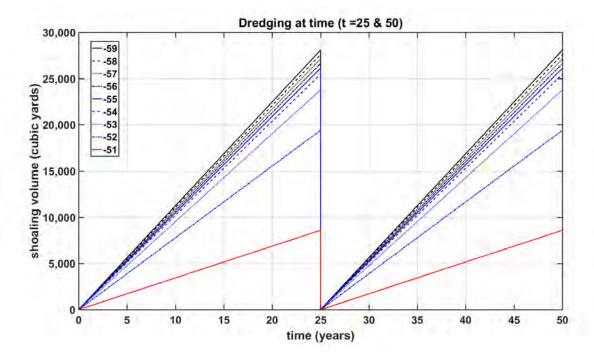


Figure 3. Computed O&M dredging volume for incremental deepening alternatives, neatline depth -51 feet to -59 feet MLLW.

Table 1. Volume in cubic yards for O&M dredging in the federal navigation channel (Blair Waterway) at project year 25 and 50

| Depth/year | 25 | 50 |
|------------|--------|--------|
| -59 | 28,069 | 28,069 |
| -58 | 27,593 | 27,593 |
| -57 | 27,111 | 27,111 |
| -56 | 26,621 | 26,621 |
| -55 | 26,101 | 26,101 |
| -54 | 25,451 | 25,451 |
| -53 | 23,767 | 23,767 |
| -52 | 19,403 | 19,403 |
| -51 | 8,582 | 8,582 |

References

Rosati, J.D. 2005. Coastal inlet navigation channel shoaling with deepening and widening. U.S. Army Corps of Engineers, Engineering Research and Development Center, Coastal Hydraulics Laboratory. ERDC/CHL CHETN-IV-64. June 2005

Vincente, C.M., and Uva, L.P. 1984. Sedimentation in dredged channels and basins -- prediction of shoaling rates," *Proceedings, 19th International Conference on Coastal Engineering*. American Society of Civil Engineers, 1863-1878.



DEPARTMENT OF THE ARMY

U.S. ARMY CORPS OF ENGINEERS, ENGINEER RESEARCH AND DEVELOPMENT CENTER
COASTAL AND HYDRAULICS LABORATORY
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CEERD-HNN-D

30 July 2019

MEMORANDUM FOR Commander, U.S. Army Corps of Engineers, Seattle District (Mr. David Michalsen/CENWS-ENH-HC), P.O. Box 3755, Seattle, WA 98124-3755

SUBJECT: Tacoma Harbor Feasibility Ship Simulation Study Report

- 1. Enclosed is the Tacoma Harbor Feasibility Ship Simulation Study Report, ERDC/CHL LR-19-8.
- 2. The purpose of the study was to assist the U.S. Army Corps of Engineers, Seattle District (CENWS), in screening a proposed deepening and widening modification to the Blair Waterway in Tacoma Harbor, WA, by completing a Feasibility Level Screening Simulation Program (FLSSP). The results from this FLSSP should be used to drive a more comprehensive ship simulation study performed during the Preconstruction, Engineering, and Design (PED) portion of the project. Enclosed is a synopsis of the testing performed from 23 -25 April 2019 as well as trackplots and runsheets (Appendix A), pilot questionnaires (Appendix B), and pilot cards (Appendix C).
- 3. If you have questions, please contact Ms. Morgan Johnston at 601-634-2365 or Mr. Ben Burnham, Chief, Navigation Branch, at 601-634-4251.

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Encl

TY V. WAMSLEY, PhD, SES Director



Tacoma Harbor Feasibility Ship Simulation Study Report

Morgan M. Johnston July 2019



Tacoma Harbor Feasibility Ship Simulation Study Report

Morgan M. Johnston

Coastal and Hydraulics Laboratory U.S. Army Engineer Research and Development Center 3909 Halls Ferry Road Vicksburg, MS 39180-6199

Final Letter Report

Prepared for U.S. Army Corps of Engineers, Seattle District 4735 E. Marginal Way South Seattle, WA 98134

ERDC/CHL LR-19-8 ii

Abstract

The Port of Tacoma is a rapidly expanding port located in the U.S. state of Washington. Together, the Port of Seattle and Port of Tacoma account for the fourth largest container terminal in the U.S. The width of the Blair Waterway is physically limited by hard constraints of existing port infrastructures on both sides. The purpose of the study was to assist the U.S. Army Corps of Engineers District, Seattle (CENWS) in screening a proposed deepening and widening modification to the Blair Waterway in Tacoma Harbor, WA by completing a Feasibility Level Screening Simulation Program (FLSSP). The results from this FLSSP should be used to drive a more comprehensive ship simulation study performed during the Preconstruction, Engineering, and Design (PED) portion of the project.

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Preface

This study was conducted for the U.S. Army Corps of Engineers, Seattle District. The technical lead at MVN was Mr. Dave Michalsen. The project manager was Ms. Kristine Ceragioli.

The U.S. Army Engineer Research and Development Center (ERDC), Coastal and Hydraulics Laboratory (CHL), Navigation Branch of the Navigation Division completed the work. At the time of this study, Mr. Tim Shelton was Chief of the Navigation Branch, and Dr. Jacqueline S. Pettway was Chief of the Navigation Division.

At the time of publication of this report, the Deputy Director of CHL was Mr. Jeffrey R. Eckstein, and the Director was Dr. Ty V. Wamsley. COL Ivan P. Beckman was the Commander of ERDC, and the Director was Dr. David. W. Pittman.

Unit Conversion Factors

| Multiply | Ву | To Obtain |
|---|------------|-------------------|
| degrees (angle) | 0.01745329 | radians |
| feet | 0.3048 | meters |
| horsepower (550 foot-pounds force per second) | 745.6999 | watts |
| knots | 0.5144444 | meters per second |
| miles (U.S. statute) | 1,609.347 | meters |

1 Introduction

The U.S. Army Engineer Research and Development Center (ERDC) assisted the U.S. Army Corps of Engineers, Seattle District (CENWS), in screening a proposed deepening and widening modification to the Blair Waterway in Tacoma Harbor, WA (Figure 1) by completing a Feasibility Level Screening Simulation Program (FLSSP). The study was performed at the ERDC Ship/Tow Simulator (STS) from 23 - 25 April 2019.



Figure 1. Blair Waterway

Background

The Port of Tacoma is a rapidly expanding port located in the U.S. state of Washington. In 2014, the Port of Seattle and Port of Tacoma began joint operations with the formation of the Northwest Seaport Alliance. Together, these ports are the fourth largest container terminal in the U.S. The width of the Blair Waterway is physically limited by hard constraints of existing port infrastructures on both sides. The current authorized depth is -51-ft Mean Lower Low Water (MLLW) for the Blair Waterway. The purpose of this project was to determine the feasibility of deepening and widening the Blair Waterway to -58-ft MLLW to allow for further utilization of deeper draft vessels. The Blair Waterway is approximately 2.75 miles long with multiple terminals and a turning basin at the end of the waterway. Major areas of concern for this project included strong

winds and maneuverability of the transiting vessel (with its necessary tugs) around docked vessels.

Proposed Alternative Tested

The proposed improvements to the Blair Waterway included a deepening and widening of the federal navigation channel, a section of realignment, and a modification to the turning basin. For all proposed simulations, the depth was deepened from -51-ft to -58-ft MLLW in the proposed navigation channel. In Figure 2, the existing federal navigation channel is shown as a black dotted line and the proposed channel tested is shown as a red solid line. The design vessel chosen for this FLSSP was the *Superium Maersk* (1307- x 191- x 53-ft). Vessel particulars can be found on the pilot card in Appendix C. While this was not an exact match for the CENWS design vessel, it provided a close approximation. The exact design vessel should be contracted for use in during Preconstruction Engineering and Design (PED) simulations.

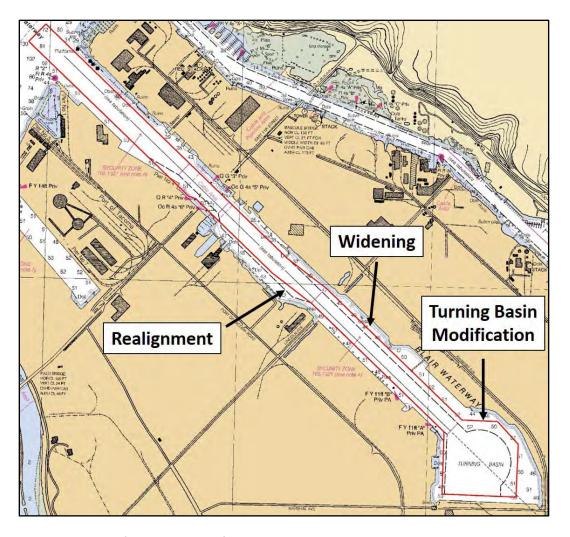


Figure 2. Proposed modifications to Blair Waterway navigation channel

Purpose

The purpose of a FLSSP is to screen proposed alternatives using lower resolution databases to limit monetary and time commitments while still providing vital insight of the proposed alternatives moving forward. The lower resolution databases are quicker and less costly to develop and easier to quickly manipulate during the course of testing. One of the most vital aspects of a FLSSP is providing the means to conduct expert elicitations. After each run, discussions were typically held to deliberate about the previous simulation and determine the next simulation. The collaboration of all parties occurred throughout the testing week as well as the final group discussion at the conclusion of the testing. Conclusions drawn from actual data should be limited due to the use of these lower resolution databases. Data processing is limited to trackplots and run sheets shown in Appendix A.

2 Simulation Overview

Participants

The FLSSP included representatives from the ERDC, the CENWS, the USACE Northwestern Division (CENWD), the Port of Tacoma, and the Puget Sound Pilots. The individuals listed below were present for the entirety of the testing week, 23 - 25 April 2019, unless stated otherwise.

ERDC: Ms. Morgan Johnston, Mr. Keith Martin, Ms. Mary Claire Allison, Ms. Kiara Pazan, Mr. Mario Sanchez, Ms. Janie Vaughan (23 - 24 April), and Mr. Dennis Webb, P.E. (former ERDC employee under contract to CHL)

CENWS: Mr. David Michalsen, Ms. Kristine Ceragioli, Mr. Daniel Bernal, Ms. Tobie LaRoy, and Mr. Don Kramer

CENWD: Mr. Tim Fleeger

Port of Tacoma: Mr. Tony Warfield, Mr. Lou Paulsen, and Mr. Zack Thomas

Puget Sound Pilots: Capt. John (Jed) Arnold and Capt. Mark Shuler

Database Development

Due to this study falling under the guidelines of a FLSSP, model development was completed with fairly low resolution.

- a. Simulated ships were limited to ships in ERDC's ship library. Ships used during simulations are shown in Table 1.
- b. Docked vessels were set as targets, which are much easier to include in simulations, but provide limited hydrodynamic interaction with the transiting vessel.
- c. Wind conditions were set at run time and did not include wind shadowing from docked vessels.

- d. Visual scenes were developed using less detail typically used for the more in-depth Preconstruction Engineering and Design (PED) phase of the project. Gantry cranes were placed in the down position at the Husky, the Washington United Terminal (WUT), and the Pierce County Terminal (PCT).
- e. Tugs were selected from ERDC's vessel inventory by each pilot and pilots provided the necessary tonnage. Tugs used over the course of the project are shown in Table 2. ERDC's vessel inventory did not include a 75T tug, therefore TUG10N was utilized as a 75T tug by reducing its maximum bollard pull to 75T.
- f. No currents were used during simulations. Currents are minimal in the Blair Waterway and pilots concluded the inclusion of currents would have little impact to the study.

Table 1. Ships used in simulations

| Model Name | Vessel Name | Vessel Type | LOA (ft) | Beam (ft) | Draft (ft) | Application |
|------------|---------------------|----------------|----------|-----------|------------|---|
| CNTNR32X | Superium Maersk | Container ship | 1,307.4 | 190.9 | 53.1 | Design vessel |
| CNTNR32L | Superium Maersk | Container ship | 1,307.4 | 190.9 | 49.4 | Docked at P3, P4, N WUT, S WUT |
| CNTNR40 | MSC Daniella 2 | Container ship | 1,201.1 | 158.8 | 49.9 | Validation, Docked at PCT |
| CARCO4X | MS Figaro | Car carrier | 649.6 | 105.8 | 24.6 | Docked at Blair, EB- 1, anchorage area |
| CRUIS09L | Freedom of the Seas | Cruise ship | 1,111.2 | 126.6 | 27.9 | Docked at TOTE |

Table 2. Tugs used in simulations

| | del me | Vessel Type | Horsepower | Max Bollard Pull (T) | LOA (ft) | Beam (ft) | Draft (ft) | Application |
|-----|-----------|----------------|------------|-------------------------|----------|-----------|------------|-----------------------|
| TUG | 10N | Pushboat | 6,100 | 98.9 | 101.0 | 36.5 | 11.7 | Used as 75T or 98T |
| TUG | 29 | Pushboat | 3,000 | 51 | 96.1 | 30.8 | 8.9 | Used as 50T |

Simulations Summary

The Blair Waterway contains the Totem Ocean Trailer Express (TOTE) Terminal, the Husky Terminal, the Washington United Terminal (WUT), the Blair Terminal, the East Blair One Terminal (EB-1), and the Peirce

Country Terminal (PCT). The Husky Terminal has two docking locations, P3 and P4. The WUT terminal has two docking locations, North WUT (N WUT) and South WUT (S WUT). Figure 3 shows the Blair Waterway with terminals and docking locations labelled. Gantry Cranes were also placed at the Husky Terminal, the WUT, and the PCT in the down position to act as visual cues for the pilots and further restrict the navigation channel.

A major concern for the project was ensuring the design vessel and its necessary tugs would be able to maneuver by docked vessels. Due to the maneuverability concern, it was important to include representative vessels docked at each terminal. Figure 3 also shows the representative vessels that were selected from the ERDC vessel library that were typically berthed at each terminal for testing runs. Vessel information for each docked vessel can be found in Table 1. During testing, it was found that CNTNR32X had an error in its code that prevented it from being a passable target. Since CNTNR32L has the same dimensions as CNTNR32X (except for draft), it was replaced by CNTNR32L when used as a docked vessel. This substitution made minimal difference to the hydrodynamics as targets provide minimal hydrodynamic interaction with the transiting vessel, but the target provided the appropriate visual cues necessary for maneuverability testing.

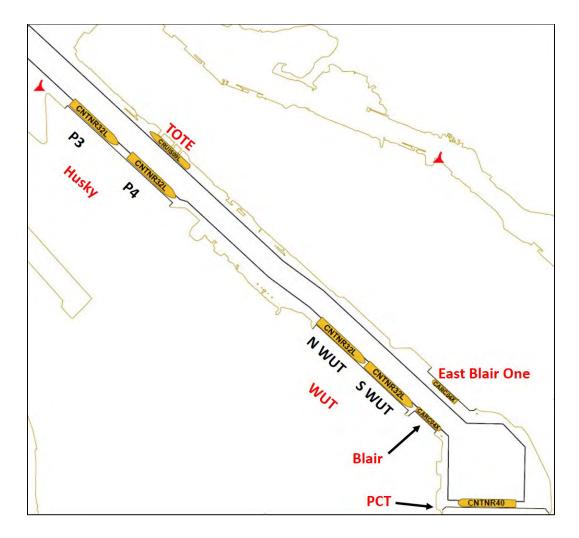


Figure 3. Blair Waterway terminals labelled with docked vessels

To create the proposed channel, the channel was dredged to -58-ft MLLW inside the new federal navigation channel. Outside the channel, 2H:1V slopes were projected up and outwards from the channel bottom to intersect with existing terrain. Additionally, it was assumed the federal channel was dredged up to the berthing areas fronting the Husky and WUT terminals maintained by the Port. During the FLSSP, the design vessel was tested in a variety of scenarios that included docking and leaving from P4, PCT, N WUT, and S WUT. The design vessel was tested leaving the Blair Waterway from the terminal's stern-first and leaving via the turning basin.

Table 3 lists the scenarios completed with the proposed channel over the three testing days. All simulations listed were completed with the design vessel as the transiting vessel. Wind conditions were set at run time and

did not include wind shadowing from docked vessels. Most of the wind conditions tested were from the southwest, although some runs were completed with wind from the north. For a few simulations, wind gust was added that varied the wind by ± 5 knots from the initial set magnitude. In several scenarios, the wind was increased throughout the simulation. This was mainly used in the initial simulations when pilots were first getting calibrated to the effects caused by the wind in the simulator. Once the pilot was comfortable with the simulated wind, the wind would then be increased. Figure 4 shows a captain piloting the STS in Tacoma Harbor during testing.

Table 3. List of completed scenarios of proposed design

| Terminal | Heading | Wind (Direction from) | Targets | Pilot | Scenario # |
|--------------------------------|------------------------------------|--|--|---------------------------|---------------|
| Length of the channel, used TB | Inbound (TB) | Ok, ended at 10k SW (Shuler) and 15k SW (Arnold) | P3, P4, N WUT, Blair, EB-1 | Arnold Shuler | V1 |
| Commencement Bay to P4 | Inbound | 20k N | TOTE, P3, P4, N WUT, S WUT, PCT, Blair, EB-1 | Arnold Schuler | 1 |
| Commencement Bay to P4 | Inbound | 25k SW | TOTE, P3, P4, N WUT, S WUT, PCT, Blair, EB-1 | Arnold (2) Schuler (2) | 2 |
| P4 | Outbound (stern) | 25k SW (±5k gusts) | P3, TOTE (Shuler only) | Arnold Shuler | 3 |
| PCT | Inbound | 25k SW (±5k gusts) | TOTE, P3, P4, N WUT, S WUT, Blair, EB-1 | Arnold Shuler | 4 |
| PCT | Outbound (starboard side to) | 20k SW | TOTE, P3, P4, S WUT, N WUT, PCT, Blair | Arnold | 5 |
| PCT | Outbound (port side to) | 20k SW | TOTE, P3, P4, S WUT, N WUT, PCT, Blair | Arnold | 6 |
| S WUT | Outbound (stern) | 5k SW, ended at 20k SW | P3, P4, N WUT, S WUT, PCT, Blair, EB-1 | Arnold | 7 |
| S WUT | Outbound (stern) | 10K SW, ended at 20k SW | TOTE, P3, P4, N WUT, Blair, EB-1 | Schuler | 8 |
| S WUT | Outbound (stern) | 25k SW (±5k gusts) | TOTE, P3, P4, N WUT, PCT, Blair, EB-1, Anchored vessel | Arnold | 9 |
| S WUT | Outbound (stern) | 20k N (±5k gusts) | TOTE, P3, P4, N WUT, PCT, Blair, EB-1, Anchored vessel | Schuler | 10 |
| S WUT | Outbound (TB) | 20k N | TOTE, P3,P4, N WUT, Blair, EB-1 | Shuler (2) Arnold | 11 |
| N WUT | Outbound (TB) | 30k SW | TOTE, P3, P4, S WUT, PCT, Blair, EB-1 | Arnold | 12 |
| N WUT | Outbound (TB) | 30k N | TOTE, P3, P4, S WUT, PCT, Blair, EB-1 | Shuler | 13 |



Figure 4. Captain piloting the STS during Tacoma Harbor FLSSP

3 Testing

The following chapter will discuss the simulations completed over the testing week. Appendix A contains first, the run sheet and then the corresponding track plot for each run. Scenario number can be found in the upper right corner for each track plot or run sheet that corresponds to the scenario number listed in Table 3. The docked targets for each run are shown in each track plot labelled with the appropriate model name. Vessel information for the docked vessels can be found in Table 1. Tug configuration for each simulation can be found on the run sheets. Pilots used either three (three tugs of max 75T bollard pull or three tugs of max 98T bollard pull) or four tugs (four tugs of max 75T bollard pull or three tugs of max 98T bollard pull and 1 tug of max 50T bollard pull). Tug information can be found in Table 2. It should be noted each pilot determined the tug strength and configuration used for each simulation. If tug availability is determined to be a concern, either economically or logistically, it may be important to limit tug availability or strength in future PED simulations.

Validation

Validation for the existing condition occurred on Tuesday, 23 April 2019. The first validation run was completed on the existing channel with no wind, no docked vessels, and with the *MSC Daniella 2*. As there were no currents used for simulations and there were only bathymetric changes between existing and proposed, the remaining validation simulations occurred in the proposed channel. After a few more validation runs using the design vessel, incorporating wind, modifying navigational aids, and populating the waterway, pilots felt the visual and environmental databases were acceptable for a FSSLP and production runs began.

The initial validation runs are not shown in this report except for the last validation run. At the time of the last validation run, pilots felt comfortable with the virtual representation of the Blair Waterway. During this last validation run, the vessel transited the entirety of the waterway including the turning basin with the wind being modified throughout the simulation. Track plots and run sheets for this transit can be found in Appendix A labelled Scenario V1. It should be noted that both pilots went outside of the channel on the north end of the turning basin.

Entrance and P4 Testing

Track plots and run sheets for entrance and P4 testing can be found in Appendix A labelled Scenarios 1-3. Scenario 1 and 2 show inbound transits starting from Commencement Bay. During two of the simulations of Scenario 2, the vessel grounded on the south side of the entrance channel. During existing conditions, the area south of the entrance is deep enough (approximately -51-ft MLLW) that vessels may go outside of the channel lines. However, in the proposed design, the depth on the southern side slope of the entrance channel is not deep enough for all the vessels that will be calling on the Blair Waterway. Pilots felt this area would be considered a limiting depth of the channel and would have to be removed if the Blair Waterway was to be deepened to the -58-ft MLLW. Pilots had minimal difficulties with the other simulations that were completed for Scenario 1 and 2 but did feel that 25k of wind from the southwest was at the maximum limit for the design vessel in the proposed channel.

Scenario 3 simulated an outbound, stern-first transit from the Husky Terminal (P4). During Scenario 3, one of the pilots grounded when the bow of the vessel clipped the north side slope of the entrance channel. While this pilot felt the grounding was avoidable, both pilots skirted along the north edge of the entrance in Scenario 3.

PCT Testing

Track plots and run sheets for entrance P4 testing can be found in Appendix A labelled Scenario 4-6. Scenario 4 simulated an inbound transit that began in Commencement Bay and ended at the PCT Terminal. Both pilots felt the wind was too strong (25 knots from the southwest with gust of \pm 5 knots) for the design vessel in the proposed channel. The difficulty caused by the wind can be noticed in the weaving track plots, as pilots must constantly counteract the effects from the wind. Additionally, both pilots exceeded the design channel lines near the East Blair One Terminal. Scenario 5 and 6 show an outbound transit from the PCT using the turning basin with the transiting vessel starting either starboard side to (Scenario 5) or port side to (Scenario 6) the dock. During Scenario 5, the vessel went slightly outside the proposed channel in the same area near the East Blair One Terminal.

WUT and Turning Basin Testing

Track plots and run sheets for the WUT and the turning basin testing can be found in Appendix A labelled Scenarios 7-13. Outbound, stern-first transits are shown in Scenarios 7-10. Meandering track lines show the challenge of the southwest wind (Scenarios 7-9) with a stern-first transit. Scenarios 9 and 10 included a docked vessel at the anchorage area in Commencement Bay. This vessel placement had minimal impact on the transit and the anchored vessel is not visible in either track plot as it was located outside of the track plot extents. In Scenario 9, the vessel grounded when it exited the channel on the south side of the entrance. This exiting approach shown in the track plot is typical in current operations, as the exiting vessel will attempt to leave the federal navigation channel as quickly as possible to make room for incoming traffic. Scenario 10 shows an outbound, stern-first transit with north wind.

Outbound transits using the turning basin can be seen in Scenario 11 for S WUT and Scenarios 12-13 for N WUT. In Scenario 11, the vessel grounded when it clipped the north corner of the turning basin while preparing for the turn. In Scenario 12, the vessel clipped the northeast corner of the turning basin. Pilots felt strongly that the "dead water" (area that looks deep but is too shallow for the vessel) on the north and east side of the turning basin was dangerous. There is no way to mark the channel extents with a buoy in the dead water area. Pilot could easily consider the turning basin larger than it is and run outside of the basin limits. In Scenario 13, the vessel went outside the proposed design channel near the East Blair One Terminal

4 Recommendations

Based on simulations completed during the FLSSP, final discussions, and final pilot surveys (Appendix B), the proposed channel was deemed acceptable if several modifications were completed on the channel. The following section describes in detail why the modifications are suggested and provide examples of proposed modifications to the channel. Further refinement of these modifications should be completed during PED simulations.

Throughout the testing week, pilots clipped the corner that connects the northern extents of the turning basin with the main navigation channel several times (Scenario V1, 4, 11, and 13) when entering the turning basin. When there is a vessel docked at the PCT, there is a tendency for the pilot to want to pull far east into the turning basin to leave as much space as possible from the docked vessel. This often led to the vessel clipping the northern corner of the turning basin. To ease the transition from the main channel into the turning basin, a chamfer was suggested to eliminate this harsh corner. In Figure 5, an example of this modification is shown as "1". This modification would also provide extra room for the swinging bow of vessel that has just finished its turn and is headed back into the main channel. To further ease the transition into the turning basin, it was also suggested to widen the area in front of the East Blair One Terminal. In Figure 5, an example of the widening described is shown as "2". Throughout the testing week, pilots went outside the channel in front of the EB-1 Terminal several times (Scenario 4, 5, 11, and 13) when entering or leaving the turning basin. The final modification suggested for the turning basin was to eliminate the "dead water" on the east side of the turning basin. Currently, there is no way to mark where the deep water on the east side of the turning basin ends and where the shallow water begins. Not knowing where the turning basin extents are can be very dangerous and pilots could easily run outside the channel lines (Scenario 4 and 12). Following simulations, it was suggested that the turning basin be expanded to eliminate this concern. In Figure 5, an example of this modification is shown as "3".

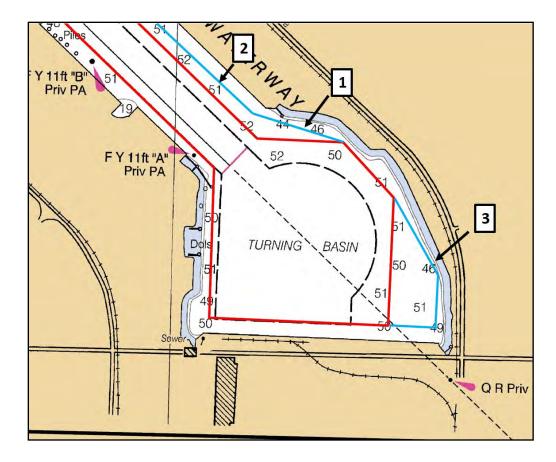


Figure 5. Suggested modifications to the turning basin

Another area of concern was the shallow areas on either side of the entrance. Throughout the testing week, pilots grounded several times on the south side (Scenario 2 and 9) and north side (Scenario 3) of the entrance when entering or leaving the Blair Waterway. The exiting approach where the vessel clips the shallow area on the south side of the entrance shown in the track plot is typical in current operations, as the exiting vessel will attempt to leave the federal navigation channel as quickly as possible to make room for incoming traffic. During strong wind events, it can be challenging for a vessel to be exactly lined up with the entrance of the Blair Waterway. If the entrance was flared out slightly, this would provide a larger safety factor for vessels entering or leaving the Blair Waterway. If a flared entrance is not feasible, at a minimum, the area south of the entrance should be dredged to remove the high spot. In Figure 6, an example of a flared southern entrance is shown as "4" and the minimum dredged area is circled in green. If possible, a similar flared entrance should be included on the north entrance (shown as "5" in Figure 6) as well.

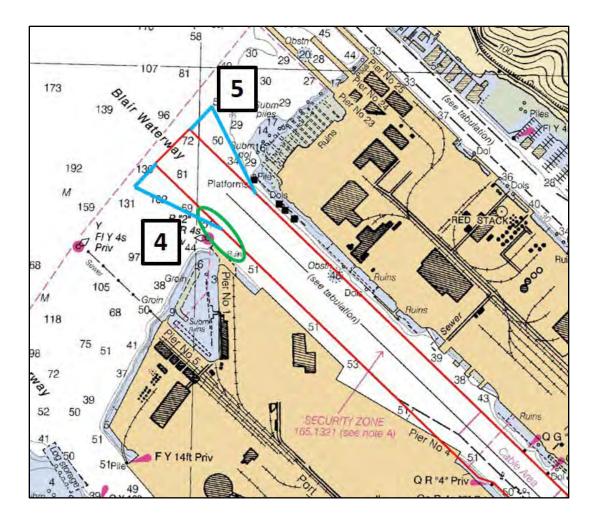


Figure 6. Suggested modifications to the entrance channel

Following the FLSSP and final discussions, several items were identified as recommendations to be included in PED ship simulations.

- a. Wind shadowing from docked vessels should be included. This could be accomplished either by the incorporation of created wind files which would include this effect or by using K-Sim (the next generation of ship simulation software).
- b. The exact design vessel should be contracted for use in PED testing.
- c. A visual cue should be added to watch the wind and determine wind strength and direction. This could be accomplished by adding smokestacks or windsocks.

d. Docked vessels should be replaced with ownships in K-Sim. This would allow ship-to-ship interaction to be modelled. The piston effect could likely be included as well.

e. Tug effectiveness should be limited during operations. This could be implemented by enforcing a degradation of tug usefulness based on the transiting vessel's speed.

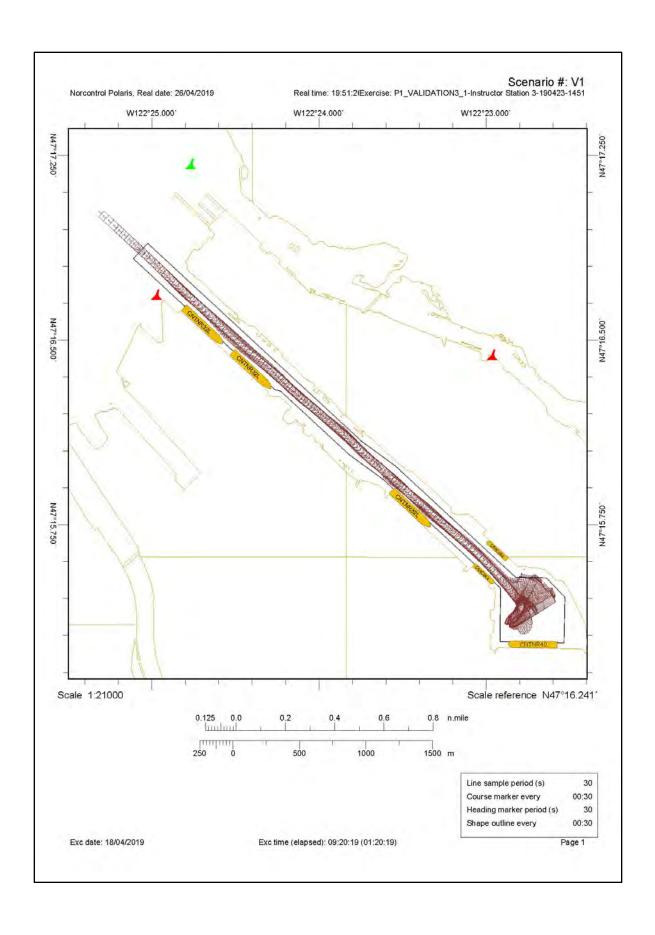
5 TSP Channel

The list below reflects the final determination of priority for the TSP channel that was determined during the final FLSSP discussion on Thursday, 25 April 2019. These modifications have been approximated in Figure 5 and Figure 6.

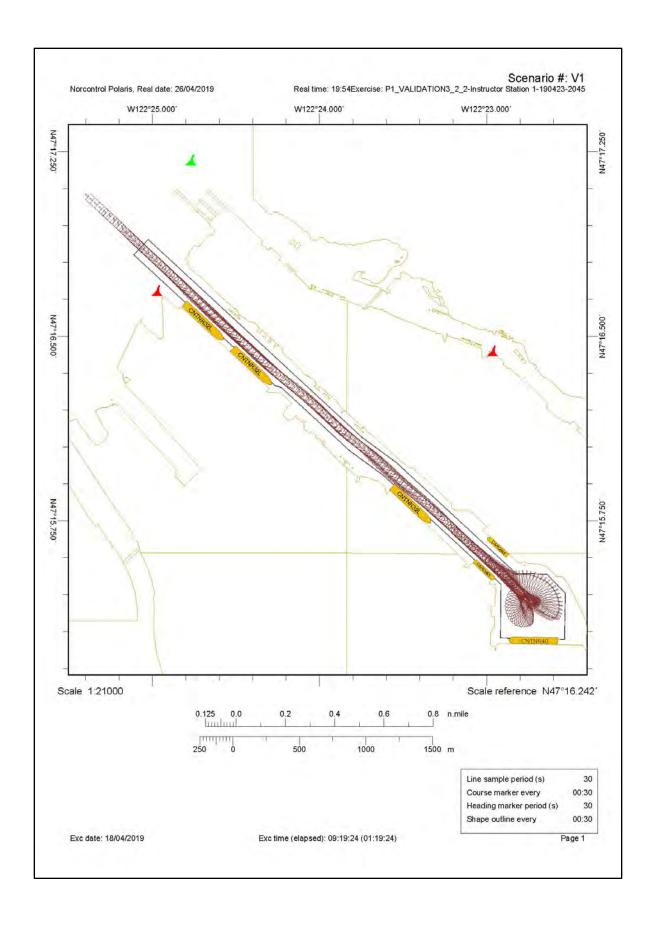
- 1. Create a chamfer along the north edge of the turning basin to ease the transition from the channel into the turning basin.
- 2. Widen the channel in front of the East Blair One Terminal.
- 3. Extend the turning basin to eliminate dead water that could cause a vessel to ground.
- 4. Eliminate the high spot on the south side of the entrance. If possible, create a flared entrance on the south side of the entrance.
- 5. Eliminate the high spot on the north side of the entrance. If possible, create a flared entrance on the north side of the entrance.

Appendix A: Track Plots and Pilot Comments

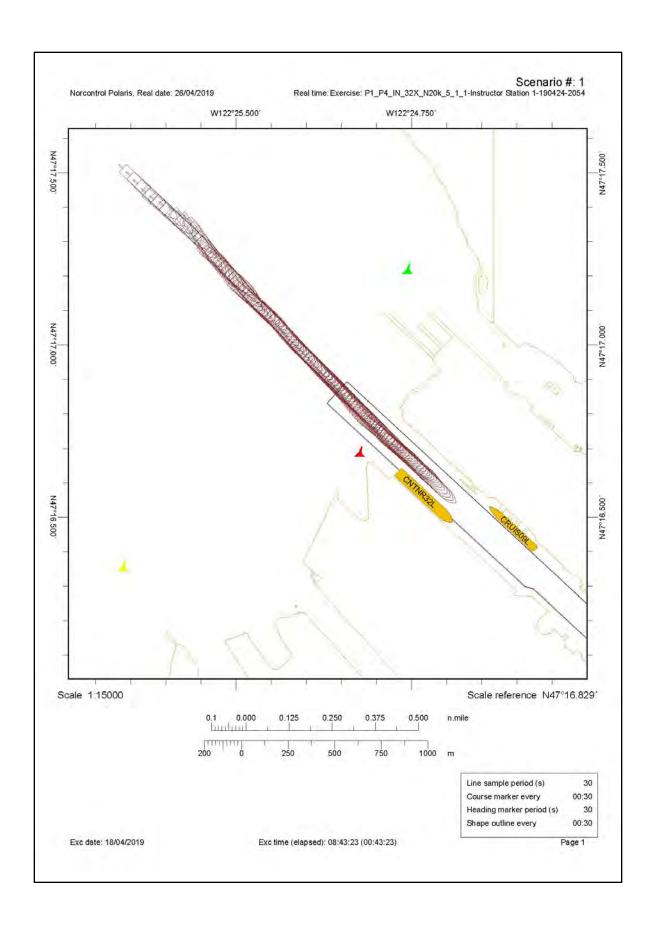
| Channel Alternative: | PO (Existing) | | (P1) | | |
|--|--|---|--|--|--|
| Dock: P3 P4 Date: Apr 23 19 | NWUT | SWUT | PCT | Blair | EB1 |
| Test Matrix Run Number | | | Repetition | n: | |
| Heading IN Inbound O Outbound | | nd (Turning Ba | | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>O4X</mark> | CNTNR42 | | | |
| Wind Condition One | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | 5 2-90T 1-50 | т 375 | T | | |
| Pilot: Capt. Jed Arnold (P | Pilot 2) | | Capt. Mark | Shuler (Pilot 2 |) |
| | OTB_32X_NE201 | k_R_1_1 | P4: CNTNR | | NWUT: CNTNR32 |
| | OTB_32X_NE201 | k_R_1_1 | | | NWUT: CNTNR32 |
| Example: P1_NW_PI_Validation Targets: TOTE: GASO7L | OTB_32X_NE201 | k_R_1_1 | | 32 ! _ | NWUT: CNTNR32 4. EB1: CAR04X |
| Example: P1_NW_PI | PS: CNTNR4 | k_R_1_1 k_ 0 e: | P4: CNTNR Blair: CARC Total tran | 32 _ 04 X sit time: | EB1: CARO4X |
| Example: P1_NW_PI_PI_Validation Targets: TOTE: GASO7L SWUT: CNTNR32. End Time: | PS: CNTNR4 | k_R_1_1 k_ 0 e: | P4: CNTNR Blair: CARC Total tran | 32 _ 04 X sit time: | EB1: CARO4X |
| Example: P1_NW_PI | PS: CNTNR4 | k_R_1_1 k_ 0 e: | P4: CNTNR Blair: CARC Total tran | 32 _ 04 X sit time: | EB1: CARO4X |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CAROAX |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CAROAX |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CARO4X |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CAROAX |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CAROAX |
| Example: P1_NW_PI PI Filename: Validation Targets: TOTE: GASO7L SWUT: CNTINES2. End Time: Comments: - Grading Simulation | P3: CNTNR32. PCT: CNTNR4 Log File Time MATERIAL WIAN TION SECOND | e: o o o o o o o o o o o o o | P4: CNTNR Blair: CARC Total tran | 321- 04X sit time: 000 to Se | EB1: CAROAX |



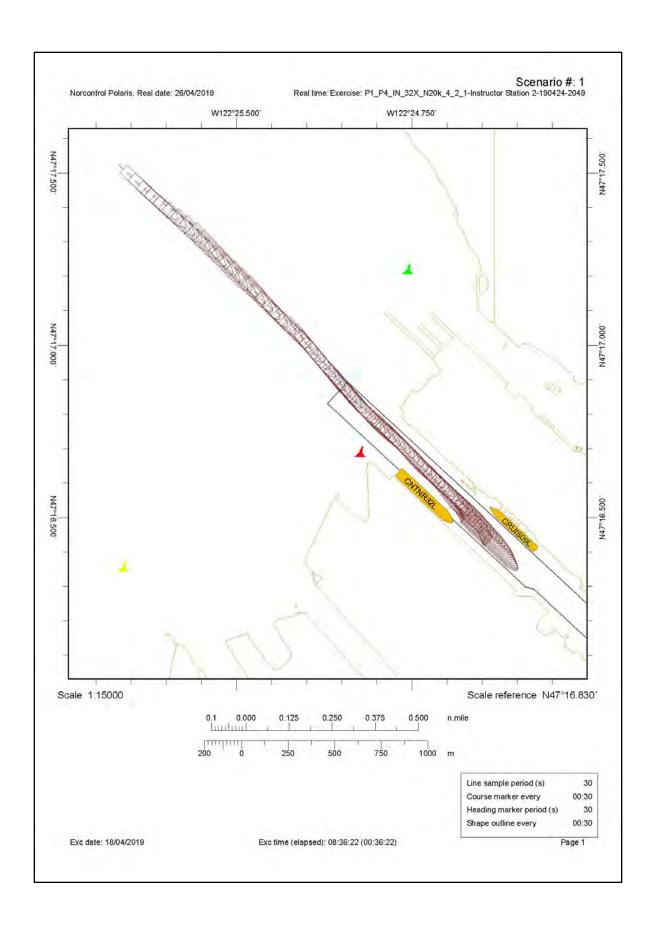
| Channel Alternative: | P0 (Existing | 3) | PI | | |
|---|----------------------|------------------------------------|-------------------|-------------------|---------------|
| Dock: P3 P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: 4/23/19 | | | | | |
| Test Matrix Run Number: | | | Repetition | n: | |
| Heading IN Inbound O Outbound | | and (Turning Ba aund (Turning B | | OS Outbo | ound (Stern) |
| Vessel: CNTNR32X Star | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | S 2-90T 1-5 | от 479 | 5T | | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | | Capt. Mark | k Shuler (Pilot 2 | |
| Filename = Alt. + Dock + He Example: P1_NW_O Filename: P1_ Validati | TB_32X_NE2 | 0k_R_1_1 | s + Pilot + Rep | etition | |
| Targets: TOTE: none | P3: CNTNR3 | | P4: CNTNR | 32 L | NWUT: CNTNR32 |
| NONE. | PCT: CNTNF | 340 | Blair: CARG | 04X | EB1: CARO4X |
| | Log File Tin | ne: 2045 | Total tran | sit time: /: | 19:23 |
| End Time: 2230 | | | | a-ch | |
| | ATOR L | SORKED A | SAX3 EXPS | CION | |
| Comments: SIMUL | ATOR U SAMSFII | SORKED A | SIMULA | TOE & M | 00EL |
| Comments: SIMUL | ATOR U SATISFII | SORKED A | AS EXPE SIMULA | TOE & M | DOEL |
| Comments: SIMUL | ATOR U | POLKED T | AS EXPE SIMULA | TOE FM | DOEL |
| Comments: SIMUL | ATOR W | POLIKED T | SIMULA | TOE & M | DOEL |
| Comments: SIMUL | ATOR U | POLKED T | SIMULA | TOE & M | DOEL |



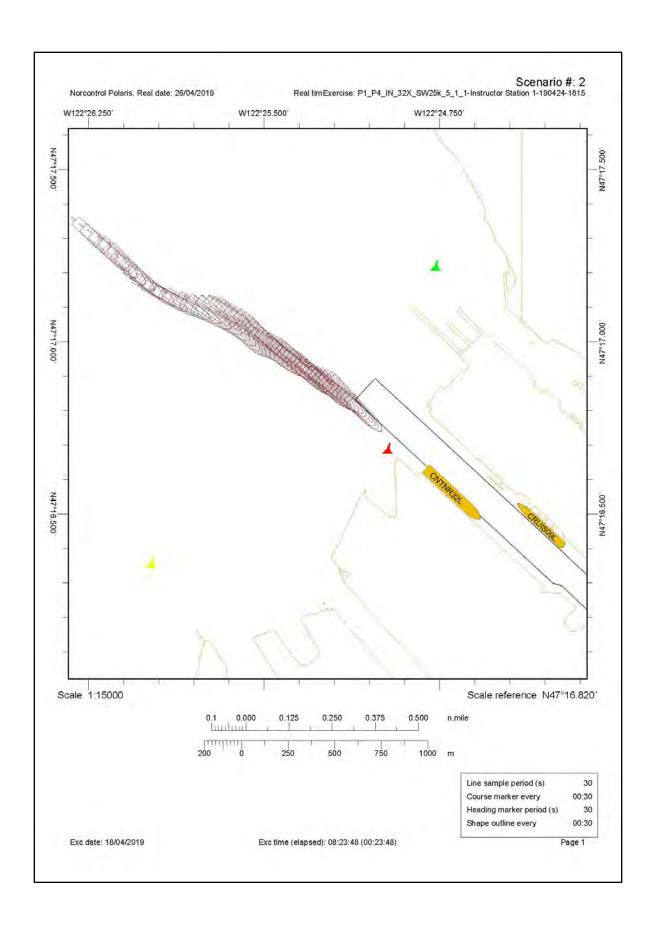
| Channel Alternative: | PO (Existing) | (P1) | | |
|--|---|--|---|--|
| Dock: P3 | NWUT SW | UT PCT | Blair | EB1 |
| Date: | | | | |
| Test Matrix Run Number: | 12 (4c) | Repetitio | n: 1 | |
| Heading: (IN Inbound) Outbound | INTB Inbound (Tu | | OS Outboo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>O4X</mark> CN | TNR40 | | |
| Wind Condition: 0 None | SW20k NE | 20k NZOk | SW25k | |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50T | (5 3-98T) | | |
| Pilot: Capt. Jed Arnold (Pile | ot 1) | Capt. Mar | k Shuler (Pilot 2) | |
| Example: P1 NW C | OTB 32X NE20k R 1 | d + Tugs + Pilot + Rep _1 Qx_N&&L _5 _ I | | |
| Example: P1_NW_C Filename: P1_NW_C CR_VISO9_L | OTB_32X_NE20k_R_1 11- P4_ iN - 3 | 1 | اد | NWUT: CNTNR32L |
| Example: P1_NW_C | OTB_32X_NE20k_R_1 11- P4- iN-3 | _1 Qx_Naok_5_1 | _ 1 332L | NWUT: CNTNR32L EB1: CAR04X |
| Example: P1_NW_C Filename: CP_VISO9 L Targets: TOTE: none | OTB_32X_NE20k_R_1 PH_ iN - 3 P3: CNTNR32L | _1 RX_N86V _5_ I P4: CNTNR Blair: CARG | _ 1 332L | EB1: CARO4X |
| Example: P1_NW_C Filename: CP_NSO9 L Targets: TOTE: none SWUT: CNTNR32L End Time: 2200 Comments: | P3: CNTNR32L PCT: CNTNR40 Log File Time: 20 | _1 Qx_Na6V5_ P4: CNTNR Blair: CARG | _ 132L 104X 1sit time: 43: | EB1: <i>CAR04X</i> |
| Example: P1_NW_C Filename: CRUSSOP L Targets: TOTE: none SWUT: CNTNR32L End Time: 2200 Comments: Commen cement (6) - DUT IN The | PS: CNTNR32L PCT: CNTNR40 Log File Time: 20 Say Start Low Sur W | P4: CNTNE Blair: CARC SY Total tran N47-17 | -1 232L 204X 204X 204X 204X 204X 204X 204X 204X | EB1: CAROAX 21 auspeable with |
| Example: P1_NW_C Filename: CP_NSO9 L Targets: TOTE: none SWUT: CNTNR32L End Time: 2200 Comments: | PS: CNTNR32L PCT: CNTNR40 Log File Time: 20 Say Start Andour will Selow 2.0 full (Advan | P4: CNTNA Blair: CARO SY Total tran N47-17 Nds 20 KD | -1 232L 204X 204X 204X 204X 204X 204X 204X 204X | EB1: CAROAX 21 ANGERABLE WITH WERY CONFORTA |



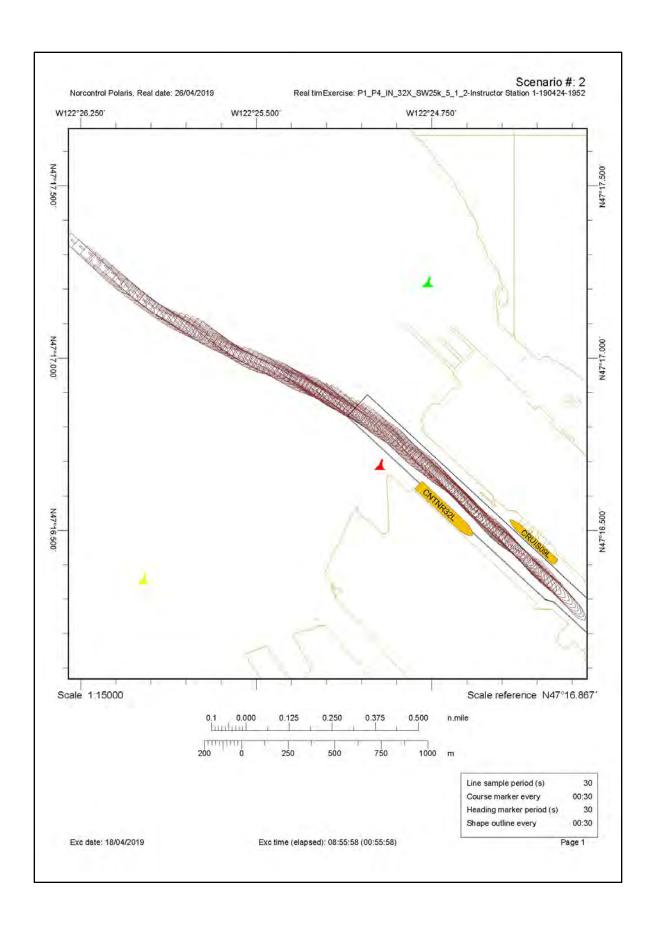
| Channel Alternative: | PO (Existing) | | P1 | | |
|--|----------------------|----------------------------------|------------|--------------------|----------------|
| Dock: P3 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: Apr 24 | | | | | |
| Test Matrix Run Number: | 12 (4c) | | Repetitio | n: \ | |
| Heading: IN Inbound O Outbound | | nd (Turning Ba and (Turning E | | OS Outbou | ınd (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | S 2-90T 1-50 | от (4 | 4-757 | | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | | Capt. Mar | k Shuler (Pilot 2) | |
| Filename = Alt. + Dock + He Example: P1_NW_C | TB_32X_NE20 | k_R_1_1 | | etition | |
| Filename: PL-P4_IN_ CRUISO9L | | WK-4- | d _ 1 | | |
| Targets: TOTE: none | P3: CNTNR32 | PL. | P4: CNTNF | ?32L | NWUT: CNTNR32L |
| SWUT: CNTNR32L | PCT: CNTNR4 | 10 | Blair: CAR | 04X | EB1: CARO4X |
| End Time: 2153 | Log File Time | e: 2049 | Total tran | sit time: 36 | :21 |
| Comments: | Start | | | | - \/ |
| Commencement Bay DOESNT S BELL F TO POS | SEM TO | WAU | C WHE | N BAC | WALKS |



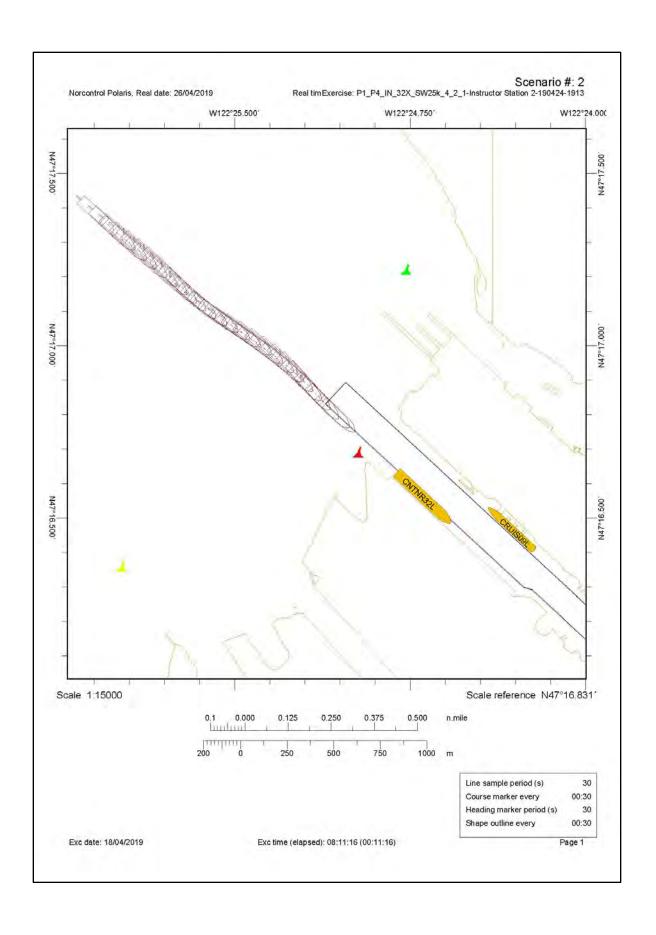
| Channel Alternative: | PO (Existing) | | P1 | | |
|---|--|-----------------|---|---|--|
| Dock: P3 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: April 24 | | | | | |
| Test Matrix Run Number: | (db) 11 | | Repetition | e l' | |
| Heading (IN Inbound) Outbound | INTB Inbound OTB Outbound | 100 | | OS Outbou | and (Stern) |
| Vessel: NTNR32X | CARO4X | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | 5 2-90T 1-50T | (4 4 | FT) (5 | 3-98T) | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | × | Capt. Mark | Shuler (Pilot 2) | |
| | N-32X-S | R_1_1 W25K _ | | 271 | NWIIT: CNTNR321 |
| | | | 5-1-1 P4: CNTNR | 32L | NWUT: CNTNR32L |
| Targets: TOTE: none | P3: CNTNR32L | | P4: CNTNR | | |
| CRUISO9L Targets: TOTE: none SWUT: CNTNR32L | | | P4: CNTNR | 04X | EB1: CARO4X |
| Targets: TOTE: none | P3: CNTNR32L | M32K - | P4: CNTNR | | EB1: CARO4X |
| CRUISO9L Targets: TOTE: none SWUT: CNTNR32L End Time: 1926 Comments: Commencement | P3: CNTNR32L PCT: CNTNR40 Log File Time: Bay Start | M32K - | P4: CNTNR Blair: CARC | o4x sit time: 23 | EB1: CARO4X |
| SWUT: CNTNR32L End Time: 1926 Comments: Commencement *Check 59, Speed | P3: CNTNR32L PCT: CNTNR40 Log File Time: Bay Start | 1815 Wask - | P4: CNTNR Blair: CARC Total tran | 04X sit time: 23 . 279, W12 | EB1: CARO4X : 47 :2.26.193, 133° |
| CRUISO9L Targets: TOTE: none SWUT: CNTNR32L End Time: 1926 Comments: Commencement *Check Sp, Speed 3.5km | P3: CNTNR32L PCT: CNTNR40 Log File Time: Bay Start 18 Tug5 | (B)5 | P4: CNTNR Blair: CARC Total tran N47-17 | 194X sit time: 23 . 279, W12 V JGE | EB1: CARO4X : 47 :2.26.193, 133° FACTOR |
| CRUISO9L Targets: TOTE: none SWUT: CNTNR32L End Time: 1926 Comments: Commencement *Check Sp, Speed 3.5km | P3: CNTNR32L PCT: CNTNR40 Log File Time: Bay Start 18 Tug5 | (B)5 | P4: CNTNR Blair: CARC Total tran N47-17 | 194X sittime: 23 . 279, W12 V JGE | EB1: CARO4X : 47 :2.26.193, 133° FACTOR |
| CRUISO9L Targets: TOTE: none SWUT: CNTNR32L End Time: 1926 Comments: Commencement *Check Sp, Speed 3.5km | P3: CNTNR32L PCT: CNTNR40 Log File Time: Bay Start 18 Tug5 | (B)5 | P4: CNTNR Blair: CARC Total tran N47-17 | 194X sittime: 23 . 279, W12 V JGE | EB1: CARO4X : 47 :2.26.193, 133° |



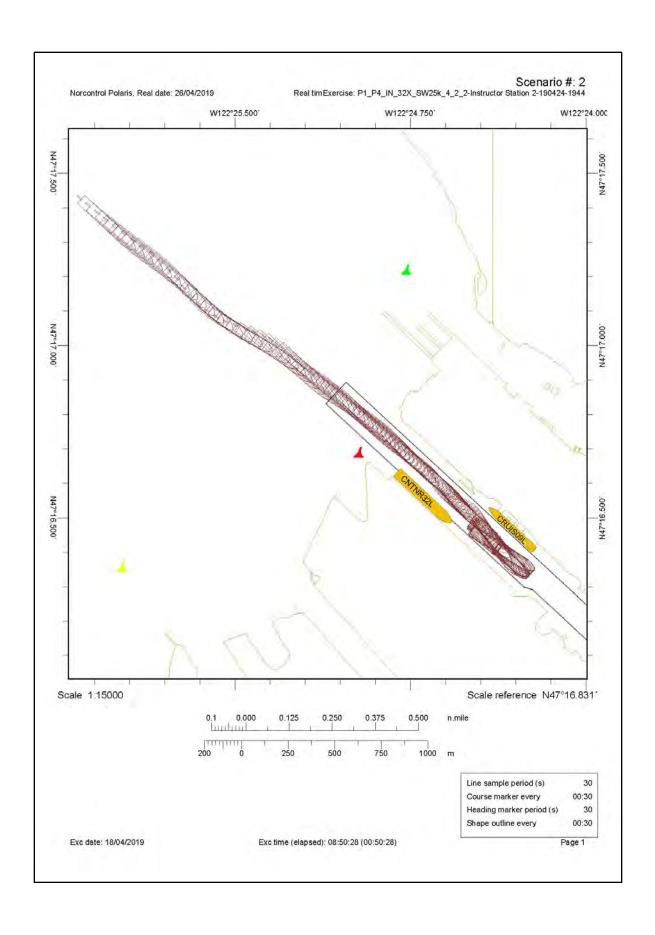
| Channel Alternative: | PO (Existing | :) | (P1) | | |
|--|----------------------|----------------------------------|-------------------|-----------------|--------------------|
| Dock: P3 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: April 24 | | | | | |
| Test Matrix Run Number: | 11 (46) | | Repetitio | n: J | |
| Heading: IN Inbound O Outbound | | nd (Turning Ba und (Turning B | | OS Outbo | ound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: O None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | S 2-90T 1-50 | от (5 3-0 | 98T | | |
| Pilot: Capt. Jed Arnold (Pil | ot 1) | | Capt. Mar | k Shuler (Pilot | 2) |
| Filename: PI-P4-IW CRUIS OF LETTE: none | | | _1_2 P4: CNTNI | ₹ <i>32L</i> | NWUT: CNTNR32L |
| Targets: TOTE: none SWUT: CNTNR32L | P3: CNTNR3. | 2L | P4: CNTNI | 04X | EB1: CARO4X |
| Targets: TOTE: none SWUT: CNTNR32L | P3: CNTNR3. | 2L | P4: CNTNI | 04X | EB1: <i>CAR04X</i> |
| Targets: TOTE: none SWUT: CNTNR32L | P3: CNTNR3. | 2L | P4: CNTNI | 04X | EB1: CARO4X |



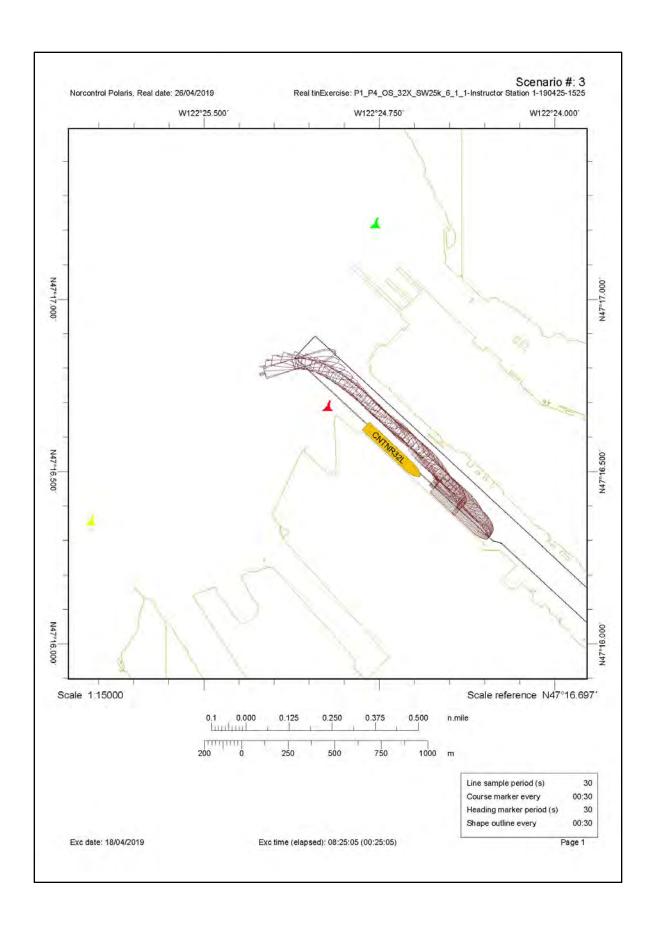
| Channel Alternative: P0 (Existing) | |) | P1 | | |
|---|--|--------------|---|-----------|----------------|
| Dock: P3 | NWUT | SW UT | PCT | Blair | EB1 |
| Date: April 24 | | | | | |
| Test Matrix Run Number: | 11 (46) | | Repetition: 1 | | |
| Heading: IN Inbound O Outbound | INTB Inbound (Turning B OTB Outbound (Turning | | | | ound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-5 | OT 4 4-2 | 5 (| | |
| Pilot: Capt. Jed Arnold (Pilot 1) | | | Capt. Mark Shuler (Pilot 2) | | |
| Filename: PI_P4_ <u>†</u> CEVISOAL Targets: TOTE: none | | | P4: CNTNR32L | | NWUT: CNTNR32L |
| SWUT: CNTNR32L | PCT: CNTNR40 | | Blair: CAR | 04X | EB1: CARO4X |
| End Time: 19:40 | Log File Time: 1913 | | Total transit time: $\{(\cdot,\cdot)\}$ | | 14 |
| Comments: Commencement Bo *check SP, speci | 1 | | | | |
| IST ATTEMPT | Tug - | PULLING | ALT, | NO ETTE | ECY . |
| | 44 | 11 | 11 . | Courses 1 | ISL. DOWN |



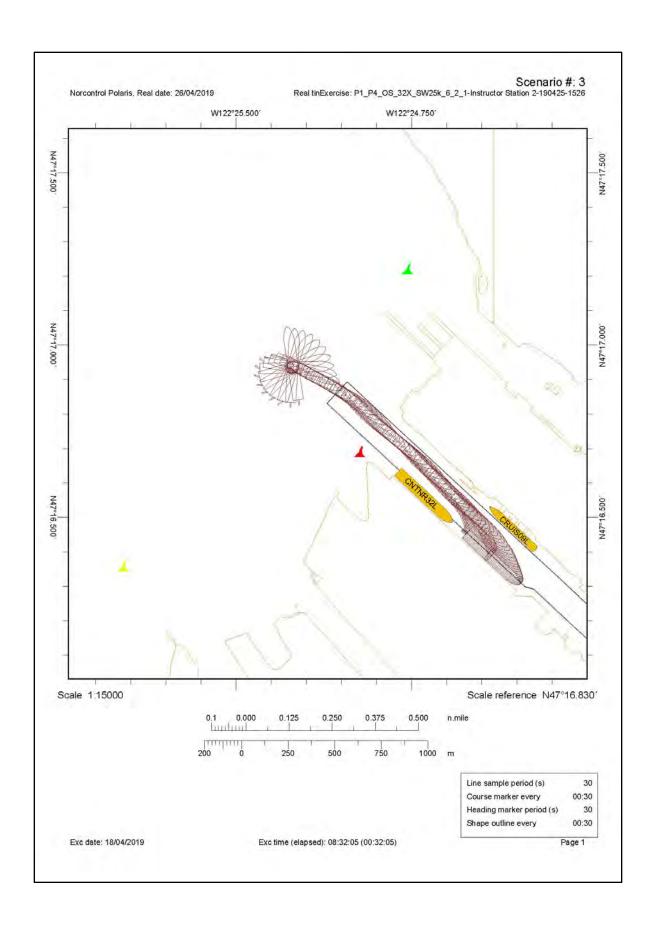
| | ive: | P0 (Existing |) | PI | | |
|--|-----------------|----------------------|----------------------------------|------------|-------------------|---------------|
| Dock: P3 | P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: April | 24 | | | | | |
| Test Matrix Run | Number: | 11(46) | | Repetitio | n: 2 | |
| Heading: N Inbo | | | nd (Turning Ba und (Turning B | | OS Outbo | und (Stern) |
| Vessel: CNTNR | 32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: | 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50 | T 1-90T | S 2-90T 1-50 | OT 4. | 4-75T | | |
| Pilot: Capt. Jed | Arnold (Pilo | ot 1) | | Capt. Mar | k Shuler (Pilot 2 | |
| | P1_NW_0 | TB_32X_NE20 | | | etition | |
| Filename: TL | | | | | | |
| Filename: $\forall \ \ \Box$ Targets: TOTE: n | | P3: CNTNR3. | 2L | P4: CNTNF | 32L | NWUT: CNTNR32 |
| Targets: TOTE: n | ohe | P3: CNTNR3. | | P4: CNTNF | | NWUT: CNTNR32 |
| Targets: TOTE: n | ońe CNTNR32L | PCT: CNTNR | 40 | Blair: CAR | 04X | EB1: CARO4X |



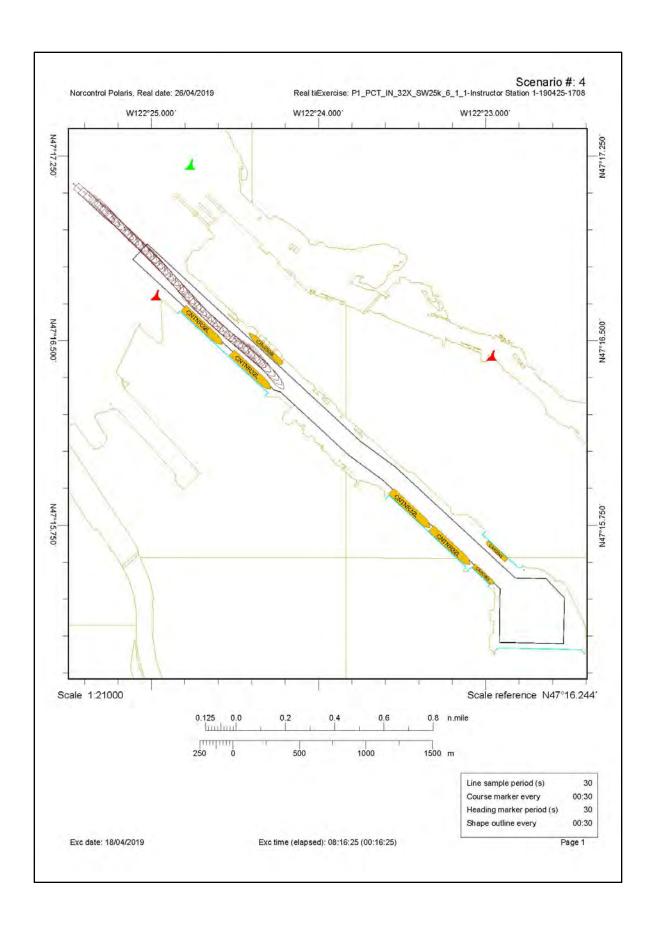
| Channel Alternative: | PO (Existing) | | P1 | | |
|---|---|-------------------|----------------------|-----------------------------|------------------------------|
| Dock: P3 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: April 24 201 | 19 | | | | |
| Test Matrix Run Number: | | | Repetition | 1: | |
| Heading: IN Inbound O Outbound | INTB Inboun OTB Outbou | | | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | 5 kn. gust |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T | 6 3-91 | 3T 1-50T) | |
| Pilot: Capt. Jed Arnold (Pi | ilot 1) | | Capt. Mar | k Shuler (Pilot 2 |) |
| Example: P1_NW_ | OTB_32X_NE20I | | | | |
| Filename: PI_P4_0 Targets: TOTE: Cryis09L | 93: CNTNR32 | | _6_1_ P4: CNTNF | | NWUT: CNTNR32 |
| | P3: CNTNR32 | L | | R32L | NWUT: CNTNR32 EB1: CARO4X |
| Targets: TOTE: Cryis09L | P3: CNTNR32 | L O | P4: CNTNF | 332L 04X | |
| SWUT: CNTNR32L End Time: 6 5 Comments: | P3: CNTNR32 PCT: CNTNR4 Log File Time | L 0 e: 1525 | P4: CNTNR Blair: CAR | 732L 04X 1sit time: 2 | EB1: <i>CAR04X</i> S: o Y |
| Targets: TOTE: Cruis09L SWUT: CNTNR32L End Time: 1615 | P3: CNTNR32 PCT: CNTNR4 Log File Time | L 0 e: 1525 | P4: CNTNR Blair: CAR | 732L 04X 1sit time: 2 | EB1: <i>CAR04X</i> S: o Y |

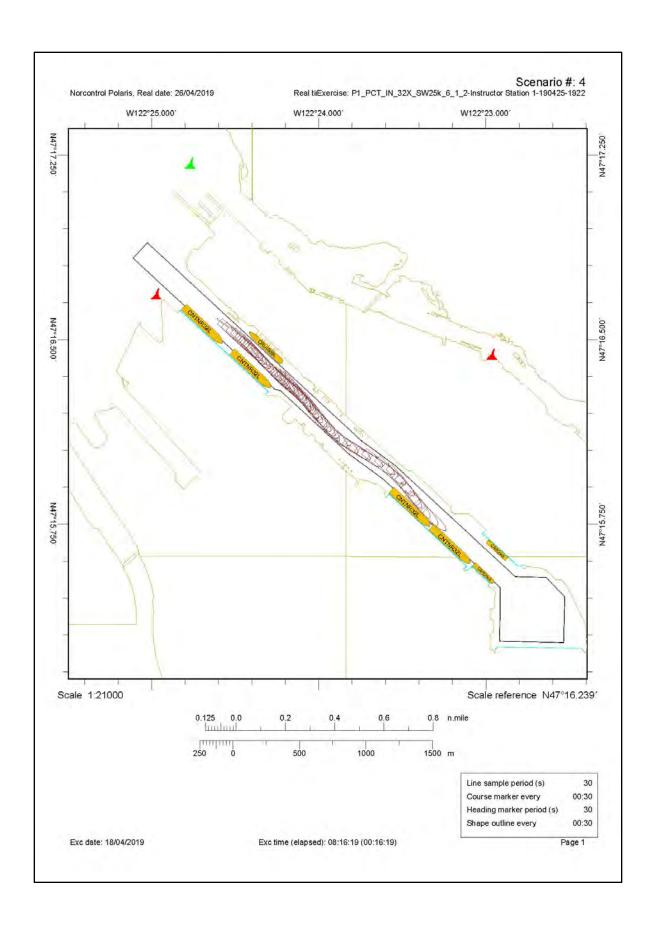


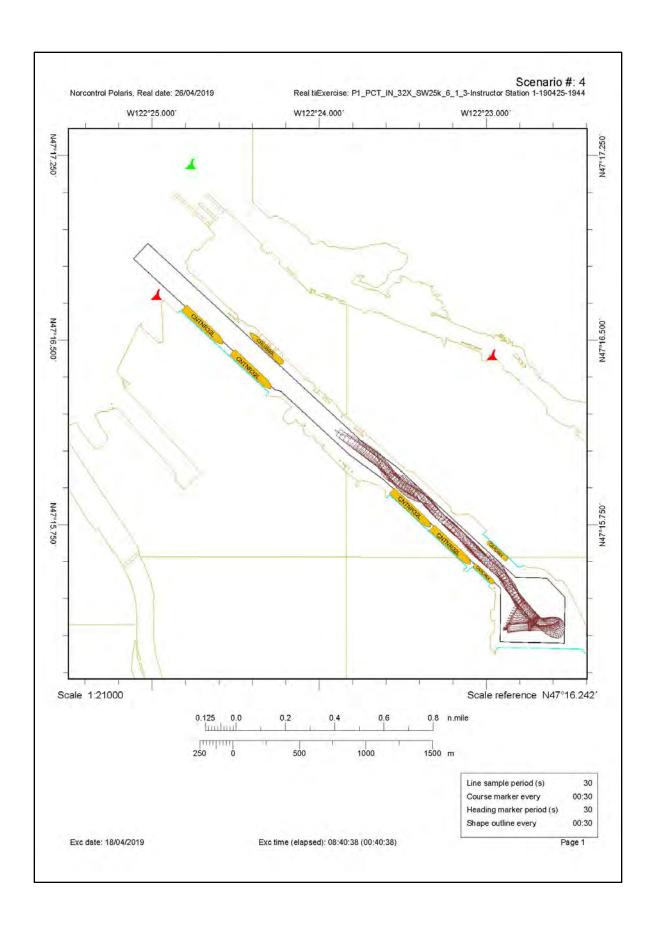
| Channel Alternative: | PO (Existing |) | P1 | | |
|--|----------------------|----------------------------------|----------------|--------------------|----------------|
| Dock: P3 | NWUT | SW UT | PCT | Blair | EB1 |
| Date: 4/24/19 | | | | | |
| Test Matrix Run Number: | | | Repetitio | on: | |
| Heading: IN Inbound O Outbound | | nd (Turning Ba und (Turning B | | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | +1-5kt |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k |) |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T | | | |
| Pilot: Capt. Jed Arnold (Pil | ot 1) | | Capt. Ma | rk Shuler (Pilot 2 | |
| Filename = Alt. + Dock + He Example: P1_NW_C Filename: P1_P4_0 | OTB_32X_NE20 |)k_R_1_1 | | petition | |
| Targets: TOTE: Cruis09L | P3: CNTNR3. | 2L | P4: CNTN | R32L | NWUT: CNTNR321 |
| SWUT: CNTNR32L | PCT: CNTNR | 40 | Blair: CAI | R04X | EB1: CARO4X |
| End Time: 1622 | Log File Tim | ne: 1526 | Total tra | nsit time: 33 | 104 |
| Comments: | | | | | |
| TUGS IN T WIND EHER DUE TO, | 5Q 001 | NFIGURA | MON | | |
| DUE TO | SIMUL | 45 S | TRONG R SIZ | 45 EXP E AND I | PECTED |
| OF VSC | ({ }) | | | V 1 | |



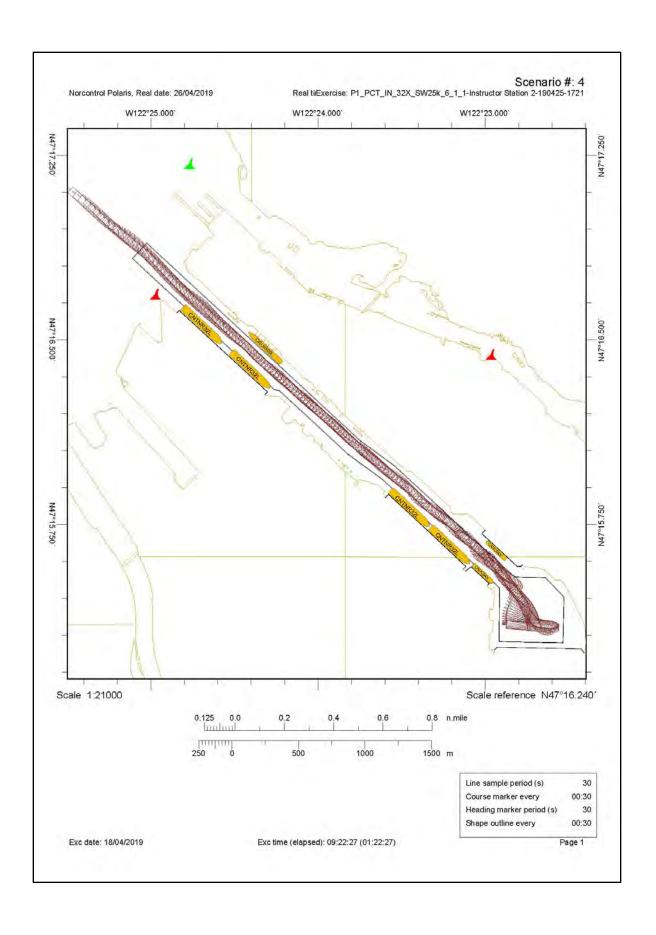
| | | | 0 | | |
|-------------------------------|----------------------|--------------------------------|-----------------|--------------------|----------------|
| Channel Alternative: | PO (Existing) | | P1 | | |
| Dock: P3 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: Apr 25 | | | | | |
| Test Matrix Run Number: | | | Repetition | 1: | |
| Heading: N Inbound O Outbound | | d (Turning Ba nd (Turning B | | OS Outbour | nd (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | 5k Gusts |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k |) |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T | 6 39 | PT 1-50T) | LOG TIMES: |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | | Capt. Mar | k Shuler (Pilot 2) | 1 1708 |
| Filename = Alt. + Dock + He | ading + Vessel | + Wind + Tug | s + Pilot + Rep | etition | _2 1922 |
| Example: P1_NW_O | | | | | -31944 |
| Filename: PI_PCT_M | 32x_5wa | 5K - 6. | _(_) | | |
| Targets: TOTE: Cruis09L | P3: CNTNR32 | L | P4: CNTNF | 132L | NWUT: CNTNR32L |
| SWUT: CNTNR32L | PCT: CNTNR4 | 10 | Blair: CAR | 04X | EB1: CARO4X |
| End Time: | Log File Time | e: 1708 | Total tran | sit time: | |
| Comments: | | | | | |
| | | | | | |
| - Initial run | | | nmunication | enor Gess | zel was backe |
| up & then | Rep Q | began | | 1 . 1 | a matile the |
| - 30 to 9 | usis wi | 1/ Too 1 | much das | ssel alluant | ce making The |
| Transit a | Manuage | asle. | / ./ | C | to The mounts |
| | 13 Th c | hannel 0 | 118 2/1016 | Lor a 3 | The dill areas |
| - Wider |) / | | | | |



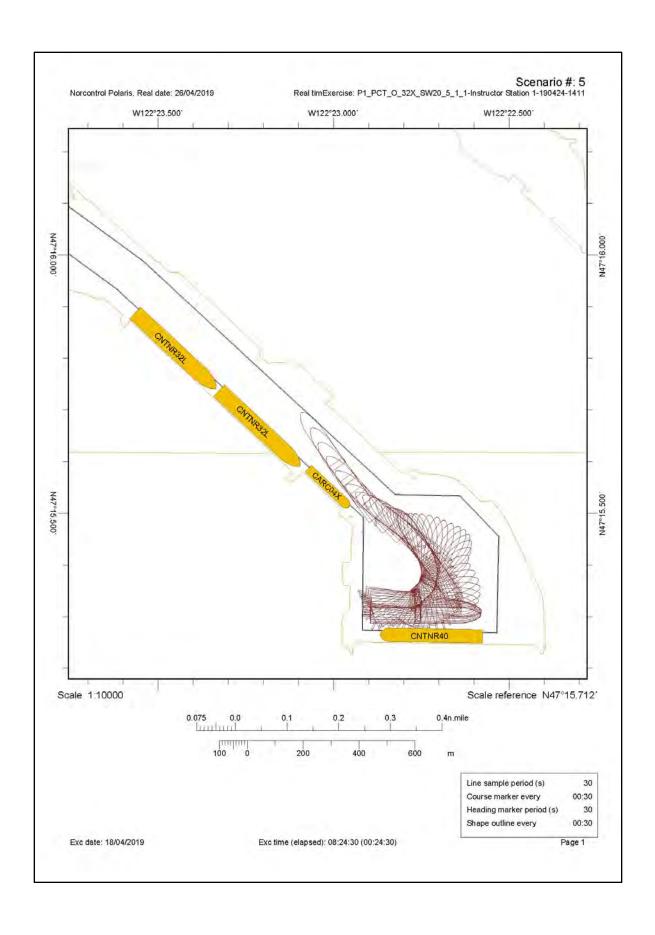




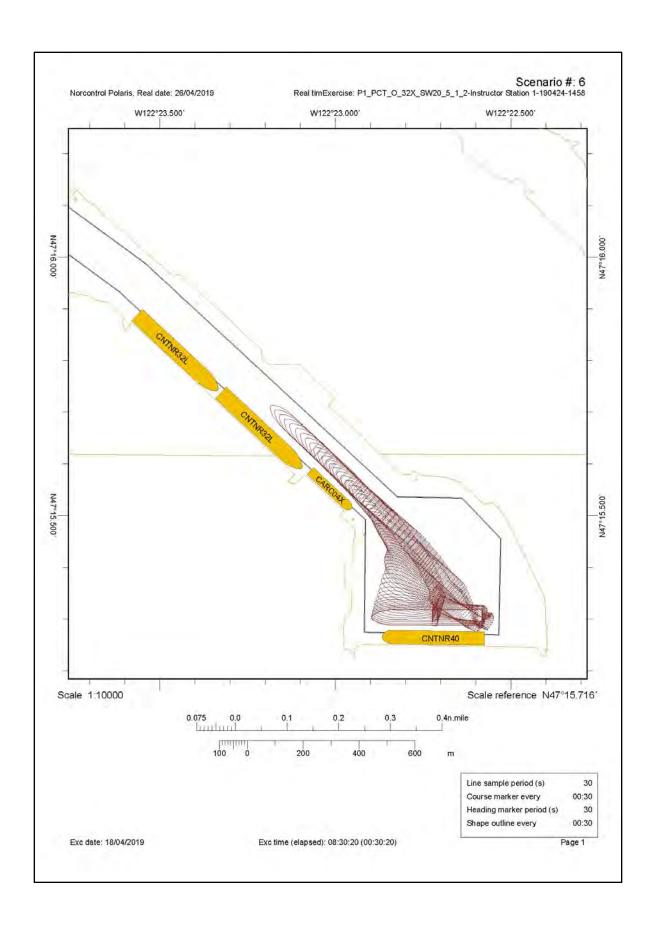
| Channel Alternative: | P0 (Existing) | | P1 | | |
|---|---|----------------------------------|-----------------|--------------------|---------------|
| Dock: P3 P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: 4/25/9 | | | | | |
| Test Matrix Run Number: | | | Repetitio | 1: | |
| Heading: (IN Inbound) O Outbound | | nd (Turning Ba and (Turning B | | OS Outbox | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | 512 Gusts |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T (| 6 3-99 | T 150T | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | | Capt. Mar | k Shuler (Pilot 2) | |
| Filename = Alt. + Dock + He Example: P1_NW_O | [[[[전기 () [] [[] [] [] [] [] [] [] [] [] [] [] [] | | s + Pilot + Rep | etition | |
| Filename: PI_PCt_1N | _32x-Sh | 125K _ 6_ | 1-6- | | |
| Targets: TOTE: Cruis09L | P3: CNTNR32 | L | P4: CNTNR | 32L | NWUT: CNTNR32 |
| SWUT: CNTNR32L | PCT: CNT NTA | 0 | Blair: CAR | 04X | EB1: CARO4X |
| End Time: 1944 | Log File Time | e: 172(| Total tran | sit time: (- 2 | 22:26 |
| Comments: Whew, | 5 T 5 | | | | |
| TUG | 5 T 5 | Q, | | | |



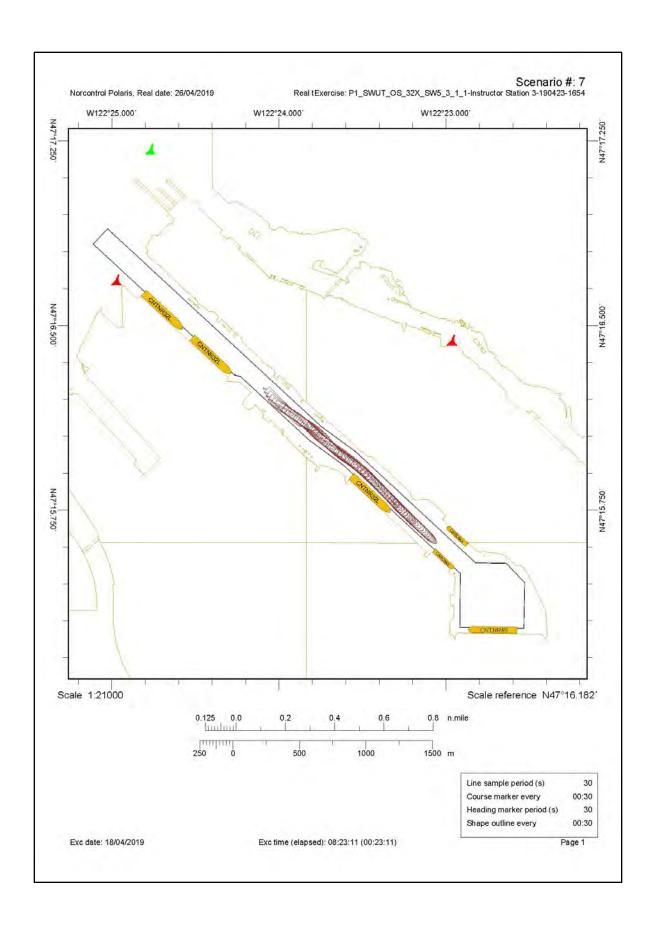
| Channel Alternative: | P0 (Existing | :) | P1 | | |
|--|----------------------|----------------------------------|----------------------|-----------------|--------------------------------|
| Dock: P3 P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: Apr 24 2019 | | | | | |
| Test Matrix Run Number: | | | Repetition | n; | |
| Heading: IN Inbound Outbound | | nd (Turning Ba und (Turning B | | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | S 2-90T 1-5 | от 🧣 🖣 | 3-987 | lia | |
| Pilot: Capt. Jed Arnold (Pil | ot 1) | | Capt. Mark | Shuler (Pilot 2 |) |
| Filename: PI_PC CEUISO9L Targets: TOTE: pine | P3: CNTNR3 | 2L | 120 _ 5 P4: CNTNR | | NWUT: CNTNR32L |
| SWUT: CNTNR32L | PCT: CNTAR | 1840 40 | Blair: CARG | 04X | EB1: CARO4X |
| End Time: 1457 | Log File Tin | ne: 1411 | Total tran | sit time: 24 | :29 |
| based o | de atte | of I expuch deep | pected per di | but co | To be NOT well be ould be bett |



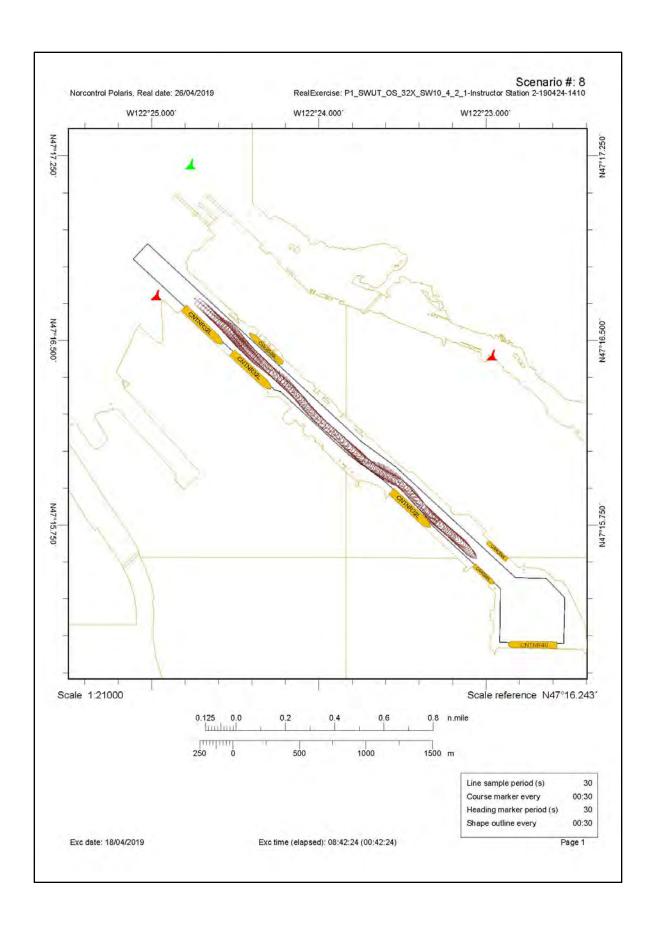
| Channel Alternative: | PO (Existing) | | P1 | | |
|---|----------------------|--------------------------------|------------------|-----------------|---------------|
| Dock: P3 P4 | NWUT | SW UT | PCT | Blair | EB1 |
| Date: April 24 | 8 | | | | |
| Test Matrix Run Number: | | | Repetition | : 2 | |
| Heading: IN Inbound O Outbound | | d (Turning Ba nd (Turning B | Color 1 The gall | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>O4X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50 | T (5 | 3-98T) | | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | | Capt. Mark | Shuler (Pilot 2 |) |
| Filename: PI PCT - C CRUISO9L Targets: TOTE: none | | | P4: CNTNR. | | NWUT: CNTNR32 |
| SWUT: CNTNR321 | PCT: CNTNR4 | 0 | Blair: CARO | 4X | EB1: CARO4X |
| | Log File Time | B: 1458 | Total trans | it time: 30 | 19 |
| End Time: 1544 | | | | | |
| Comments: | RT | | | | |
| comments: Portside to 1 | PCT ET WKS | more (| obvious i | WITH TO | he madeuver; |
| Comments: | est was | ve "Heno | 1 creep | | |



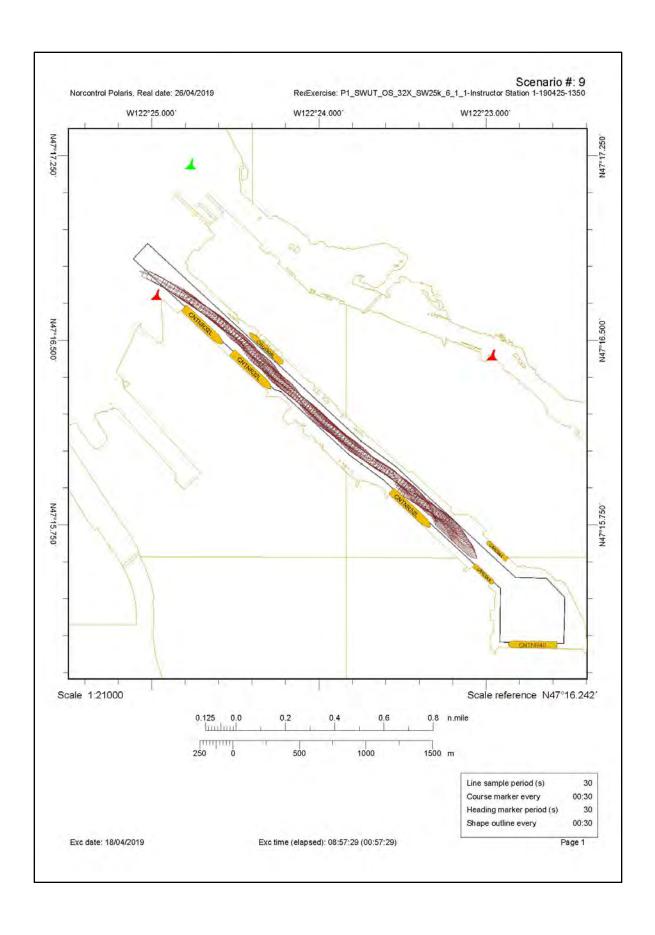
| Channel Alternative: | PO (Existing) | (P1) | | |
|--|---|--|--------------------|--------------------------------|
| Dock: P3 P4 | NWUT SWUT | PCT | Blair | EB1 |
| Date: April 23 2 | ga | | | |
| Test Matrix Run Number: | 71 | Repetition: | | |
| Heading: IN Inbound O Outbound | INTB Inbound (Turning Ba | | OS Outbo | ound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> CNTNR40 | | | Stort |
| Wind Condition: 0 None | SW20k NE20k | N20k | SW25k | (SKT SW) |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50T (3 T | 5-T | | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | Capt. Mark Sh | uler (Pilot 2 | 2) |
| Filename: PI_SWUT | OTB_32X_NE20k_R_1_1 T_05_32X_ S N5 P3: CNTNR32 k | -3_1_1 P4: CNTNR32* | | NWUT: CNTNR32 |
| Filename: PI_SWUT | -05_32X_\$N5 | P4: CNTNR32 | | |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAME SWUT | PCT: CNTNR40 | P4: CNTNR32 | | EB1: CARO4X |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CAPAR321 End Time: 17:51 | -05_32X_\$N5 | P4: CNTNR32 | | EB1: CARO4X |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PCT: CNTNR40 Log File Time: 1654 | P4: CNTNR32* Blair: CAR04X Total transit t | ime: 23 | EB1: <i>CAR04X</i> 3- 09 |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PCT: CNTNR40 Log File Time: 1654 | P4: CNTNR32* Blair: CAR04X Total transit t | ime: 23 | EB1: <i>CAR04X</i> 3- 09 |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PCT: CNTNR40 | P4: CNTNR32* Blair: CARO4X Total transit to 10 knots, the K 67/ The | ilme: 23 en 201 | EB1: CAROAX 3: 09 chots (wind) |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PS-32X-SN5 P3: CNTNR32L PCT: CNTNR40 Log File Time: 1654 (neveased 1 | P4: CNTNR32* Blair: CARO4X Total transit to 10 knots, the K 67/ The | ilme: 23 en 201 | EB1: CAROAX 3: 09 chots (wind) |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PS-32X-SN5 P3: CNTNR32L PCT: CNTNR40 Log File Time: 1654 (neveased 1 | P4: CNTNR32* Blair: CARO4X Total transit to 10 knots, the K 67/ The | ilme: 23 en 201 | EB1: CAROAX 3: 09 chots (wind) |
| Filename: PI_SWUT Targets: TOTE: none SWUT: CNAMR321 End Time: 7:5 | PS-32X-SN5 P3: CNTNR32L PCT: CNTNR40 Log File Time: 1654 (neveased 1 | P4: CNTNR32* Blair: CARO4X Total transit to 10 knots, the K 67/ The | ilme: 23 en 201 | EB1: CAROAX 3: 09 chots (wind) |



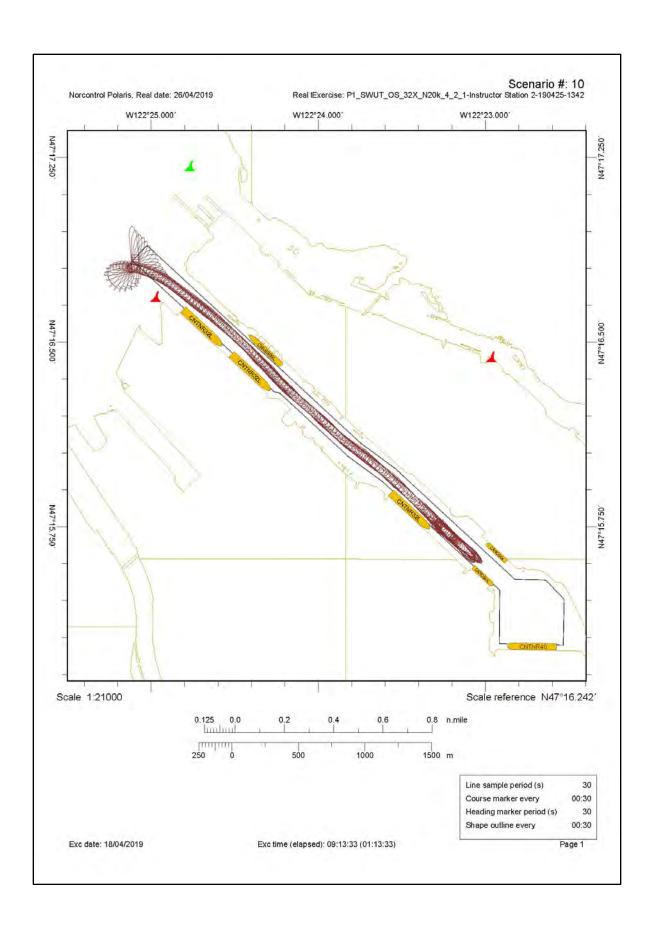
| Channel Alternative: | PO (Existing) | P1 | |
|-----------------------------------|--|-------------------------------|---------------------------|
| Dock: P3 P4 | NWUT SWUT | PCT Blair | EB1 |
| Date: Apr 24 , 2019 | | | |
| Test Matrix Run Number: | | Repetition: | 55 x0° |
| Heading: IN Inbound O Outbound | INTB Inbound (Turning Ba OTB Outbound (Turning B | | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X CNTNR40</mark> | | |
| Wind Condition: 0 None | SW20k NE20k | N20k SW25k | IOK SW |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50T 475 | | |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | Capt. Mark Shuler (Pilot 2 | |
| Example: P1_NW_O | ading + Vessel + Wind + Tug TB_32X_NE20k_R_1_1 SS_32X_SW10_4 | | |
| CEVESO9 | P3: CNTNR32L | P4: CNTNR32L | NWUT: CNTNR32L |
| SWUT: CNTNR32L | PCT: CNTNR40 | Blair: CARO4X | EB1: CARO4X |
| End Time: 15:14 | Log File Time: \4\□ | Total transit time: 42 | .22 |
| Comments: MODEL WORK JANIES DROP | ED WELL EXC | EPT FOR STER ADDED REALISM | N SCREEN. A TO TRANSIT |
| | | | |



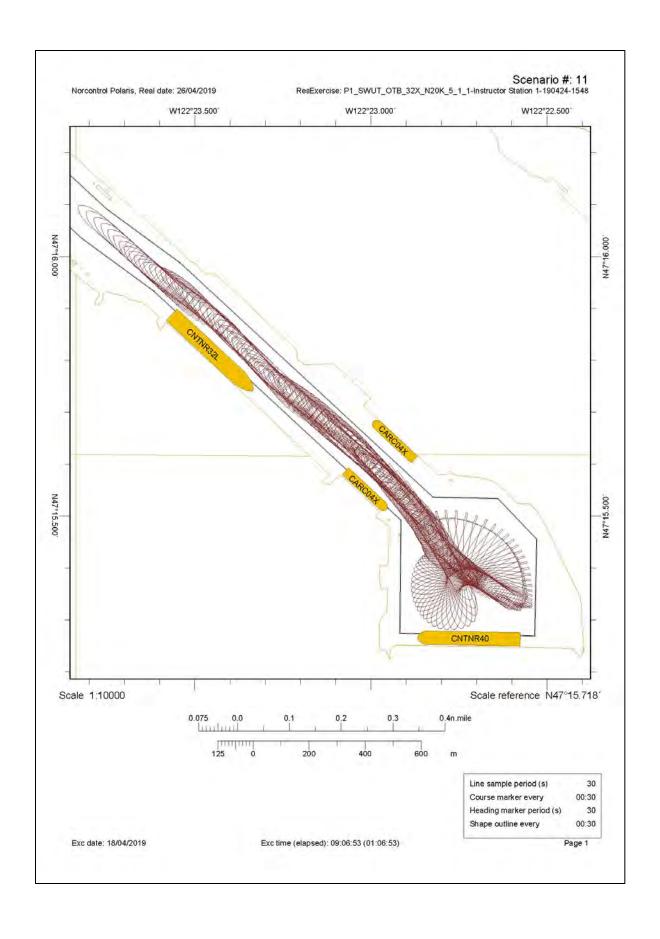
| Channel Alternative: | P0 (Existing) | P1 | |
|--------------------------------|---|---------------------|---|
| Dock: P3 P4 | NWUT SWUT | PCT B | air EB1 |
| Date: Apr 25 | | | |
| Test Matrix Run Number: | | Repetition: | |
| Heading: IN Inbound O Outbound | INTB Inbound (Turnir OTB Outbound (Turn | | S Outbound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> CNTNF | 440 | 15 K+5 |
| Wind Condition: 0 None | SW20k NE20k | N20k SI | W25k |
| Tugs: 3 3-75T | 4 4-75T 5-3-98 | 6 3-98T 1-5 | 50T) |
| Pilot: Capt. Jed Arnold (Pilo | ot 1) | Capt. Mark Shule | r (Pilot 2) |
| | TB_32X_NE20k_R_1_1 _ OS _ 32× _SW 2 | | |
| Targets: TOTE: Cruis09L | P3: CNTNR32L | P4: CNTNR32L | NWUT: CNTNR321 |
| SWUT: CNTNR32L | PCT: CNTNR40 | Blair: CARO4X | EB1: CARO4X |
| End Time: 1510 | Log File Time: 135 | O Total transit tim | e: 57:28 |
| Comments: 5 km of | just added gio | ndeel. | |
| especially represents | ing a entr | Typical one | be very helpful That trackline For a 45+ ship |



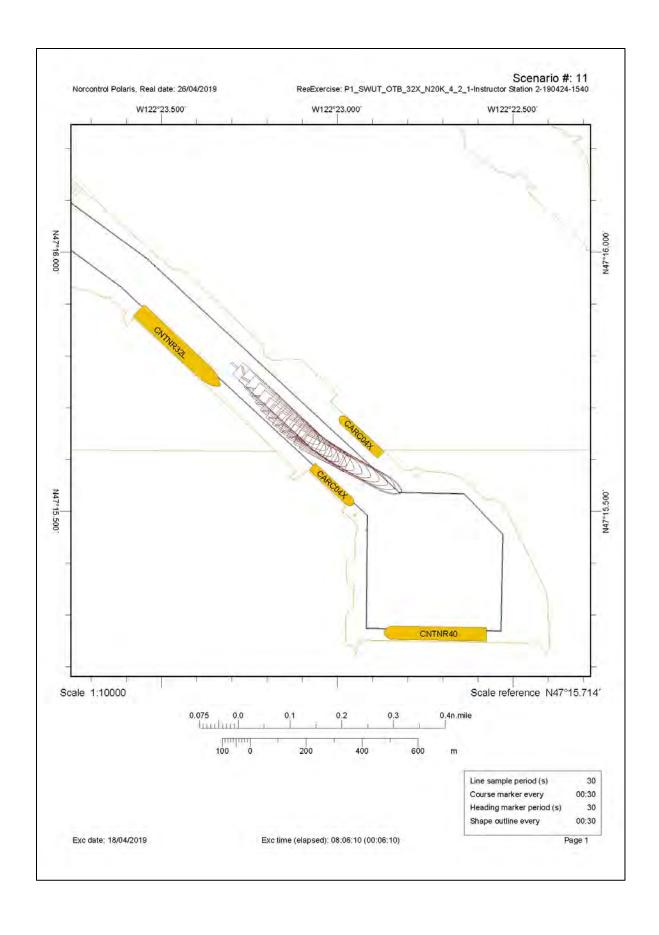
| Channel Alternative: | P0 (Existing) | | P1 | | |
|--|----------------------|----------------------------------|-----------|-----------------------|-------------------------------|
| Dock: P3 P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: Apr 25 | | | | | |
| Test Matrix Run Number: | | | Repetitio | n: | |
| Heading: IN Inbound O Outbound | | nd (Turning Ba and (Turning B | | OS Outbox | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | 9 | tsk gusts | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T | | | |
| Pilot: Capt. Jed Arnold (Pil | ot 1) | | Capt. Ma | k Shuler (Pilot 2) | |
| Anchored 3C. Targets: TOTE: Cruis09L SWUT: CNTN/R32L End Time: 520 Comments: | PCT: CNTNR4 | 10 e: 2049 | | 04X nsit time: 🐫 | NWUT: CNTNR32L EB1: CAR04X |
| Tugs IN A L FWD PORT BOW PORT TRANS STBD TRANS WINDS VS | oiT oiT | | | | ESTIDADMRI S |
| | | | | , — | |



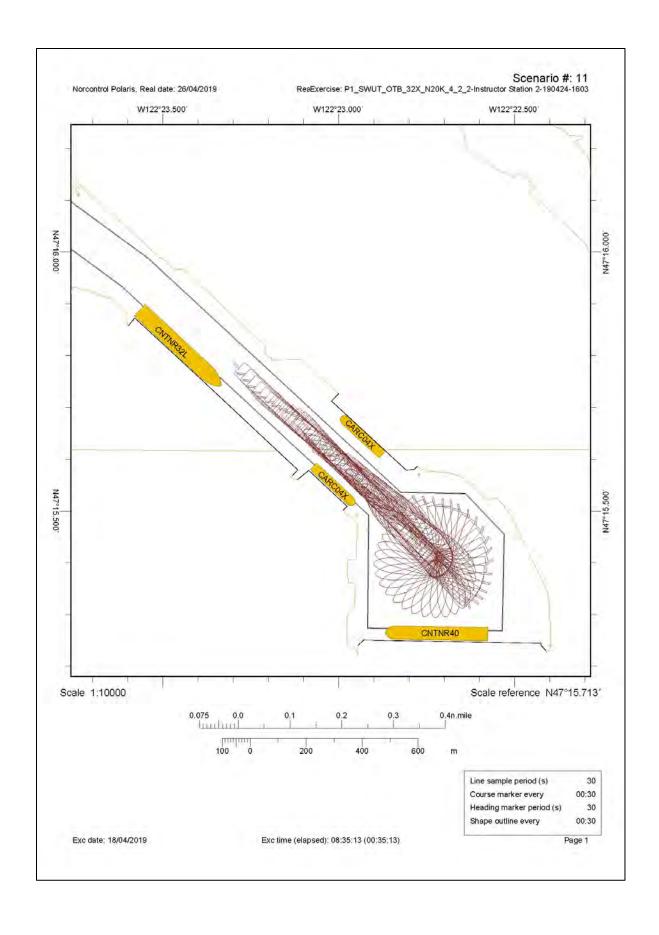
| Channel Alternative: | P0 (Existing) | P1 | | |
|--|-------------------------|----------------------|-----------------|-------------|
| Dock: P3 P4 | NWUT SV | PCT PCT | Blair | EB1 |
| Date: Apr 24 | | | | |
| Test Matrix Run Number: | 40 | Repetition | : | |
| Heading: IN Inbound O Outbound | INTB Inbound (Tu | | OS Outbo | und (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> CN | ITNR <mark>40</mark> | | |
| Wind Condition: 0 None | SW20k NI | 20k N20k | SW25k | |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50T | (METERS) | 5 39 | (18 |
| Pilot: Capt. Jed Arnold (Pi | ot 1) | Capt. Mark | Shuler (Pilot 2 |) |
| CIANITE CATEGORAL | PCT: CNTNR40 | Blair: CARO | 4X | EB1: CARO4X |
| End Time: 1709 Comments: 98T 600d estate Charles was 10 flatten | 2000 1200g | IT WAS NOTICE | able Trys | were good. |



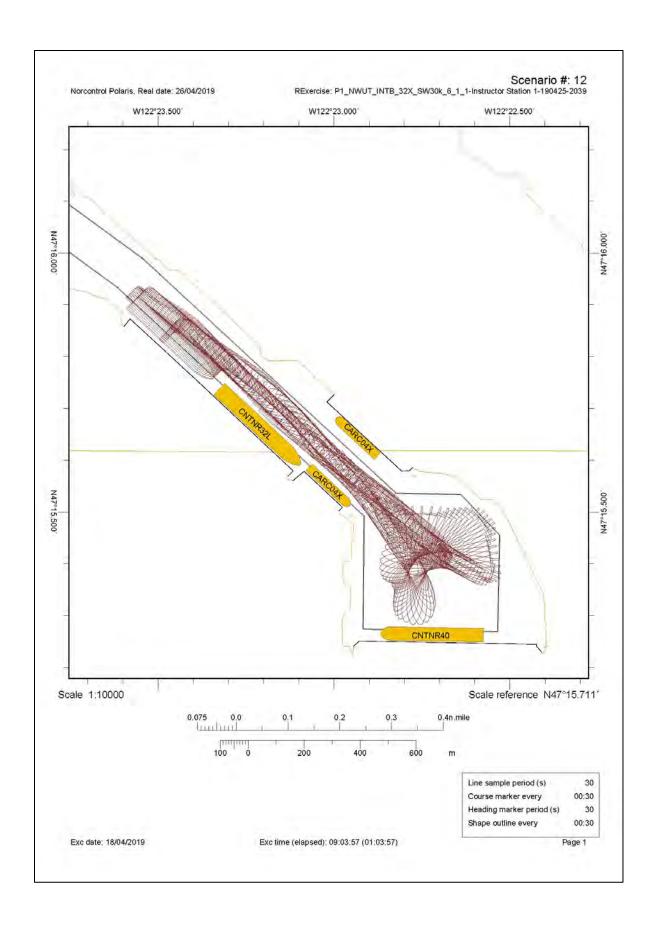
| Channel Alternative: | PO (Existing) | P1 | |
|--------------------------------|--|--------------------------|----------------|
| Dock: P3 P4 | NWUT SWUT | PCT Blair | EB1 |
| Date: Apr 24 | | | |
| Test Matrix Run Number: | 40 | Repetition: | |
| Heading: IN Inbound O Outbound | INTB Inbound (Turning B | | oound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> CNTNR <mark>40</mark> | | |
| Wind Condition: 0 None | SW20k NE20k | N20k SW25k | |
| Tugs: R 2-50T 1-90T | \$ 2-90T 1-50T 44 4 | TOT | |
| Pilot: Capt. Jed Arnold (Pilo | et 1) | Capt. Mark Shuler (Pilot | 2)/ |
| | TB_32X_NE20k_R_1_1 | | |
| Filename: PI_SWUT | OTB 30X NOCL | 4-2-1 | |
| Targets: TOTE: none | P3: CNTNR32L | P4: CNTNR32L | NWUT: CNTNR32L |
| SWUT: CNINR32L | PCT: CNTNR40 | Blair: CARO4X | EB1: CARO4X |
| End Time: 15:56. | Log File Time: 1540 | Total transit time: O | 6:09 |
| Comments: | | | |
| PAN AGR | DUND, MODEL | WORKED GOO | Δ |
| | | | |
| | | | |
| | | | |



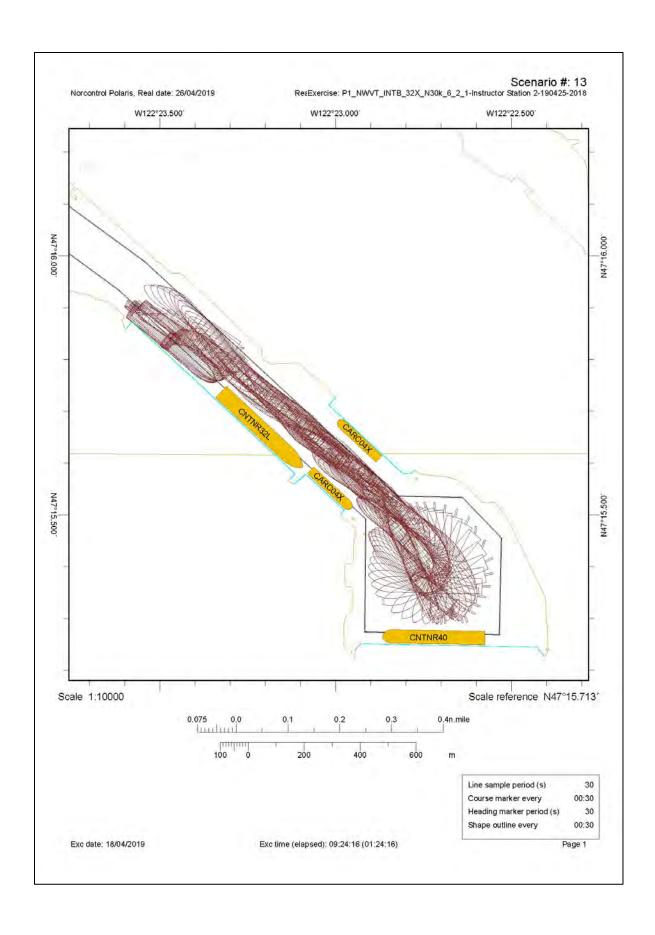
| Channel Alternative: | PO (Existing) | P1 | |
|--------------------------------|---|--------------------------|------------------|
| Dock: P3 P4 | NWUT SWUT | PCT Blai | EB1 |
| Date: 4/24/2019 | | | |
| Test Matrix Run Number: | | Repetition: ∂ | |
| Heading: IN Inbound O Outbound | INTB Inbound (Turning E | | Outbound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> CNTNR40 | i. | |
| Wind Condition: 0 None | SW20k NE20k | N20k SW2 | .5k |
| Tugs: R 2-50T 1-90T | S 2-90T 1-50T प | 4-75 T | |
| Pilot: Capt. Jed Arnold (Pi | lot 1) | Capt. Mark Shuler | Pilot 2) |
| | leading + Vessel + Wind + Tu OTB_32X_NE20k_R_1_1 | igs + Pilot + Repetition | |
| Filename: PI_SWUT | - OTB - 32X - N | 20K -4-2-2 | |
| Targets: TOTE: none | P3: CNTNR32L | P4: CNTNR32L | NWUT: CNTNR32L |
| SWUT: CNIMR32L | PCT: CNTNR40 | Blair: CARO4X | EB1: CARO4X |
| End Time: 1641 | Log File Time: 1603 | Total transit time: | 35:12 |
| Comments: | | | |
| MODEL LOOK | RKED AS PLA | NNED, fairly acc DE. | |



| Dock: P3 Date: リカラ | P4 (| NWUT) | Carlo La | | | | |
|-----------------------|----------------|----------------------|-------------------------------|---------|------------------|-------------|---------------------------|
| Date: 4/5 | | | SWUT | PCT | Blair | EB | 1 |
| IN | 119 | | | | | | |
| Test Matrix Rur | | | | Repe | etition: | | |
| Heading: IN Inb | ound bound | | nd (Turning B und (Turning | | OS O | utbound (St | ern) |
| Vessel: (CNTN | R32X | CAR <mark>04X</mark> | CNTNR40 | | | | |
| Wind Condition | : O None | SW20k | NE20k | N20 | k SW2 | sk SV | N 30K) |
| Tugs: | 3 3-75T | 4 4-75T | 5 3-98T | 6 | 3-987 | -50T | |
| Pilot: Capt. Jed | d Arnold (Pile | ot 1) | | Capt | . Mark Shuler (P | lot 2) | |
| SWUT: | CNTNR32L | PCT: CNTNR | ne: 2039 | | : CAR04X | | 1: CAR04X |
| | | | | | | | side es que durives |
| The 58 | dreds | e lines. | but The | New. | Il propos | ed IN | es give |
| Nece3861 | y ma | NEUVERIN | 5 0000 | 1-6V 1. | kese legge | deep | dust-1025 |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |



| Channel Alternative: | PO (Existing) |) | (P1) | | |
|--|--|--|-------------------------------------|------------------------------------|-------------------------------|
| Dock: P3 P4 | NWUT | SWUT | PCT | Blair | EB1 |
| Date: 4/25/19 | | | | | |
| Test Matrix Run Number: | | | Repetition | : | |
| Heading: IN Inbound O Outbound | | nd (Turning Ba und (Turning B | | OS Outl | oound (Stern) |
| Vessel: CNTNR32X | CAR <mark>04X</mark> | CNTNR40 | | | |
| Wind Condition: 0 None | SW20k | NE20k | N20k | SW25k | (30K N) |
| Tugs: 3 3-75T | 4 4-75T | 5 3-98T | | | |
| Pilot: Capt. Jed Arnold (Pi | ilot 1) | | Capt. Mark | Shuler (Pilot | : 2) |
| Example: P1_NW_ Filename: P1_NWU | | | 130K_6_ | 2_1 | |
| Filename: PI_NWU | T_INTB- | -32x - 1 | | | NAMES CASTAGON |
| Filename: PI_NW_ Targets: TOTE: Cruis09L | | -32x - 1 | P4: CNTNR. | 32L | NWUT: CNTNR32L |
| Filename: PI_NWU | T_INTB - P3: CNTNR3. | -32x - 1 21 | | 32L | NWUT: CNTNR32L EB1: CAR04X |
| Filename: PI_NWU Targets: TOTE: Cruis09L | P3: CNTNR3. | -32x - 1 21 | P4: CNTNR. Blair: CARG | 32L 04X | |
| Filename: PI_NWU Targets: TOTE: Cruis09L SWUT: CNTNR32L End Time: Z\S\ Comments: | P3: CNTNR3: PCT: CNTNRA Log File Tim | -32x - 1 ²¹ 40 ne: 2018 | P4: CNTNR. Blair: CARG | 32L 04X sit time: \ | EB1: CARO4X |
| Filename: PI_NWU Targets: TOTE: Cruis09L SWUT: CNTNR32L End Time: Z\S\ Comments: | P3: CNTNR3: PCT: CNTNRA Log File Tim | -32x - 1 ²¹ 40 ne: 2018 | P4: CNTNR. Blair: CARG | 32L 04X sit time: \ | EB1: CARO4X |
| Filename: PI_NWU Targets: TOTE: Cruis09L SWUT: CNTNR32L End Time: Z\S | P3: CNTNR3: PCT: CNTNRA Log File Tim | -32x - 1 ²¹ 40 ne: 2018 | P4: CNTNR. Blair: CARG | 32L 04X sit time: \ | EB1: CARO4X |
| Filename: PI_NWU Targets: TOTE: Cruis09L SWUT: CNTNR32L End Time: Z\S\ Comments: | P3: CNTNR3: PCT: CNTNR4 Log File Tim SQ . | -32x - 1 21 40 ne: 2018 HIGHLY | P4: CNTNR. Blair: CARC Total trans | 32L 04X sit time: \ ENGIN | EB1: CARO4X |



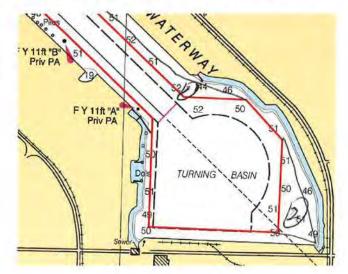
Appendix B: Pilot Questionnaires

| Tacoma H | arbor Feasibility Level Simulation Study – Final Questionnaire |
|------------------------|--|
| Name: | Soha Arnold |
| ERDC's Shi proposed | of the proposed deepening and widening of the Blair Waterway in Tacoma Harbor was conducted at ip/Tow Simulator (STS) 23-25 April 2019. The purpose was to provide a preliminary evaluation of modifications to Blair Waterway. Additional and final simulation will be conducted during the PED the study to address any additional concerns raised between Feasibility and PED. |
| | easibility Level simulation, several assumptions were made to reduce the overall time and cost of the t compared to a full ship simulation study. |
| a. | Was the visual scene adequate? Was it detailed enough or not detailed enough? Detailed enough to get vesults + Data. |
| b. | Were the environment conditions (wind conditions) reasonable? Yes and useful in determining change change therestors the |
| c, | Screening for the project only lasted about a week. This is about one third of the simulation testing typically done for final channel design. Do you think the number of pilots participating and time spent testing was adequate for a Feasibility Level study? Yes Though Time Allowed only daylight sinulations. |
| d. | The Corps of Engineers was represented by the ERDC, the Seattle District, and the Northwestern Division. The Port of Tacoma and the Puget Sound Pilots were represented during this effort. Should additional parties have been represented? I felt the parties present wave all that was all that was all that was a little of the parties present wave all that was a little of the parties present wave all that was a little of the parties present wave all that was a little of the parties present was a l |

| e. Please comment on the response of the vessels models, both ships and tugs. Good for The study purposes Though There is what's room for more do Tail related to meet a trail ship behavior. |
|--|
| f. How were the other aspects of the simulation? All was good communications at times were difficult but more from The pilots every then operators. |
| Were simulations representative of real life piloting operations? To a point yes as far as intercetions with other team To a point yes as far as intercetions with other team To a point yes as far as intercetions with other team To a point yes as far as intercetions. |
| Did you feel the design vessel (1307-x 191-x 53-ft) would be able to back out of the Blair Waterway if necessary from the WUT? Why or why not? You definitely I feel with environmental quidlines It is very possible. |
| |

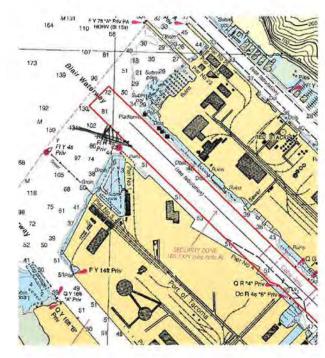
4. Did you feel the turning basin was adequate for the design vessel (1307- x 191- x 53-ft) to be able to use? Why

while like To see greater dredsing in These areas 0 H(2)



5. Did you feel the design vessel (1307- x 191- x 53-ft) would be able to dock at P3 and P4 based on the proposed channel design? Why or why not?

Yes Though a Having out on The 5 side of The extende would make for better approach 5 on The SW Winds.



6. Did you feel the design vessel (1307- x 191- x 53-ft) would be able to dock at Washington United Terminal (N WUT and S WUT) based on the proposed channel design? Why or why not? Mes us proposed it is quite predictable That 7. Based upon the simulator runs, what possible limits or restrictions MIGHT be considered for the design vessel for using the proposed Blair Waterway? Design versel for The simulation sents and in real ferms "State" of deck fittings @ a minimum of numT 8. Do you believe the tugs readily available (70 T and 50 T) for the Blair Waterway would be sufficient for the design vessel to transit the proposed Blair Waterway? If not, what might be required? AT A minimum 3 70 not tugs would be required for preficteditify in Transit in wind conditions 9. Are there any aspects of the project that were not adequately addressed by USACE and should be updated Seventi were Assissed & adequately reducessed

10. Given the physical limitations of the width between the berthed vessels at Husky P4 and TOTE, was there for Transits adequate clearance to pass a design vessel enroute to WUT?

11. Given the physical limitations of width between the berthed vessels at East Blair 1 and Blair, was there adequate clearance to pass a design vessel into the turning basin?

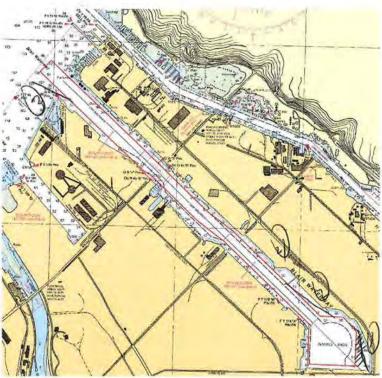
ON a inbound vesser yes, outbound only , RoRo

12. Any additional comments? Dredge adjustments

45 discussed with

The Turn Basia Est

+ Entrance improvered 3



Tacoma Harbor Feasibility Level Simulation Study - Final Questionnaire

Name: MARK SILVER

Screening of the proposed deepening and widening of the Blair Waterway in Tacoma Harbor was conducted at ERDC's Ship/Tow Simulator (STS) 23-25 April 2019. The purpose was to provide a preliminary evaluation of proposed modifications to Blair Waterway. Additional and final simulation will be conducted during the PED portion of the study to address any additional concerns raised between Feasibility and PED.

- 1. As a Feasibility Level simulation, several assumptions were made to reduce the overall time and cost of the project compared to a full ship simulation study.
 - a. Was the visual scene adequate? Was it detailed enough or not detailed enough?

VISUALS WERE VERY ADEQUATE ALL THE NECESSITIES WERE PRESENT

b. Were the environment conditions (wind conditions) reasonable?

YES

c. Screening for the project only lasted about a week. This is about one third of the simulation testing typically done for final channel design. Do you think the number of pilots participating and time spent testing was adequate for a Feasibility Level study?

YES

d. The Corps of Engineers was represented by the ERDC, the Seattle District, and the Northwestern Division. The Port of Tacoma and the Puget Sound Pilots were represented during this effort. Should additional parties have been represented?

NOT ATTHIS POINT IN TIME

e. Please comment on the response of the vessels models, both ships and tugs.

I AM NOT FAMILIAR ENOUGH WITH THE

SUPERIUM MASRSK TO KNOW WHETER SHO

RESPONDED COFFECTLY.

TUG EFFECT ON MODEL OTHER THEN THE

MASRSK YSL SEEMED ACCURATE.

f. How were the other aspects of the simulation?

EQUIPMENT VERY GOOD, QUICK TO UNDERSTAND AND OPERATE

2. Were simulations representative of real life piloting operations?

SOME WHAT. I FIND MYSELF LEARNING TO DRIVE THE SIMULATOR. EX. I WOULD NEVER ORDER"
FULL ASTERN, WHERE AS ON A SIMULATOR, I DO.

3. Did you feel the design vessel (1307- x 191- x 53-ft) would be able to back out of the Blair Waterway if necessary from the WUT? Why or why not?

YES. WINDS LESS THAN 25 KTS.

ADEQUATE TUGS,

ADEQUATE WATER.

YELS WE BACK OUT.

KEEP SPD TO ZKTS OR LESS

4. Did you feel the turning basin was adequate for the design vessel (1307- x 191- x 53-ft) to be able to use? Why or why not?

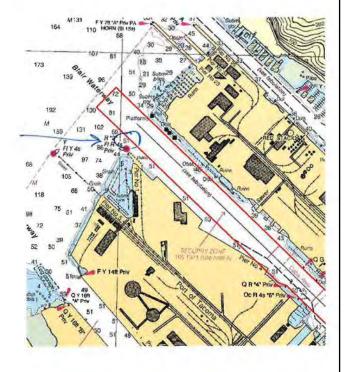
NO, DEPTH NEED TO BE SAME PRIGHT TO THE BEACH

VES, IF CIRCLED AREAS ARE DRENGED TO ADEQUATE DEPTH.



5. Did you feel the design vessel (1307- x 191- x 53-ft) would be able to dock at P3 and P4 based on the proposed channel design? Why or why not?

YES
IF DEEDGED TO
ADEQUATE DEPHT
ALL WAY TO DOCK
AND ALONG DOCK
FACE CLEAR OUT TO
HAIZBOR,



6. Did you feel the design vessel (1307- x 191- x 53-ft) would be able to dock at Washington United Terminal (N WUT and S WUT) based on the proposed channel design? Why or why not?

VES WITHIN GIVEN PARAMETERS 1) WINDS LESS than ZEKTS 2) ADEQUATE TUGS.

7. Based upon the simulator runs, what possible limits or restrictions MIGHT be considered for the design vessel for using the proposed Blair Waterway?

ONCE THE PILOTS HAVE EXPERIENCE WITH THE USL, NO RESTRICTIONS OTHER THEN TUSS'S WIND.

8. Do you believe the tugs readily available (70 T and 50 T) for the Blair Waterway would be sufficient for the design vessel to transit the proposed Blair Waterway? If not, what might be required?

FOT TUGS ARE THE MINIMUM I WOULD DESIRE

9. Are there any aspects of the project that were not adequately addressed by USACE and should be updated going forward?

WITH THE DESIGN USL BEIZTHEND @ WUT, BRINGING IN A LARGE USL TO PCT/OR INTO THE TURNING BASIN.

10. Given the physical limitations of the width between the berthed vessels at Husky P4 and TOTE, was there adequate clearance to pass a design vessel enroute to WUT?

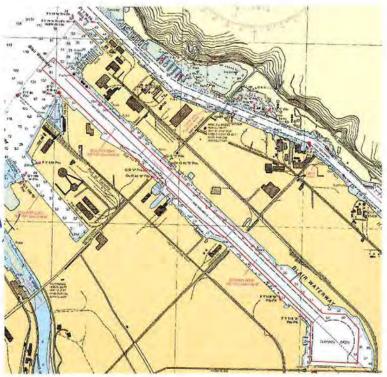
YES

11. Given the physical limitations of width between the berthed vessels at East Blair 1 and Blair, was there adequate clearance to pass a design vessel into the turning basin?

YES

12. Any additional comments?

THE MODEL WAS
EASILY HANDLED UNDER
PROPER CONDITIONS
AND SPD. THE
DESIGN VSL SHOULD
EASILY TRANSIT
THE BLAIR WATERWA



Appendix C: Pilot Card

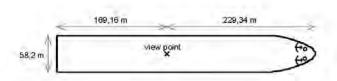
PILOT CARD

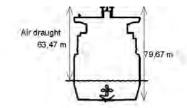
CNTNR32X Version 4

| Ship's name | Superium Maersk | | | | | | | | | | | | | | |
|-------------|-----------------|----|----|---|---|----|--------------|------|--------|----|---|--------|--------------|--------|--------|
| Call Sign | | | | | | | Deadweight _ | | 155912 | | | tonnes | Year built | | |
| Draught aft | 16.2 | m/ | 53 | Ħ | 2 | in | Forward | 16.1 | m / | 52 | ñ | 10 in | Displacement | 222316 | tonnes |

SHIP'S PARTICULARS

| Length overall | 398.5 | m | Anchor chain: | Port | 28.1 | shackles | Starboard | 28.1 | shackles |
|--------------------|-------|---|---------------|------|------|----------|------------|-----------------|----------|
| Breadth | 58.2 | m | | | | | | | |
| Bulbous bow | No | | | | | | (1 shackle | = 27,432 m = 15 | fathoms) |





PROPULSION PARTICULARS

| Type of engine | | Diesel | | Maximum power | 74985 kW (101951 hp) |
|--------------------------|-------------|-----------|------|---------------|-----------------------|
| Manoeuvring engine order | | RPM Pitch | | | Speed (knots) |
| | | | | Loaded | Ballast |
| Full sea speed | sea speed 1 | | N/A | 24.3 | N/A |
| Full Ahead | 0.8 | 83,7 | N/A | 21.4 | N/A |
| Half Ahead | 0.5 | 62.0 | NVA | 15.7 | N/A |
| Slow Ahead | 0.25 | 36/2 | N/A | 8.8 | N/A |
| Dead Slow Ahead | 0.125 | 21.0 | N/A | 4.8 | N/A |
| Dead Slow Astern | -0.125 | -19.3 | N/A. | | |
| Slow Astern | -0.25 | -36.8 | N/A. | 14, | |
| Half Astern | -0.5 | -61.3 | N/A | | |
| Full Astern | -1 | -69.8 | N/A | | |

| Type of rudder | Normal | Maximum | angle | 35 | |
|--|----------|--------------|-----------------------|----------|---|
| Hard-over to hard-over | 14 | s | | | |
| Rudder angle for neutral effect | 0 | → " | | | |
| Thruster: Bow 3280 | kW(4460 | _ hp) Stern | 3280 KW (| 4460 hp) | |
| | CHECKED | F ABOARD ANI | DREADY | | |
| Anchors | | | ndicators: | | |
| | | " | | | |
| Whistle | | | Rudder | | |
| Radar 3 cm | | 10 cm | Rpm/pitch | | |
| ARPA | + 1/ | | Rate of turn | | |
| Speed log Dopple | : Yes/No | c | ompass system | | |
| Water speed | | | onstant gyro error ± | | |
| | | | | | |
| Ground speed | | | HF | | |
| Dual-axis | | E | lec. pos. fix. system | | - |
| Engine telegraphs | | | Туре | | |
| Steering gear | | | | | |
| Number of power units operating | | | | | |
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Prepared by:

Dredged Material Management Office Seattle District, U.S. Army Corps of Engineers

MEMORANDUM FOR: RECORD

SUBJECT: DMMP ADVISORY DETERMINATION REGARDING THE POTENTIAL SUITABILITY OF PROPOSED DREDGED MATERIAL FROM THE BLAIR WATERWAY IN TACOMA HARBOR FOR UNCONFINED OPEN-WATER DISPOSAL AT THE COMMENCEMENT BAY DISPOSAL SITE OR FOR BENEFICIAL USE.

1. <u>Introduction</u>. This memorandum reflects the consensus advisory determination of the Dredged Material Management Program (DMMP) agencies (U.S. Army Corps of Engineers, Washington State Department of Ecology, Washington State Department of Natural Resources, and the Environmental Protection Agency) regarding the potential suitability of up to 2.5 million cubic yards (cy) of dredged material from the Blair Waterway for open-water disposal at the Commencement Bay disposal site or for potential beneficial use.

The DMMP agencies cooperatively manage eight open-water disposal sites in Puget Sound. The disposal site in closest proximity to Tacoma Harbor is the non-dispersive site located in Commencement Bay. Dredged material evaluation guidelines for disposal at the Commencement Bay site can be found in the DMMP Dredged Material Evaluation and Disposal Procedures User Manual (DMMP, 2018). These procedures are summarized in Exhibit A of this memorandum.

Blair Waterway is an authorized federal navigation channel located in Tacoma, Washington. The existing authorized dimensions of the waterway are 520 ft wide from the mouth to 11th Street, 345 ft wide through the 11th Street reach, 520 ft from 11th Street to Lincoln Avenue, 330 ft from Lincoln Avenue to the turning basin, and a 1300 ft turning basin, all to a depth of -51 feet MLLW. During the last deepening event in 2000-2001, the waterway was dredged to -51 feet MLLW, plus 2 ft of overdepth. Due to minimal accumulation of sediments since then, mudline elevations within the existing navigation channel remain at -51 ft MLLW or deeper.

The U.S. Army Corps of Engineers (USACE) and Port of Tacoma (POT) are conducting a feasibility study to investigate potential deepening and widening alternatives for the Blair Waterway (Figure 1). Depths up to -58 feet MLLW, plus 2 feet of overdepth, are being evaluated. This DMMP memorandum presents and evaluates sediment characterization data collected from Blair Waterway with the purpose of advising USACE and POT regarding the probable suitability of sediment from Blair Waterway for open-water disposal or beneficial use.

Under the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA), the U.S. EPA designated the Commencement Bay Nearshore/Tideflats Superfund site in 1983. The site includes three main components: remediation of the sediments and source control for Commencement Bay waterways, remediation of Tacoma Tar Pits, and remediation of the Asarco Smelter Facility and surrounding impacted areas. Multiple waterways within Commencement Bay are covered under the sediment operable unit for the Superfund Site. Blair Waterway was originally included under the sediment and source control operable unit, but was delisted by the U.S. EPA in 1996 because it was

cleaned up under an agreement known as the Puyallup Land Claim Settlement between EPA, the Port of Tacoma, and the Puyallup Tribe. Another notable Superfund action in Blair Waterway included dredging of tributyltin (TBT) contaminated sediments at Pier 4 as part of a Time Critical Removal Action. This action was completed in 2016 under the regulatory authority of the U.S. EPA and included removal of 71,000 cubic yards of contaminated sediment in conjunction with the redevelopment of Pier 4.

Project summary and tracking information is shown in Table 1.

Table 1. Project Summary

| Project ranking | Channel: Low-moderate |
|---------------------------------|-------------------------------------|
| | Sideslopes: Moderate |
| Proposed dredging volume | 2.5 million cy |
| Maximum proposed dredging depth | - 58 ft MLLW, plus 2 feet overdepth |
| Sampling Dates | February 18 – February 22, 2019 |
| EIM Study ID | POTBD19 |

2. <u>Sediment Evaluation Strategy for the Tacoma Harbor Feasibility Study.</u> Several factors were taken into consideration in development of a sediment evaluation strategy for the Blair Waterway.

DMMP Recency Guidelines – The DMMP recency guidelines specify the length of time that sediment characterization data remain adequate and valid for decision-making without further testing. The length of the recency period is determined by the rank of a project, the rank being driven by the available information on chemical and biological-response characteristics of project sediments and the number, kinds, and proximity of chemical sources (existing and historical). Blair Waterway has a split ranking; the existing navigation channel is ranked low and areas outside the navigation channel have project-specific rankings based on site characteristics (DMMP, 2018). For the purpose of this advisory evaluation, the DMMP agencies agreed to consider the entire project area as having an overall rank of low-moderate. The recency period for low-moderate-ranked areas is six years. Since it was unlikely that construction would occur within six years following sediment sampling for the feasibility study, a decision was made to wait until the Preconstruction Engineering Design (PED) phase of the project to conduct a full DMMP characterization for final decision-making. More limited sediment characterization would be done during this feasibility study.

Level of Effort – Since full DMMP characterization will not be completed until PED, the study team needed to determine the level of effort that would be adequate to support the evaluation of alternatives during feasibility. In consultation with the DMMP agencies, the study team decided that a 20% level of effort would suffice. Additionally, bioassays and bioaccumulation testing were not conducted for this effort. This level of effort was selected to provide a meaningful representation of levels and patterns of contamination in Blair Waterway, without incurring the expense of a full characterization.

3. <u>DMMP Sampling and Testing Requirements</u>. DMMP sampling and testing requirements are dependent on the rank of the project. As indicated previously, Blair Waterway was ranked "low-moderate" for this evaluation in order to determine the appropriate level of sampling. For low-moderate-ranked projects, one field sample must be taken for every 8,000 cy of sediment.

Typically the dredge prism would be divided up into dredged material management units (DMMUs) based on the design of the project. A DMMU is a volume of sediment that can be independently dredged from adjacent sediment and for which a separate disposal decision can be made. Allowed volumes per DMMU are based on rank, surface versus subsurface DMMUs, and homogeneity/heterogeneity of the sediments. However, since the study is in the feasibility phase a specific dredge design has not been developed. The dredged material volume and prism associated with the selected alternative will not be known until the feasibility study has been completed.

For the purposes of sediment characterization conducted during feasibility, the dredged material volume associated with maximum proposed dredging was calculated, along with the number of field samples required for full DMMP characterization, see Table 2 below. The number of field samples required for full characterization was multiplied by 0.20 (for a 20% level of effort), resulting in a need for 63 field samples for the advisory-level characterization.

Table 2 Sampling Rationale

| Waterway | Total Volume (cubic yards) ¹ | Rank ² | Total Number of Cores | Total Number of Samples Required for Full Characterization | 20% of Total Number of Samples Required for Advisory-level Characterization | |
|-----------------------------|--|-------------------------------|---|---|--|--|
| Blair Navigation Channel | 2,247,500 | Low-moderate: 8,000 cy/sample | 20 (2 to 3 samples analyzed per core) | 313 | 42 | |
| Side slopes | 209,500 | 0,000 cyrsampie | 5 (2 to 3 samples analyzed per core) | 313 | 63 | |

Notes:

To provide higher-resolution data for the feasibility study, a decision was made to not composite individual samples, as is often done in DMMP sediment characterization, but to instead analyze individual field samples. To get a good spatial distribution, 25 sampling locations were identified throughout the waterway (Figure 2). The location of the sampling stations was determined in coordination with the Port of Tacoma, the Port's contractor, the DMMP agencies and the Puyallup Tribe. Due to elevated concern over the quality of the material in the sideslopes, 5 sampling locations were placed in the side slopes in to characterize these areas at a sampling intensity closer to a moderate-rank level. For a moderate-rank project one sample is required for every 4,000 cy of material. The estimated volume of the sideslopes is 209,500 cy – so 11 samples are needed to sample the sideslopes at 20% of the "moderate-ranked" intensity. Thus the 5 identified cores, with 2 to 3 samples each (a single core can provide multiple depth interval samples), was sufficient to meet the 20% level of effort for the side slopes. The additional samples collected in the side slopes were subtracted from the total number of samples needed in the rest of the waterway, so that the total number of samples analyzed equaled 63.

^{1.} The total estimated volume including navigation channel and side slopes is 2,457,000 cy.

Native Material – An additional goal of sampling was to determine the elevation of the native horizon. Previous deepening of Blair Waterway was to -51 ft MLLW plus 2 ft of overdepth. The native horizon was expected to be around -53 ft MLLW.

The native horizon was identified based on evaluation of the core lithology by sampling personnel familiar with the characteristics of the native sediments in Tacoma Harbor. Based on review of uplands geotechnical boring and available sediment cores in the Blair Waterway, the native unit was expected to consist of moist, medium dense to dense, gray to grayish brown, fine to medium sand with various amounts of silt and trace shell hash and occasional interbeds of moist, medium stiff, light gray, clayey silt.

- 4. <u>Sampling</u>. Field sampling took place February 18-22, 2019 using a vibracore sampler. Cores were processed at the Port of Tacoma facility at the head of the Sitcum Waterway in Tacoma, WA and samples were then transported to ARI in Tukwila, WA and submitted for analysis. Figure 2 shows the target and actual coring locations and Table 3 gives the station coordinates and other core collection data. Samples were collected within 10 feet of the target location coordinates, with the following exceptions:
 - Location C-8 was moved 85 feet northeast due to core refusal on a hard, uneven bottom, likely riprap
 - Location C-13 was moved 41 feet to the southeast to avoid contact with buried sewer lines
 - Location C-25 was shifted 84 feet due to the presence of a cargo vessel for the extent of field sampling operations

The approved sampling and analysis plan (Anchor QEA, 2019a) was followed to the maximum extent possible. Additional deviations from the SAP were reported in the final sediment characterization report (Anchor QEA, 2019b), including:

- Holding cores overnight before processing, which was done to minimize the number of field sampling days. Cores held overnight were securely stored upright on the sampling vessel behind a locked gate. Ambient overnight temperatures during the sampling period ranged from 3.3 to 5 °C, with an average of 4.3 °C. These holding conditions are in accordance with standard custody and temperature requirements for holding sediment cores.
- As a result of holding cores overnight, additional compaction of some cores occurred between
 the time they were collected and processed. This additional compaction was not accounted for
 in the core logs and depths reported in the data report and in this advisory memo.
- Due to the difficulty of collecting cores in the sideslopes, only three cores were collected from sideslopes instead of the five that were originally planned. During SAP development C-1 was initially considered a sideslope sample, but during finalization of the sampling plan that location was moved to the edge of navigation channel and therefore was not considered a side slope sample. Location C-8 was moved out of the sideslopes during sampling due to difficulty coring. Nine samples were analyzed for the full DMMP list of chemicals from the three sideslope samples (C-12, C-13, and C-17) in Round 1, and an additional four samples were analyzed for conventionals and dioxins/furans in Round 2. In total, 13 sideslope samples were analyzed, sufficient to meet the sampling intensity for a moderate rank.

Core intervals collected for sampling were determined based on the core lithology to avoid excessive testing of the native material while simultaneously ensuring that the native material was adequately tested. The following guidelines were used:

- At least two samples (depth intervals) from each core were analyzed.
- Samples were analyzed from the top down, and no more than three samples per core were analyzed.
- Minimum sample size was a 2-foot interval, in order to have sufficient volume of sediment for all analyses.
- The length of the top non-native interval was determined by the depth of the native horizon. As many 2-foot intervals as could be delineated were collected and analyzed from the non-native layer.
- At a minimum the surface non-native or mixed interval and the top interval of native material were analyzed.
- In sideslope samples, the first interval of native material was analyzed as long as it was within the top three depth intervals of the core. If not, the native intervals were archived and analysis was only triggered if there were SL or BT exceedances in the shallower interval.

6. Chemical Analysis.

To avoid excessive testing of native sediments a tiered testing approach was used. Analysis by the analytical laboratory occurred in two rounds. Round 1 included 57 samples identified based on the core lithology. All Round 1 samples included testing of the full suite of DMMP COCs, including conventionals, metals, semivolatiles, pesticides, PCBs, bulk TBT and dioxins/furans. Table 4 lists the sediment samples that were analyzed in Round 1 and Round 2. Six analyses were triggered for Round 2 based on the results of Round 1, as described below:

- Location C-2: This location did not have any SL or BT exceedances, but TBT increased with depth from 7.35 μg/kg in the 0-2 ft sample to 17.3 μg/kg in the 2-4 ft sample. Based on proximity to historically elevated TBT concentrations at depth (2016 EPA TBT Time Critical Removal Action) and the observed increasing concentrations with depth, Round 2 chemistry results were triggered in the next two deeper samples to evaluate the chemical trend. Results were non-detect in both intervals.
- Location C-12: Dioxin/furan concentrations were above 10 pptr TEQ in the 0-2 ft, 2-4 ft, and 4-6 ft intervals (56.21, 54.47, and 17.74 pptr TEQ, respectively). Round 2 chemistry samples were triggered in the next two deeper samples and were below the SL of 4 pptr TEQ. Additionally, total PCBs were above the SL of 130 μg/kg in the 0-2 ft interval (173.3 μg/kg), but below the SL in the 2-4 ft interval.
- Location C-13: Dioxin/furan concentrations were above 4 pptr TEQ in the 0-2 and 2-4 ft intervals (5.34 and 7.73 pptr TEQ, respectively) and above 10 pptr TEQ in the 4-6 ft interval (11.88 pptr TEQ). Round 2 chemistry samples were triggered in the next two deeper samples. The 6-8 ft. interval was above 4 pptr TEQ (7.64 pptr TEQ), and the 8-10 interval was below 4 pptr TEQ.

Tables 5 and 6 present the sediment conventionals and chemistry results, respectively. Figure 3 shows boxplots of TOC, percent sand and percent fines for the project. Samples were grouped into one of three categories based on core lithology: 1) samples that were identified as native, 2) samples from cores where the native layer was undetermined and 3) samples identified as non-native material.

Samples identified as native have a higher percentage of sand and lower percentage of fines than the non-native and unidentified material, consistent with the expected characteristics of the native material. The depth (in ft MLLW) of the native layer as identified during core processing is shown in Figure 4.

A total of 8 cores out of the 25 collected contained one or more samples with at least one SL or BT exceedance. The other 17 cores did not contain any samples with SL or BT exceedances. Figure 5 provides a summary of all the detected and undetected SL exceedances from all analytical results. The non-native surface intervals of C-3 and C-11 had nondetected exceedances of the SL for total chlordane (when all five total chlordane constituents were reported at the lower method detection limit). There were three cores with detected exceedances of SLs: C-7 was above the SL for hexachlorobutadiene in the 2-4 foot (native) interval, C-10 was above the BT for TBT in the 2-4 foot (non-native) interval, and C-12 was above the SL for total PCBs in the non-native surface interval.

Dioxin/furan results are summarized in Table 7. Elevated dioxins/furans were found throughout the mouth and middle sections of the waterway. Dioxin concentrations above 4 pptr TEQ and less than 10 pptr TEQ were found in non-native samples in cores C-7, C-8, C-10, C-11 and C-12. Dioxin concentrations above the bioaccumulation trigger of 10 pptr TEQ were found in three cores: C-12, C-13 and C-15. As mentioned above, additional samples from C-12 and C-13 were triggered in Round 2 to identify the vertical extent of elevated dioxin/furan concentrations. In all cores, samples were analyzed at deeper intervals until dioxin/furan concentrations less than 4 pptr TEQ were found. All native samples contained dioxins/furans less than 4 pptr TEQ, and all samples (both non-native and native) from the head of the waterway had dioxin/furan concentrations less than 4 pptr TEQ.

7. <u>DMMP Advisory Suitability Evaluation</u>. A DMMP suitability determination is typically based solely on the evaluation guidelines found in the DMMP User Manual current at the time of testing. However, the dredged material evaluation guidelines used by the DMMP agencies are constantly evolving as technological and scientific advances are made. Those changes could include updates to the bioaccumulation triggers or testing guidelines. However, there are no such changes currently pending. Therefore the DMMP agencies used the current evaluation guidelines to determine the potential suitability of Blair Waterway sediments for open-water disposal.

Tables 8 and 9 present the results of the DMMP evaluation, along with the rationale for determining the potential suitability or unsuitability of each sample for open-water disposal. In these tables, samples were separated into those identified as native sediment (Table 9) and those identified as non-native or undetermined sediment (Table 8). Sample ID refers to the intervals of sediment core starting with A at the top of each core. For each station/interval tested, one of the following determinations was provided:

Suitable – No SL or BT exceedances; dioxins/furans below 4 pptr TEQ.

Likely Suitable – No SL or BT exceedances occurred; dioxins/furans below 10 pptr TEQ but above 4 pptr TEQ.

Possibly Suitable – Detected or undetected SL exceedances and dioxins/furans < 10 pptr TEQ.

Unsuitable – BT exceedance and/or dioxins/furans > 10 pptr TEQ, with or without other SL exceedance.

To facilitate the use of this information in the estimation of quantities of suitable and unsuitable dredged material for the Tacoma Harbor Deepening feasibility study, the DMMP agencies adopted a probability approach for the Blair Waterway. Sampling stations with similar suitability characteristics in the non-native intervals of sediment were grouped to form three distinct sections within the waterway (Table 8; Figure 6) regardless of whether they were on the sideslope or in the channel. To establish a logical segmentation of the waterway for planning purposes, numerical probabilities were assigned to each station and those probabilities averaged and rounded down to the nearest 5%. Numeric probabilities were assigned as follows:

- suitable = 100% probability of being suitable for open-water disposal
- ➤ likely suitable = 75%
- possibly suitable = 50%
- unsuitable = 0%

At the head of the waterway all samples in all cores were below SLs and dioxins/furans were less than 4 pptr TEQ. All of this material was classified as suitable and the average suitability probability was 100%.

The middle portion of the waterway had the lowest suitability probabilities. Three cores, C-12, C-13 and C-15 contained unsuitable material due to dioxins/furans above 10 pptr TEQ and one core, C-10, contained unsuitable material due to TBT. One sample in core C-11 contained possibly unsuitable material due to a non-detect exceedance of total chlordane and dioxins/furans between 4-10 pptr TEQ. In all of these cores, lower intervals of the core were analyzed until clean material was confirmed. Overall, the average suitability probability for surface non-native material in the middle portion of the waterway is 63.6%.

The mouth of the waterway was largely suitable, with only one sample (C-3) with a possibly suitable classification due to a single non-detect exceedance of total chlordane. The average suitability probability for surface non-native material in the mouth of the waterway is 92.9%.

The same probability approach was applied to the native sediments. Among all sediments throughout the waterway that were identified as native material, only one sample was classified as possibly suitable (due to a single exceedance of hexachlorobutadiene in C-7) and the rest were classified as suitable. Therefore, the average suitability probability of identified native sediments is 98.1%

The predictive ability of the feasibility-level sediment characterization completed for the deepening study does not match the mathematical precision of the calculated probability averages. Therefore, the calculated averages were rounded down to the nearest 5%. The rounded probability values are found in Tables 8 and 9 and illustrated in Figures 6 and 7.

In summary, the non-native sediments showed a range of contaminant concentrations. The probability of suitability for open-water disposal was estimated by the DMMP agencies in the non-native sediments to be 90% suitable in mouth, 60% suitable in the middle and 100% suitable in the head, as shown in

Figure 6. Nearly all identified native sediment is suitable for open-water disposal, with an average probability of being suitable for open-water disposal of 95%.

This advisory determination only applies to the areas identified and documented in this document. Additional areas not considered here, especially in the sideslopes and/or near outfalls, may have a different sediment contaminant profile. The results from the sideslope samples in this study as well as historical information from cutback projects throughout Blair Waterway give a strong indication that material outside of the navigation channel (i.e. closer to shore) considered in this advisory memo is more likely to be unsuitable. The DMMP agencies recommend a more conservative assumption of the probability of suitability for areas outside the areas evaluated in this advisory memo.

8. <u>Suitability for Beneficial Use</u>. The DMMP agencies do not determine the suitability of material for beneficial use projects. It is up to the project proponents, the site receiving the material, and other interested stakeholders including applicable resource agencies and Tribes to determine the physical and chemical suitability of dredged materials for a beneficial use site.

However, typically the first step taken to evaluate sediments for beneficial use is comparison against the State's Sediment Quality Standards (SQS), which has been done in Tables 10 and 11. Many of the SQS standards are in organic carbon normalized units. Ecology's recommendation for organic carbon normalizing is to only use this approach for sediments with TOC concentrations between 0.5 - 3.5% (Ecology, 2017). Samples were divided into two groups, those with TOC between 0.5 - 3.5% (12 samples) and those with TOC less than 0.5% (51 samples). There were no samples with TOC greater than 3.5%.

For the 12 samples with TOC greater than 0.5%, results are compared to SQS and are shown in Table 10. Non-detect results for two chemicals, 1,2,4-trichlorobenzene and hexachlorobenzene, were above the SQS as initially reported by the laboratory. As is typically done by the DMMP agencies when there is a non-detect exceedance, the results are re-evaluated by the analytical laboratory to see if there was any evidence that the compounds of interest were detected at levels between the method detection limit (MDL) and the method reporting limit (MRL). If there is no evidence, then the results are reported as non-detect at the lower MDL. For these samples (and all samples in the project) there was no evidence that 1,2,4-trichlorobenzene or hexachlorobenzene were detected above the MDL, so the results for these two compounds were reported at the lower level, as indicated in Table 10.

11 of the 12 samples in Table 10 were less than the SQS. Sample C-12-A exceeds the SQS for PCBs and is not suitable for beneficial use. All other samples are below SQS, indicating that they would likely be suitable for beneficial use.

For the 51 samples with TOC less than 0.5%, results are compared to the dry weight based SQS values and are shown in Table 11. The dry-weight SQS values are based on the same apparent effects thresholds (AET) as the DMMP SLs, and are the same for all but two chemicals. The dry-weight SQS for pentachlorophenol is $360 \,\mu\text{g/kg}$, lower than the DMMP SL of $400 \,\mu\text{g/kg}$, and the dry-weight SQS for acenaphthylene is $1300 \,\mu\text{g/kg}$, higher than the DMMP SL of $560 \,\mu\text{g/kg}$. With only one exception, all samples for all chemicals, including pentachlorophenol, are less than the dry-weight SQS, indicating these sediments would likely be suitable for beneficial use. Sample C-7-B had a

detected concentration of hexachlorobutadiene above the dry-weight SQS, indicating that this material is likely not suitable for beneficial use.

Comparison to SQS is not the only consideration in assessing beneficial use. Based on initial coordination with other resource agencies and the Puyallup Tribe, the following assumptions were also taken into consideration:

- If material is unsuitable for the Commencement Bay open-water disposal site then it is also unsuitable for beneficial use
- NMFS' proposed PAH level for the protection of fish of 2,000 μg/kg¹ is appropriate for aquatic beneficial use
- Only material with dioxin less than 4 pptr TEQ is appropriate for beneficial use

Table 12 shows the average percent likelihood of suitability for beneficial use of this material based on all these considerations. The results are summarized below:

Table 12. Summary of Beneficial Use Suitability for Tacoma Harbor

| Area | Average percent likelihood of suitability for beneficial use |
|--------|--|
| Mouth | 85% |
| Middle | 40% |
| Head | 100% |
| Native | 95% |

 Sediment Exposed by Dredging. The sediment to be exposed by dredging must either meet the State of Washington Sediment Quality Standards (SQS) or the State's Antidegradation standard (Ecology, 2013) as outlined by DMMP guidance (DMMP, 2008).

This sediment core characterization in the Blair Waterway clearly demonstrated that contamination decreases with depth. With the exception of cores C-7, C-10, and C-13, the highest COC concentrations were found at the top of the core with contamination decreasing with depth. For C-7, there was elevated hexachlorobutadiene in the 2-4 foot layer that was not observed at the surface, but the layer below, representing -54 to -56 ft MLLW, was less than SL and SQS. For C-10, TBT was elevated (but below screening levels) in the 2-4 foot layer but decreased with depth and was no longer detected at depths below -53 ft MLLW. For the sideslope sample C-13, dioxins appeared to be highest in the 4-6 foot layer (11.88 pptr TEQ), and was below 4 pptr TEQ in the 8-10 foot layer (-47 to -49 ft MLLW).

At the current level of sampling density and dredge design, it is difficult to determine antidegradation within the side slope regions, although the data gathered in this characterization indicates that antidegradation can be met without need for cover. This uncertainty is being addressed by new rankings for sideslopes during full characterization.

The available information indicates that it is highly likely that antidegradation will be met in the

¹ The National Marine Fisheries Service (NMFS) proposed a screening level of 2,000 μg/kg total PAH for the protection of fish at the Regional Sediment Evaluation Team annual meeting in November 2014.

navigation channel once native material is reached.

10. <u>Underlying Assumptions</u>. Several key assumptions were made by the DMMP agencies in conducting this advisory suitability evaluation. These assumptions are discussed in the following paragraphs.

Dioxins/Furans - Samples with concentrations of dioxins/furans at or below 4 pptr TEQ were deemed suitable for open-water disposal, as this concentration is the site management objective for nondispersive disposal sites. Concentrations of dioxins/furans between 4 and 10 pptr TEQ were considered likely to be eligible for open-water disposal because there is a large volume of clean native material that would be dredged during deepening, and this material can be used to bring the project volume-weighted average below the site management objective of 4 pptr TEQ. USACE planners will need to plan for the additional volume of clean sediment required to meet the volume-weighted average guidelines at the Commencement Bay disposal site. This will likely reduce the amount of material available for beneficial use. It was also assumed that dredging and disposal will be sequenced such that suitable dredged material with relatively higher concentrations of dioxins/furans will be placed first at the Commencement Bay site, followed by native material with very low concentrations, thereby leaving a surface layer of sediment at the disposal site with a low dioxin/furan concentration. Dioxin/furan concentrations above 10 pptr TEQ were determined to be unsuitable for open-water disposal. DMMUs with dioxin/furan concentrations above 10 pptr TEQ would need to pass bioaccumulation testing in order to qualify for open-water disposal. The DMMP agencies made the conservative assumption for the purpose of this evaluation that either bioaccumulation testing for dioxins/furans would not be conducted or, if tested, these samples would fail bioaccumulation testing.

Bioassays – Bioassay testing was not conducted for this advisory-level characterization due to schedule restrictions. Therefore the assignment of potential suitability of samples with SL exceedances was based on the experience and best professional judgment of the DMMP agencies assuming that bioassays would be conducted during full characterization. There were only two samples with SL exceedances with no other exceedances (i.e. they did not have dioxin above 4 pptr TEQ or other BT exceedance) – one detected exceedance of hexachlorobutadiene and one non-detect exceedance of total chlordane. Based on prior experience testing sediments with minor SL exceedances of these chemicals, the DMMP assigned both of these samples a 50% chance of being suitable for open-water disposal.

11. DMMP Guidance for Full Characterization and Dredging. As indicated previously, full characterization of potential dredged material from the Blair Waterway must be completed in order to complete a suitability determination for this project prior to dredging. The testing results from this feasibility study indicated that the appropriate ranking for full characterization is variable throughout the waterway. Therefore, unless new information becomes available in the interim, sampling requirements for full characterization will be based on rank according to the following chart:

| Sediment Category | Waterway Area | Rank |
|---------------------------|---------------------|--|
| Sideslopes | Head | Moderate to High |
| | Middle | High |
| | Mouth | Moderate to High |
| Surface material | Head | Low-Moderate |
| | Middle | Moderate to High |
| | Mouth | Low-Moderate to Moderate |
| Confirmed native material | Throughout waterway | No further testing, except for confirmatory testing around C-7 and where full characterization identifies SL/BT failures at the native/non-native boundary |

Two of the three side slope cores (C12, C13) were determined to be unsuitable without further testing (bioaccumulation for dioxins for both; PCB toxicity for C12). Since most of the nearshore areas are not often dredged, and are closer to sources of contamination, DMMP is assigning ranks to the sideslopes that are higher than originally assigned for sampling for this advisory determination. For the full determination, it will be important to have sufficient dredge design details to inform where sideslopes will either be dredged or will slough due to dredging along the base of the slope, so that appropriate sediment locations and depths are characterized.

The concentrations of chemicals of concern in the identified native material were far below the DMMP SLs, with only one exception. There was a detected exceedance of SL for one chemical in a single sample in the middle section of the waterway (C-7). Therefore, throughout the project area, confirmed native sediment will be assumed to be suitable for open-water disposal by the DMMP agencies and will be exempt from analysis during full characterization with two exceptions: native material around C-7 which will require confirmatory testing to verify its suitability, and where full characterization identifies SL/BT failures at the native/non-native boundary. Samples from native material DMMUs will need to be collected and archived pending results of overlying DMMUs.

There is also a high probability of encountering BT exceedances for dioxin, and to a lesser extent TBT, during full characterization, particularly in the middle portion of the waterway and in sideslopes. Bioaccumulation testing requires large volumes of sediment and the testing is costly. Whether and when to collect adequate volumes of sediment to conduct this testing will be up to USACE and the Port of Tacoma.

DMMUs that are found unsuitable for open-water disposal will need to be disposed in an appropriate upland facility. To ensure that the unsuitable material is separated from the suitable material during dredging, a minimum one-foot vertical buffer and an appropriate horizontal buffer will need to be added to the unsuitable portions of the dredge prism. This means that in areas where the top four feet are found unsuitable for open-water disposal, at minimum the top five feet of sediment will need to be dredged and taken upland. The one-foot vertical buffer is not the same as the overdepth allowance. If the dredging contract includes one foot of overdepth, the dredge cut would be five feet, plus one foot of overdepth. USACE planners will need to include the horizontal and vertical buffers in volume calculations for upland disposal.

Since the last deepening of the Blair Waterway in 2000/2001, maintenance dredging has not occurred in the navigation channel, and has occurred in the berthing areas three times for different areas: at GP Gypsum, Husky Terminal and Washington United Terminal. Therefore, there is a good chance that debris will be encountered during dredging. This debris must be removed from sediment prior to disposal at the Commencement Bay open-water disposal site. The dredger will likely be required to screen the surface non-native sediments in areas with suitable material using a grid with a maximum opening size of 12 inches by 12 inches. Native material and material found unsuitable for open-water disposal will not need to be screened. However, if large (greater than 12 inches by 12 inches) woody debris or other large natural debris is found in native sediments, this debris will need to be removed from the dredged material prior to disposal at the Commencement Bay open-water disposal site.

The DMMP agencies are in the process of revising the disposal site monitoring program for all disposal sites in Puget Sound. The process is expected to be completed within a few years, but there are many unknowns at this time. Currently the following changes are reasonably likely to have an impact on future use of the disposal sites:

Disposal tipping fees - DNR is likely to pursue an increase in the disposal tipping fee within the next 5-10 years. The current tipping fee of \$0.45/cy was last increased in 1994. It is premature to estimate what the increased fee might be.

Preventing off-site migration of dredged material - Off-site migration has historically been an issue at the Commencement Bay disposal site, even resulting in the need to temporarily shut down use of the site after significant off-site migration. For projects disposing of a large amount of material in a short period of time there is an increased concern over off-site migration.

In 2009 the DMMP agencies completed a supplemental EIS (SAIC, 2009) for reauthorization of the Commencement Bay open-water disposal site. The preferred alternative chosen for management of the disposal site, Alternative 2, included increasing the cumulative disposal volume of the site to 23 million cubic yards (mcy) with three coordinate shifts within the target area and consideration of the need to implement institutional controls on disposal to better manage the site. Institutional controls considered and studied included specific requirements for tug/barge orientation or direction during disposal and disposal during a specified portion of the tidal cycle.

Due to the potential large volume of material from this project that could be disposed at the Commencement Bay site, additional measures will need to be taken to ensure that the disposed material is not migrating off-site. The DMMP agencies recommend physical monitoring of the site before the start of the project to get a baseline and subsequent physical monitoring of the site after every 500,000 cy disposed or at the end of each dredging year, whichever is more frequent. Physical monitoring includes a multibeam bathymetric survey and SPI monitoring.

If results of the physical monitoring indicate that significant off-site migration is occurring, the DMMP agencies will consider implementation of institutional controls to better manage the site.

12. References.

Anchor, 2019a. Sampling and Analysis Plan – Dredged Material Characterization – Tacoma Harbor Deepening Study. Prepared by Anchor QEA, LLC for Port of Tacoma, February 2019

Anchor, 2019b. Sediment Characterization Data Report – Dredged Material Characterization – Tacoma Harbor Deepening Study. Prepared by Anchor QEA, LLC for Northwest Seaport Alliance, April 2019

DMMP, 2018. *Dredged Material Evaluation and Disposal Procedures (Users Manual)*. Prepared by the Seattle District Dredged Material Management Office for the Dredged Material Management Program, December 2018.

DMMP, 2011. *Marine Sediment Quality Screening Levels: Adopting RSET Marine SLs for Use in DMMP.* A Clarification Paper prepared by Laura Inouye (Ecology) and David Fox (USACE) for the Dredged Material Management Program, June 2011.

DMMP, 2010. *Dredged Material Management Program New Interim Guidelines for Dioxins*. December 6, 2010.

DMMP, 2008. *Quality of Post-Dredge Sediment Surfaces (Updated)*. A Clarification Paper Prepared by David Fox (USACE), Erika Hoffman (EPA) and Tom Gries (Ecology) for the Dredged Material Management Program, June 2008.

Ecology, 2013. *Sediment Management Standards – Chapter 173-204 WAC.* Washington State Department of Ecology, February 2013.

Ecology, 2017. Sediment Cleanup User's Manual II (SCUM II), Guidance for Implementing the Cleanup Provisions of the Sediment Management Standards, Chapter 173-204 WAC. Prepared by the Toxics Cleanup Program, Department of Ecology. Final originally published March 2015, revised December 2017.

SAIC, 2009. Reauthorization of Dredged Material Management Program Disposal Site at Commencement Bay, Supplemental Environmental Impact Statement. Prepared by SAIC for the Dredged Material Management Program, August 2009.

10. Agency Signatures.

The signed copy is on file in the Dredged Material Management Office.

| Concur: | |
|----------|---|
| Date | Kelsey van der Elst - Seattle District Corps of Engineers |
| Date | Justine Barton - Environmental Protection Agency |
| Date | Laura Inouye, Ph.D Washington Department of Ecology |
| Date | Abby Barnes - Washington Department of Natural Resources |

Copies furnished:

DMMP signatories
Kristine Koch, EPA Superfund RPM
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Donald Kramer, USACE Planner
Kristen Kerns, USACE Risk Assessor
Daniel Bernal, USACE Coastal Engineer
Walker Messer, USACE Economist
Kaitlin Whitlock, USACE Biologist

Exhibit A – DMMP Evaluation Procedures

The DMMP evaluation procedures are fully described in DMMP (2018). This exhibit includes information about several key elements relevant for the Blair Waterway suitability evaluation.

Ranking:

For DMMP dredged material evaluations, dredging projects are assigned to one of four possible ranks: high, moderate, low-moderate, or low. These ranks reflect the potential for adverse biological effects or elevated concentrations of chemicals of concern. The higher the rank, the higher the concern, and the more intense the sampling and testing requirements needed to adequately characterize the dredged material. Project or area ranking is based on the available information on chemical and biological-response characteristics of the sediments, as well as the number, kinds, and proximity of chemical sources (existing and historical).

DMMUs:

Tiered testing is conducted for smaller units within the area to be dredged. These units are termed Dredged Material Management Units (DMMUs). A DMMU is the smallest volume of dredged material capable of being dredged independently from adjacent units and for which a separate disposal decision can be made.

Full Characterization:

Full DMMP characterization includes minimum sampling and testing requirements, which are typically based on the rank, volume and depth of the dredging project. For example, in a moderate-ranked area, field samples are restricted to representing no more than 4,000 cubic yards and each DMMU can represent no more than 16,000 cubic yards of dredged material in the surface layer (0-4 feet below mudline). In subsurface sediment (> 4 feet below mudline), field samples are restricted to representing no more than 4,000 cubic yards, but DMMUs can represent up to 24,000 cubic yards, depending on site-specific conditions. Best professional judgment may need to be applied in addressing certain scenarios, for example areas with increasing contamination with depth or adjacent to a cleanup site. Full characterization typically results in a DMMP suitability determination.

Tiered Testing:

The DMMP dredged material suitability determination process consists of four tiers of evaluation and testing. A brief discussion of these tiers follows.

Tier 1 analysis involves the review of existing sediment data and site history, including all potential sources (e.g., outfalls, spills, etc.) for sediment contamination. The Tier 1 evaluation informs the sediment evaluation process for the project.

Tier 2 analysis consists of chemical testing of sediment samples. Table 5 includes the chemicals of concern analyzed in DMMP projects at the time of the Blair Waterway sediment characterization

in 2019. This list includes metals, semivolatiles, pesticides and PCBs, which are all considered standard chemicals of concern. Certain other chemicals of concern, including dioxins/furans and tributyltin, are analyzed in areas that are of concern for these chemicals.

Tier 3 consists of biological testing. DMMUs with exceedances of the chemical screening levels (SLs) or bioaccumulation triggers (BTs) listed in Table 5 require biological testing in Tier 3 to determine their toxicity and/or bioaccumulation potential respectively.

If the Tier 2 analysis indicates that all chemical concentrations are below the SLs and BTs, then no biological testing is necessary. If there is one or more SL exceedance, the DMMU is subjected to a suite of Tier 3 bioassays, consisting of an amphipod mortality test, a larval development test, and the juvenile infaunal growth test. If one or more BT is exceeded, the DMMU is subjected to bioaccumulation testing for the chemical/s exceeding BT.

Tier 4 evaluations are conducted only if standard chemical and biological evaluations are insufficient to determine the suitability of dredged material for open-water disposal. A Tier 4 assessment is a special, non-routine evaluation which might include time-sequenced bioaccumulation or tissue analysis of organisms collected from the area to be dredged. Tier 4 could also include a risk assessment. Tier 4 assessments are rarely needed.

Dioxin Guidelines:

The DMMP agencies implemented revised dioxin/furan guidelines in 2010 for dredged material disposed at the eight multiuser open-water disposal sites in Puget Sound. Implementation of the revised guidelines followed a 3-year study, which included analysis of dioxins/furans in sediment and tissue samples collected from the five non-dispersive sites, as well as determination of background sediment concentrations of dioxins/furans at non-urban sites throughout the Sound (including Hood Canal, the San Juan Islands and the Strait of Juan de Fuca).

The background sediment concentration was determined to be 4 pptr TEQ. The TEQ is the summation of all 17 congeners of dioxins/furans having 2005 World Health Organization Toxic Equivalency Factors. The revised dioxin guidelines for Puget Sound disposal sites are based on this background concentration.

The non-dispersive site management objective is 4 pptr TEQ. DMMUs with dioxin/furan concentrations below 10 pptr TEQ are allowed for disposal as long as the volume-weighted average concentration of dioxins/furans in material from the entire dredging project does not exceed 4 pptr TEQ. DMMUs exceeding 10 pptr may still be placed at non-dispersive sites if they pass bioaccumulation testing that show that the dioxins/furans are not bioavailable. The dioxin concentrations of DMMUs passing bioaccumulation testing are not included in the volume-weighted average.



Figure 1
Site Map and Study Area

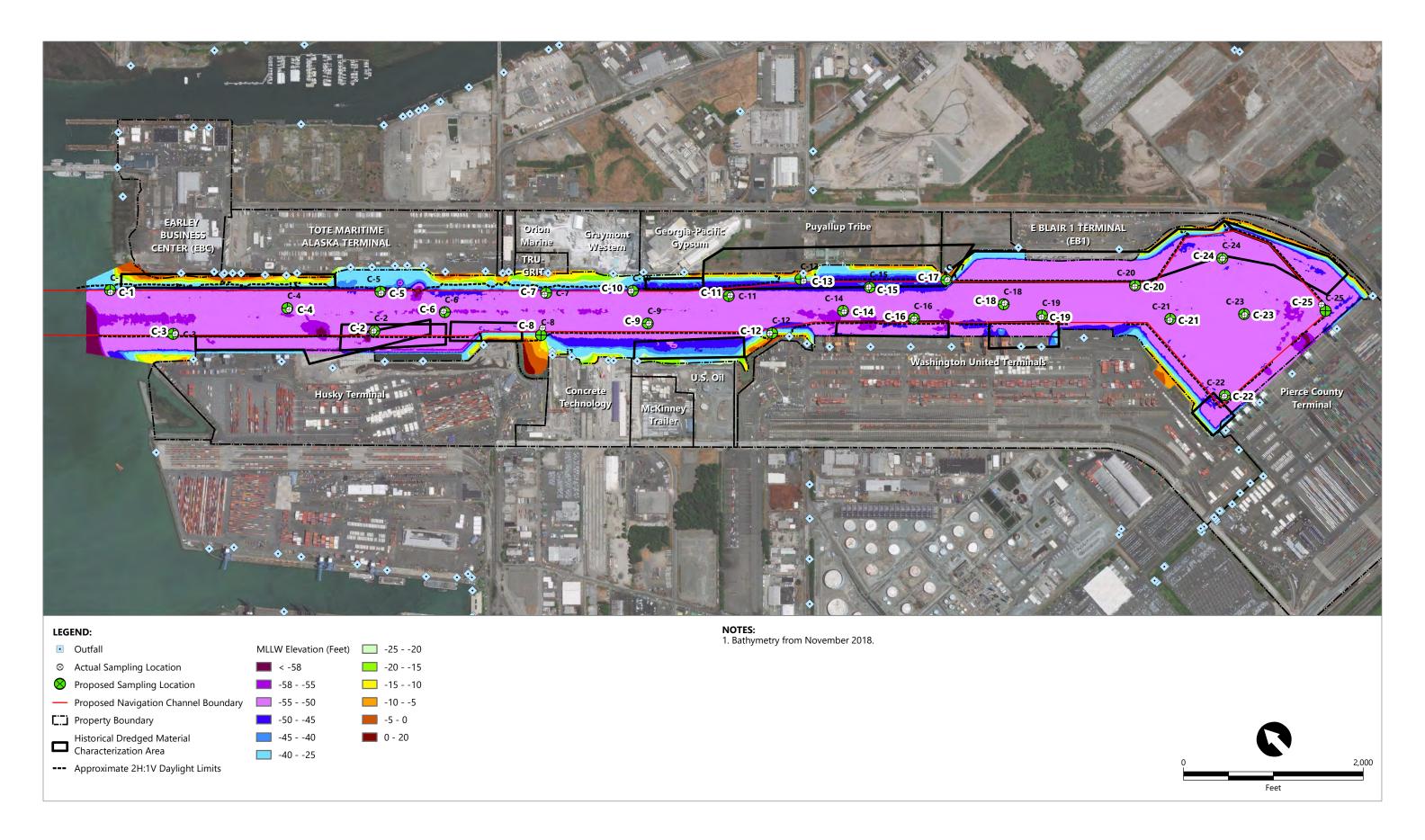
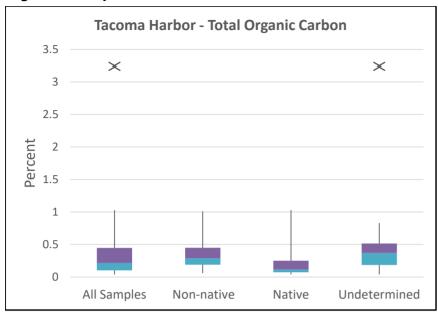
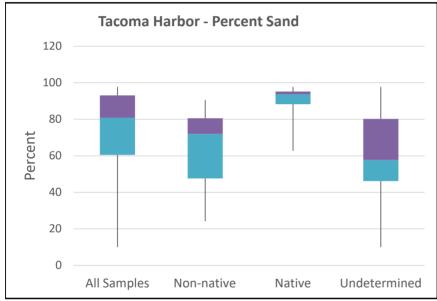
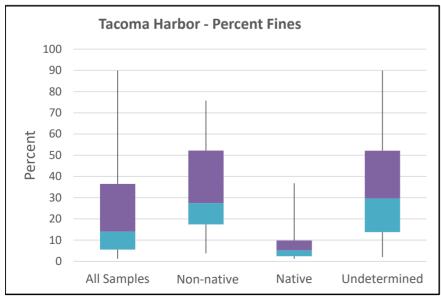


Figure 2
Proposed and Actual Sampling Locations

Figure 3. Boxplots of conventionals results from Tacoma Harbor Deepening Study







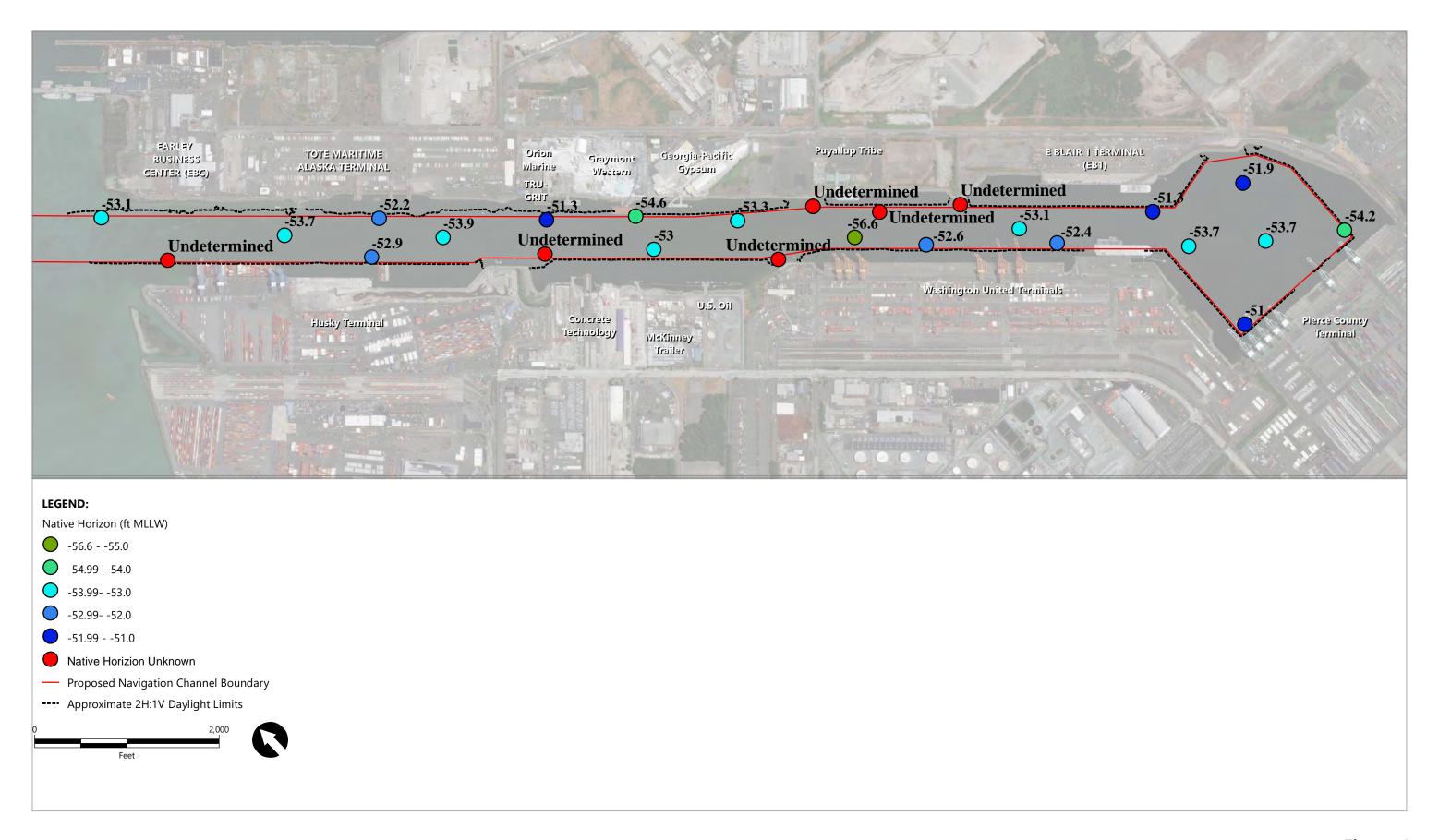


Figure 4
Depth of Native Horizon (ft MLLW)

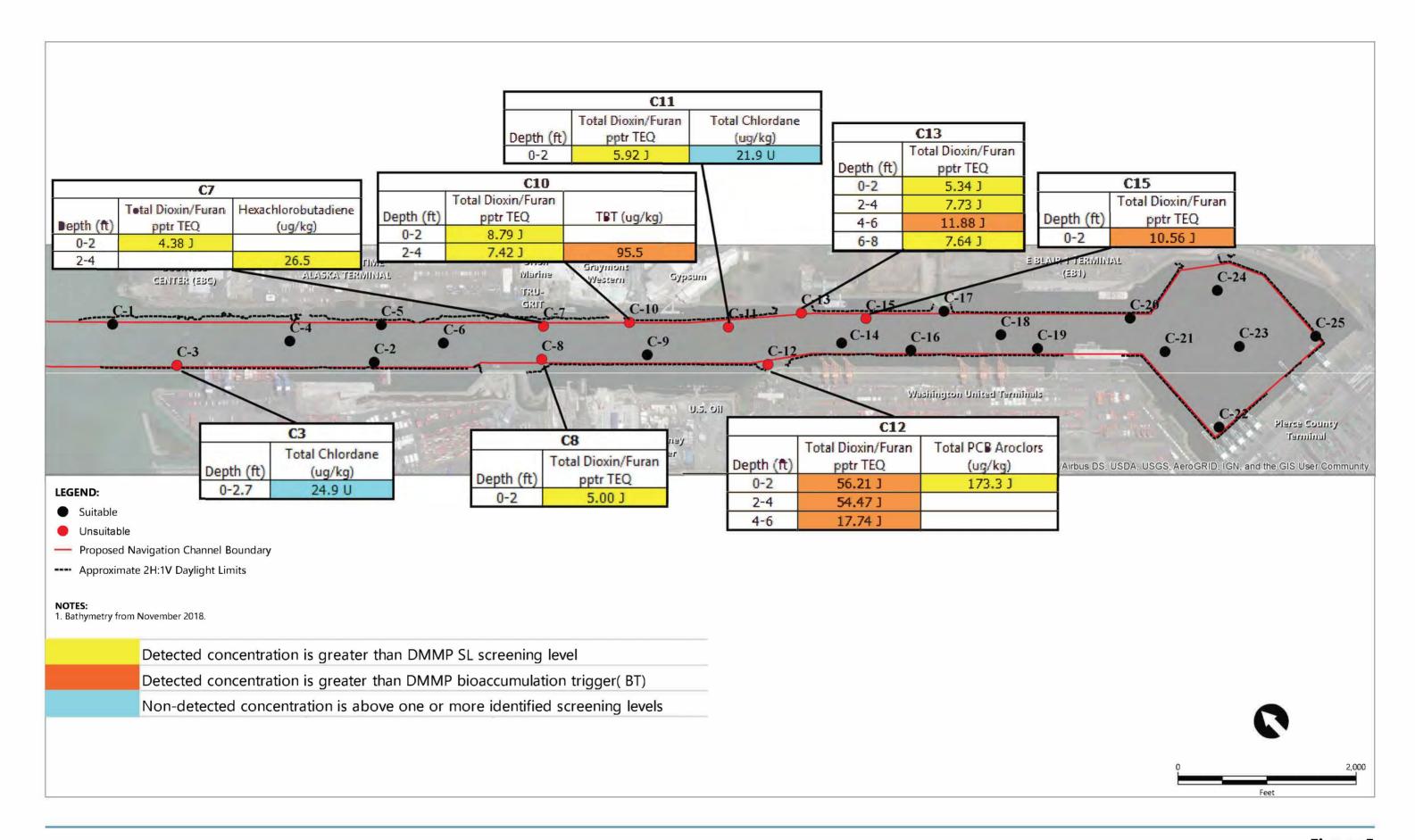


Figure 5
Summary of SL/BT Exceedances
Tacoma Harbor Deepening

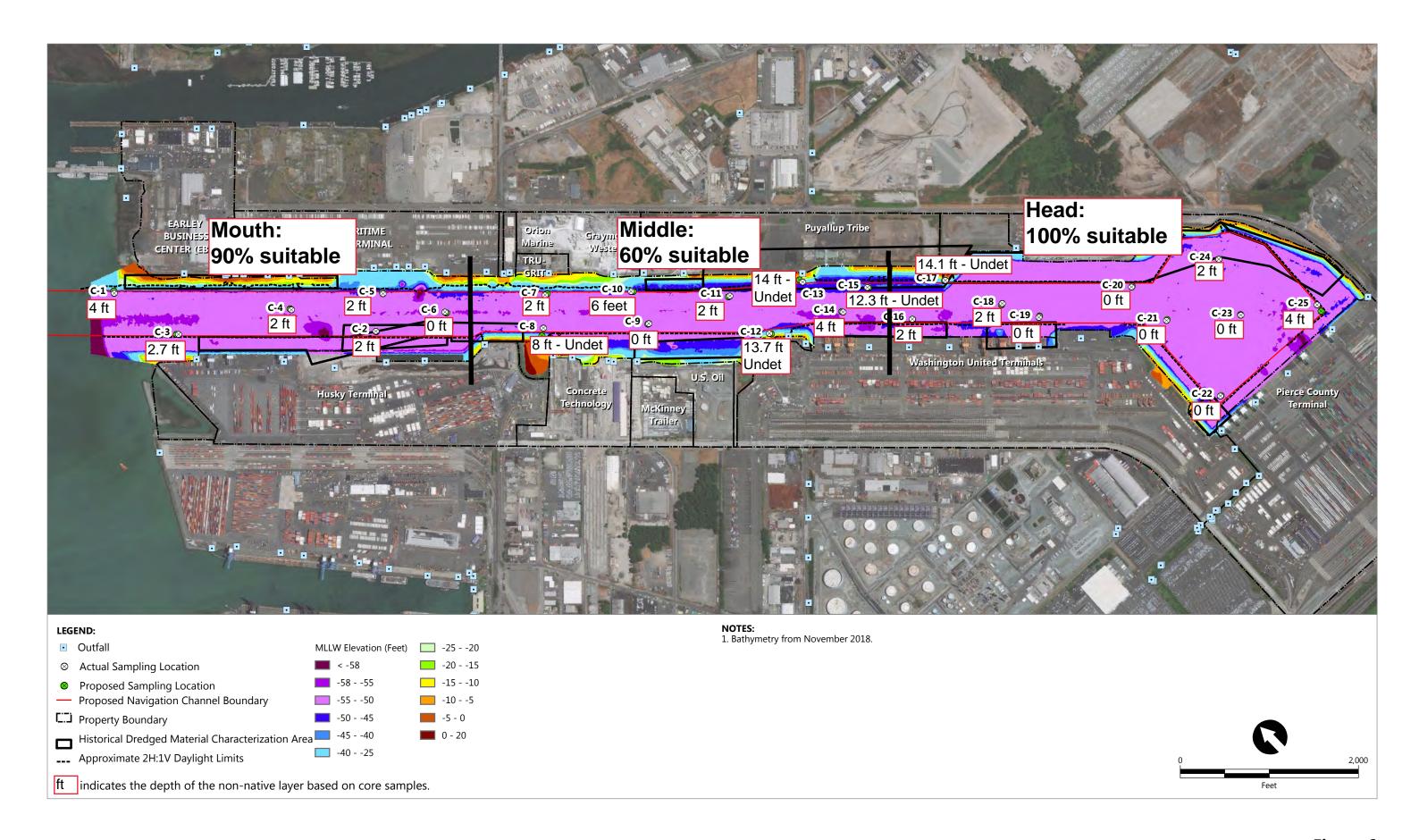


Figure 6
Probability of Suitability for Open-Water Disposal of Non-Native Material

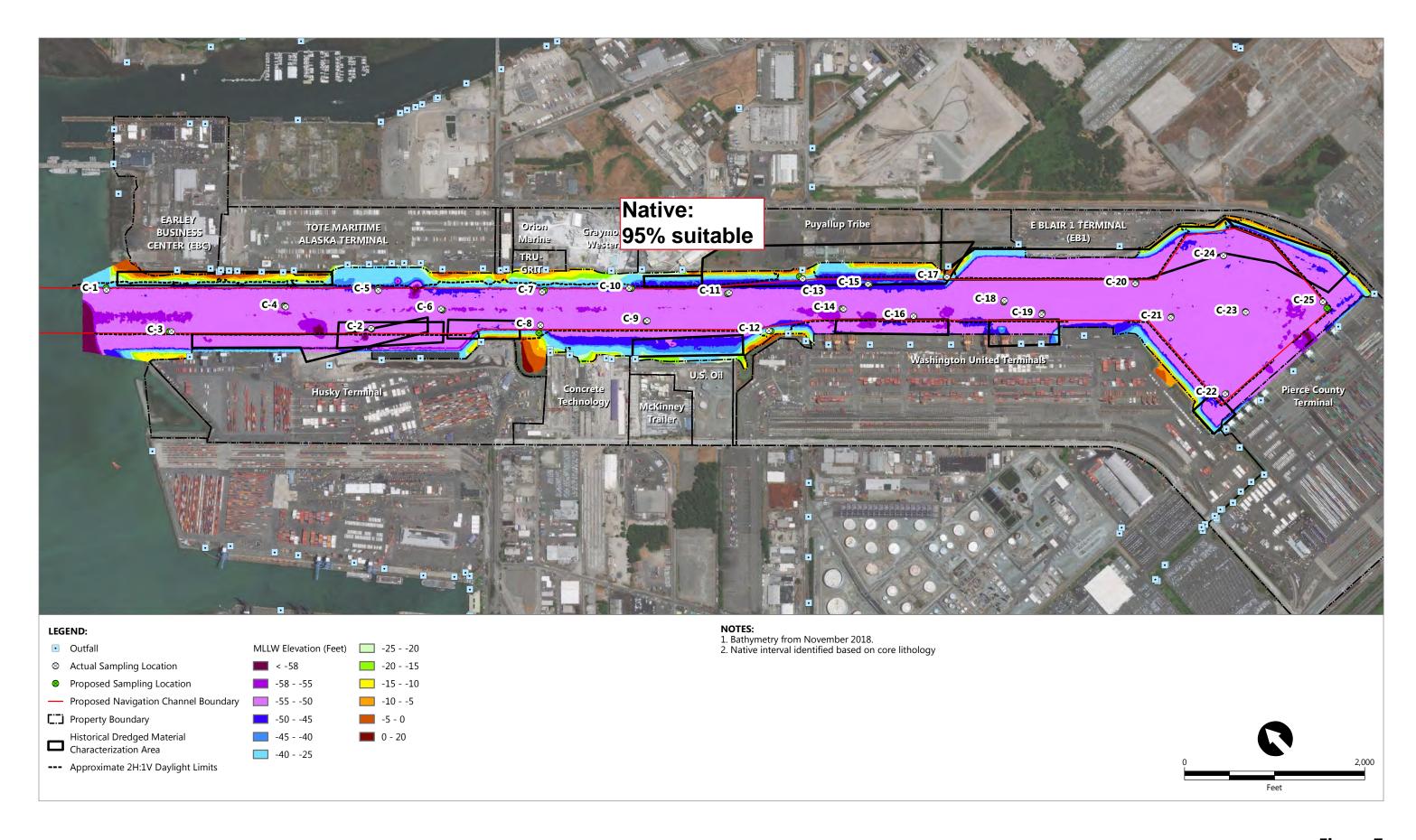


Figure 7
Probability of Suitability for Open-Water Disposal for Native Material

Table 3
Sample Coordinates and Core Collection Data

| | | Location ¹ | | Measured Water Depth (feet) | Water Level (ft MLLW) ² | Mudline Elevation (feet | Drive Penetration | Collection Recovery Measurement | Recovery ³ | Native Horizon Elevation |
|---------|-----------|-----------------------|--------------|-----------------------------------|--|-------------------------------|-------------------|---------------------------------------|-----------------------|-----------------------------|
| Station | Date | X Coordinate | Y Coordinate | | | MLLW) | (feet) | (feet) | (%) | (feet MLLW) |
| C-1 | 2/18/2019 | 1165157.4 | 715708.8 | 61.7 | 11.8 | -49.9 | 13.5 | 13.1 | 97.0 | -53.1 |
| C-2 | 2/18/2019 | 1166970.1 | 713363.2 | 63.2 | 11.8 | -51.4 | 11.0 | 9.7 | 88.2 | -52.9 |
| C-3 | 2/18/2019 | 1165354.3 | 714876.0 | 59.2 | 6.7 | -52.5 | 12.0 | 11.9 | 99.2 | Undetermined |
| C-4 | 2/18/2019 | 1166455.2 | 714192.3 | 61.5 | 7.8 | -53.7 | 9.7 | 9.7 | 100.0 | -53.7 |
| C-5 | 2/20/2019 | 1167320.0 | 713610.6 | 58.5 | 7.0 | -51.5 | 14.6 | 14.0 | 95.9 | -52.2 |
| C-6 | 2/18/2019 | 1167677.8 | 712979.4 | 65.6 | 11.7 | -53.9 | 10.0 | 9.6 | 96.0 | -53.9 |
| C-7 | 2/20/2019 | 1168617.2 | 712335.3 | 59.2 | 8.8 | -50.4 | 13.8 | 13.5 | 97.8 | -51.3 |
| C-8 | 2/21/2019 | 1168345.9 | 712082.2 | 55.8 | 3.8 | -52.0 | 11.0 | 9.5 | 86.4 | Undetermined |
| C-9 | 2/20/2019 | 1169230.3 | 711295.5 | 59.4 | 6.4 | -53.0 | 9.7 | 9.5 | 97.9 | -53.0 |
| C-10 | 2/20/2019 | 1169339.5 | 711694.4 | 59.9 | 10.9 | -49.0 | 13.5 | 13.4 | 99.3 | -54.6 |
| C-11 | 2/20/2019 | 1170100.3 | 710890.6 | 56.7 | 5.1 | -51.6 | 13.9 | 13.0 | 93.5 | -53.3 |
| C-12 | 2/22/2019 | 1170124.7 | 710281.3 | 27.7 | 5.0 | -22.7 | 14.7 | 14.7 | 100.0 | Undetermined |
| C-13 | 2/22/2019 | 1170797.6 | 710436.2 | 48.4 | 9.4 | -39.0 | 14.7 | 14.3 | 97.3 | Undetermined |
| C-14 | 2/21/2019 | 1170888.7 | 709878.9 | 57.0 | 4.4 | -52.6 | 9.6 | 9.2 | 95.8 | -56.6 |
| C-15 | 2/22/2019 | 1171275.8 | 709886.8 | 57.3 | 11.7 | -45.6 | 14.7 | 12.6 | 85.7 | Undetermined |
| C-16 | 2/22/2019 | 1171390.8 | 709280.6 | 62.2 | 11.6 | -50.6 | 9.7 | 9.6 | 99.0 | -52.6 |
| C-17 | 2/22/2019 | 1171960.3 | 709337.6 | 31.2 | 9.5 | -21.7 | 15.0 | 14.5 | 96.7 | Undetermined |
| C-18 | 2/19/2019 | 1172236.9 | 708704.3 | 63.4 | 11.2 | -52.2 | 9.0 | 7.1 | 78.9 | -53.1 |
| C-19 | 2/19/2019 | 1172424.4 | 708310.0 | 62.7 | 10.3 | -52.4 | 9.6 | 8.0 | 83.3 | -52.4 |
| C-20 | 2/19/2019 | 1173409.8 | 707832.4 | 57.0 | 5.7 | -51.3 | 13.8 | 13.6 | 98.6 | -51.3 |
| C-21 | 2/19/2019 | 1173431.1 | 707291.8 | 59.4 | 5.7 | -53.7 | 9.6 | 8.6 | 89.6 | -53.7 |
| C-22 | 2/19/2019 | 1173278.7 | 706259.8 | 56.7 | 5.7 | -51.0 | 13.2 | 13.0 | 98.5 | -51.0 |
| C-23 | 2/21/2019 | 1174069.4 | 706752.9 | 64.1 | 10.4 | -53.7 | 8.5 | 7.5 | 88.2 | -53.7 |
| C-24 | 2/22/2019 | 1174329.1 | 707378.1 | 61.2 | 10.1 | -51.1 | 9.7 | 9.3 | 95.9 | -51.9 |
| C-25 | 2/22/2019 | 1174764.8 | 706243.0 | 56.7 | 5.3 | -51.4 | 9.7 | 9.6 | 99.0 | -54.2 |

Notes

MLLW: mean lower low water

^{1.} Coordinates are in North American Datum of 1983 Washington State Plane South, U.S. feet.

^{2.} Water level obtained using real-time kinematic GPS.

^{3.} Percent recovery calculated based on collection measurement.

Table 4
Core Sampling Intervals and Analysis

| Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Round 1 Sampling Status ¹ | Round 2 Analyses |
|---------|---------------|------------------------|---------------------------------|--------------------------------------|-----------------------|
| C-1 | C-1-A-190219 | 0 to 2 | -49.9 to -51.9 | Full Suite | |
| | C-1-B-190219 | 2 to 4 | -51.9 to -53.9 | Full Suite | |
| | C-1-C-190219 | 4 to 6 | -53.9 to -55.9 | Full Suite | |
| | C-1-D-190219 | 6 to 8 | -55.9 to -57.9 | Archive | |
| | C-1-E-190219 | 8 to 9.9 | -57.9 to -59.8 | Archive | |
| C-2 | C-2-A-190219 | 0 to 2 | -51.4 to -53.4 | Full Suite | |
| | C-2-B-190219 | 2 to 4 | -53.4 to -55.4 | Full Suite | |
| | C-2-C-190219 | 4 to 6 | -55.4 to -57.4 | Archive | Conventionals and TBT |
| | C-2-D-190219 | 6 to 8.6 | 57.4 to -60.0 | Archive | Conventionals and TBT |
| C-3 | C-3-A-190218 | 0 to 2.7 | -52.5 to -55.2 | Full Suite | |
| | C-3-B-190218 | 2.7 to 5.8 | -55.2 to -58.3 | Full Suite | |
| | C-3-C-190218 | 5.8 to 7.5 | -58.3 to -60.0 | Archive | |
| | C-3-Z-190218 | 7.5 to 9.5 | -60.0 to -62.0 | Archive | |
| | C-3-Z2-190218 | 9.5 to 11.2 | -62.0 to -63.7 | Archive | |
| C-4 | C-4-A-190218 | 0 to 2 | -53.6 to -55.6 | Full Suite | |
| | C-4-B-190218 | 2 to 4 | -55.6 to -57.6 | Full Suite | |
| | C-4-C-190218 | 4 to 6 | -57.6 to -59.6 | Archive | |
| | C-4-Z-190218 | 6 to 8.2 | -59.6 to -61.8 | Archive | |
| C-5 | C-5-A-190221 | 0 to 2 | -51.5 to -53.5 | Full Suite | |
| | C-5-B-190221 | 2 to 4 | -53.5 to -55.5 | Full Suite | |
| | C-5-C-190221 | 4 to 6 | -55.5 to -57.5 | Archive | |
| | C-5-D-190221 | 6 to 8.5 | -57.5 to -60.0 | Archive | |
| | C-5-Z-190221 | 8.5 to 10.5 | -60.0 to -62.0 | Archive | |
| C-6 | C-6-A-190219 | 0 to 2 | -53.9 to -55.9 | Full Suite | |
| | C-6-B-190219 | 2 to 4 | -55.9 to -57.9 | Full Suite | |
| | C-6-C-190219 | 4 to 6.1 | -57.9 to -60.0 | Archive | |
| | C-6-Z-190219 | 6.1 to 8.1 | 60.0 to -62.0 | Archive | |
| C-7 | C-7-A-190221 | 0 to 2 | -50.4 to -52.4 | Full Suite | |
| | C-7-B-190221 | 2 to 4 | -52.4 to -54.4 | Full Suite | |
| | C-7-C-190221 | 4 to 6 | -54.4 to -56.4 | Full Suite | |
| | C-7-D-190221 | 6 to 8 | -56.4 to -58.4 | Archive | |

Table 4
Core Sampling Intervals and Analysis

| Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Round 1 Sampling Status ¹ | Round 2 Analyses |
|---------|---------------|------------------------|---------------------------------|--------------------------------------|-----------------------|
| | C-7-E-190221 | 8 to 9.6 | -58.4 to -60.0 | Archive | |
| | C-7-Z-190221 | 9.6 to 11.6 | -60.0 to -62.0 | Archive | |
| C-8 | C-8-A-190221 | 0 to 2 | -52.0 to -54.0 | Full Suite | |
| | C-8-B-190221 | 2 to 4 | -54.0 to -56.0 | Full Suite | |
| | C-8-C-190221 | 4 to 6 | -56.0 to -58.0 | Archive | |
| | C-8-D-190221 | 6 to 8 | -58.0 to -60.0 | Archive | |
| | C-8-Z-190221 | 8 to 8.3 | -60.0 to -60.3 | Archive | |
| C-9 | C-9-A-190220 | 0 to 2 | -53.0 to -55.0 | Full Suite | |
| | C-9-B-190220 | 2 to 4 | -55.0 to -57.0 | Full Suite | |
| | C-9-C-190220 | 4 to 7 | -57.0 to -60.0 | Archive | |
| | C-9-Z-190220 | 7 to 9 | -60.0 to -62.0 | Archive | |
| C-10 | C-10-A-190221 | 0 to 2 | -49.0 to -51.0 | Full Suite | |
| | C-10-B-190221 | 2 to 4 | -51.0 to -53.0 | Full Suite | |
| | C-10-C-190221 | 4 to 6 | -53.0 to -55.0 | Full Suite | |
| | C-10-D-190221 | 6 to 8 | -55.0 to -57.0 | Archive | |
| | C-10-E-190221 | 8 to 11 | -57.0 to -60.0 | Archive | |
| | C-10-Z-190221 | 11 to 13 | -60.0 to -62.0 | Archive | |
| C-11 | C-11-A-190220 | 0 to 2 | -51.6 to -53.6 | Full Suite | |
| | C-11-B-190220 | 2 to 4 | -53.6 to -55.6 | Full Suite | |
| | C-11-C-190220 | 4 to 6.3 | -55.6 to -57.9 | Archive | |
| | C-11-D-190220 | 6.3 to 8.4 | -57.9 to -60.0 | Archive | |
| | C-11-Z-190220 | 8.4 to 10.4 | -60.0 to -62.0 | Archive | |
| C-12 | C-12-A-190223 | 0 to 2 | -22.7 to -24.7 | Full Suite | |
| | C-12-B-190223 | 2 to 4 | -24.7 to -26.7 | Full Suite | |
| | C-12-C-190223 | 4 to 6 | -26.7 to -28.7 | Full Suite | |
| | C-12-D-190223 | 6 to 8 | -28.7 to -30.7 | Archive | conventionals and D/F |
| | C-12-E-190223 | 8 to 10 | -30.7 to -32.7 | Archive | conventionals and D/F |
| | C-12-F-190223 | 10 to 12 | -32.7 to -34.7 | Archive | |
| | C-12-G-190223 | 12 to 13.7 | -34.7 to -36.4 | Archive | |
| C-13 | C-13-A-190223 | 0 to 2 | -39.0 to -41 | Full Suite | |
| | C-13-B-190223 | 2 to 4 | -41.0 to -43.0 | Full Suite | |

Table 4
Core Sampling Intervals and Analysis

| Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Round 1 Sampling Status ¹ | Round 2 Analyses |
|---------|----------------|------------------------|---------------------------------|--------------------------------------|-----------------------|
| | C-13-C-190223 | 4 to 6 | -43.0 to -45.0 | Full Suite | |
| | C-13-D-190223 | 6 to 8 | -45.0 to -47.0 | Archive | conventionals and D/F |
| | C-13-E-190223 | 8 to 10 | -47.0 to -49.0 | Archive | conventionals and D/F |
| | C-13-F-190223 | 10 to 12 | -49.0 to -51.0 | Archive | |
| | C-13-G-190223 | 12 to 14 | -51.0 to -53.0 | Archive | |
| C-14 | C-14-A-190221 | 0 to 2 | -52.6 to -54.6 | Full Suite | |
| | C-14-B-190221 | 2 to 4 | -54.6 to -56.6 | Full Suite | |
| | C-14-C-190221 | 4 to 6 | -56.6 to -58.6 | Archive | |
| | C-14-C-190221 | 6 to 7.4 | -58.6 to -60.0 | Archive | |
| | C-14-Z-190221 | 7.4 to 7.6 | -60.0 to -60.6 | Archive | |
| C-15 | C-15-A-190222 | 0 to 2 | -45.6 to -47.6 | Full Suite | |
| | C-15-B-190222 | 2 to 4 | -47.6 to -49.6 | Full Suite | |
| | C-15-C-190222 | 4 to 6 | -49.6 to -51.6 | Full Suite | |
| | C-15-D-190222 | 6 to 8 | -51.6 to -53.6 | Archive | |
| | C-15-E-190222 | 8 to 10 | -53.6 to -55.6 | Archive | |
| | C-15-F-190222 | 10 to 12.3 | -55.6 to -57.9 | Archive | |
| C-16 | C-16-A-190223 | 0 to 2 | -50.6 to -52.6 | Full Suite | |
| | C-16-B-190223 | 2 to 4 | -52.6 to -54.6 | Full Suite | |
| | C-16-C-190223 | 4 to 6.5 | -54.6 to -57.1 | Archive | |
| C-17 | C-17-A-190222 | 0 to 2 | -19.7 to -21.7 | Full Suite | |
| | C-17-B-190222 | 2 to 4 | -21.7 to -23.7 | Full Suite | |
| | C-17-C-190222 | 4 to 8 | -23.7 to -25.7 | Full Suite | |
| | C-17-D-190222 | 8 to 10 | -25.7 to -27.7 | Archive | |
| | C-17-E-190222 | 10 to 12 | -27.7 to -29.7 | Archive | |
| | C-17-F-190222 | 12 to 14.1 | -29.7 to -31.8 | Archive | |
| C-18 | C-18-A1-190220 | 0 to 2.3 | -52.2 to -54.5 | Full Suite | |
| | C-18-B1-190220 | 3.9 to 6.3 | -54.5 to -56.9 | Full Suite | |
| C-19 | C-19-A-190220 | 0 to 2 | -52.4 to -54.4 | Full Suite | |
| | C-19-B-190220 | 2 to 4 | -54.4 to -56.4 | Full Suite | |
| | C-19-C-190220 | 4 to 6 | -56.4 to -58.4 | Archive | |
| | C-19-D-190220 | 6 to 7.9 | -58.4 to -60.3 | Archive | |

Table 4
Core Sampling Intervals and Analysis

| Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Round 1 Sampling Status ¹ | Round 2 Analyses |
|---------|----------------|------------------------|---------------------------------|--------------------------------------|------------------|
| C-20 | C-20-A-190219 | 0 to 2 | -51.3 to -53.3 | Full Suite | |
| | C-20-B-190219 | 2 to 4 | -53.3 to -55.3 | Full Suite | |
| | C-20-C-190219 | 4 to 6 | -55.3 to -57.3 | Archive | |
| | C-20-D-190219 | 6 to 8.7 | -57.3 to -60.0 | Archive | |
| | C-20-Z-190219 | 8.7 to 10.6 | -60.0 to -61.9 | Archive | |
| C-21 | C-21-A-190219 | 0 to 2 | -53.7 to -55.7 | Full Suite | |
| | C-21-B-190219 | 2 to 4 | -55.7 to -57.7 | Full Suite | |
| | C-21-C-190219 | 4 to 6.3 | -57.7 to -60.0 | Archive | |
| | C-21-Z-190219 | 6.3 to 8.3 | -60.0 to -62.0 | Archive | |
| C-22 | C-22-A-190219 | 0 to 2 | -51.0 to -53.0 | Full Suite | |
| | C-22-B-190219 | 2 to 4 | -53.0 to -55.0 | Full Suite | |
| | C-22-C-190219 | 4 to 6 | -55.0 to -57.0 | Archive | |
| | C-22-D-190219 | 6 to 9 | -57.0 to -60.0 | Archive | |
| | C-22-Z-190219 | 9 to 11 | -60.0 to -62.0 | Archive | |
| C-23 | C-23-A1-190222 | 0 to 2 | -53.7 to -55.7 | Full Suite | |
| | C-23-B1-190222 | 2 to 4 | -55.7 to -57.7 | Full Suite | |
| C-24 | C-24-A-190223 | 0 to 2 | -51.1 to -53.1 | Full Suite | |
| | C-24-B-190223 | 2 to 4 | -53.1 to -55.1 | Full Suite | |
| | C-24-C-190223 | 4 to 6.6 | -55.1 to -57.7 | Archive | |
| C-25 | C-25-A-190222 | 0 to 2 | -51.4 to -53.4 | Full Suite | |
| | C-25-B-190222 | 2 to 4 | -53.4 to -55.4 | Full Suite | |
| | C-25-C-190222 | 4 to 6 | -55.4 to -57.4 | Archive | |
| | C-25-D-190222 | 6 to 8.6 | -57.4 to -60.0 | Archive | |
| | C-25-Z-190222 | 8.6 to 9.3 | -60.0 to -60.7 | Archive | |

Notes:

MLLW: mean lower low water

^{1.} The full suite of testing parameters include semivolatile organic compounds, polycyclic aromatic hydrocarbons, pesticides, polychlorinated biphenyls, metals, sulfide, ammonia, total organic carbon, grain size, total volatile solids, and total solids, dioxins and furans, and tributytin.

Table 5 **Sample Results Summary - Conventionals and Physical Tests**

| Samp | ole ID | C-1-A-190219 | C-1-B-190219 | C-1-C-190219 | C-2-A-190219 | C-2-B-190219 | C-2-C-190219 | C-2-D-190219 | C-3-A-190218 | C-3-B-190218 | C-4-A-190218 |
|---------------------------------|------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| C | Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 6 - 8.6 ft | 0 - 2.7 ft | 2.7 - 5.8 ft | 0 - 2 ft |
| Analyte | Method | | | | | | | | | | |
| Conventional Parameters (mg/kg) | | | | | • | • | | • | • | | - |
| Ammonia as nitrogen | SM4500NH3H | 2.09 | 0.81 | 0.68 | 2.64 | 2.24 | | | 3.01 | 8.74 | 0.63 |
| Sulfide | SM4500S2D | 388 | 104 | 93.3 | 117 | 1.89 | | | 529 | 115 | 29.6 |
| Conventional Parameters (%) | | | | | | | | | | | |
| Total organic carbon | SW9060A | 0.71 | 0.21 | 0.09 | 0.37 | 0.26 | 1.03 | 0.45 | 0.49 | 0.27 | 0.15 |
| Total solids | SM2540G | 71.88 | 80.16 | 78.63 | 74.57 | 78.53 | 73.42 | 80.56 | 68.43 | 77.92 | 78.72 |
| Total volatile solids | PSEP-TVS | 2.4 | 1.34 | 1.23 | 1.88 | 1.45 | | | 2.1 | 1.56 | 1.35 |
| Grain Size (%) | | | | | | | | | | | |
| Gravel | PSEP-PS | 0 | 0.3 | 0 | 0.5 | 0.1 | 0.4 | 0.5 | 0 | 0.1 | 0.1 |
| Sand, very coarse | PSEP-PS | 0.2 | 0.6 | 0.7 | 0.5 | 0.9 | 0.7 | 0.9 | 0.7 | 0.1 | 0.2 |
| Sand, coarse | PSEP-PS | 3.1 | 9.1 | 8.9 | 7 | 12.9 | 2.9 | 6.2 | 3.2 | 0.2 | 3.3 |
| Sand, medium | PSEP-PS | 12.5 | 33.4 | 38.9 | 28.6 | 38.4 | 17.6 | 32.3 | 8.3 | 1 | 25 |
| Sand, fine | PSEP-PS | 13.6 | 25.1 | 31.1 | 24.8 | 18.7 | 36.8 | 38.7 | 15.8 | 26.5 | 46 |
| Sand, very fine | PSEP-PS | 12.5 | 12.4 | 10.4 | 11.1 | 5.1 | 20.7 | 9.4 | 16 | 42.4 | 16 |
| Total Sand | PSEP-PS | 41.9 | 80.6 | 90 | 72 | 76 | 78.7 | 87.5 | 44 | 70.2 | 90.5 |
| Silt, coarse | PSEP-PS | 12.9 | 5.3 | 3.7 | 7.3 | 6.1 | 9.3 | 3.8 | 11.2 | 8 | 4.3 |
| Silt, medium | PSEP-PS | 14.3 | 4.6 | 1.8 | 6 | 6.7 | 4.5 | 2.5 | 12.9 | 8.6 | 1.3 |
| Silt, fine | PSEP-PS | 11 | 3.3 | 1.4 | 4.8 | 4.5 | 2.3 | 1.7 | 11.1 | 3.3 | 1 |
| Silt, very fine | PSEP-PS | 5.6 | 1.6 | 0.7 | 2.6 | 2.5 | 1.4 | 1.1 | 4.7 | 2.4 | 0.5 |
| Clay, coarse | PSEP-PS | 4.2 | 1.2 | 0.6 | 1.8 | 1.3 | 0.9 | 0.8 | 4.6 | 2 | 0.5 |
| Clay, medium | PSEP-PS | 3 | 0.9 | 0.4 | 1.5 | 0.8 | 0.7 | 0.5 | 3.6 | 1.6 | 0.4 |
| Clay, fine | PSEP-PS | 6.9 | 2.2 | 1.3 | 3.5 | 2 | 1.8 | 1.5 | 7.8 | 3.8 | 1.4 |
| Total Fines | PSEP-PS | 57.9 | 19.1 | 9.9 | 27.5 | 23.9 | 20.9 | 11.9 | 55.9 | 29.7 | 9.4 |

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 5 **Sample Results Summary - Conventionals and Physical Tests**

| | Sample ID | C-4-B-190218 | C-5-A-190221 | C-5-B-190221 | C-6-A-190219 | C-6-B-190219 | C-7-A-190221 | C-7-B-190221 | C-7-C-190221 | C-8-A-190221 | C-8-B-190221 | C-9-A-190220 |
|-------------------------------|-----------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | Depth | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft |
| Analyte | | | | | | | | | | | | |
| Conventional Parameters (mg/l | kg) | | | | | | | | | | | |
| Ammonia as nitrogen | | 0.5 U | 3.9 | 14.8 | 0.41 U | 1.58 | 4.01 | 1.06 | 1.18 | 6.98 | 27.9 | 5.97 |
| Sulfide | | 8.33 | 32.9 | 6.35 | 13.5 | 1.11 U | 258 | 7.28 | 0.887 U | 153 | 4.52 | 0.984 U |
| Conventional Parameters (%) | | | | | | | | | | | | |
| Total organic carbon | | 0.12 | 0.28 | 0.74 J | 0.22 | 0.71 | 0.55 | 0.44 | 0.2 | 0.54 | 0.39 | 0.11 |
| Total solids | | 79.07 | 80.52 | 74.08 | 90.85 | 77.91 | 60.4 | 79.72 | 81.42 | 74.91 | 74.88 | 84.21 |
| Total volatile solids | | 1.07 | 3.39 | 2.45 | 1.36 | 2.26 | 1.33 | 1.57 | 1.28 | 1.95 | 2.13 | 0.92 |
| Grain Size (%) | | | | | | | | | | | | |
| Gravel | | 0.3 | 0.1 | 0.5 | 1.1 | 0.5 | 0.4 | 0.3 | 0.2 | 3.6 | 0 | 0.1 |
| Sand, very coarse | | 0.3 | 0.7 | 2.2 | 1 | 0.9 | 0.4 | 0.9 | 0.4 | 0.6 | 0.2 | 0.5 |
| Sand, coarse | | 5.2 | 8.4 | 14.2 | 16.9 | 4.5 | 2.5 | 4.4 | 2.9 | 2 | 0.3 | 8.4 |
| Sand, medium | | 34.2 | 28.9 | 19.1 | 51 | 34.4 | 21.9 | 36.5 | 26.4 | 7 | 0.4 | 35.9 |
| Sand, fine | | 45.5 | 26.2 | 18.7 | 21.5 | 42.8 | 28 | 44.9 | 49.2 | 14.8 | 1.4 | 33 |
| Sand, very fine | | 10.3 | 11.5 | 16.6 | 3.7 | 11.3 | 11.3 | 6.9 | 13.9 | 18.7 | 8.4 | 9.3 |
| Total Sand | | 95.5 | 75.7 | 70.8 | 94.1 | 93.9 | 64.1 | 93.6 | 92.8 | 43.1 | 10.7 | 87.1 |
| Silt, coarse | | 4.1 U | 8.5 | 9.6 | 1.4 | 1.1 | 7.9 | 1.5 | 3.1 | 16.3 | 17.7 | 3.8 |
| Silt, medium | | 4.1 U | 5.4 | 8 | 1 | 1.2 | 8.4 | 1.1 | 1.1 | 11.7 | 24.6 | 3 |
| Silt, fine | | 4.1 U | 3.4 | 3.8 | 0.7 | 1 | 6.3 | 0.8 | 0.6 | 8.1 | 17.4 | 2.3 |
| Silt, very fine | | 4.1 U | 2.1 | 2 | 0.4 | 0.5 | 3.9 | 0.6 | 0.3 | 5 | 10.4 | 1.1 |
| Clay, coarse | | 4.1 U | 1.4 | 1.4 | 0.4 | 0.2 | 2.8 | 0.5 | 0.4 | 3.5 | 5.8 | 0.5 |
| Clay, medium | | 4.1 U | 0.9 | 1 | 0.3 | 0.3 | 1.8 | 0.3 | 0.2 | 2.4 | 4.1 | 0.4 |
| Clay, fine | | 4.1 U | 2.5 | 2.7 | 0.7 | 1.2 | 4.6 | 1.4 | 1.2 | 6.4 | 9.3 | 1.5 |
| Total Fines | | 4.1 U | 24.2 | 28.5 | 4.9 | 5.5 | 35.7 | 6.2 | 6.9 | 53.4 | 89.3 | 12.6 |

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 5 **Sample Results Summary - Conventionals and Physical Tests**

| | Sample ID | C-9-B-190220 | C-10-A-190221 | C-10-B-190221 | C-10-C-190221 | C-11-A-190220 | C-11-B-190220 | C-12-A-190223 | C-12-B-190223 | C-12-C-190223 | C-12-D-190223 | C-12-E-190223 |
|-------------------------------|-----------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| | Depth | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 6 - 8 ft | 8 - 10 ft |
| Analyte | | | | | | | | | | | | |
| Conventional Parameters (mg/k | (g) | | | | | | | | | | | |
| Ammonia as nitrogen | | 36.4 | 8.44 | 8.05 | 11.9 | 4.27 | 0.95 | 3.31 | 4.36 | 12 | | |
| Sulfide | | 1.03 U | 627 | 592 | 0.989 U | 605 | 1.12 U | 57.1 | 104 | 113 | | |
| Conventional Parameters (%) | | | | | | | | | | | | |
| Total organic carbon | | 0.19 | 1.01 | 0.45 | 0.19 | 0.86 | 0.14 | 0.61 J | 0.37 J | 0.75 J | 0.1 | 0.21 |
| Total solids | | 78.65 | 66.64 | 73.29 | 99.27 | 68.52 | 80.63 | 72.61 | 74.39 | 75.94 | 82.52 | 81.81 |
| Total volatile solids | | 1.34 | 2.88 | 1.92 | 1.67 | 2.45 | 1.06 | 2.13 | 2.08 | 1.86 | | |
| Grain Size (%) | | | | | | | | | | | | |
| Gravel | | 0.2 | 0.7 | 0.1 | 0.2 | 0.2 | 0.3 | 3.5 | 2.9 | 0.6 | 2.8 | 13.7 |
| Sand, very coarse | | 0.3 | 0.2 | 0.2 | 0.5 | 0.4 | 0.3 | 2.5 | 1.8 | 0.5 | 4 | 13.9 |
| Sand, coarse | | 2.7 | 0.9 | 2.1 | 6.5 | 2.5 | 3.9 | 14.5 | 8.5 | 3.5 | 34 | 26.5 |
| Sand, medium | | 9.2 | 5 | 7.2 | 19.8 | 12.5 | 35.6 | 16.9 | 14.2 | 10.5 | 29.5 | 15.9 |
| Sand, fine | | 22 | 12.9 | 15.5 | 20.1 | 20.1 | 43.9 | 13.1 | 17 | 18.8 | 11.8 | 10.6 |
| Sand, very fine | | 28.6 | 12.9 | 19.7 | 12.8 | 12.1 | 9.4 | 10.7 | 12.9 | 15.1 | 4.6 | 8.8 |
| Total Sand | | 62.8 | 31.9 | 44.7 | 59.7 | 47.6 | 93.1 | 57.7 | 54.4 | 48.4 | 83.9 | 75.7 |
| Silt, coarse | | 9.3 | 13.8 | 14.3 | 9.7 | 10.7 | 2 | 9.7 | 9.2 | 10.5 | 3.2 | 3.5 |
| Silt, medium | | 9.2 | 14.5 | 13.5 | 8.9 | 14.2 | 1.1 | 8.2 | 9.9 | 13.3 | 2.7 | 1.7 |
| Silt, fine | | 7.6 | 13.4 | 9.9 | 7.1 | 11.9 | 0.7 | 6.2 | 7.4 | 8.7 | 2.2 | 1.5 |
| Silt, very fine | | 3.5 | 7.5 | 5.1 | 4.1 | 5.8 | 0.6 | 3.9 | 4.6 | 5.5 | 1.5 | 1.2 |
| Clay, coarse | | 2.4 | 5.7 | 3.7 | 3 | 3 | 0.4 | 2.9 | 3.3 | 3.6 | 1.1 | 0.9 |
| Clay, medium | | 1.5 | 3.4 | 2.1 | 1.9 | 1.7 | 0.3 | 2.5 | 2.6 | 2.9 | 0.8 | 0.7 |
| Clay, fine | | 3.3 | 9.2 | 6.7 | 5.5 | 4.9 | 1.5 | 5.4 | 5.7 | 6.4 | 1.8 | 1.1 |
| Total Fines | | 36.8 | 67.5 | 55.3 | 40.2 | 52.2 | 6.6 | 38.8 | 42.7 | 50.9 | 13.3 | 10.6 |

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 5
Sample Results Summary - Conventionals and Physical Tests

| | Sample ID | C-13-A-190223 | C-13-B-190223 | C-13-C-190223 | C-13-D-190223 | C-13-E-190223 | C-14-A-190221 | C-14-B-190221 | C-15-A-190222 | C-15-B-190222 | C-15-C-190222 | C-16-A-190223 |
|------------------------------|-----------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| | Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 6 - 8 ft | 8 - 10 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft |
| Analyte | | | | | | | | | | | | |
| Conventional Parameters (mg, | /kg) | | | | | | • | | | | • | |
| Ammonia as nitrogen | | 4.85 | 19.3 | 23.8 | | | 8.62 | 20.3 | 2.33 | 2.08 | 2.4 | 2.82 |
| Sulfide | | 402 | 339 | 5.5 | | | 11.4 | 1.1 U | 224 | 1.12 U | 1.07 U | 203 |
| Conventional Parameters (%) | | | | | | | | | | | | |
| Total organic carbon | | 0.59 J | 0.39 J | 0.18 J | 0.19 | 0.04 | 0.09 | 0.15 | 0.25 J | 0.1 J | 0.17 J | 0.25 J |
| Total solids | | 77.45 | 74.72 | 83.95 | 84.57 | 85.03 | 86.15 | 84.18 | 75.49 | 82.44 | 83.22 | 94.31 |
| Total volatile solids | | 1.73 | 1.92 | 1.12 | | | 0.88 | 1.27 | 1.69 | 1.08 | 1.23 | 18.98 |
| Grain Size (%) | | | | | | | | | | | | |
| Gravel | | 24.4 | 0.9 | 4.4 | 7.9 | 0.2 | 10.8 | 1.2 | 4.3 | 6.5 | 1.1 | 1.4 |
| Sand, very coarse | | 3.6 | 1.5 | 3.8 | 4 | 1.7 | 6.9 | 3.8 | 3 | 5.9 | 3.5 | 1.8 |
| Sand, coarse | | 10.1 | 8.6 | 16.1 | 18.5 | 18.5 | 25.9 | 16.9 | 14.2 | 21.2 | 19.6 | 13.3 |
| Sand, medium | | 19.6 | 18.8 | 33.2 | 35.9 | 56.2 | 34.3 | 34.1 | 31.2 | 37.9 | 38.7 | 40.7 |
| Sand, fine | | 14.8 | 15.4 | 20 | 14.9 | 19.9 | 15.3 | 23.5 | 22.3 | 16.9 | 20.9 | 18.7 |
| Sand, very fine | | 6.5 | 12.5 | 8.1 | 3.4 | 1.4 | 2.9 | 6.9 | 8.5 | 4.7 | 5.8 | 5.7 |
| Total Sand | | 54.6 | 56.8 | 81.2 | 76.7 | 97.7 | 85.3 | 85.2 | 79.2 | 86.6 | 88.5 | 80.2 |
| Silt, coarse | | 4.2 | 9.7 | 4.7 | 1.6 | 2 U | 0.7 | 4.6 | 3.2 | 2.3 | 2.8 | 3.8 |
| Silt, medium | | 4.3 | 9 | 2.6 | 3.6 | 2 U | 0.5 | 2.5 | 3.6 | 1.1 | 1.9 | 3.4 |
| Silt, fine | | 4.5 | 7.2 | 2.1 | 3.3 | 2 U | 0.6 | 1.8 | 4.1 | 0.8 | 1.4 | 4.1 |
| Silt, very fine | | 2 | 4.2 | 1.5 | 2.4 | 2 U | 0.5 | 1.3 | 1.4 | 0.8 | 1.1 | 1.9 |
| Clay, coarse | | 1.7 | 3.6 | 0.9 | 1.4 | 2 U | 0.5 | 1 | 0.9 | 0.4 | 0.9 | 1.3 |
| Clay, medium | | 1.5 | 2.7 | 0.7 | 1 | 2 U | 0.3 | 0.8 | 0.8 | 0.4 | 0.6 | 1.2 |
| Clay, fine | | 2.9 | 5.8 | 1.8 | 2 | 2 U | 0.7 | 1.8 | 2.3 | 1.2 | 1.7 | 2.6 |
| Total Fines | | 21.1 | 42.2 | 14.3 | 15.3 | 2 U | 3.8 | 13.8 | 16.3 | 7 | 10.4 | 18.3 |

Notes:

Bold: Detected result

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 5 **Sample Results Summary - Conventionals and Physical Tests**

| | Sample ID | C-16-B-190223 | C-17-A-190222 | C-17-B-190222 | C-17-C-190222 | C-18-A1-190220 | C-18-B1-190220 | C-19-A-190220 | C-19-B-190220 | C-20-A-190219 | C-20-B-190219 | C-21-A-190219 |
|------------------------------|-----------|---------------|---------------|---------------|---------------|----------------|----------------|---------------|---------------|---------------|---------------|---------------|
| | Depth | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 8 ft | 0 - 2.3 ft | 3.9 - 6.3 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft |
| Analyte | | | | | | | | | | | | |
| Conventional Parameters (mg/ | kg) | | | | | | | | | | | |
| Ammonia as nitrogen | | 1.8 | 9.64 | 24.6 | 21.8 | 1.73 | 0.88 | 0.41 | 0.62 | 3.61 | 3.17 | 0.44 U |
| Sulfide | | 1.11 U | 491 | 1.73 U | 1.07 U | 98.7 | 0.97 U | 1.01 U | 4.57 | 27.1 | 1.01 U | 7.09 |
| Conventional Parameters (%) | | | | | | | | | | | | |
| Total organic carbon | | 0.05 J | 0.83 J | 3.24 J | 0.39 J | 0.29 J | 0.13 J | 0.09 | 0.1 | 0.08 | 0.04 | 0.49 |
| Total solids | | 82.56 | 66.23 | 52.51 | 72.42 | 79.18 | 89.34 | 96.68 | 84.76 | 83.46 | 88.17 | 86.32 |
| Total volatile solids | | 0.98 | 3.54 | 9.48 | 6.55 | 1.34 | 1.55 | 0.85 | 1.11 | 0.96 | 0.96 | 1.72 |
| Grain Size (%) | | | | | | | | | | | | |
| Gravel | | 1.5 | 0 | 0.2 | 0 | 1.1 | 3.1 | 2.1 | 2.5 | 1.1 | 4.7 | 1.1 |
| Sand, very coarse | | 4.1 | 0.8 | 3.1 | 0.1 | 3.7 | 9.1 | 8.8 | 7 | 7.2 | 9.7 | 4.1 |
| Sand, coarse | | 20.2 | 1.3 | 1.7 | 0.4 | 21.6 | 33.5 | 40.9 | 25.7 | 31 | 46.7 | 17.2 |
| Sand, medium | | 55.6 | 2.1 | 1.7 | 1.5 | 36.5 | 44.3 | 33.7 | 33.7 | 32.6 | 31.8 | 43.2 |
| Sand, fine | | 14.1 | 2.5 | 2.4 | 5.6 | 14.9 | 7.3 | 10.4 | 17.7 | 15.4 | 5.5 | 31.1 |
| Sand, very fine | | 1.6 | 3.3 | 5.2 | 21.7 | 4.8 | 0.6 | 1.6 | 3.6 | 6.1 | 0.5 | 2.1 |
| Total Sand | | 95.6 | 10 | 14.1 | 29.3 | 81.5 | 94.8 | 95.4 | 87.7 | 92.3 | 94.2 | 97.7 |
| Silt, coarse | | 2.8 U | 5.5 | 6.8 | 20.2 | 3.8 | 2 U | 2.4 U | 2.3 | 2.5 | 1.2 U | 1.3 U |
| Silt, medium | | 2.8 U | 12.9 | 13.7 | 18.6 | 3.7 | 2 U | 2.4 U | 2.5 | 1.2 | 1.2 U | 1.3 U |
| Silt, fine | | 2.8 U | 18.7 | 18.5 | 11.3 | 3 | 2 U | 2.4 U | 1.8 | 0.8 | 1.2 U | 1.3 U |
| Silt, very fine | | 2.8 U | 19.4 | 17 | 7.2 | 2.3 | 2 U | 2.4 U | 0.9 | 0.5 | 1.2 U | 1.3 U |
| Clay, coarse | | 2.8 U | 13.6 | 10.9 | 4.5 | 1.4 | 2 U | 2.4 U | 0.5 | 0.4 | 1.2 U | 1.3 U |
| Clay, medium | | 2.8 U | 7.6 | 6.9 | 2.8 | 1.2 | 2 U | 2.4 U | 0.3 | 0.3 | 1.2 U | 1.3 U |
| Clay, fine | | 2.8 U | 12.2 | 12 | 6 | 2 | 2 U | 2.4 U | 1.4 | 1 | 1.2 U | 1.3 U |
| Total Fines | | 2.8 U | 89.9 | 85.8 | 70.6 | 17.4 | 2 U | 2.4 U | 9.7 | 6.7 | 1.2 U | 1.3 U |

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 5
Sample Results Summary - Conventionals and Physical Tests

| Sample ID | C-21-B-190219 | C-22-A-190219 | C-22-B-190219 | C-23-A1-190222 | C-23-B1-190222 | C-24-A-190223 | C-24-B-190223 | C-25-A-190222 | C-25-B-190222 |
|---------------------------------|---------------|---------------|---------------|----------------|----------------|---------------|---------------|---------------|---------------|
| Depth | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | | | | |
| Conventional Parameters (mg/kg) | | | | | | | | | |
| Ammonia as nitrogen | 0.45 U | 1.95 | 2.19 | 0.41 U | 0.38 U | 1.68 | 1.79 | 36.7 | 41.9 |
| Sulfide | 1.19 U | 1.01 U | 1.07 U | 1.01 U | 1.07 U | 1.76 | 1 U | 1.31 U | 1.17 U |
| Conventional Parameters (%) | | | | | | | | | |
| Total organic carbon | 0.11 | 0.07 | 0.04 | 0.07 | 0.04 | 0.06 J | 0.04 J | 0.29 J | 0.44 J |
| Total solids | 87 | 91.38 | 90.92 | 91.48 | 90.58 | 84.92 | 90.11 | 77.35 | 75.07 |
| Total volatile solids | 1.1 | 0.83 | 0.93 | 1.01 | 0.83 | 1.05 | 0.98 | 1.66 | 2.67 |
| Grain Size (%) | | | | | | | | | |
| Gravel | 0.4 | 0.4 | 0.4 | 2.6 | 4.1 | 15.3 | 4.5 | 0.1 | 0.5 |
| Sand, very coarse | 4.2 | 2.2 | 2.4 | 11.4 | 13.8 | 13.7 | 18.3 | 0.4 | 0.5 |
| Sand, coarse | 17.3 | 19.9 | 22.9 | 42.4 | 48.7 | 26.9 | 33 | 2 | 2.8 |
| Sand, medium | 43.5 | 45.3 | 47.6 | 32.9 | 26.9 | 26.7 | 34.2 | 5.3 | 31.1 |
| Sand, fine | 30.5 | 25.3 | 22.5 | 5.4 | 3.7 | 9.5 | 7.9 | 6.9 | 24.2 |
| Sand, very fine | 1.6 | 2.6 | 2.1 | 0.8 | 0.6 | 2.4 | 0.6 | 9.6 | 5.9 |
| Total Sand | 97.1 | 95.3 | 97.5 | 92.9 | 93.7 | 79.2 | 94 | 24.2 | 64.5 |
| Silt, coarse | 2.5 U | 1.4 | 2 U | 0.9 | 2.1 U | 1.1 | 1.4 U | 19.7 | 6.2 |
| Silt, medium | 2.5 U | 0.9 | 2 U | 0.6 | 2.1 U | 1 | 1.4 U | 25.3 | 12.2 |
| Silt, fine | 2.5 U | 0.8 | 2 U | 0.9 | 2.1 U | 0.9 | 1.4 U | 13.8 | 6.9 |
| Silt, very fine | 2.5 U | 0.3 | 2 U | 0.7 | 2.1 U | 0.7 | 1.4 U | 6.4 | 3.6 |
| Clay, coarse | 2.5 U | 0.2 | 2 U | 0.5 | 2.1 U | 0.5 | 1.4 U | 3.1 | 1.9 |
| Clay, medium | 2.5 U | 0.1 | 2 U | 0.2 | 2.1 U | 0.4 | 1.4 U | 2.2 | 1.4 |
| Clay, fine | 2.5 U | 0.6 | 2 U | 0.5 | 2.1 U | 1.1 | 1.4 U | 5.3 | 2.9 |
| Total Fines | 2.5 U | 4.3 | 2 U | 4.3 | 2.1 U | 5.7 | 1.4 U | 75.8 | 35.1 |

Notes:

Bold: Detected result

ft: feet

J: Estimated value

mg/kg: milligram per kilogram

Table 6

| Sample Results Summary - N Sample ID Depth Analyte | | DMMP BT | C-1-A-190219 0 - 2 ft | C-1-B-190219 2 - 4 ft | C-1-C-190219 4 - 6 ft | C-2-A-190219 0 - 2 ft | C-2-B-190219 2 - 4 ft | C-2-C-190219 4 - 6 ft | C-2-D-190219 6 - 8.6 ft |
|--|------------|-------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|----------------------------|
| Metals (mg/kg) | DIVINIF 3L | DIVIIVIF B1 | | | | | | | |
| Antimony | 150 | | 0.28 UJ | 0.23 UJ | 0.23 UJ | 0.25 UJ | 0.24 UJ | | |
| Arsenic | 57 | 507.1 | 3.24 | 1.67 | 1.06 | 4.97 | 1.95 | | |
| Cadmium | 5.1 | | 0.09 J | 0.11 U | 0.12 U | 0.05 J | 0.05 J | | |
| Chromium | 260 | | 14.7 | 11 | 9.49 | 12.5 | 12.7 | | |
| Copper | 390 | | 26.7 | 13.7 | 10.3 | 18.3 | 16.6 | | |
| Lead | 450 | 975 | 6.01 | 2.33 | 1.33 | 3.46 | 2.15 | | |
| Mercury | 0.41 | 1.5 | 0.0423 | 0.025 | 0.0114 J | 0.0249 J | 0.0167 J | | |
| Selenium | | 3 | 0.97 | 0.72 | 0.69 | 0.95 | 1.11 | | |
| Silver Zinc | 6.1 410 | | 0.12 J 33.3 | 0.06 J 19.3 | 0.03 J 14.9 | 0.08 J 27 | 0.05 J 23.7 | | |
| Organometallic Compounds (µg/kg) | 410 | | 33.3 | 19.5 | 14.5 | 21 | 23.7 | | |
| Tributyltin (ion) | | 73 | 0.913 J | 3.42 U | 3.49 U | 7.35 | 17.3 | 3.6 U | 3.43 U |
| Semivolatile Organics (µg/kg) | I | ,,, | 0.5155 | 5.42 0 | 3.43 0 | 7.55 | 17.5 | 3.0 0 | 3.43 0 |
| 1,2,4-Trichlorobenzene | 31 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| 1,2-Dichlorobenzene | 35 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| 1,4-Dichlorobenzene | 110 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| 2,4-Dimethylphenol | 29 | | 24.9 UJ | 24 UJ | 24.1 UJ | 24.4 UJ | 24.3 UJ | | |
| 2-Methylphenol (o-Cresol) | 63 | | 3 J | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| 4-Methylphenol (p-Cresol) | 670 | | 5 | 4.8 U | 4.8 U | 2.9 J | 4.9 U | | |
| Benzoic acid | 650 | | 84.7 J | 95.9 UJ | 96.3 UJ | 97.5 UJ | 97 UJ | | |
| Benzyl alcohol | 57 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| bis(2-Ethylhexyl)phthalate | 1300 | | 49.8 U | 47.9 U | 48.2 U | 48.8 U | 48.5 U | | |
| Butylbenzyl phthalate | 63 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Diethyl phthalate | 200 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Dimethyl phthalate | 71 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| Di-n-butyl phthalate | 1400 | | 37.3 | 22.5 | 22.4 | 40.6 | 14.9 J | | |
| Di-n-octyl phthalate | 6200 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Hexachlorobenzene | 22 | 168 | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| Hexachlorobutadiene | 11 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| n-Nitrosodiphenylamine | 28 | | 5 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U | | |
| Pentachlorophenol | 400 | 504 | 19.9 UJ | 19.2 UJ | 19.3 UJ | 19.5 UJ | 19.4 UJ | | |
| Phenol | 420 | | 13.5 U | 4.8 U | 4.8 U | 7.8 U | 4.9 U | | |
| Polycyclic Aromatic Hydrocarbons (µg/kg) | • | | • | • | • | | • | | • |
| 2-Methylnaphthalene | 670 | | 24.7 | 8.6 J | 19.3 U | 19.5 U | 6.4 J | | |
| Acenaphthene | 500 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Acenaphthylene | 560 | | 19.9 U | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Anthracene | 960 | | 14.8 J | 19.2 U | 19.3 U | 7.7 J | 19.4 U | | |
| Benzo(a)anthracene | 1300 | | 24.1 | 16.6 J | 19.3 U | 17.5 J | 5.2 J | | |
| Benzo(a)pyrene | 1600 | | 20.3 | 16.7 J | 19.3 U | 16.3 J | 19.4 U | | |
| Benzo(b,j,k)fluoranthenes | | | 57.7 | 35.3 J | 38.5 U | 38.8 J | 38.8 U | | |
| Benzo(g,h,i)perylene | 670 | | 14.6 J | 8 J | 19.3 U | 10.1 J | 19.4 U | | |
| Chrysene | 1400 | | 37.5 | 21.2 | 19.3 U | 24 | 6.7 J | | |
| Dibenzo(a,h)anthracene | 230 | | 4.4 J | 3.7 J | 4.8 U | 2.7 J | 4.9 U | | |
| Dibenzofuran | 540 | | 8.7 J | 19.2 U | 19.3 U | 19.5 U | 19.4 U | | |
| Fluoranthene | 1700 | 4600 | 47.4 | 22 | 19.3 U | 32.1 | 7.7 J | | |
| Fluorene | 540 | | 8.3 J | 19.2 U | 19.3 U | 19.5 U | 19.4 U | - | |
| Indeno(1,2,3-c,d)pyrene | 600 | | 13.4 J | 7.4 J | 19.3 U | 8.3 J | 19.4 U | | |
| Naphthalene | 2100 | | 21.5 | 8.7 J | 19.3 U | 11.7 J | 5.3 J | | |
| Phenanthrene | 1500 | | 45.7 | 13.6 J | 19.3 U | 24.9 | 13 J | | |
| Pyrene | 2600 | 11980 | 61.5 | 27.1 | 19.3 U | 39.5 | 9.3 J | | |
| Total Benzofluoranthenes (b,j,k) (U = 0) | 3200 | | 57.7 | 35.3 J | 38.5 U | 38.8 J | 38.8 U | | |
| Total HPAH (DMMP) (U = 0) ¹ | 12000 | | 280.9 J | 158 J | 38.5 U | 189.3 J | 28.9 J | | |
| Total LPAH (DMMP) (U = 0) ² | 5200 | | 90.3 J | 22.3 J | 19.3 U | 44.3 J | 18.3 J | | |
| Total PAH (DMMP) (U = 0) | | | 371.2 J | 180.3 J | 38.5 U | 233.6 J | 47.2 J | | |
| Pesticides (µg/kg) ³ | | | <u> </u> | | | | | | • |
| 4,4'-DDD (p,p'-DDD) | 16 | | 0.31 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U | | |
| 4,4'-DDE (p,p'-DDE) | 9 | | 0.13 U | 0.13 U | 0.32 U | 0.32 U | 0.13 U | | |
| 4,4'-DDT (p,p'-DDT) | 12 | | 0.32 U | 0.32 U | 0.13 U | 0.32 U | 0.32 U | | |
| 4,4 - 551 (β,β -551) Aldrin | 9.5 | | 0.36 U | 0.36 U | 0.36 U | 0.37 U | 0.37 U | | |
| Chlordane, alpha- (Chlordane, cis-) | | | 0.11 U | 0.11 U | 0.30 U | 0.11 U | 0.11 U | | |
| Chlordane, beta- (Chlordane, trans-) | | | 2.04 U | 0.97 U | 0.32 U | 0.33 U | 0.32 U | | |
| Dieldrin | 1.9 | | 0.11 U | | |
| Heptachlor | 1.5 | | 0.05 U | 0.04 U | 0.05 U | 0.05 U | 0.05 U | | |
| Nonachlor, cis- | | | 0.2 U | 0.2 U | 0.21 U | 0.21 U | 0.21 U | | |
| Nonachlor, trans- | | | 0.22 U | 0.22 U | 0.22 U | 0.23 U | 0.23 U | | |
| Oxychlordane | | | 0.12 U | 0.12 U | 0.13 U | 0.13 U | 0.13 U | | |
| Sum 4,4 DDT, DDE, DDD $(U = 0)^4$ | | 50 | 0.32 U | | |
| | | | | | | | | | |
| Total DMMP Chlordane (U = 0) ⁵ | 2.8 | 37 | 2.04 U | 0.97 U | 0.32 U | 0.33 U | 0.32 U | | |
| PCB Aroclors (μg/kg) Aroclor 1016 | | | 3.9 U | 3.9 U | 4 U | 4 U | 4 U | | |
| | | | 3.9 U | 3.9 U | 4 U | 4 U | 4 U | | † |
| Aroclor 1221 Aroclor 1232 | | | 3.9 U | 3.9 U | 4 U | 4 U | 4 U | | |
| | + | | | | 4 U | | | | |
| Aroclor 1242 | | | 3.9 U 3.9 U | 3.9 U | 4 U 4 U | 4 U 4 U | 4 U 4 U | | |
| Aroclor 1248 | | | 3.9 U | 3.9 U | 4 U 4 U | | 4 U | | |
| Aroclor 1254 | | | 2.1 J | 3.9 U | 4 U | 2 J 4 U | 4 U | | |
| Aroclor 1260 | | | 2.1 J 3.9 U | 3.9 U | 4 U | 4 U | 4 U | | † |
| Aroclor 1262 | | | 3.9 U 3.9 U | 3.9 U | 4 U 4 U | 4 U | 4 U | | |
| Aroclor 1268 Total DMMP PCR Aroclors (II = 0) | 130 | | 3.9 U 5.1 J | 3.9 U 3.9 U | 4 U | 4 U | 4 U | | |
| Total DMMP PCB Aroclors (U = 0) | 130 | | 3.13 | 3.5 U | 4 0 | 2 J | 4 0 | | |
| PCB Aroclors (mg/kg-OC) ⁶ | T | 38 | I | | | | | | |
| Total DMMP PCB Aroclors (U = 0) | | . ,,, | 0.72 J | 1.86 U | 4.44 U | 0.54 J | 1.54 U | | |

Notes:

Detected concentration is greater than DMMP SL screening level

Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels

Non-detected concentration is a TOC is <0.5% (see footnote 6)

Bold: Detected result

- 1. Total HPAH consists of the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,j,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- $2. Total\ LPAH\ consists\ of\ the\ sum\ of\ naphthalene,\ acenaphthylene,\ acenaphthene,\ fluorene,\ phenanthrene,\ and\ anthracene.$
- 3. Pesticides are reported to the method detection limit.
- $\stackrel{\cdot}{\text{4.}}$ Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are <0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram BT: Bioaccumulation Trigger

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

ML: Maximum Level
PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Metals (mg/kg) Antimony Arsenic Cadmium Chromium Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol (p-Cresol) 4-Methylphenol | C-3-A-190218 0 - 2.7 ft 0.29 UJ 3.7 0.06 J 12.3 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 19.3 U 4.8 U 4.8 U 4.9 | C-3-B-190218 2.7 - 5.8 ft 0.25 UJ 1.77 0.12 U 10.9 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 4.9 U | C-4-A-190218 0 - 2 ft 0.25 UJ 1.12 0.12 U 11.8 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U 16.8 J 19.4 U 19.4 U 4.9 U 4.9 U 19.4 U | C-4-B-190218 2 - 4 ft 0.24 UJ 1.01 0.12 U 10.8 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 94.3 UJ 18.9 U 18.9 U 18.9 U | 0.23 UJ 1.59 0.04 J 11.3 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | C-5-B-190221 2 - 4 ft 0.25 UJ 1.63 0.05 J 12.7 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U | C-6-A-190219 0 - 2 ft 0.21 UJ 1.14 0.12 9.11 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U 49.5 U | C-6-B-190219 2 - 4 ft 0.26 UJ 1.41 0.13 U 11.1 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U |
|--|--|--|--|--|---|---|--|--|
| Metals (mg/kg) Antimony Arsenic Cadmium Chromium Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (o-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhardene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(a,h)anthracene Dibenzofuran Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 3.7 0.06 J 12.3 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 5.4 85.1 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U | 1.77 0.12 U 10.9 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 4.9 U | 1.12 0.12 U 11.8 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U | 1.01 0.12 U 10.8 10.8 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U | 1.59 0.04 J 11.3 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 1.63 0.05 J 12.7 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U | 1.14 0.12 9.11 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 1.41 0.13 U 11.1 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Antimony Arsenic Cadmium Chromium Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (p-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Dientyl phthalate Dientyl phthalate Din-butyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Din-otyl phthalate Din-octyl phthalate Din | 3.7 0.06 J 12.3 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 5.4 85.1 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U | 1.77 0.12 U 10.9 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 4.9 U | 1.12 0.12 U 11.8 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U | 1.01 0.12 U 10.8 10.8 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U | 1.59 0.04 J 11.3 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 1.63 0.05 J 12.7 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U | 1.14 0.12 9.11 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 1.41 0.13 U 11.1 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U |
| Arsenic Cadmium Chromium Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,4-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (o-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhesyl)phthalate Butylbenzyl phthalate Diethyl phthalate Dienhyl phthalate Din-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Di-n-otyl phthalate Di-n-oty | 3.7 0.06 J 12.3 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 5.4 85.1 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U | 1.77 0.12 U 10.9 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 4.9 U | 1.12 0.12 U 11.8 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U | 1.01 0.12 U 10.8 10.8 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U | 1.59 0.04 J 11.3 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 1.63 0.05 J 12.7 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U | 1.14 0.12 9.11 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 1.41 0.13 U 11.1 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Chromium Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,2-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhalate Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 12.3 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U | 10.9 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 15.8 J 19.7 U 4.9 U 19.7 U 4.9 U | 11.8 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U 4.6 U 19.4 U 4.9 U 4.9 U | 10.8 10.8 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 11.3 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 12.7 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 9.11 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 11.1 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Copper Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 25.5 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U | 14.9 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 4.9 U 19.7 U 4.9 U | 11.9 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U 4.6 U 19.4 U 4.9 U 4.9 U 96.1 | 10.8 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.8 U 4.8 U 4.9 U | 14.4 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 16.9 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 10.3 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 15.6 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Lead Mercury Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 6.26 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U | 1.55 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U | 1.26 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U 4.6 U 19.4 U 4.9 U 4.9 U 96.1 | 1.21 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 24.1 U 94.3 UJ 18.9 U | 2.25 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 1.86 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 4.9 U 4.9 U | 1.42 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 1.46 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J |
| Selenium Silver Zinc Organometallic Compounds (μg/kg) Tributyltin (ion) Semivolatile Organics (μg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (ο-Cresol) 4-Methylphenol (ρ-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Di-n-otyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhenol Phenol Polycyclic Aromatic Hydrocarbons (μg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)anthracene Benzo(bj,k)fluoranthenes Benzo(bj,k)fluoranthenes Benzo(bj,k)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 0.0599 J 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U 4.9 U 4.9 U 4.9 U | 0.0231 UJ 0.81 0.04 J 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 19.7 U 4.9 U | 0.026 UJ 0.61 U 0.04 J 20 3.49 UJ 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.6 U 19.4 U 4.9 U 4.9 U | 0.0254 UJ 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 0.0269 U 0.79 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 0.0227 U 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 0.0241 U 0.77 0.04 J 17.9 1.05 J 5 U 5 U 24.8 UJ 5 U 99.1 UJ 19.8 U | 0.00982 J 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Selenium Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Dientyl phthalate Dimethyl phthalate Din-n-ottyl phthalate Din-n-ottyl phthalate Di-n-ottyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)anthracene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 0.93 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U | 0.81 0.04 J 19.9 3.54 UJ 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U | 0.61 U 0.04 J 20 3.49 UJ 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 4.9 U 4.9 U 96.1 | 0.77 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 0.79 0.06 J 21.1 0.768 J 5 U 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 0.76 0.06 J 24 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 0.77 0.04 J 17.9 1.05 J 5 U 5 U 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 0.74 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 37.8 J 19.7 U |
| Silver Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Dien-butyl phthalate Din-o-ctyl phthalate Di-n-otyl phthalate Di-n-otyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 0.12 J 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 4.9 U 4.9 U 4.9 U | 0.04 J 19.9 3.54 UJ 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 49.9 U 4.9 U | 4.9 U 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 4.9 U | 0.04 J 19.4 3.79 UJ 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U | 0.06 J 21.1 0.768 J 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 4.9 U 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 5 U 5 U 24.8 UJ 5 U 99.1 UJ | 0.06 J 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Zinc Organometallic Compounds (µg/kg) Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Dien-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobendl Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)pyrene Benzo(b,i,)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 34.4 2.16 J 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 19.9 3.54 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 49.1 U 49.2 U 19.7 U 49.1 U 49.2 U 49.2 U 49.7 U 49.9 U 49.9 U | 3.49 UJ 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 4.9 U 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 4.9 U 4.9 U 96.1 | 19.4 3.79 UJ 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 21.1 0.768 J 5 U 5 U 5 U 24.9 U 5 U 21.2 J 19.9 U 49.8 U | 3.48 U 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 5 U 5 U 24.8 UJ 5 U 99.1 UJ | 18.8 0.477 J 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| Tributyltin (ion) Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 4.8 U 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 49.4 U 49.9 U | 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 5 U 5 U 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J |
| Semivolatile Organics (µg/kg) 1,2,4-Trichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Dien-butyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobendl Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)pyrene Benzo(bj,k)fluoranthenes Benzo(bj,k)fluoranthenes Benzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 4.8 U 4.8 U 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 4.9 U 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 49.4 U 49.9 U | 4.7 U 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 5 U 5 U 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 0.9 J 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J |
| 1,2,4-Trichlorobenzene 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Pentachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobenzene Dibycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)anthracene Benzo(bj,k)fluoranthenes Benzo(bj,k)fluoranthenes Benzo(bj,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U | 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U | 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 5 U 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| 1,2-Dichlorobenzene 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(a,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 4.8 U 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U | 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U | 4.9 U 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 4.7 U 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 5 U 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| 1,4-Dichlorobenzene 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Penachlorobenzene Hexachlorobenzene Hexachlorobenzene Hexachlorobhenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 4.8 U 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U | 4.9 U 24.6 UJ 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U | 4.9 U 24.3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U | 4.7 U 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-butyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Din-octyl phthalate Di-n-octyl phthalate Di-n-otyl phthalate Phenol Peverolic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthylene Anthracene Benzo(a)phyrene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(a,h)anthracene Dibenzo(a,h)anthracene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 24.1 UJ 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.8 U | 24.6 UJ 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U 4.9 U | 24,3 UJ 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 23.6 UJ 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 24.9 U 5 U 5 U 21.2 J 19.9 U 49.8 U | 24.4 U 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 24.8 UJ 5 U 5 U 99.1 UJ 19.8 U | 24.6 UJ 4.9 U 4.9 U 37.8 J 19.7 U |
| 2-Methylphenol (o-Cresol) 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Din-butyl phthalate Din-butyl phthalate Din-octyl phthalate Acachorobanzene Hexachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 4.8 U 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U 4.9 U 4.9 U | 4.9 U 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U 4.9 U | 4.9 U 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 4.7 U 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 5 U 99.1 UJ 19.8 U | 4.9 U 4.9 U 37.8 J 19.7 U |
| 4-Methylphenol (p-Cresol) Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Din-butyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobhanie Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 5.4 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U | 4.9 U 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U 4.9 U 4.9 U | 4.9 U 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 4.7 U 94.3 UJ 18.9 U 47.1 U 18.9 U | 5 U 21.2 J 19.9 U 49.8 U | 4.9 U 56.2 J 19.5 U 48.9 U | 5 U 99.1 UJ 19.8 U | 4.9 U 37.8 J 19.7 U |
| Benzoic acid Benzyl alcohol bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Diethyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 85.1 J 13.4 J 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U | 15.8 J 19.7 U 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 16.8 J 19.4 U 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 94.3 UJ 18.9 U 47.1 U 18.9 U | 21.2 J 19.9 U 49.8 U | 56.2 J 19.5 U 48.9 U | 99.1 UJ 19.8 U | 37.8 J 19.7 U |
| bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate Diethyl phthalate Dimethyl phthalate Di-n-butyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(bj,k)fluoranthenes Benzo(g,hi)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0)¹ | 29.5 J 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U | 49.2 U 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 48.6 U 19.4 U 19.4 U 4.9 U 96.1 | 47.1 U 18.9 U | 49.8 U | 48.9 U | | |
| Butylbenzyl phthalate Diethyl phthalate Dimethyl phthalate Din-n-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 19.3 U 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 4.8 U | 19.7 U 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 19.4 U 19.4 U 4.9 U 96.1 | 18.9 U | | | 49.5 U | 49211 |
| Diethyl phthalate Dimethyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(bj,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 19.3 U 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U | 19.7 U 4.9 U 69.7 19.7 U 4.9 U | 19.4 U 4.9 U 96.1 | | 10011 | | | 7J.L U |
| Dimethyl phthalate Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(b,j,k)fluoranthenes Benzo(a,h)anthracene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 4.8 U 118 19.3 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 4.9 U 69.7 19.7 U 4.9 U 4.9 U | 4.9 U 96.1 | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Di-n-butyl phthalate Di-n-octyl phthalate Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 118 19.3 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 69.7 19.7 U 4.9 U 4.9 U | 96.1 | | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Di-n-octyl phthalate Hexachlorobenzene Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 19.3 U 4.8 U 4.8 U 4.8 U 19.3 UJ | 19.7 U 4.9 U 4.9 U | | 4.7 U | 5 U | 4.9 U | 5 U | 4.9 U |
| Hexachlorobenzene Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)anthracene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) | 4.8 U 4.8 U 4.8 U 19.3 UJ | 4.9 U 4.9 U | 19411 | 108 | 19.9 U | 23.3 U | 43.4 | 56.1 |
| Hexachlorobutadiene n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) | 4.8 U 4.8 U 19.3 UJ | 4.9 U | | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| n-Nitrosodiphenylamine Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 4.8 U 19.3 UJ | | 4.9 U | 4.7 U 4.7 U | 5 U | 4.9 U | 5 U 5 U | 4.9 U |
| Pentachlorophenol Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) | 19.3 UJ | 4.9 U | 4.9 U 4.9 U | 4.7 U | 5 U | 4.9 U 4.9 U | 5 U | 4.9 U 4.9 U |
| Phenol Polycyclic Aromatic Hydrocarbons (µg/kg) 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | | 19.7 UJ | 19.4 UJ | 18.9 UJ | 5.4 J | 5.5 J | 19.8 UJ | 19.7 UJ |
| 2-Methylnaphthalene Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | | 6.1 U | 5.6 U | 4.7 U | 6.4 U | 8.1 U | 5 U | 6.4 U |
| Acenaphthene Acenaphthylene Anthracene Benzo(a)anthracene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | • | | | <u>'</u> | | | | |
| Acenaphthylene Anthracene Benzo(a)anthracene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 18.4 J | 8 J | 19.4 U | 18.9 U | 19.9 U | 17.2 J | 19.8 U | 21.3 |
| Anthracene Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 7 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Benzo(a)anthracene Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 19.3 U | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Benzo(a)pyrene Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 13.9 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 20.7 | 19.7 U | 19.4 U | 18.9 U | 7.4 J | 5.2 J | 19.8 U | 19.7 U |
| Benzo(g,h,i)perylene Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 26.8 | 19.7 U | 19.4 U | 18.9 U | 8.5 J | 19.5 U | 19.8 U | 19.7 U |
| Chrysene Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 75.9 20.1 | 39.4 U 19.7 U | 38.9 U 19.4 U | 37.7 U 18.9 U | 26.9 J 19.9 U | 39.1 U 19.5 U | 39.6 U 19.8 U | 39.3 U 19.7 U |
| Dibenzo(a,h)anthracene Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) | 34.4 | 5.3 J | 19.4 U | 18.9 U | 19.9 U | 7.1 J | 19.8 U | 7.4 J |
| Dibenzofuran Fluoranthene Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 7.6 | 4.9 U | 4.9 U | 4.7 U | 5 U | 4.9 U | 5 U | 4.9 U |
| Fluorene Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 12 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 5.4 J |
| Indeno(1,2,3-c,d)pyrene Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 38.3 | 19.7 U | 19.4 U | 18.9 U | 11.9 J | 19.5 U | 19.8 U | 19.7 U |
| Naphthalene Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 11 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Phenanthrene Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 16.7 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.5 U | 19.8 U | 19.7 U |
| Pyrene Total Benzofluoranthenes (b_j,k) $(U=0)$ Total HPAH $(DMMP)$ $(U=0)^1$ | 31 | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 7.9 J | 19.8 U | 11.1 J |
| Total Benzofluoranthenes (b,j,k) (U = 0) Total HPAH (DMMP) (U = 0) ¹ | 36.9 | 13 J | 5.9 J | 18.9 U | 12.9 J | 19.1 J | 19.8 U | 23.7 |
| Total HPAH (DMMP) (U = 0) ¹ | 63.5 | 19.7 U | 19.4 U | 18.9 U | 15.9 J | 19.5 U | 6.3 J | 19.7 U |
| | 75.9 | 39.4 U | 38.9 U | 37.7 U | 26.9 J | 39.1 U | 39.6 U | 39.3 U |
| Total LPAH (DMMP) (U = 0) ² | 304 J | 5.3 J | 38.9 U | 37.7 U | 82.3 J | 12.3 J | 6.3 J | 7.4 J |
| | 99.8 J | 13 J | 5.9 J | 18.9 U | 12.9 J | 27 J | 19.8 U | 34.8 J |
| Total PAH (DMMP) (U = 0) | 403.8 J | 18.3 J | 5.9 J | 37.7 U | 95.2 J | 39.3 J | 6.3 J | 42.2 J |
| Pesticides (µg/kg) ³ | 1.50.11 | 0.22.11 | 1.50.111 | 15411 | 0.22.11 | 0.22.11 | 0.22.11 | 0.22.11 |
| 4,4'-DDD (p,p'-DDD) 4,4'-DDE (p,p'-DDE) | 1.59 U 0.67 U | 0.32 U 0.13 U | 1.58 UJ 0.67 U | 1.54 U 0.65 U | 0.32 U 0.13 U | 0.32 U 0.13 U | 0.32 U 0.13 U | 0.32 U 0.13 U |
| 4,4'-DDT (p,p'-DDT) | 1.62 U | 0.13 U | 1.6 UJ | 1.57 U | 0.13 U | 0.13 UJ | 0.13 U | 0.13 U |
| Aldrin | 1.84 U | 0.37 U | 1.82 U | 1.78 U | 0.37 U | 0.37 U | 0.37 U | 0.37 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.55 U | 0.11 U | 0.55 U | 0.54 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Chlordane, beta- (Chlordane, trans-) | 24.9 U | 0.33 U | 1.61 U | 1.58 U | 0.33 U | 0.33 U | 0.32 U | 0.33 U |
| Dieldrin | 0.57 U | 0.11 U | 0.57 U | 0.55 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Heptachlor | 0.23 U | 0.05 U | 0.23 U | 0.22 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Nonachlor, cis- | 1.04 U | 0.21 U | 1.04 UJ | 1.01 U | 0.21 U | 0.21 U | 0.21 U | 0.21 U |
| Nonachlor, trans- | 1.13 U | 0.23 U | 1.13 UJ | 1.1 U | 0.23 U | 0.23 U | 0.23 U | 0.23 U |
| Oxychlordane | 0.64 U | 0.13 U | 0.63 UJ | 0.62 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U |
| Sum 4,4 DDT, DDE, DDD (U = 0) ⁴ | 1.62 U | 0.32 U | 1.6 UJ | 1.57 U | 0.32 U | 0.32 UJ | 0.32 U | 0.32 U |
| Total DMMP Chlordane (U = 0) ⁵ | 24.9 U | 0.33 U | 1.61 UJ | 1.58 U | 0.33 U | 0.33 U | 0.32 U | 0.33 U |
| PCB Aroclors (µg/kg) | 4 | 4.11 | 411 | 2011 | 2011 | 4.11 | 2011 | 4.11 |
| Aroclor 1016 | 4 U | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 3.9 U | 4 U |
| Aroclor 1221 Aroclor 1232 | 4 U 4 U | 4 U 4 U | 4 U 4 U | 3.9 U 3.9 U | 3.8 U 3.8 U | 4 U 4 U | 3.9 U 3.9 U | 4 U 4 U |
| Aroclor 1232 Aroclor 1242 | 4 U | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 3.9 U | 4 U |
| Aroclor 1242 Aroclor 1248 | 4 U | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 3.9 U | 4 U |
| Aroclor 1246 Aroclor 1254 | 4 U | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 1.9 J | 4 U |
| Aroclor 1260 | 3.8 J | 4 U | 4 U | 3.9 U | 0.8 J | 4 U | 3.9 U | 4 U |
| Aroclor 1262 | 4 UJ | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 3.9 U | 4 U |
| Aroclor 1268 | 4 UJ | 4 U | 4 U | 3.9 U | 3.8 U | 4 U | 3.9 U | 4 U |
| Total DMMP PCB Aroclors (U = 0) | | 4 U | 4 U | 3.9 U | 0.8 J | 4 U | 1.9 J | 4 U |
| PCB Aroclors (mg/kg-OC) ⁶ | 3.8 J | | | | | | | |
| Total DMMP PCB Aroclors (U = 0) | 3.8 J | 1.48 U | 2.67 U | 3.25 U | 0.29 J | 0.54 U | 0.86 J | 0.56 U |

Detected concentration is greater than DMMP SL screening level Detected concentration is greater than DMMP BT screening level Non-detected concentration is above one or more identified screening levels

TOC is <0.5% (see footnote 6)

Bold: Detected result

- $1. \, Total \, HPAH \, consists \, of \, the \, sum \, of \, fluoranthene, \, pyrene, \, benzo(a) anthracene, \, chrysene, \, benzo(b,j,k) fluoranthenes, \, benzo(a) pyrene, \, indeno(1,2,3,-c,d) pyrene$ dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are < 0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram BT: Bioaccumulation Trigger

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Sample ID | C-7-A-190221 | C-7-B-190221 | C-7-C-190221 | C-8-A-190221 | C-8-B-190221 | C-9-A-190220 | C-9-B-1902 |
|--|--------------|--------------|--------------|--------------|--------------|--------------|------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | | |
| etals (mg/kg) | | | | | | | |
| Antimony | 0.32 UJ | 0.23 UJ | 0.24 UJ | 0.26 UJ | 0.25 UJ | 0.23 UJ | 0.24 UJ |
| Arsenic | 4.52 | 1.76 | 1.39 | 4.3 | 2.66 | 2.08 | 2.58 |
| Cadmium | 0.08 J | 0.12 U | 0.12 U | 0.07 J | 0.07 J | 0.11 U | 0.09 J |
| Chromium | 16.3 | 8.75 | 9.6 | 13.6 | 16.8 | 11.3 | 11.8 |
| Copper | 25.2 | 10.1 | 9.06 | 24.4 | 28.3 | 10.7 | 14.4 |
| Lead | 6.14 | 1.11 | 1.06 | 5.97 | 3.39 | 1.25 | 1.61 |
| Mercury | 0.0278 J | 0.0266 U | 0.0214 U | 0.0351 J | 0.0183 J | 0.0217 U | 0.00517 J |
| Selenium | 1.05 | 0.66 | 0.56 J | 0.89 | 0.94 | 0.76 | 0.84 |
| Silver | 0.11 J | 0.04 J | 0.03 J | 0.11 J | 0.09 J | 0.04 J | 0.06 J |
| Zinc | 37.2 | 16.4 | 16.7 | 34.1 | 32.1 | 18 | 19.7 |
| ganometallic Compounds (µg/kg) | 31,2 | 10.4 | 10.7 | 34.1 | 32.1 | 10 | 13.1 |
| | 2 55 1 | 2.45.11 | 2.76.11 | 2.45.1 | 2.65.11 | 2 0 5 1 1 1 | 2 70 111 |
| Tributyltin (ion) | 2.55 J | 3.45 U | 3.76 U | 3.45 J | 3.65 U | 3.85 UJ | 3.79 UJ |
| mivolatile Organics (μg/kg) | | 1011 | 4011 | 4011 | F.11 | F.11 | 4011 |
| 1,2,4-Trichlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| 1,2-Dichlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| 1,4-Dichlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| 2,4-Dimethylphenol | 24.8 U | 24.3 U | 24.7 U | 24.4 U | 24.9 U | 24.8 UJ | 23.8 UJ |
| 2-Methylphenol (o-Cresol) | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| 4-Methylphenol (p-Cresol) | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| Benzoic acid | 26.5 J | 97.1 U | 98.8 U | 37.1 J | 99.5 U | 99.1 UJ | 95.3 UJ |
| Benzyl alcohol | 19.9 U | 19.4 U | 19.8 U | 19.5 U | 19.9 U | 10.1 J | 9.7 J |
| bis(2-Ethylhexyl)phthalate | 29.9 J | 48.6 U | 49.4 U | 48.8 U | 49.8 U | 49.5 U | 47.7 U |
| Butylbenzyl phthalate | 19.9 U | 19.4 U | 19.8 U | 19.5 U | 19.9 U | 19.8 U | 19.1 U |
| Diethyl phthalate | 19.9 U | 19.4 U | 25.5 U | 67 U | 27.7 U | 19.8 U | 19.1 U |
| Dimethyl phthalate | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| Di-n-butyl phthalate | 48.3 U | 19.4 U | 30.6 U | 19.5 U | 19.9 U | 23.4 | 40.5 |
| Di-n-octyl phthalate | 19.9 U | 19.4 U | 19.8 U | 19.5 U | 19.9 U | 19.8 U | 19.1 U |
| Hexachlorobenzene | 19.9 U | 19.4 U | 4.9 U | 4.9 U | 19.9 U | 19.8 U | 4.8 U |
| | | | | | | | |
| Hexachlorobutadiene | 5 U | 26.5 | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| n-Nitrosodiphenylamine | 5 U | 4.9 U | 4.9 U | 4.9 U | 5 U | 5 U | 4.8 U |
| Pentachlorophenol | 19.9 UJ | 19.4 UJ | 19.8 UJ | 19.5 UJ | 19.9 UJ | 19.8 UJ | 19.1 UJ |
| Phenol | 6.2 U | 5.4 U | 4.9 U | 4.9 U | 5 U | 5 U | 5.3 U |
| ycyclic Aromatic Hydrocarbons (µg/kg) | | 1 | T | T | T | | |
| 2-Methylnaphthalene | 19.9 U | 7.8 J | 9.8 J | 35.1 | 9.8 J | 19.8 U | 19.1 U |
| Acenaphthene | 19.9 U | 19.4 U | 19.8 U | 7.7 J | 19.9 U | 19.8 U | 19.1 U |
| Acenaphthylene | 19.9 U | 19.4 U | 19.8 U | 6.4 J | 19.9 U | 19.8 U | 19.1 U |
| Anthracene | 13.2 J | 19.4 U | 19.8 U | 20.1 | 19.9 U | 19.8 U | 19.1 U |
| Benzo(a)anthracene | 29.8 | 19.4 U | 19.8 U | 38.4 | 5.4 J | 19.8 U | 19.1 U |
| Benzo(a)pyrene | 37.8 | 19.4 U | 19.8 U | 41.8 | 19.9 U | 19.8 U | 19.1 U |
| Benzo(b,j,k)fluoranthenes | 121 | 38.8 U | 39.5 U | 98.7 | 39.8 U | 39.6 U | 38.1 U |
| Benzo(g,h,i)perylene | 29.3 | 19.4 U | 19.8 U | 27.1 | 19.9 U | 19.8 U | 19.1 U |
| Chrysene | 50.8 | 19.4 U | 19.8 U | 71.7 | 17.6 J | 19.8 U | 19.1 U |
| Dibenzo(a,h)anthracene | 8.8 | 4.9 U | 4.9 U | 11.8 | 5 U | 5 U | 4.8 U |
| Dibenzofuran | 19.9 U | 19.4 U | 19.8 U | 12.3 J | 19.9 U | 19.8 U | 19.1 U |
| Fluoranthene | 47.3 | 19.4 U | 19.8 U | 64.5 | 19.9 U | 19.8 U | 19.1 U |
| Fluorene | 5.8 J | 19.4 U | 19.8 U | 10.3 J | 19.9 U | 19.8 U | 19.1 U |
| | | | | | | | |
| Indeno(1,2,3-c,d)pyrene | 27.7 | 19.4 U | 19.8 U | 25.1 | 19.9 U | 19.8 U | 19.1 U |
| Naphthalene | 17 J | 19.4 U | 8.5 J | 26 | 19.9 U | 19.8 U | 19.1 U |
| Phenanthrene | 33.8 | 14.7 J | 19.8 U | 59.9 | 22.6 | 19.8 U | 14.7 J |
| Pyrene | 65.8 | 19.4 U | 19.8 U | 81.6 | 19.9 U | 19.8 U | 19.1 U |
| Total Benzofluoranthenes (b,j,k) (U = 0) | 121 | 38.8 U | 39.5 U | 98.7 | 39.8 U | 39.6 U | 38.1 U |
| Total HPAH (DMMP) (U = 0) ¹ | 418.3 | 38.8 U | 39.5 U | 460.7 | 23 J | 39.6 U | 38.1 U |
| Total LPAH (DMMP) (U = 0) ² | 69.8 J | 14.7 J | 8.5 J | 130.4 J | 22.6 | 19.8 U | 14.7 J |
| Total PAH (DMMP) (U = 0) | 488.1 J | 14.7 J | 8.5 J | 591.1 J | 45.6 J | 39.6 U | 14.7 J |
| ticides (µg/kg) ³ | <u> </u> | | | | | | |
| 4.5 | 0.32 U | 0.31 U |
| 4,4'-DDD (p,p'-DDD) 4,4'-DDE (p,p'-DDE) | | | | | | | |
| | 0.13 U | 0.13 U |
| 4,4'-DDT (p,p'-DDT) | 0.32 U | 0.32 U |
| Aldrin | 0.37 U | 0.36 U | 0.37 U | 0.37 U | 0.37 U | 0.37 U | 0.36 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.11 U | 0.11 U |
| Chlordane, beta- (Chlordane, trans-) | 0.32 U | 0.32 U | 0.32 U | 0.33 U | 0.33 U | 0.33 U | 0.32 U |
| Dieldrin | 0.11 U | 0.11 U |
| Heptachlor | 0.05 U | 0.05 U |
| Nonachlor, cis- | 0.21 U | 0.21 U |
| Nonachlor, trans- | 0.23 U | 0.22 U |
| Oxychlordane | 0.13 U | 0.13 U |
| Sum 4,4 DDT, DDE, DDD (U = 0) ⁴ | 0.32 U | 0.32 U |
| Total DMMP Chlordane $(U = 0)^5$ | 0.32 U | 0.32 U | 0.32 U | 0.33 U | 0.33 U | 0.33 U | 0.32 U |
| · · · | U.32 U | U.32 U | U.32 U | U.33 U | V.33 U | U.33 U | U.32 U |
| B Aroclors (µg/kg) | 4.11 | 4.11 | 4 11 | 411 | 2011 | 4.11 | 2011 |
| Aroclor 1016 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| Aroclor 1221 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| Aroclor 1232 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| Aroclor 1242 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| Aroclor 1248 | 3.4 J | 4 U | 4 U | 3.8 J | 3.9 U | 4 U | 3.9 U |
| Aroclor 1254 | 3.9 J | 4 U | 4 U | 5 | 3.9 U | 4 U | 3.9 U |
| Aroclor 1260 | 2.1 J | 4 U | 4 U | 3 J | 3.9 U | 4 U | 3.9 U |
| Aroclor 1262 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| Aroclor 1268 | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U | 3.9 U |
| | | | 1 | 44.0. | 2011 | | 3.9 U |
| Total DMMP PCB Aroclors (U = 0) | 9.4 J | 4 U | 4 U | 11.8 J | 3.9 U | 4 U | 5.9 U |

Detected concentration is greater than DMMP SL screening level

Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels

Bold: Detected result

- 1. Total HPAH consists of the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,j,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

TOC is <0.5% (see footnote 6)

- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are <0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

ML: Maximum Level
PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Sample ID | C-10-A-190221 | C-10-B-190221 | C-10-C-190221 | C-11-A-190220 | C-11-B-190220 | C-12-A-190223 | C-12-B-190223 | C-12-C-190223 |
|--|------------------------|-----------------------|-----------------------|-----------------------|-----------------------|-----------------------|------------------------|------------------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft |
| Analyte | | | | | | | | |
| Metals (mg/kg) | 0.20 111 | 0.35.111 | 0.2111 | 0.20 111 | 0.25 111 | 0.27 111 | 0.25 111 | 0.25.111 |
| Antimony Arsenic | 0.28 UJ 5.95 | 0.25 UJ 3.4 | 0.2 UJ 1.88 | 0.28 UJ 4.8 | 0.25 UJ 1.3 | 0.27 UJ 6.8 | 0.25 UJ 5.07 | 0.25 UJ 5.07 |
| Cadmium | 0.13 J | 0.12 J | 0.1 | 0.09 J | 0.12 U | 0.14 | 0.13 | 0.14 |
| Chromium | 15.6 | 11.3 | 8.23 | 14.3 | 10.7 | 16.3 | 16.2 | 16.7 |
| Copper | 31.8 | 19.1 | 11.8 | 27.3 | 11.1 | 29.2 | 23.8 | 24.7 |
| Lead | 8.1 | 4.2 | 1.46 | 6.34 | 1.33 | 14.8 | 6.32 | 5.11 |
| Mercury | 0.0428 J | 0.0271 J | 0.00691 J | 0.0352 | 0.0241 U | 0.0703 | 0.0607 | 0.0549 |
| Selenium | 1 | 0.74 | 0.61 | 1.04 | 0.61 J | 0.79 | 1.03 | 0.73 |
| Silver | 0.16 J | 0.09 J | 0.04 J | 0.13 J | 0.04 J | 0.14 J | 0.09 J | 0.09 J |
| Zinc | 43.4 | 25.5 | 15.8 | 36.7 | 18.7 | 43.7 | 30.4 | 29.8 |
| Organometallic Compounds (µg/kg) | ı | | 1 | | 1 | | T | |
| Tributyltin (ion) | 5.67 | 95.5 | 3.81 U | 2.8 J | 3.79 UJ | 13.4 | 0.525 J | 3.65 U |
| Semivolatile Organics (μg/kg) | | | | | | | | |
| 1,2,4-Trichlorobenzene | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.7 U | 4.8 U | 5 U | 5 U |
| 1,2-Dichlorobenzene 1,4-Dichlorobenzene | 4.9 U 4.9 U | 4.8 U 4.8 U | 4.8 U 4.8 U | 4.7 U 4.7 U | 4.7 U 4.7 U | 6.1 3.7 J | 5 U 5 U | 5 U 5 U |
| 2,4-Dimethylphenol | 4.9 U | 23.8 U | 4.8 U | 3.1 J | 23.5 UJ | 10.6 J | 2.8 J | 24.9 U |
| 2-Methylphenol (o-Cresol) | 4.9 U | 4.8 U | 4.8 U | 2.2 J | 4.7 U | 4.8 U | 5 U | 5 U |
| 4-Methylphenol (p-Cresol) | 6.4 | 2.7 J | 4.8 U | 6.8 | 4.7 U | 14.4 | 5.1 | 2.8 J |
| Benzoic acid | 146 | 43.3 J | 96 U | 93.3 J | 94 UJ | 228 J | 77 J | 46.1 J |
| Benzyl alcohol | 19.7 U | 19.1 U | 19.2 U | 17.9 J | 18.8 U | 19 U | 19.8 U | 19.9 U |
| bis(2-Ethylhexyl)phthalate | 56.7 | 32.8 J | 48 U | 30.2 J | 47 U | 106 | 32.9 J | 49.8 U |
| Butylbenzyl phthalate | 19.7 U | 19.1 U | 19.2 U | 19 U | 18.8 U | 19 U | 19.8 U | 19.9 U |
| Diethyl phthalate | 19.7 U | 19.1 U | 24.5 U | | 18.8 U | 19 U | 38.2 U | 19.9 U |
| Dimethyl phthalate | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.7 U | 3.1 J | 5 U | 5 U |
| Di-n-butyl phthalate | 41.4 U | 20.6 U | 30.4 U | 72.2 | 17.7 J | 19 U | 6 J | 19.9 U |
| Di-n-octyl phthalate | 19.7 U | 19.1 U | 19.2 U | 19 U | 18.8 U | 19 U | 19.8 U | 19.9 U |
| Hexachlorobenzene | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.7 U | 4.8 U | 5 U | 5 U |
| Hexachlorobutadiene | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.7 U | 4.8 U | 5 U | 5 U |
| n-Nitrosodiphenylamine | 3.4 J | 4.8 U | 4.8 U | 4.7 U | 4.7 U | 4.8 U | 5 U | 5 U |
| Pentachlorophenol | 9.3 J | 19.1 UJ | 19.2 UJ | 4.1 J | 18.8 UJ | 11.2 J | 10.1 J | 19.9 UJ |
| Phenol | 15 U | 9.7 U | 4.8 U | 20.3 | 4.7 U | 53 U | 23.1 U | 17.5 U |
| Polycyclic Aromatic Hydrocarbons (μg/kg) 2-Methylnaphthalene | 28.6 | 10.6 J | 19.2 U | 17.7 J | 18.8 U | 21.5 | 19.8 U | 19.9 U |
| Acenaphthene | 7.5 J | 19.1 U | 19.2 U | 19 U | 18.8 U | 21.1 | 8.2 J | 19.9 U |
| Acenaphthylene | 11 J | 19.1 U | 19.2 U | 19 U | 18.8 U | 10.9 J | 19.8 U | 19.9 U |
| Anthracene | 28.7 | 16.1 J | 19.2 U | 18.6 J | 18.8 U | 26.6 J | 14.4 J | 8.5 J |
| Benzo(a)anthracene | 56.2 | 33.6 | 19.2 U | 42.5 | 18.8 U | 25.1 | 13.1 J | 81 |
| Benzo(a)pyrene | 67.2 | 45.7 | 19.2 U | 46.1 | 18.8 U | 40.3 | 18.8 J | 9.7 J |
| Benzo(b,j,k)fluoranthenes | 205 | 115 | 38.4 U | 118 | 37.6 U | 114 | 49.2 | 22.5 J |
| Benzo(g,h,i)perylene | 48.5 | 30.3 | 19.2 U | 33.1 | 18.8 U | 30.8 | 17.2 J | 9.7 J |
| Chrysene | 82.7 | 53.7 | 19.2 U | 61.4 | 18.8 U | 51.1 | 23.4 | 11.8 J |
| Dibenzo(a,h)anthracene | 18.8 | 12.4 | 4.8 U | 9.2 | 4.7 U | 11 | 6 | 2.7 J |
| Dibenzofuran | 16.6 J | 7.2 J | 19.2 U | 9 J | 18.8 U | 23.9 | 9.6 J | 19.9 U |
| Fluoranthene | 110 | 52 | 19.2 U | 52.1 | 18.8 U | 90.9 | 36 | 18.5 J |
| Fluorene | 15.7 J | 7.3 J | 19.2 U | 8 J | 18.8 U | 28 | 12.5 J | 19.9 U |
| Indeno(1,2,3-c,d)pyrene | 43.9 | 28.7 | 19.2 U | 29.5 | 18.8 U | 25.4 | 14.6 J | 7.3 J |
| Naphthalene Phenanthrene | 27.7 | 15.9 J | 19.2 U | 20.1 | 18.8 U | 60.2 | 27.9 | 16.9 J |
| | 53.3 174 | 43 79.1 | 7.7 J 6.6 J | 39.2 76 | 18.8 U | 78.3 | 38.5 71.1 | 24.2 40.1 |
| Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) | 205 | 115 | 38.4 U | 118 | 18.8 U 37.6 U | 215 114 | 49.2 | 40.1 22.5 J |
| - | | | | | | | | |
| Total HPAH (DMMP) (U = 0) ¹ | 806.3 | 450.5 | 6.6 J | 467.9 | 37.6 U | 603.6 | 249.4 J | 130.3 J |
| Total LPAH (DMMP) $(U = 0)^2$ | 143.9 J | 82.3 J | 7.7 J | 85.9 J | 18.8 U | 225.1 J | 101.5 J | 49.6 J |
| Total PAH (DMMP) (U = 0) | 950.2 J | 532.8 J | 14.3 J | 553.8 J | 37.6 U | 828.7 J | 350.9 J | 179.9 J |
| Pesticides (µg/kg) ³ | | | | | 1 | | | |
| 4,4'-DDD (p,p'-DDD) | 1.59 U | 0.32 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U | 0.31 U | 1.93 U |
| 4,4'-DDE (p,p'-DDE) | 0.67 U 1.61 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U |
| 4,4'-DDT (p,p'-DDT) Aldrin | 1.61 U 1.83 U | 0.32 U 0.37 U | 0.32 U 0.36 U | 0.32 U 0.37 U | 0.31 U 0.35 U | 3.96 U 0.37 U | 3.39 U 0.36 U | 2.42 U 0.36 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.55 U | 0.37 U 0.11 U | 0.36 U 0.11 U | 0.37 U | 0.35 U 0.11 U | 0.37 U 0.11 U | 0.36 U 0.11 U | 0.36 U 0.11 U |
| Chlordane, beta- (Chlordane, trans-) | 1.62 U | 0.11 U | 0.11 U | 14.9 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Dieldrin | 0.57 U | 0.32 U | 0.32 U | 0.11 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| Heptachlor | 0.23 U | 0.05 U | 0.05 U | 1.49 U | 0.04 U | 0.05 U | 0.04 U | 0.04 U |
| Nonachlor, cis- | 1.04 U | 0.21 U | 0.21 U | 0.21 U | 0.2 U | 0.21 U | 0.2 U | 0.2 U |
| Nonachlor, trans- | 1.13 U | 0.23 U | 0.22 U | 0.23 U | 0.22 U | 0.23 U | 0.22 U | 0.22 U |
| Oxychlordane | 0.64 U | 0.13 U | 0.13 U | 21.9 U | 0.12 U | 0.13 U | 0.12 U | 0.12 U |
| Sum 4,4 DDT, DDE, DDD (U = 0) ⁴ | 1.61 U | 0.32 U | 0.32 U | 0.32 U | 0.31 U | 3.96 U | 3.39 U | 2.42 U |
| Total DMMP Chlordane (U = 0) ⁵ | 1.62 U | 0.32 U | 0.32 U | 21.9 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| PCB Aroclors (µg/kg) | | 3.52.5 | 2.52.5 | | 5.5. 5 | 0.52.5 | 0.52 5 | 0.52.0 |
| Aroclor 1016 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 3.9 U | 3.8 U |
| Aroclor 1221 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 3.9 U | 3.8 U |
| Aroclor 1232 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 3.9 U | 3.8 U |
| Aroclor 1242 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 3.9 U | 3.8 U |
| Aroclor 1248 | 5.8 | 4.1 | 3.9 U | 4 U | 3.8 U | 52.7 | 44.9 | 11 |
| Aroclor 1254 | 9 | 5 J | 3.9 U | 3.4 J | 3.8 U | 94.3 J | 33.5 J | 7.8 |
| Aroclor 1260 | 5.5 J | 2.1 J | 3.9 U | 2.6 J | 3.8 U | 26.3 J | 11.7 J | 5.7 J |
| Aroclor 1262 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 UJ | 3.9 UJ | 3.8 UJ |
| Aroclor 1268 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 UJ | 3.9 UJ | 3.8 UJ |
| Total DMMP PCB Aroclors (U = 0) | 20.3 J | 11.2 J | 3.9 U | 6 J | 3.8 U | 173.3 J | 90.1 J | 24.5 J |
| | | | | | | | | |
| PCB Aroclors (mg/kg-OC) ⁶ Total DMMP PCB Aroclors (U = 0) | 2.01 J | 2.49 J | 2.05 U | 0.70 J | 2.71 U | 28.41 J | 24.35 J | 3.27 J |

Detected concentration is greater than DMMP SL screening level Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels TOC is <0.5% (see footnote 6)

Bold: Detected result

- 1. Total HPAH consists of the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,j,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are <0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram BT: Bioaccumulation Trigger

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

ML: Maximum Level
PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Sample Results Summary - M Sample ID | | C-13-B-190223 | C-13-C-190223 | C-14-A-190221 | C-14-B-190221 | C-15-A-190222 | C-15-B-190222 | C-15-C-190222 |
|--|-------------------------|-------------------------|-------------------|-----------------------|------------------|------------------------|-------------------|-------------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft |
| Analyte | | | | | | | | |
| Metals (mg/kg) | 0.24 UJ | 0.25 UJ | 0.22 UJ | 0.23 UJ | 0.23 UJ | 0.25 UJ | 0.22 UJ | 0.22 UJ |
| Antimony Arsenic | 6.08 | 6.67 | 3.88 | 4.18 | 5.08 | 6.4 | 2.74 | 4.28 |
| Cadmium | 0.11 J | 0.11 J | 0.05 J | 0.11 U | 0.06 J | 0.05 J | 0.11 U | 0.04 J |
| Chromium | 13 | 13.5 | 12 | 11.3 | 13 | 12.4 | 9.38 | 11.5 |
| Copper | 66.1 | 22.7 | 14.1 | 12.3 | 14.6 | 21.3 | 11.5 | 14.3 |
| Lead | 4.5 | 5.04 | 1.67 | 1.54 | 1.8 | 5.36 | 1.36 | 1.74 |
| Mercury | 0.0252 | 0.0381 | 0.011 J | 0.0216 U | 0.0216 U | 0.027 J | 0.0142 J | 0.0148 J |
| Selenium | 0.77 | 0.89 | 0.73 | 0.95 | 0.78 | 0.77 | 0.62 | 0.66 |
| Silver Zinc | 0.08 J 43.1 | 0.11 J 34.2 | 0.05 J 22.2 | 0.04 J 21.7 | 0.05 J 22.2 | 0.09 J 30 | 0.04 J 18 | 0.05 J 22.5 |
| Organometallic Compounds (µg/kg) | 43.1 | 34.2 | 22.2 | 21.1 | 22.2 | 30 | 10 | 22.5 |
| Tributyltin (ion) | 1.68 J | 3.69 | 3.81 U | 3.74 U | 3.82 U | 1.99 J | 3.77 U | 3.84 U |
| Semivolatile Organics (μg/kg) | <u>'</u> | | | | · | | | |
| 1,2,4-Trichlorobenzene | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 1,2-Dichlorobenzene | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 1,4-Dichlorobenzene | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 UJ | 5 UJ | 5 UJ |
| 2,4-Dimethylphenol | 24.5 U | 24.8 U | 24.5 U | 24.3 U | 24.7 U | 23.6 UJ | 24.8 UJ | 24.8 UJ |
| 2-Methylphenol (o-Cresol) | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 4-Methylphenol (p-Cresol) | 4.9 U | 3.1 J | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Benzolc acid | 71.1 J | 76.3 J | 22.3 J | 97.1 U | 98.6 U | 79.4 J | 99 U | 99 UJ |
| Benzyl alcohol | 19.6 U 30.4 J | 3.4 J 41.7 J | 19.6 U 49 U | 19.4 U 54.7 | 19.7 U 49.3 U | 18.9 U 61.8 | 19.8 U 49.5 U | 19.8 U 49.5 U |
| bis(2-Ethylhexyl)phthalate Butylbenzyl phthalate | 30.4 J 19.6 U | 41.7 J 19.9 U | 49 U 19.6 U | 54.7 19.4 U | 49.3 U 19.7 U | 61.8 7.8 J | 49.5 U 19.8 U | 49.5 U 19.8 U |
| Diethyl phthalate | 19.6 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 31.9 U |
| Dimethyl phthalate | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Di-n-butyl phthalate | 19.6 U | 19.9 U | 19.6 U | 34.4 U | 39.9 U | 121 U | 81.4 U | 38.6 U |
| Di-n-octyl phthalate | 19.6 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Hexachlorobenzene | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Hexachlorobutadiene | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| n-Nitrosodiphenylamine | 4.9 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Pentachlorophenol | 19.6 UJ | 19.9 UJ | 19.6 UJ | 19.4 UJ | 7.7 J | 18.9 UJ | 19.8 UJ | 19.8 UJ |
| Phenol | 23.7 U | 31.6 U | 8.2 U | 4.9 U | 4.9 U | 13.7 U | 5.9 U | 7 U |
| Polycyclic Aromatic Hydrocarbons (μg/kg) | | | | | T | T | T | |
| 2-Methylnaphthalene | 7.1 J | 7 J | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Acenaphthene | 19.6 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Acenaphthylene | 19.6 U 6.9 J | 19.9 U 10.6 J | 19.6 U 19.6 UJ | 19.4 U 19.4 U | 19.7 U 19.7 U | 18.9 U 6.1 J | 19.8 U 19.8 UJ | 19.8 U 19.8 UJ |
| Anthracene Benzo(a)anthracene | 17.1 J | 19.2 J | 19.6 U | 19.4 U | 19.7 U | 10.2 J | 19.8 U | 19.8 U |
| Benzo(a)pyrene | 23.1 | 29.4 | 19.6 U | 19.4 U | 19.7 U | 18.9 | 19.8 U | 19.8 U |
| Benzo(b,j,k)fluoranthenes | 62.9 | 85.1 | 39.2 U | 38.8 U | 39.4 U | 54.5 | 39.6 U | 39.6 U |
| Benzo(g,h,i)perylene | 20.8 | 26.9 | 19.6 U | 19.4 U | 19.7 U | 10.9 J | 19.8 U | 19.8 U |
| Chrysene | 27.8 | 32.4 | 19.6 U | 19.4 U | 19.7 U | 17 J | 19.8 U | 19.8 U |
| Dibenzo(a,h)anthracene | 6.6 | 8.6 | 4.9 U | 4.9 U | 4.9 U | 4.8 | 5 U | 5 U |
| Dibenzofuran | 19.6 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Fluoranthene | 25.5 | 25.2 | 19.6 U | 19.4 U | 19.7 U | 16.5 J | 19.8 U | 19.8 U |
| Fluorene | 19.6 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Indeno(1,2,3-c,d)pyrene | 15.9 J | 21.9 | 19.6 U | 19.4 U | 19.7 U | 10.6 J | 19.8 U | 19.8 U |
| Naphthalene | 7.9 J | 9 J | 19.6 U | 19.4 U | 19.7 U | 8.9 J | 19.8 UJ | 19.8 UJ |
| Phenanthrene | 16.3 J | 21.4 | 5.8 J | 19.4 U | 19.7 U | 15.8 J | 6.1 J | 19.8 U |
| Pyrene Total Benzofluoranthenes (b,j,k) (U = 0) | 48.8 62.9 | 68.5 85.1 | 19.6 U 39.2 U | 19.4 U 38.8 U | 19.7 U 39.4 U | 27.5 54.5 | 19.8 U 39.6 U | 19.8 U 39.6 U |
| - | | | 1 | | | | | |
| Total HPAH (DMMP) (U = 0) ¹ | 248.5 J | 317.2 J | 39.2 U | 38.8 U | 39.4 U | 170.9 J | 39.6 U | 39.6 U |
| Total LPAH (DMMP) (U = 0) ² | 31.1 J | 41 J | 5.8 J | 19.4 U | 19.7 U | 30.8 J | 6.1 J | 19.8 UJ |
| Total PAH (DMMP) (U = 0) | 279.6 J | 358.2 J | 5.8 J | 38.8 U | 39.4 U | 201.7 J | 6.1 J | 39.6 UJ |
| Pesticides (μg/kg) ³ | 0.22.11 | 0.24.11 | 0.22.11 | 0.22.11 | 0.22.11 | 0.24.11 | 0.22.11 | 0.22.11 |
| 4,4'-DDD (p,p'-DDD) 4,4'-DDE (p,p'-DDE) | 0.32 U 0.13 U | 0.31 U 0.13 U | 0.32 U 0.13 U | 0.32 U | 0.32 U 0.13 U | 0.31 U 0.13 U | 0.32 U 0.13 U | 0.32 U 0.13 U |
| 4,4'-DDE (p,p'-DDE) 4,4'-DDT (p,p'-DDT) | 0.13 U 0.32 U | 0.13 U | 0.13 U | 0.13 U 0.32 U | 0.13 U 0.32 U | 0.13 U | 0.13 U 0.32 U | 0.13 U 0.32 U |
| 4,4 -DD1 (ρ,ρ -DD1) Aldrin | 0.37 U | 0.32 U | 0.32 U | 0.32 U | 0.37 U | 0.31 U | 0.32 U | 0.32 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.37 U | 0.30 U | 0.36 U | 0.37 U | 0.37 U | 0.33 U | 0.37 U | 0.37 U |
| Chlordane, beta- (Chlordane, trans-) | 0.32 U | 1.94 U | 0.32 U | 0.32 U | 0.33 U | 0.31 U | 0.32 U | 0.32 U |
| Dieldrin | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Heptachlor | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.04 U | 0.05 U | 0.05 U |
| Nonachlor, cis- | 0.21 U | 0.2 U | 0.21 U | 0.21 U | 0.21 U | 0.2 U | 0.21 U | 0.21 U |
| Nonachlor, trans- | 0.23 U | 0.22 U | 0.23 U | 0.23 U | 0.23 U | 0.22 U | 0.23 U | 0.23 U |
| Oxychlordane | 0.13 U | 0.12 U | 0.13 U | 0.13 U | 0.13 U | 0.12 U | 0.13 U | 0.13 U |
| Sum 4,4 DDT, DDE, DDD $(U = 0)^4$ | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U | 0.32 U |
| Total DMMP Chlordane (U = 0) ⁵ | 0.32 U | 1.94 U | 0.32 U | 0.32 U | 0.33 U | 0.31 U | 0.32 U | 0.32 U |
| PCB Aroclors (µg/kg) | | | | | | | | |
| Aroclor 1016 | 4 U | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 4 U |
| Aroclor 1221 | 4 U | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 4 U |
| Aroclor 1232 | 4 U | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 4 U |
| Aroclor 1242 | 4 U | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 4 U |
| Aroclor 1248 | 6.5 | 8 | 3.7 J | 3.9 U | 4 U | 8.2 | 4 U | 4 U |
| Aroclor 1254 | 3.3 J | 5.9 | 3.9 U | 3.9 U | 4 U | 8.1 J | 4 U | 4 U |
| Aroclor 1260 | 1.9 J | 9.2 J | 3.9 U | 3.9 U | 4 U | 3.1 J | 4 U | 4 U |
| Aroclor 1262 | 4 UJ | 3.9 UJ | 3.9 U | 3.9 U | 4 U | 3.8 U | 4 U | 4 U |
| Aroclor 1268 | 4 UJ | 3.9 UJ | 3.9 U | 3.9 U | 4 U 4 U | 3.8 U | 4 U | 4 U 4 U |
| Total DMMP PCB Aroclors (U = 0) | 11.7 J | 23.1 J | 3.7 J | 3.9 U | 4 0 | 19.4 J | 4 U | 4 U |
| | | | | | | | | |
| PCB Aroclors (mg/kg-OC) ⁶ Total DMMP PCB Aroclors (U = 0) | 1.98 J | 5.92 J | 2.06 J | 4.33 U | 2.67 U | 7.76 J | 4 U | 2.35 U |

Detected concentration is greater than DMMP SL screening level Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels TOC is <0.5% (see footnote 6)

Bold: Detected result

- $1. \, Total \, HPAH \, consists \, of \, the \, sum \, of \, fluoranthene, \, pyrene, \, benzo(a) anthracene, \, chrysene, \, benzo(b,j,k) fluoranthenes, \, benzo(a) pyrene, \, indeno(1,2,3,-c,d) pyrene$ dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are < 0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram BT: Bioaccumulation Trigger

DMMP: Dredged Material Management Program

 $\label{eq:hpah:high-molecular-weight polycyclic} \ aromatic \ hydrocarbon$

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Sample Results Summary - M | | | Pesticides, an | d PCBs | | | |
|--|------------------|------------------|------------------------|------------------------|-------------------------|------------------|------------------------|
| Sample ID | | C-16-B-190223 | C-17-A-190222 | C-17-B-190222 | C-17-C-190222 | C-18-A1-190220 | C-18-B1-190220 |
| Depth Analyte | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 8 ft | 0 - 2.3 ft | 3.9 - 6.3 ft |
| Metals (mg/kg) | | | | | | | J. |
| Antimony | 0.2 UJ | 0.23 UJ | 0.28 UJ | 0.37 UJ | 0.25 UJ | 0.24 U | 0.22 U |
| Arsenic | 3.82 | 2.21 | 3.74 | 3.44 | 2.15 | 3.2 | 3.89 |
| Classician | 0.07 J | 0.11 U | 0.05 J | 0.21 | 0.04 J | 0.05 J | 0.11 U |
| Chromium Copper | 10.2 14.9 | 10.6 10.5 | 16.3 32.6 | 16.4 30.7 | 14.4 21.2 | 11.5 16.1 | 10.1 |
| Lead | 2.82 | 1.29 | 3.94 | 3.12 | 2.07 | 2.81 | 1.51 |
| Mercury | 0.0195 J | 0.00813 J | 0.0296 | 0.0373 | 0.0201 J | 0.0291 U | 0.021 U |
| Selenium | 0.67 | 0.69 | 1.11 | 1.22 | 0.98 | 0.7 | 0.88 |
| Silver | 0.08 J | 0.04 J | 0.1 J | 0.1 J | 0.07 J | 0.05 J | 0.04 J |
| Zinc | 22.5 | 19.7 | 30.4 | 25.3 | 23.9 | 25.6 | 29.6 |
| Organometallic Compounds (μg/kg) | 45.0 | 0.005.1 | 2.61.11 | 20411 | 2.00.11 | 2241 | 2.64.111 |
| Tributyltin (ion) Semivolatile Organics (μg/kg) | 15.8 | 0.895 J | 3.61 U | 3.84 U | 3.69 U | 2.31 J | 3.64 UJ |
| 1,2,4-Trichlorobenzene | 4.8 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U |
| 1,2-Dichlorobenzene | 4.8 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U |
| 1,4-Dichlorobenzene | 4.8 U | 4.9 U | 5 UJ | 4.9 UJ | 4.8 UJ | 4.8 U | 4.7 U |
| 2,4-Dimethylphenol | 23.9 U | 24.6 U | 24.8 UJ | 2.6 J | 23.9 UJ | 24.2 U | 23.6 U |
| 2-Methylphenol (o-Cresol) | 4.8 U | 4.9 U | 2.7 J | 3.1 J | 4.8 U | 4.8 U | 4.7 U |
| 4-Methylphenol (p-Cresol) | 4.8 U | 4.9 U | 4.7 J | 7.6 | 2 J | 3.1 J | 4.7 U |
| Benzoic acid | 68.4 J | 98.6 UJ | 310 | 10.5.11 | 32.9 J | 214 J | 60.2 J |
| Benzyl alcohol bis(2-Ethylhexyl)phthalate | 19.1 U 47.8 U | 19.7 U 49.3 U | 19.9 U 49.7 U | 19.5 U 48.7 U | 19.2 U 29.6 J | 19.4 U 48.4 U | 18.9 U 47.2 U |
| Butylbenzyl phthalate | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Diethyl phthalate | 23.2 U | 19.7 U | 19.9 U | 19.5 U | 24.6 U | 7.2 J | 9.2 J |
| Dimethyl phthalate | 4.8 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U |
| Di-n-butyl phthalate | 19.1 U | 19.7 U | 97.9 U | 99.9 U | 91.1 U | 19.4 U | 18.9 U |
| Di-n-octyl phthalate | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Hexachlorobenzene | 4.8 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U |
| Hexachlorobutadiene | 4.8 U 4.8 U | 4.9 U 4.9 U | 5 U | 4.9 U 4.9 U | 4.8 U 4.8 U | 4.8 U 4.8 U | 4.7 U 4.7 U |
| n-Nitrosodiphenylamine Pentachlorophenol | 19.1 UJ | 19.7 UJ | 4.5 J | 19.5 UJ | 19.2 UJ | 19.4 UJ | 18.9 UJ |
| Phenol | 18.3 U | 8.1 U | 41 | 34.7 | 7.3 U | 38.7 | 13.4 U |
| Polycyclic Aromatic Hydrocarbons (µg/kg) | | | | | | l . | .1 |
| 2-Methylnaphthalene | 19.1 U | 19.7 U | 11.7 J | 7.1 J | 6.2 J | 19.4 U | 7.5 J |
| Acenaphthene | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Acenaphthylene | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Anthracene | 8.8 J | 19.7 UJ | 19.9 UJ | 19.5 UJ | 19.2 UJ | 5.9 J | 18.9 U |
| Benzo(a)anthracene Benzo(a)pyrene | 11.9 J 10.8 J | 19.7 U 19.7 U | 6.5 J 19.9 U | 19.5 U 19.5 U | 19.2 U 19.2 U | 9 J 16.4 J | 18.9 U 18.9 U |
| Benzo(b,j,k)fluoranthenes | 38.2 U | 39.4 U | 22.7 J | 39 U | 38.3 U | 42.2 | 37.8 U |
| Benzo(g,h,i)perylene | 7.7 J | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 9.7 J | 18.9 U |
| Chrysene | 28.8 | 19.7 U | 14.7 J | 8.8 J | 5.9 J | 18.2 J | 18.9 U |
| Dibenzo(a,h)anthracene | 2.7 J | 4.9 U | 2.6 J | 4.9 U | 4.8 U | 3.8 J | 4.7 U |
| Dibenzofuran | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Fluoranthene | 12.3 J | 19.7 U | 8 J | 19.5 U | 4.9 J | 13.9 J | 18.9 U |
| Fluorene | 19.1 U | 19.7 U | 19.9 U | 19.5 U | 19.2 U | 19.4 U | 18.9 U |
| Indeno(1,2,3-c,d)pyrene Naphthalene | 19.1 U 19.1 U | 19.7 U 19.7 U | 19.9 U 6.3 J | 19.5 U 6.8 J | 19.2 U 8.1 J | 8.2 J 7.9 J | 18.9 U 5.4 J |
| Phenanthrene | 15.8 J | 19.7 U | 25.2 | 13.7 J | 14.6 J | 11.9 J | 6.3 J |
| Pyrene | 23.5 | 19.7 U | 21.3 | 19.5 U | 6.2 J | 48.3 | 18.9 U |
| Total Benzofluoranthenes (b,j,k) (U = 0) | 38.2 U | 39.4 U | 22.7 J | 39 U | 38.3 U | 42.2 | 37.8 U |
| Total HPAH (DMMP) (U = 0) ¹ | 97.7 J | 39.4 U | 75.8 J | 8.8 J | 17 J | 169.7 J | 37.8 U |
| Total LPAH (DMMP) (U = 0) ² | 24.6 J | 19.7 UJ | 31.5 J | 20.5 J | 22.7 J | 25.7 J | 11.7 J |
| Total PAH (DMMP) (U = 0) | 122.3 J | 39.4 UJ | 107.3 J | 29.3 J | 39.7 J | 195.4 J | 11.7 J |
| Pesticides (µg/kg)³ | | | | | | | |
| 4,4'-DDD (p,p'-DDD) | 0.31 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U |
| 4,4'-DDE (p,p'-DDE) | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U |
| 4,4'-DDT (p,p'-DDT) | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U |
| Aldrin Chlordane, alpha- (Chlordane, cis-) | 0.36 U 0.11 U | 0.37 U 0.11 U | 0.37 U 0.11 U | 0.37 U 0.11 U | 0.36 U 0.11 U | 0.36 U 0.11 U | 0.37 U 0.11 U |
| Chlordane, aipna- (Chlordane, cis-) Chlordane, beta- (Chlordane, trans-) | 0.11 U 0.32 U | 0.11 U 0.33 U | 0.11 U | 0.11 U 0.33 U | 0.11 U 0.32 U | 0.11 U 0.99 U | 0.11 U |
| Dieldrin | 0.11 U | 0.33 U | 0.11 U | 0.33 U | 0.32 U | 0.99 U | 0.32 U |
| Heptachlor | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U | 0.05 U |
| Nonachlor, cis- | 0.2 U | 0.21 U | 0.21 U | 0.21 U | 0.21 U | 0.21 U | 0.21 U |
| Nonachlor, trans- | 0.22 U | 0.23 U | 0.23 U | 0.23 U | 0.22 U | 0.22 U | 0.23 U |
| Oxychlordane | 0.12 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U |
| Sum 4,4 DDT, DDE, DDD (U = 0) ⁴ | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U | 0.32 U |
| Total DMMP Chlordane (U = 0) ⁵ | 0.32 U | 0.33 U | 0.33 U | 0.33 U | 0.32 U | 0.99 U | 0.32 U |
| PCB Aroclors (µg/kg) | | | | | | | T |
| Aroclor 1016 | 4 U | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U |
| Aroclor 1221 Aroclor 1232 | 4 U | 4 U 4 U | 4 U 4 U | 4 U 4 U | 4 U 4 U | 3.9 U 3.9 U | 4 U 4 U |
| Aroclor 1232 Aroclor 1242 | 4 U | 4 U | 4 U | 4 U | 4 U | 3.9 U | 4 U |
| Aroclor 1242 Aroclor 1248 | 2 J | 4 U | 2.5 J | 4 U | 4 U | 3.9 U | 4 U |
| Aroclor 1254 | 2.2 J | 4 U | 2.4 J | 4 U | 4 U | 3.9 U | 4 U |
| Aroclor 1260 | 1.1 J | 4 U | 1.1 J | 4 U | 4 U | 3.9 UJ | 4 U |
| Aroclor 1262 | 4 U | 4 U | 4 U | 4 U | 4 U | 3.9 UJ | 4 U |
| Aroclor 1268 | 4 U | 4 U | 4 U | 4 U | 4 U | 3.9 UJ | 4 U |
| Total DMMP PCB Aroclors (U = 0) | 5.3 J | 4 U | 6 J | 4 U | 4 U | 3.9 UJ | 4 U |
| PCB Aroclors (mg/kg-OC) ⁶ | | | | T | | | |
| Total DMMP PCB Aroclors (U = 0) | 2.12 J Notes: | 8 U | 0.72 J | 0.12 U | 1.03 U | 1.34 UJ | 3.08 U |

Notes:

Detected concentration is greater than DMMP SL screening level

Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels

TOC is <0.5% (see footnote 6)

Bold: Detected result

- 1. Total HPAH consists of the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,j,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are <0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

ML: Maximum Level
PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 6

| Sample ID Depth Analyte | C-19-A-190220 0 - 2 ft | C-19-B-190220 2 - 4 ft | C-20-A-190219 0 - 2 ft | C-20-B-190219 2 - 4 ft | C-21-A-190219 0 - 2 ft | C-21-B-190219 2 - 4 ft | C-22-A-190219 0 - 2 ft | C-22-B-190219 2 - 4 ft |
|---|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| | | | | | | | | |
| | | | | | | | | |
| Metals (mg/kg) Antimony | 0.19 UJ | 0.23 UJ | 0.23 UJ | 0.21 UJ | 0.23 UJ | 0.21 UJ | 0.2 UJ | 0.2 UJ |
| Arsenic | 1.89 | 2.53 | 1.28 | 1.1 | 4.41 | 2.26 | 1.59 | 1.31 |
| Cadmium | 0.1 U | 0.12 U | 0.05 J | 0.03 J | 0.11 U | 0.05 J | 0.1 U | 0.1 U |
| Chromium | 9.73 | 10.3 | 9.69 | 10.4 | 7.99 | 8.59 | 11.3 | 9.53 |
| Copper | 12.7 | 15.2 | 13.9 | 14 | 14.9 | 14.9 | 12.7 | 10.9 |
| Lead | 1.54 | 1.84 | 1.41 | 1.5 | 1.43 | 1.49 | 1.36 | 1.41 |
| Mercury | 0.0187 U | 0.0204 U | 0.00698 J | 0.00973 J | 0.0112 J | 0.0134 J | 0.00859 J | 0.00788 J |
| Selenium Silver | 0.62 | 0.77 0.05 J | 0.51 J | 0.82 0.04 J | 0.82 0.04 J | 0.82 | 0.72 0.03 J | 0.84 |
| Zinc | 0.04 J 20.9 | 21.3 | 0.04 J 18.7 | 20.1 | 18 | 0.03 J 20.1 | 19.2 | 0.03 J 17.6 |
| Organometallic Compounds (µg/kg) | 20.3 | 21.3 | 10.7 | 20.1 | | 20.1 | 13.2 | 17.0 |
| Tributyltin (ion) | 0.417 J | 1.07 J | 3.79 U | 3.76 U | 3.63 U | 3.76 U | 3.53 U | 3.57 U |
| Semivolatile Organics (µg/kg) | | | | | | | | |
| 1,2,4-Trichlorobenzene | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 1,2-Dichlorobenzene | 4.9 U | 4.9 U | 5 U | 0.8 J | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 1,4-Dichlorobenzene | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 2,4-Dimethylphenol 2-Methylphenol (o-Cresol) | 24.4 UJ 4.9 U | 24.6 UJ 4.9 U | 24.8 UJ 5 U | 24.3 UJ 4.9 U | 23.9 UJ 4.8 U | 24.2 UJ 4.8 U | 24.7 UJ 4.9 U | 24.7 UJ 4.9 U |
| 4-Methylphenol (p-Cresol) | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Benzoic acid | 97.7 UJ | 19.6 J | 99.1 UJ | 97.1 UJ | 95.7 UJ | 96.7 UJ | 98.7 UJ | 98.6 UJ |
| Benzyl alcohol | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| bis(2-Ethylhexyl)phthalate | 48.9 U | 49.2 U | 49.5 U | 48.6 U | 47.9 U | 48.3 U | 49.4 U | 49.3 U |
| Butylbenzyl phthalate | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Diethyl phthalate | 19.5 U | 19.7 U | 35.8 U | 28.9 U | 19.1 U | 19.3 U | 19.7 U | 21.9 U |
| Dimethyl phthalate | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Di-n-butyl phthalate | 161 | 133 | 36.8 | 22.6 | 17.2 J | 39.8 | 18.8 J | 19.7 U |
| Di-n-octyl phthalate | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Hexachlorobenzene Hexachlorobutadiene | 4.9 U 4.9 U | 4.9 U 4.9 U | 5 U 5 U | 4.9 U 4.9 U | 4.8 U 4.8 U | 4.8 U | 4.9 U 4.9 U | 4.9 U |
| n-Nitrosodiphenylamine | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U 4.8 U | 4.9 U | 4.9 U 4.9 U |
| Pentachlorophenol | 19.5 UJ | 19.7 UJ | 19.8 UJ | 19.4 UJ | 19.1 UJ | 19.3 UJ | 19.7 UJ | 19.7 UJ |
| Phenol | 4.9 U | 5.3 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Polycyclic Aromatic Hydrocarbons (µg/kg) | | | | | | | | |
| 2-Methylnaphthalene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 7.3 J | 19.3 U | 19.7 U | 19.7 U |
| Acenaphthene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Acenaphthylene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Anthracene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Benzo(a)anthracene | 19.5 U 19.5 U | 19.7 U 19.7 U | 19.8 U 19.8 U | 19.4 U 19.4 U | 7 J 19.1 U | 19.3 U 19.3 U | 19.7 U 19.7 U | 19.7 U 19.7 U |
| Benzo(a)pyrene Benzo(b,j,k)fluoranthenes | 39.1 U | 39.3 U | 39.6 U | 38.9 U | 38.3 U | 38.7 U | 39.5 U | 39.5 U |
| Benzo(g,h,i)perylene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Chrysene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 14.3 J | 19.3 U | 19.7 U | 19.7 U |
| Dibenzo(a,h)anthracene | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Dibenzofuran | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Fluoranthene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 5.8 J | 19.3 U | 19.7 U | 19.7 U |
| Fluorene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Indeno(1,2,3-c,d)pyrene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Naphthalene Phenanthrene | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Pyrene Pyrene | 19.5 U 19.5 U | 19.7 U 5.5 J | 19.8 U 5.9 J | 19.4 U 19.4 U | 38.1 8.1 J | 19.3 U 19.3 U | 19.7 U 19.7 U | 19.7 U 19.7 U |
| Total Benzofluoranthenes (b,j,k) (U = 0) | 39.1 U | 39.3 U | 39.6 U | 38.9 U | 38.3 U | 38.7 U | 39.5 U | 39.5 U |
| Total HPAH (DMMP) $(U = 0)^1$ | 39.1 U | 5.5 J | 5.9 J | 38.9 U | 35.2 J | 38.7 U | 39.5 U | 39.5 U |
| Total LPAH (DMMP) (U = 0) ² | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 38.1 | 19.3 U | 19.7 U | 19.7 U |
| Total PAH (DMMP) (U = 0) | 39.1 U | 5.5 J | 19.8 U | 38.9 U | 73.3 J | 38.7 U | 39.5 U | 39.5 U |
| Pesticides (µg/kg) ³ | 33.1.0 | 5.5 5 | 0.00 | 30.3 0 | 70.00 | 30 0 | 33.3 0 | 53.5 0 |
| 4,4'-DDD (p,p'-DDD) | 0.31 U | 0.31 U | 0.3 U | 0.31 U | 0.31 U | 0.31 U | 0.31 U | 0.32 U |
| 4,4'-DDE (p,p'-DDE) | 0.13 U |
| 4,4'-DDT (p,p'-DDT) | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| Aldrin | 0.36 U | 0.36 U | 0.35 U | 0.36 U | 0.35 U | 0.36 U | 0.36 U | 0.36 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.11 U |
| Chlordane, beta- (Chlordane, trans-) | 0.32 U | 0.32 U | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| Dieldrin | 0.11 U |
| Heptachlor | 0.04 U | 0.05 U | 0.04 U | 0.05 U | 0.04 U | 0.05 U | 0.05 U | 0.05 U |
| Nonachlor, cis- Nonachlor, trans- | 0.2 U 0.22 U | 0.21 U 0.22 U | 0.2 U 0.22 U | 0.21 U 0.22 U | 0.2 U 0.22 U | 0.2 U 0.22 U | 0.21 U 0.22 U | 0.21 U 0.22 U |
| Oxychlordane | 0.22 U | 0.22 U | 0.22 U | 0.22 U | 0.22 U 0.12 U | 0.22 U | 0.22 U 0.13 U | 0.22 U 0.13 U |
| Sum 4,4 DDT, DDE, DDD (U = 0) ⁴ | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| Total DMMP Chlordane $(U = 0)^5$ | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.32 U |
| PCB Aroclors (µg/kg) | U.32 U | U.32 U | U.3 I U | U.32 U | 0.310 | U.32 U | U.32 U | U.32 U |
| Aroclor 1016 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1221 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1232 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1242 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1248 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1254 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1260 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1262 | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |
| Aroclor 1268 | | 20 | 3 | 20 | 20 | 20 | 20 | |
| Aroclor 1268 Total DMMP PCB Aroclors (U = 0) PCB Aroclors (mg/kg-OC) ⁶ | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |

Detected concentration is greater than DMMP SL screening level Detected concentration is greater than DMMP BT screening level Non-detected concentration is above one or more identified screening levels

TOC is <0.5% (see footnote 6)

Bold: Detected result

- $1. \, Total \, HPAH \, consists \, of \, the \, sum \, of \, fluoranthene, \, pyrene, \, benz(a) anthracene, \, chrysene, \, benzo(b,j,k) fluoranthenes, \, benzo(a) pyrene, \, indeno(1,2,3,-c,d) pyrene,$ dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.
- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are < 0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram BT: Bioaccumulation Trigger

DMMP: Dredged Material Management Program

 $\label{eq:hpah:high-molecular-weight polycyclic} \ aromatic \ hydrocarbon$

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

PCB: polychlorinated biphenyl

pct: percent SL: Screening Level

TOC: total organic carbon U: Compound analyzed, but not detected above detection limit

Table 6

| Sample ID | C-23-A1-190222 | C-23-B1-190222 | C-24-A-190223 | C-24-B-190223 | C-25-A-190222 | C-25-B-19022 |
|---|----------------|------------------|---------------|------------------|------------------|------------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | |
| etals (mg/kg) | • | | | • | • | • |
| Antimony | 0.21 UJ | 0.21 UJ | 0.22 UJ | 0.21 UJ | 0.24 UJ | 0.24 UJ |
| Arsenic | 2.41 | 2 | 1.99 | 1.16 | 2.79 | 2.59 |
| Cadmium | 0.04 J | 0.04 J | 0.11 U | 0.1 U | 0.05 J | 0.12 U |
| Chromium | 10.1 | 9.02 | 11.3 | 9.86 | 15.5 | 13.2 |
| Copper | 15.1 | 12.8 | 13.4 | 11.2 | 27.7 | 19.4 |
| Lead | 1.84 | 1.45 | 1.64 | 1.6 | 2.42 | 1.79 |
| | | 0.0101 J | 0.0112 J | | | |
| Mercury | 0.0232 U | | | 0.00818 J | 0.0219 J | 0.0191 J |
| Selenium | 0.66 | 0.84 | 0.62 | 0.64 | 0.85 | 0.73 |
| Silver | 0.04 J | 0.04 J | 0.04 J | 0.04 J | 0.07 J | 0.05 J |
| Zinc | 23.8 | 21.2 | 23 | 22.4 | 73.9 | 20.1 |
| rganometallic Compounds (µg/kg) | 1 | 1 | | I | 1 | 1 |
| Tributyltin (ion) | 3.51 U | 3.46 U | 3.78 U | 3.53 U | 3.6 U | 3.77 U |
| emivolatile Organics (μg/kg) | • | | | | | |
| 1,2,4-Trichlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 1,2-Dichlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 1,4-Dichlorobenzene | 5 UJ | 4.9 UJ | 4.9 U | 4.9 U | 4.9 UJ | 4.8 UJ |
| 2,4-Dimethylphenol | 24.9 UJ | 24.6 UJ | 24.5 U | 24.7 U | 24.7 UJ | 24.2 UJ |
| 2-Methylphenol (o-Cresol) | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 4-Methylphenol (p-Cresol) | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Benzoic acid | 15.4 J | 98.6 U | 43.9 J | 25.5 J | 33.6 J | 84.3 J |
| | | | | | | |
| Benzyl alcohol | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| bis(2-Ethylhexyl)phthalate | 49.9 U | 49.3 U | 49.1 U | 49.4 U | 30.4 J | 31.4 J |
| Butylbenzyl phthalate | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Diethyl phthalate | 30.9 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Dimethyl phthalate | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Di-n-butyl phthalate | 87.1 U | 142 U | 19.6 U | 19.8 U | 140 U | 171 U |
| Di-n-octyl phthalate | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Hexachlorobenzene | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Hexachlorobutadiene | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| n-Nitrosodiphenylamine | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Pentachlorophenol | 20 UJ | 4.9 U 19.7 UJ | | 4.9 U 19.8 UJ | 4.9 U 19.8 UJ | 4.8 U 19.3 UJ |
| | | | 19.6 UJ | | | |
| Phenol | 6.8 U | 6.5 U | 10 U | 7.9 U | 14.8 U | 19.5 U |
| olycyclic Aromatic Hydrocarbons (µg/kg) | T | T | | T | 1 | 1 |
| 2-Methylnaphthalene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 17.9 J |
| Acenaphthene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Acenaphthylene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Anthracene | 20 UJ | 19.7 UJ | 19.6 UJ | 19.8 UJ | 19.8 UJ | 19.3 UJ |
| Benzo(a)anthracene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Benzo(a)pyrene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Benzo(b,j,k)fluoranthenes | 39.9 U | 39.4 U | 39.3 U | 39.6 U | 39.5 U | 38.7 U |
| Benzo(g,h,i)perylene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Chrysene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| - / | | | | | | |
| Dibenzo(a,h)anthracene | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Dibenzofuran | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 5.9 J |
| Fluoranthene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Fluorene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Indeno(1,2,3-c,d)pyrene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Naphthalene | 20 UJ | 19.7 UJ | 19.6 U | 19.8 U | 19.8 UJ | 5.8 J |
| Phenanthrene | 20 U | 19.7 U | 19.6 U | 19.8 U | 6.7 J | 15 J |
| Pyrene | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Total Benzofluoranthenes (b,j,k) (U = 0) | 39.9 U | 39.4 U | 39.3 U | 39.6 U | 39.5 U | 38.7 U |
| | | | | | | |
| Total HPAH (DMMP) (U = 0) ¹ | 39.9 U | 39.4 U | 39.3 U | 39.6 U | 39.5 U | 38.7 U |
| Total LPAH (DMMP) $(U = 0)^2$ | 20 UJ | 19.7 UJ | 19.6 UJ | 19.8 UJ | 6.7 J | 20.8 J |
| Total PAH (DMMP) (U = 0) | 39.9 UJ | 39.4 UJ | 39.3 UJ | 39.6 UJ | 6.7 J | 20.8 J |
| esticides (µg/kg)³ | | | | | | • |
| 4,4'-DDD (p,p'-DDD) | 0.31 U | 0.31 U | 0.31 U | 0.31 U | 0.31 U | 0.31 U |
| 4,4'-DDE (p,p'-DDE) | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U | 0.13 U |
| | 1 | | | | | |
| 4,4'-DDT (p,p'-DDT) | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U |
| Aldrin | 0.36 U | 0.36 U | 0.36 U | 0.36 U | 0.35 U | 0.36 U |
| Chlordane, alpha- (Chlordane, cis-) | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Chlordane, beta- (Chlordane, trans-) | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U |
| Dieldrin | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U | 0.11 U |
| Heptachlor | 0.05 U | 0.04 U | 0.05 U | 0.05 U | 0.04 U | 0.05 U |
| Nonachlor, cis- | 0.2 U | 0.2 U | 0.21 U | 0.21 U | 0.2 U | 0.2 U |
| Nonachlor, trans- | 0.22 U | 0.22 U | 0.22 U | 0.22 U | 0.22 U | 0.22 U |
| Oxychlordane | 0.12 U | 0.12 U | 0.13 U | 0.13 U | 0.12 U | 0.12 U |
| Sum 4,4 DDT, DDE, DDD $(U = 0)^4$ | | | | | | |
| | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U |
| Total DMMP Chlordane (U = 0) ⁵ | 0.32 U | 0.31 U | 0.32 U | 0.32 U | 0.31 U | 0.32 U |
| CB Aroclors (μg/kg) | | | | | | |
| Aroclor 1016 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1221 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1232 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1242 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1242 Aroclor 1248 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| | | | | | | |
| Aroclor 1254 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1260 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1262 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Aroclor 1268 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| T-+-I DAMAD DCD AI (II O) | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| Total DMMP PCB Aroclors (U = 0) | 3.9 0 | 3.5 0 | | | | |

Detected concentration is greater than DMMP SL screening level

Detected concentration is greater than DMMP BT screening level

Non-detected concentration is above one or more identified screening levels

Bold: Detected result

- 1. Total HPAH consists of the sum of fluoranthene, pyrene, benz(a)anthracene, chrysene, benzo(b,j,k)fluoranthenes, benzo(a)pyrene, indeno(1,2,3,-c,d)pyrene, dibenzo(a,h)anthracene, and benzo(g,h,i)perylene.
- 2. Total LPAH consists of the sum of naphthalene, acenaphthylene, acenaphthene, fluorene, phenanthrene, and anthracene.
- 3. Pesticides are reported to the method detection limit.
- 4. Total DDT consists of the sum of 4,4'-DDD, 4,4'-DDE, and 4,4'-DDT.

TOC is <0.5% (see footnote 6)

- $5. \ Chlordane\ includes\ cis-chlordane,\ trans-chlordane,\ cis-nonaclor,\ trans-nonaclor,\ and\ oxychlordane.$
- 6. The normal range for OC-normalization is 0.5% to 3.5%. Several TOC values are <0.5%, and the dry weight result should be used for screening.

μg/kg: microgram per kilogram

DMMP: Dredged Material Management Program

HPAH: high-molecular-weight polycyclic aromatic hydrocarbon

J: Estimated value

LPAH: low-molecular-weight polycyclic aromatic hydrocarbon

mg/kg: milligram per kilogram

mg/kg-OC: milligram per kilogram total organic carbon normalized

ML: Maximum Level
PCB: polychlorinated biphenyl

pct: percent

SL: Screening Level TOC: total organic carbon

Table 7

Summary of Dioxin/Furan Results

| Sample ID | C-1-A-190219 | C-1-B-190219 | C-1-C-190219 | C-2-A-190219 | C-2-B-190219 | C-3-A-190218 | C-3-B-190218 | C-4-A-190218 | C-4-B-190218 | C-5-A-190221 | C-5-B-190221 |
|--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2.7 ft | 2.7 - 5.8 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | | | | | | |
| Dioxin Furans (ng/kg) | | | | | | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 1.87 J | 0.51 J | 0.08 J | 1.23 J | 0.26 J | 2.53 J | U 80.0 | 0.05 UJ | 0.05 UJ | 0.59 J | 0.67 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 1.78 J | 0.32 J | 0.03 J | 0.96 J | 0.19 J | 2.42 J | 0.02 J | 0.05 UJ | 0.05 UJ | 0.36 J | 0.01 J |

| Sample ID Depth Analyte | C-6-A-190219 0 - 2 ft | C-6-B-190219 2 - 4 ft | C-7-A-190221 0 - 2 ft | C-7-B-190221 2 - 4 ft | C-7-C-190221 4 - 6 ft | C-8-A-190221 0 - 2 ft | C-8-B-190221 2 - 4 ft | C-9-A-190220 0 - 2 ft | C-9-B-190220 2 - 4 ft | C-10-A-190221 0 - 2 ft | C-10-B-190221 2 - 4 ft |
|--|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|---------------------------|
| Dioxin Furans (ng/kg) | | | | | | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 0.74 J | 0.05 J | 4.38 J | 0.53 J | 0.68 J | 5.00 J | 0.60 J | 0.06 J | 0.06 J | 8.79 J | 7.42 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 0.57 J | 5.60E-04 J | 4.21 J | 0.02 J | 2.97E-05 J | 4.88 J | 0.07 J | 0.01 J | 2.88E-03 J | 8.40 J | 7.29 J |

| Sample ID Depth Analyte | | C-11-A-190220 0 - 2 ft | C-11-B-190220 2 - 4 ft | C-12-A-190223 0 - 2 ft | C-12-B-190223 2 - 4 ft | C-12-C-190223 4 - 6 ft | C-12-D-190223 6 - 8 ft | C-12-E-190223 8 - 10 ft | C-13-A-190223 0 - 2 ft | C-13-B-190223 2 - 4 ft | C-13-C-190223 4 - 6 ft |
|--|--------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|----------------------------|---------------------------|---------------------------|---------------------------|
| Dioxin Furans (ng/kg) | | | | | | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 0.61 J | 5.92 J | 0.18 J | 56.21 J | 54.47 J | 17.74 J | 0.63 J | 0.07 J | 5.34 J | 7.73 J | 11.88 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 0.42 J | 5.76 J | 0.09 J | 56.21 J | 54.01 J | 17.55 J | 0.51 J | 2.76E-03 J | 5.06 J | 7.55 J | 11.73 J |

Notes:

Detected concentration is greater than DMMP SL screening level (4 ng/kg TEQ)

Detected concentration is greater than DMMP BT screening level (10 ng/kg TEQ)

Bold: Detected result

*: EMPC value reported by laboratory; treated as non-detect (U) in the TEQ calculation

BT: Bioaccumulation Trigger

D/F: dioxins/furans

DMMP: Dredged Material Management Program

J: Estimated value

ML: Maximum Level

ng/kg: nanogram per kilogram

SL: Screening Level

TEF: toxic equivalence factor

TEQ: toxic equivalent

Table 7

Summary of Dioxin/Furan Results

| Sample ID | C-13-D-190223 | C-13-E-190223 | C-14-A-190221 | C-14-B-190221 | C-15-A-190222 | C-15-B-190222 | C-15-C-190222 | C-16-A-190223 | C-16-B-190223 | C-17-A-190222 | C-17-B-190222 |
|--|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Depth | 6 - 8 ft | 8 - 10 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | | | | | | |
| Dioxin Furans (ng/kg) | | | | | | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 7.64 J | 0.07 J | 0.68 J | 0.56 J | 10.56 J | 0.15 J | 0.07 J | 2.75 J | 0.18 J | 1.86 J | 0.19 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 7.29 J | 0.01 J | 6.68E-03 J | 0.07 J | 9.37 J | U 80.0 | 0.01 J | 2.66 J | 0.11 J | 1.81 J | 0.11 J |

| Sample ID Depth | | C-18-A1-190220 0 - 2.3 ft | C-18-B1-190220 3.9 - 6.3 ft | C-19-A-190220 0 - 2 ft | C-19-B-190220 2 - 4 ft | C-20-A-190219 0 - 2 ft | C-20-B-190219 2 - 4 ft | C-21-A-190219 0 - 2 ft | C-21-B-190219 2 - 4 ft | C-22-A-190219 0 - 2 ft | C-22-B-190219 2 - 4 ft |
|--|--------|------------------------------|--------------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|---------------------------|
| Analyte | | | | | | | | | | | |
| Dioxin Furans (ng/kg) | | | | | | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 0.10 J | 2.99 J | 0.08 J | 0.27 J | 0.39 J | 0.50 J | 0.04 J | 0.08 J | 0.06 J | 0.15 J | 0.13 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 0.02 J | 2.93 J | 0.03 J | 0.14 J | 0.27 J | 0.42 J | 4.80E-04 J | 0.02 J | 0.02 J | 0.09 J | 0.06 J |

| Sample ID | C-23-A1-190222 | C-23-B1-190222 | C-24-A-190223 | C-24-B-190223 | C-25-A-190222 | C-25-B-190222 |
|--|----------------|----------------|---------------|---------------|---------------|---------------|
| Depth | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | | | | | | |
| Dioxin Furans (ng/kg) | | | | | | |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 1/2) | 0.35 J | 0.08 J | 0.63 J | 0.05 J | 0.07 J | 0.07 J |
| Total Dioxin/Furan TEQ 2005 (Mammal) (U = 0) | 0.27 J | 0.01 J | 0.48 J | 5.5E-03 J | 0.02 J | 0.01 J |

Notes:

Detected concentration is greater than DMMP SL screening level (4 ng/kg TEQ)

Detected concentration is greater than DMMP BT screening level (10 ng/kg TEQ)

Bold: Detected result

*: EMPC value reported by laboratory; treated as non-detect (U) in the TEQ calculation

BT: Bioaccumulation Trigger

D/F: dioxins/furans

DMMP: Dredged Material Management Program

J: Estimated value

ML: Maximum Level

ng/kg: nanogram per kilogram

SL: Screening Level

TEF: toxic equivalence factor

TEQ: toxic equivalent

Table 8
Suitability Probabilities for Open-Water Disposal of Non-Native Material

| Area | Station | sediment category | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Analyses ¹ | Detected SL/BT Exceedance | Dioxins/furans above 4/10 pptr TEQ | Suitable/Unsuitable | Suitability Probablility | Average suitability probability | Rounded Suitability Probability |
|---------------|---------|-------------------|-----------|------------------------|---------------------------------|-----------------------|----------------------------|--|---------------------|--------------------------|---------------------------------------|---------------------------------------|
| | C-1 | surf | А | 0 to 2 | -49.9 to -51.9 | Full Suite | no | no | suitable | 100 | | |
| | C-1 | surf | В | 2 to 4 | -51.9 to -53.9 | Full Suite | no | no | suitable | 100 | | |
| | C-2 | surf | А | 0 to 2 | -51.4 to -53.4 | Full Suite | no | no | suitable | 100 | 92.86 | |
| Mouth | C-3 | undetermined | А | 0 to 2.7 | -52.5 to -55.2 | Full Suite | Total Chlordane non-detect | no | possibly suitable | 50 | | 90 |
| | C-3 | undetermined | В | 2.7 to 5.8 | -55.2 to -58.3 | Full Suite | no | no | suitable | 100 | | |
| | C-4 | surf | А | 0 to 2 | -53.6 to -55.6 | Full Suite | no | no | suitable | 100 | | |
| | C-5 | surf | А | 0 to 2 | -51.5 to -53.5 | Full Suite | no | no | suitable | 100 | | |
| | C-7 | surf | А | 0 to 2 | -50.4 to -52.4 | Full Suite | no | 4.38 | likely suitable | 75 | | |
| | C-8 | undetermined | А | 0 to 2 | -52.0 to -54.0 | Full Suite | no | 5.00 | likely suitable | 75 | | |
| | C-8 | undetermined | В | 2 to 4 | -54.0 to -56.0 | Full Suite | no | no | suitable | 100 | | |
| | C-10 | surf | А | 0 to 2 | -49.0 to -51.0 | Full Suite | no | 8.79 | likely suitable | 75 | | |
| | C-10 | surf | В | 2 to 4 | -51.0 to -53.0 | Full Suite | Tributyltin | 7.42 | unsuitable | 0 | | |
| | C-10 | surf | С | 4 to 6 | -53.0 to -55.0 | Full Suite | no | no | suitable | 100 | | |
| | C-11 | surf | А | 0 to 2 | -51.6 to -53.6 | Full Suite | Total Chlordane non-detect | 5.92 | possibly suitable | 50 | | |
| | C-12 | undetermined | А | 0 to 2 | -22.7 to -24.7 | Full Suite | Total PCB Aroclors | 56.2 | unsuitable | 0 | | |
| | C-12 | undetermined | В | 2 to 4 | -24.7 to -26.7 | Full Suite | no | 54.5 | unsuitable | 0 | | |
| | C-12 | undetermined | С | 4 to 6 | -26.7 to -28.7 | Full Suite | no | 17.7 | unsuitable | 0 | | |
| N 4: -I -II - | C-12 | undetermined | D | 6 to 8 | -28.7 to -30.7 | D/F | no | no | suitable | 100 | 63.63636364 | 60 |
| Middle | C-12 | undetermined | E | 8 to 10 | -30.7 to -32.7 | D/F | no | no | suitable | 100 | | 60 |
| | C-13 | undetermined | А | 0 to 2 | -39.0 to -41 | Full Suite | no | 5.34 | likely suitable | 75 | | |
| | C-13 | undetermined | В | 2 to 4 | -41.0 to -43.0 | Full Suite | no | 7.73 | likely suitbble | 75 | | |
| | C-13 | undetermined | С | 4 to 6 | -43.0 to -45.0 | Full Suite | no | 11.88 | unsuitable | 0 | | |
| | C-13 | undetermined | D | 6 to 8 | -45.0 to -47.0 | D/F | no | 7.64 | likely suitable | 75 | | |
| | C-13 | undetermined | E | 8 to 10 | -47.0 to -49.0 | D/F | no | no | suitable | 100 | | |
| | C-14 | surf | А | 0 to 2 | -52.6 to -54.6 | Full Suite | no | no | suitable | 100 | | |
| | C-14 | surf | В | 2 to 4 | -54.6 to -56.6 | Full Suite | no | no | suitable | 100 | | |
| | C-15 | undetermined | А | 0 to 2 | -45.6 to -47.6 | Full Suite | no | 10.6 | unsuitable | 0 | | |
| | C-15 | undetermined | В | 2 to 4 | -47.6 to -49.6 | Full Suite | no | no | suitable | 100 | | |
| | C-15 | undetermined | С | 4 to 6 | -49.6 to -51.6 | Full Suite | no | no | suitable | 100 | | |
| | C-16 | surf | А | 0 to 2 | -50.6 to -52.6 | Full Suite | no | no | suitable | 100 | | |
| | C-17 | undetermined | А | 0 to 2 | -19.7 to -21.7 | Full Suite | no | no | suitable | 100 | | |
| | C-17 | undetermined | В | 2 to 4 | -21.7 to -23.7 | Full Suite | no | no | suitable | 100 | | |
| Usad | C-17 | undetermined | С | 4 to 8 | -23.7 to -25.7 | Full Suite | no | no | suitable | 100 | 100 | 100 |
| Head | C-18 | surf | А | 0 to 2.3 | -52.2 to -54.5 | Full Suite | no | no | suitable | 100 | | 100 |
| | C-24 | surf | Α | 0 to 2 | -51.1 to -53.1 | Full Suite | no | no | suitable | 100 | | |
| | C-25 | surf | А | 0 to 2 | -51.4 to -53.4 | Full Suite | no | no | suitable | 100 | | |
| | C-25 | surf | В | 2 to 4 | -53.4 to -55.4 | Full Suite | no | no | suitable | 100 | | |

Legend

| Legena | |
|-------------------|--|
| | Probability of being suitable during full characterization |
| suitable | 100 |
| likely suitable | 75 |
| possibly suitable | 50 |
| unsuitable | 0 |

above SL, BT or dioxin above 4 pptr TEQ
dioxin above 10 pptr TEQ
all less than SLs/BTs

Table 9
Suitability Probabilities for Open-Water Disposal of Native Material

| Station | | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Analyses ¹ | Detected SL/BT Exceedance | Dioxins/furans above 4 pptr TEQ | Suitable/Unsuitable | Suitability Probablility | Average suitability probability | Rounded Suitability Probability |
|---------|--------|--------------|------------------------|---------------------------------|-----------------------|---------------------------|------------------------------------|---------------------|--------------------------|---------------------------------|------------------------------------|
| C-1 | native | С | 4 to 6 | -53.9 to -55.9 | Full Suite | no | no | suitable | 100 | | |
| C-2 | native | В | 2 to 4 | -53.4 to -55.4 | Full Suite | no | no | suitable | 100 | | |
| C-2 | native | С | 4 to 6 | -55.4 to -57.4 | ТВТ | no | no | suitable | 100 | | |
| C-2 | native | D | 6 to 8.6 | 57.4 to -60.0 | ТВТ | no | no | suitable | 100 | | |
| C-4 | native | В | 2 to 4 | -55.6 to -57.6 | Full Suite | no | no | suitable | 100 | | |
| C-5 | native | В | 2 to 4 | -53.5 to -55.5 | Full Suite | no | no | suitable | 100 | | |
| C-6 | native | Α | 0 to 2 | -53.9 to -55.9 | Full Suite | no | no | suitable | 100 | | |
| C-6 | native | В | 2 to 4 | -55.9 to -57.9 | Full Suite | no | no | suitable | 100 | | |
| C-7 | native | В | 2 to 4 | -52.4 to -54.4 | Full Suite | Hexachlorobutadiene | no | possibly suitable | 50 | | |
| C-7 | native | С | 4 to 6 | -54.4 to -56.4 | Full Suite | no | no | suitable | 100 | 98.07692308 | |
| C-9 | native | Α | 0 to 2 | -53.0 to -55.0 | Full Suite | no | no | suitable | 100 | | |
| C-9 | native | В | 2 to 4 | -55.0 to -57.0 | Full Suite | no | no | suitable | 100 | | |
| C-11 | native | В | 2 to 4 | -53.6 to -55.6 | Full Suite | no | no | suitable | 100 | | 95 |
| C-16 | native | В | 2 to 4 | -52.6 to -54.6 | Full Suite | no | no | suitable | 100 | | 93 |
| C-18 | native | В | 3.9 to 6.3 | -54.5 to -56.9 | Full Suite | no | no | suitable | 100 | | |
| C-19 | native | Α | 0 to 2 | -52.4 to -54.4 | Full Suite | no | no | suitable | 100 | | |
| C-19 | native | В | 2 to 4 | -54.4 to -56.4 | Full Suite | no | no | suitable | 100 | | |
| C-20 | native | Α | 0 to 2 | -51.3 to -53.3 | Full Suite | no | no | suitable | 100 | | |
| C-20 | native | В | 2 to 4 | -53.3 to -55.3 | Full Suite | no | no | suitable | 100 | | |
| C-21 | native | Α | 0 to 2 | -53.7 to -55.7 | Full Suite | no | no | suitable | 100 | | |
| C-21 | native | В | 2 to 4 | -55.7 to -57.7 | Full Suite | no | no | suitable | 100 | | |
| C-22 | native | Α | 0 to 2 | -51.0 to -53.0 | Full Suite | no | no | suitable | 100 | | |
| C-22 | native | В | 2 to 4 | -53.0 to -55.0 | Full Suite | no | no | suitable | 100 | | |
| C-23 | native | Α | 0 to 2 | -53.7 to -55.7 | Full Suite | no | no | suitable | 100 | | |
| C-23 | native | В | 2 to 4 | -55.7 to -57.7 | Full Suite | no | no | suitable | 100 | | |
| C-24 | native | В | 2 to 4 | -53.1 to -55.1 | Full Suite | no | no | suitable | 100 | | |

Legend

| Legena | |
|-------------------|--|
| | Probability of being suitable during full characterization |
| suitable | 100 |
| likely suitable | 75 |
| possibly suitable | 50 |
| unsuitable | 0 |

above SL, BT or dioxin above 4 pptr TEQ
dioxin above 10 pptr TEQ
all less than SLs/BTs

Table 10
SMS Comparison for Samples with TOC above 0.5%

| Analyte Conventional Parameters (%) Total organic carbon Metals (mg/kg) Arsenic Cadmium Chromium | 57 5.1 260 390 | 0.71 3.24 0.09 J | Result Value VQ 0.74 | Result Value VQ 0.71 | Result Value VQ | Result Value VQ | Result Value VQ | | | | | | |
|--|-------------------------|------------------------|-----------------------|-----------------------|--------------------|-----------------|--------------------|------------------|------------------|------------------|------------------|------------------|------------------|
| Total organic carbon Metals (mg/kg) Arsenic Cadmium | 5.1 260 | 3.24 | | 0.71 | | | nesale value ve | Result Value VQ |
| Metals (mg/kg) Arsenic Cadmium | 5.1 260 | 3.24 | | 0.71 | | | | | | | | | |
| Arsenic Cadmium | 5.1 260 | | | | 0.55 | 0.54 | 1.01 | 0.86 | 0.61 | 0.75 | 0.59 | 0.83 | 3.24 |
| Cadmium | 5.1 260 | | | 1.11 | 4.50 | 4.0 | 5.05 | 4.0 | | 5.07 | | 0.74 | 0.44 |
| | 260 | () ()9 | 1.63 | 1.41 | 4.52 | 4.3 | 5.95 | 4.8 | 6.8 | 5.07 | 6.08 | 3.74 | 3.44 |
| Chromium | | | 0.05 J | 0.13 U | 0.08 J | 0.07 J | 0.13 J | 0.09 J | 0.14 | 0.14 | 0.11 J | 0.05 J | 0.21 |
| 6 | 390 | 14.7 | 12.7 | 11.1 | 16.3 | 13.6 | 15.6 | 14.3 27.3 | 16.3 | 16.7 | 13 | 16.3 | 16.4 |
| Copper | 450 | 26.7 6.01 | 16.9 1.86 | 15.6 1.46 | 25.2 6.14 | 24.4 5.97 | 31.8 8.1 | 6.34 | 29.2 14.8 | 24.7 5.11 | 66.1 4.5 | 32.6 3.94 | 30.7 3.12 |
| Lead Mercury | 0.41 | 0.0423 | 0.0227 U | 0.00982 J | 0.0278 J | 0.0351 J | 0.0428 J | 0.0352 | 0.0703 | 0.0549 | 0.0252 | 0.0296 | 0.0373 |
| Silver | 6.1 | 0.0423 0.12 J | 0.0227 U | 0.00762 J | 0.0276 J 0.11 J | 0.0331 J | 0.0428 J 0.16 J | 0.0332 0.13 J | 0.0703 0.14 J | 0.09 J | 0.0232 0.08 J | 0.0270 0.1 J | 0.0373 0.1 J |
| Zinc | 410 | 33.3 | 24 | 18.8 | 37.2 | 34.1 | 43.4 | 36.7 | 43.7 | 29.8 | 43.1 | 30.4 | 25.3 |
| Semivolatile Organics (ug/kg) | 410 | 33.3 | 24 | 10.0 | 37.2 | 34.1 | 45.4 | 30.7 | 43.7 | 27.0 | 45.1 | 30.4 | 25.5 |
| Benzoic acid | 650 | 84.7 J | 56.2 J | 37.8 J | 26.5 J | 37.1 J | 146 | 93.3 J | 228 J | 46.1 J | 71.1 J | 310 | 164 |
| Benzyl alcohol | 57 | 19.9 U | 19.5 U | 19.7 U | 19.9 U | 19.5 U | 19.7 U | 75.5 J | 19 U | 19.9 U | 19.6 U | 19.9 U | 19.5 U |
| 2,4-Dimethylphenol | 29 | 24.9 UJ | 24.4 U | 24.6 UJ | 24.8 U | 24.4 U | 3.4 J | 3.1 J | 10.6 J | 24.9 U | 24.5 U | 24.8 UJ | 2.6 J |
| 2-Methylphenol (o-Cresol) | 63 | 3 J | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.9 U | 2.2 J | 4.8 U | 5 U | 4.9 U | 2.7 J | 3.1 J |
| 4-Methylphenol (p-Cresol) | 670 | 5 | 4.9 U | 4.9 U | 5 U | 4.9 U | 6.4 | 6.8 | 14.4 | 2.8 J | 4.9 U | 4.7 J | 7.6 |
| Pentachlorophenol | 360 | 19.9 UJ | 5.5 J | 19.7 UJ | 19.9 UJ | 19.5 UJ | 9.3 J | 4.1 J | 11.2 J | 19.9 UJ | 19.6 UJ | 4.5 J | 19.5 UJ |
| Phenol | 420 | 13.5 U | 8.1 U | 6.4 U | 6.2 U | 4.9 U | 15 U | 20.3 | 53 U | 17.5 U | 23.7 U | 41 | 34.7 |
| Semivolatile Organics (mg/kg OC) | - | | - | | | | | | | | - | | |
| 1,2,4-Trichlorobenzene | 0.81 | 0.38 U | 0.35 U | 0.37 U | 0.49 U | 0.48 U | 0.26 U | 0.29 U | 0.41 U | 0.36 U | 0.44 U | 0.33 U | 0.08 U |
| 1,2-Dichlorobenzene | 2.3 | 0.70 U | 0.13 J | 0.69 U | 0.70 U | 0.69 U | 0.69 U | 0.66 U | 0.86 | 0.70 U | 0.69 U | 0.70 U | 0.69 U |
| 1,4-Dichlorobenzene | 3.1 | 0.70 U | 0.69 U | 0.69 U | 0.70 U | 0.69 U | 0.69 U | 0.66 U | 0.52 J | 0.70 U | 0.69 U | 0.70 UJ | 0.69 UJ |
| Hexachlorobenzene | 0.38 | 0.10 U | 0.09 U | 0.10 U | 0.13 U | 0.13 U | 0.07 U | 0.08 U | 0.11 U | 0.09 U | 0.12 U | 0.08 U | 0.02 U |
| bis(2-Ethylhexyl)phthalate | 47 | 7.01 U | 6.89 U | 6.93 U | 4.21 J | 6.87 U | 7.99 | 4.25 J | 14.93 | 7.01 U | 4.28 J | 7.00 U | 6.86 U |
| Butylbenzyl phthalate | 4.9 | 2.80 U | 2.75 U | 2.77 U | 2.80 U | 2.75 U | 2.77 U | 2.68 U | 2.68 U | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Diethyl phthalate | 61 | 2.80 U | 2.75 U | 2.77 U | 2.80 U | 9.44 U | 2.77 U | | 2.68 U | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Dimethyl phthalate | 53 | 0.70 U | 0.69 U | 0.69 U | 0.70 U | 0.69 U | 0.69 U | 0.66 U | 0.44 J | 0.70 U | 0.69 U | 0.70 U | 0.69 U |
| Di-n-butyl phthalate | 220 | 5.25 | 3.28 U | 7.90 | 6.80 U | 2.75 U | 5.83 U | 10.17 | 2.68 U | 2.80 U | 2.76 U | 13.79 U | 14.07 U |
| Di-n-octyl phthalate | 58 | 2.80 U | 2.75 U | 2.77 U | 2.80 U | 2.75 U | 2.77 U | 2.68 U | 2.68 U | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Hexachlorobutadiene | 3.9 | 0.70 U | 0.66 U | 0.69 U | 0.91 U | 0.91 U | 0.49 U | 0.55 U | 0.79 U | 0.67 U | 0.83 U | 0.60 U | 0.15 U |
| Dibenzofuran | 15 | 1.23 J | 2.75 U | 0.76 J | 2.80 U | 1.73 J | 2.34 J | 1.27 J | 3.37 | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| n-Nitrosodiphenylamine | 11 | 0.70 U | 0.69 U | 0.69 U | 0.70 U | 0.69 U | 0.48 J | 0.66 U | 0.68 U | 0.70 U | 0.69 U | 0.70 U | 0.69 U |
| Polycyclic Aromatic Hydrocarbons (mg/kg | | | | | | | | | | | | | |
| 2-Methylnaphthalene | 38 | 3.48 | 2.42 J | 3.00 | 2.80 U | 4.94 | 4.03 | 2.49 J | 3.03 | 2.80 U | 1.00 J | 1.65 J | 1.00 J |
| Acenaphthene | 16 | 2.80 U | 2.75 U | 2.77 U | 2.80 U | 1.08 J | 1.06 J | 2.68 U | 2.97 | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Acenaphthylene | 66 | 2.80 U | 2.75 U | 2.77 U | 2.80 U | 0.90 J | 1.55 J | 2.68 U | 1.54 J | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Anthracene | 220 | 2.08 J | 2.75 U | 2.77 U | 1.86 J | 2.83 | 4.04 | 2.62 J | 3.75 J | 1.20 J | 0.97 J | 2.80 UJ | 2.75 UJ |
| Benzo(a)anthracene | 110 | 3.39 | 0.73 J | 2.77 U | 4.20 | 5.41 | 7.92 | 5.99 | 3.54 | 1.13 J | 2.41 J | 0.92 J | 2.75 U |
| Benzo(a)pyrene | 99 230 | 2.86 8.13 | 2.75 U 5.51 U | 2.77 U 5.54 U | 5.32 17.04 | 5.89 | 9.46 28.87 | 6.49 | 5.68 | 1.37 J 3.17 J | 3.25 | 2.80 U | 2.75 U 5.49 U |
| Benzo(b,j,k)fluoranthenes Benzo(g,h,i)perylene | 31 | 8.13 2.06 J | 2.75 U | 2.77 U | 4.13 | 13.90 3.82 | 6.83 | 16.62 4.66 | 16.06 4.34 | 3.17 J 1.37 J | 8.86 2.93 | 3.20 J 2.80 U | 5.49 U 2.75 U |
| Chrysene | 110 | 5.28 | 1.00 J | 1.04 J | 7.15 | 10.10 | 11.65 | 8.65 | 7.20 | 1.37 J 1.66 J | 3.92 | 2.60 U 2.07 J | 2.75 U 1.24 J |
| Dibenzo(a,h)anthracene | 12 | 0.62 J | 0.69 U | 0.69 U | 1.24 | 1.66 | 2.65 | 1.30 | 1.55 | 0.38 J | 0.93 | 0.37 J | 0.69 U |
| Fluoranthene | 160 | 6.68 | 2.75 U | 2.77 U | 6.66 | 9.08 | 15.49 | 7.34 | 12.80 | 2.61 J | 3.59 | 1.13 J | 2.75 U |
| Fluorene | 23 | 1.17 J | 2.75 U | 2.77 U | 0.82 J | 1.45 J | 2.21 J | 1.13 J | 3.94 | 2.80 U | 2.76 U | 2.80 U | 2.75 U |
| Indeno(1,2,3-c,d)pyrene | 34 | 1.89 J | 2.75 U | 2.77 U | 3.90 | 3.54 | 6.18 | 4.15 | 3.58 | 1.03 J | 2.24 J | 2.80 U | 2.75 U |
| Naphthalene | 99 | 3.03 | 1.11 J | 1.56 J | 2.39 J | 3.66 | 3.90 | 2.83 | 8.48 | 2.38 J | 1.11 J | 0.89 J | 0.96 J |
| Phenanthrene | 100 | 6.44 | 2.69 J | 3.34 | 4.76 | 8.44 | 7.51 | 5.52 | 11.03 | 3.41 | 2.30 J | 3.55 | 1.93 J |
| Pyrene | 1000 | 8.66 | 2.75 U | 2.77 U | 9.27 | 11.49 | 24.51 | 10.70 | 30.28 | 5.65 | 6.87 | 3.00 | 2.75 U |
| PCB Aroclors (mg/kg-OC) ⁶ | | | | | | , - | | | | | | | |
| Total DMMP PCB Aroclors (U = 0) | 12 | 0.72 J | 0.54 U | 0.56 U | 1.71 J | 2.19 J | 2.01 J | 0.7 J | 28.41 J | 3.27 J | 1.98 J | 0.72 J | 0.12 U |

non-detect reported at MDL

non-detect exceedance

detected exceedance

DMMP Advisory Memo

Tacoma Harbor Deepening Study

Table 11
SMS Comparison for Samples with TOC less than 0.5%

| Sa | mple ID | C-1-B-190219 | C-1-C-190219 | C-2-A-190219 | C-2-B-190219 | C-3-A-190218 | C-3-B-190218 | C-4-A-190218 | C-4-B-190218 | C-5-A-190221 | C-6-A-190219 | C-7-B-190221 | C-7-C-190221 | C-8-B-190221 |
|--|---------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|--------------|
| | Depth | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2.7 ft | 2.7 - 5.8 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft | 2 - 4 ft |
| Analyte | SQS | | | | | | | | | | | | | |
| Conventional Parameters (%) | | | | | | | | | | | | | | |
| Total organic carbon | | 0.21 | 0.09 | 0.37 | 0.26 | 0.49 | 0.27 | 0.15 | 0.12 | 0.28 | 0.22 | 0.44 | 0.2 | 0.39 |
| Metals (mg/kg) | | | | | | | | | | | | | | |
| Arsenic | 57 | 1.67 | 1.06 | 4.97 | 1.95 | 3.7 | 1.77 | 1.12 | 1.01 | 1.59 | 1.14 | 1.76 | 1.39 | 2.66 |
| Cadmium | 5.1 | 0.11 U | 0.12 U | 0.05 J | 0.05 J | 0.06 J | 0.12 U | 0.12 U | 0.12 U | 0.04 J | 0.12 | 0.12 U | 0.12 U | 0.07 J |
| Chromium | 260 | 11 | 9.49 | 12.5 | 12.7 | 12.3 | 10.9 | 11.8 | 10.8 | 11.3 | 9.11 | 8.75 | 9.6 | 16.8 |
| Copper | 390 | 13.7 | 10.3 | 18.3 | 16.6 | 25.5 | 14.9 | 11.9 | 10.8 | 14.4 | 10.3 | 10.1 | 9.06 | 28.3 |
| Lead | 450 | 2.33 | 1.33 | 3.46 | 2.15 | 6.26 | 1.55 | 1.26 | 1.21 | 2.25 | 1.42 | 1.11 | 1.06 | 3.39 |
| Mercury | 0.41 | 0.025 | 0.0114 J | 0.0249 J | 0.0167 J | 0.0599 J | 0.0231 UJ | 0.026 UJ | 0.0254 UJ | 0.0269 U | 0.0241 U | 0.0266 U | 0.0214 U | 0.0183 J |
| Silver | 6.1 | 0.06 J | 0.03 J | 0.08 J | 0.05 J | 0.12 J | 0.04 J | 0.04 J | 0.04 J | 0.06 J | 0.04 J | 0.04 J | 0.03 J | 0.09 J |
| Zinc | 410 | 19.3 | 14.9 | 27 | 23.7 | 34.4 | 19.9 | 20 | 19.4 | 21.1 | 17.9 | 16.4 | 16.7 | 32.1 |
| Semivolatile Organics (ug/kg) | | | | | | | | | | | | | | |
| Benzoic acid | 650 | 95.9 UJ | 96.3 UJ | 97.5 UJ | 97 UJ | 85.1 J | 15.8 J | 16.8 J | 94.3 UJ | 21.2 J | 99.1 UJ | 97.1 U | 98.8 U | 99.5 U |
| Benzyl alcohol | 57 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 13.4 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Hexachlorobutadiene | 11 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 26.5 | 4.9 U | 5 U |
| 2,4-Dimethylphenol | 29 | 24 UJ | 24.1 UJ | 24.4 UJ | 24.3 UJ | 24.1 UJ | 24.6 UJ | 24.3 UJ | 23.6 UJ | 24.9 U | 24.8 UJ | 24.3 U | 24.7 U | 24.9 U |
| 2-Methylphenol (o-Cresol) | 63 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| 4-Methylphenol (p-Cresol) | 670 | 4.8 U | 4.8 U | 2.9 J | 4.9 U | 5.4 | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| Pentachlorophenol | 360 | 19.2 UJ | 19.3 UJ | 19.5 UJ | 19.4 UJ | 19.3 UJ | 19.7 UJ | 19.4 UJ | 18.9 UJ | 5.4 J | 19.8 UJ | 19.4 UJ | 19.8 UJ | 19.9 UJ |
| Phenol | 420 | 4.8 U | 4.8 U | 7.8 U | 4.9 U | 30 | 6.1 U | 5.6 U | 4.7 U | 6.4 U | 5 U | 5.4 U | 4.9 U | 5 U |
| Semivolatile Organics (ug/kg) | | | | | | | | | | | | | | |
| 1,2,4-Trichlorobenzene | 31 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| 1,2-Dichlorobenzene | 35 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| 1,4-Dichlorobenzene | 110 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| Hexachlorobenzene | 22 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 3 J | 4.9 U | 5 U |
| bis(2-Ethylhexyl)phthalate | 1300 | 47.9 U | 48.2 U | 48.8 U | 48.5 U | 29.5 J | 49.2 U | 48.6 U | 47.1 U | 49.8 U | 49.5 U | 48.6 U | 49.4 U | 49.8 U |
| Butylbenzyl phthalate | 63 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 19.3 U | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Diethyl phthalate | 200 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 19.3 U | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 25.5 U | 27.7 U |
| Dimethyl phthalate | 71 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| Di-n-butyl phthalate | 1400 | 22.5 | 22.4 | 40.6 | 14.9 J | 118 | 69.7 | 96.1 | 108 | 19.9 U | 43.4 | 19.4 U | 30.6 U | 19.9 U |
| Di-n-octyl phthalate | 6200 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 19.3 U | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Dibenzofuran | 540 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 12 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| n-Nitrosodiphenylamine | 28 | 4.8 U | 4.8 U | 4.9 U | 4.9 U | 4.8 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| Polycyclic Aromatic Hydrocarbons (ug/kg) | | | | | | | • | | | | | | • | |
| 2-Methylnaphthalene | 670 | 8.6 J | 19.3 U | 19.5 U | 6.4 J | 18.4 J | 8 J | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 7.8 J | 9.8 J | 9.8 J |
| Acenaphthene | 500 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 7 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Acenaphthylene | 1300 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 19.3 U | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Anthracene | 960 | 19.2 U | 19.3 U | 7.7 J | 19.4 U | 13.9 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Benzo(a)anthracene | 1300 | 16.6 J | 19.3 U | 17.5 J | 5.2 J | 20.7 | 19.7 U | 19.4 U | 18.9 U | 7.4 J | 19.8 U | 19.4 U | 19.8 U | 5.4 J |
| Benzo(a)pyrene | 1600 | 16.7 J | 19.3 U | 16.3 J | 19.4 U | 26.8 | 19.7 U | 19.4 U | 18.9 U | 8.5 J | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Benzo(b,j,k)fluoranthenes | 3200 | 35.3 J | 38.5 U | 38.8 J | 38.8 U | 75.9 | 39.4 U | 38.9 U | 37.7 U | 26.9 J | 39.6 U | 38.8 U | 39.5 U | 39.8 U |
| Benzo(g,h,i)perylene | 670 | 8 J | 19.3 U | 10.1 J | 19.4 U | 20.1 | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Chrysene | 1400 | 21.2 | 19.3 U | 24 | 6.7 J | 34.4 | 5.3 J | 19.4 U | 18.9 U | 11.7 J | 19.8 U | 19.4 U | 19.8 U | 17.6 J |
| Dibenzo(a,h)anthracene | 230 | 3.7 J | 4.8 U | 2.7 J | 4.9 U | 7.6 | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 5 U |
| Fluoranthene | 1700 | 22 | 19.3 U | 32.1 | 7.7 J | 38.3 | 19.7 U | 19.4 U | 18.9 U | 11.9 J | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Fluorene | 540 | 19.2 U | 19.3 U | 19.5 U | 19.4 U | 11 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Indeno(1,2,3-c,d)pyrene | 600 | 7.4 J | 19.3 U | 8.3 J | 19.4 U | 16.7 J | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 19.8 U | 19.9 U |
| Naphthalene | 2100 | 8.7 J | 19.3 U | 11.7 J | 5.3 J | 31 | 19.7 U | 19.4 U | 18.9 U | 19.9 U | 19.8 U | 19.4 U | 8.5 J | 19.9 U |
| Phenanthrene | 1500 | 13.6 J | 19.3 U | 24.9 | 13 J | 36.9 | 13 J | 5.9 J | 18.9 U | 12.9 J | 19.8 U | 14.7 J | 19.8 U | 22.6 |
| Pyrene | 2600 | 27.1 | 19.3 U | 39.5 | 9.3 J | 63.5 | 19.7 U | 19.4 U | 18.9 U | 15.9 J | 6.3 J | 19.4 U | 19.8 U | 19.9 U |
| PCB Aroclors (μg/kg) | | · | | | | | | | | | | <u> </u> | | |
| Total DMMP PCB Aroclors (U = 0) | 130 | 3.9 U | 4 U | 2 J | 4 U | 3.8 J | 4 U | 4 U | 3.9 U | 0.8 J | 1.9 J | 4 U | 4 U | 3.9 U |

non-detect exceedance detected exceedance AET-based SQS different from DMMP SL

Table 11
SMS Comparison for Samples with TOC less than 0.5%

| Sample I | D | C-9-A-190220 | C-9-B-190220 | C-10-B-190221 | C-10-C-190221 | C-11-B-190220 | C-12-B-190223 | C-13-B-190223 | C-13-C-190223 | C-14-A-190221 | C-14-B-190221 | C-15-A-190222 | C-15-B-190222 | C-15-C-190222 |
|--|------|--------------|--------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Dept | th | 0 - 2 ft | 2 - 4 ft | 2 - 4 ft | 4 - 6 ft | 2 - 4 ft | 2 - 4 ft | 2 - 4 ft | 4 - 6 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 4 - 6 ft |
| Analyte | sqs | | | | | | | | | | | | | |
| Conventional Parameters (%) | | | • | | | | • | | | • | • | • | | |
| Total organic carbon | | 0.11 | 0.19 | 0.45 | 0.19 | 0.14 | 0.37 | 0.39 | 0.18 | 0.09 | 0.15 | 0.25 | 0.1 | 0.17 |
| Metals (mg/kg) | | | | | | | | | | | | | | |
| Arsenic | 57 | 2.08 | 2.58 | 3.4 | 1.88 | 1.3 | 5.07 | 6.67 | 3.88 | 4.18 | 5.08 | 6.4 | 2.74 | 4.28 |
| Cadmium | 5.1 | 0.11 U | 0.09 J | 0.12 J | 0.1 | 0.12 U | 0.13 | 0.11 J | 0.05 J | 0.11 U | 0.06 J | 0.05 J | 0.11 U | 0.04 J |
| Chromium | 260 | 11.3 | 11.8 | 11.3 | 8.23 | 10.7 | 16.2 | 13.5 | 12 | 11.3 | 13 | 12.4 | 9.38 | 11.5 |
| Copper | 390 | 10.7 | 14.4 | 19.1 | 11.8 | 11.1 | 23.8 | 22.7 | 14.1 | 12.3 | 14.6 | 21.3 | 11.5 | 14.3 |
| Lead | 450 | 1.25 | 1.61 | 4.2 | 1.46 | 1.33 | 6.32 | 5.04 | 1.67 | 1.54 | 1.8 | 5.36 | 1.36 | 1.74 |
| Mercury | 0.41 | 0.0217 U | 0.00517 J | 0.0271 J | 0.00691 J | 0.0241 U | 0.0607 | 0.0381 | 0.011 J | 0.0216 U | 0.0216 U | 0.027 J | 0.0142 J | 0.0148 J |
| Silver | 6.1 | 0.04 J | 0.06 J | 0.09 J | 0.04 J | 0.04 J | 0.09 J | 0.11 J | 0.05 J | 0.04 J | 0.05 J | 0.09 J | 0.04 J | 0.05 J |
| Zinc | 410 | 18 | 19.7 | 25.5 | 15.8 | 18.7 | 30.4 | 34.2 | 22.2 | 21.7 | 22.2 | 30 | 18 | 22.5 |
| Semivolatile Organics (ug/kg) | | | | | | | | | | | | | | |
| Benzoic acid | 650 | 99.1 UJ | 95.3 UJ | 43.3 J | 96 U | 94 UJ | 77 J | 76.3 J | 22.3 J | 97.1 U | 98.6 U | 79.4 J | 99 U | 99 UJ |
| Benzyl alcohol | 57 | 10.1 J | 9.7 J | 19.1 U | 19.2 U | 18.8 U | 19.8 U | 3.4 J | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Hexachlorobutadiene | 11 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 2,4-Dimethylphenol | 29 | 24.8 UJ | 23.8 UJ | 23.8 U | 24 U | 23.5 UJ | 2.8 J | 24.8 U | 24.5 U | 24.3 U | 24.7 U | 23.6 UJ | 24.8 UJ | 24.8 UJ |
| 2-Methylphenol (o-Cresol) | 63 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 4-Methylphenol (p-Cresol) | 670 | 5 U | 4.8 U | 2.7 J | 4.8 U | 4.7 U | 5.1 | 3.1 J | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Pentachlorophenol | 360 | 19.8 UJ | 19.1 UJ | 19.1 UJ | 19.2 UJ | 18.8 UJ | 10.1 J | 19.9 UJ | 19.6 UJ | 19.4 UJ | 7.7 J | 18.9 UJ | 19.8 UJ | 19.8 UJ |
| Phenol | 420 | 5 U | 5.3 U | 9.7 U | 4.8 U | 4.7 U | 23.1 U | 31.6 U | 8.2 U | 4.9 U | 4.9 U | 13.7 U | 5.9 U | 7 U |
| Semivolatile Organics (ug/kg) | | | | | | | | | | | | | | |
| 1,2,4-Trichlorobenzene | 31 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 1,2-Dichlorobenzene | 35 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| 1,4-Dichlorobenzene | 110 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 UJ | 5 UJ | 5 UJ |
| Hexachlorobenzene | 22 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| bis(2-Ethylhexyl)phthalate | 1300 | 49.5 U | 47.7 U | 32.8 J | 48 U | 47 U | 32.9 J | 41.7 J | 49 U | 54.7 | 49.3 U | 61.8 | 49.5 U | 49.5 U |
| Butylbenzyl phthalate | 63 | 19.8 U | 19.1 U | 19.1 U | 19.2 U | 18.8 U | 19.8 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 7.8 J | 19.8 U | 19.8 U |
| Diethyl phthalate | 200 | 19.8 U | 19.1 U | 19.1 U | 24.5 U | 18.8 U | 38.2 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 31.9 U |
| Dimethyl phthalate | 71 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Di-n-butyl phthalate | 1400 | 23.4 | 40.5 | 20.6 U | 30.4 U | 17.7 J | 6 J | 19.9 U | 19.6 U | 34.4 U | 39.9 U | 121 U | 81.4 U | 38.6 U |
| Di-n-octyl phthalate | 6200 | 19.8 U | 19.1 U | 19.1 U | 19.2 U | 18.8 U | 19.8 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Dibenzofuran | 540 | 19.8 U | 19.1 U | 7.2 J | 19.2 U | 18.8 U | 9.6 J | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| n-Nitrosodiphenylamine | 28 | 5 U | 4.8 U | 4.8 U | 4.8 U | 4.7 U | 5 U | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.7 U | 5 U | 5 U |
| Polycyclic Aromatic Hydrocarbons (ug/kg) | | | | | | | • | | | | | | | |
| 2-Methylnaphthalene | 670 | 19.8 U | 19.1 U | 10.6 J | 19.2 U | 18.8 U | 19.8 U | 7 J | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Acenaphthene | 500 | 19.8 U | 19.1 U | 19.1 U | 19.2 U | 18.8 U | 8.2 J | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Acenaphthylene | 1300 | 19.8 U | 19.1 U | 19.1 U | 19.2 U | 18.8 U | 19.8 U | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Anthracene | 960 | 19.8 U | 19.1 U | 16.1 J | 19.2 U | 18.8 U | 14.4 J | 10.6 J | 19.6 UJ | 19.4 U | 19.7 U | 6.1 J | 19.8 UJ | 19.8 UJ |
| Benzo(a)anthracene | 1300 | 19.8 U | 19.1 U | 33.6 | 19.2 U | 18.8 U | 13.1 J | 19.2 J | 19.6 U | 19.4 U | 19.7 U | 10.2 J | 19.8 U | 19.8 U |
| Benzo(a)pyrene | 1600 | 19.8 U | 19.1 U | 45.7 | 19.2 U | 18.8 U | 18.8 J | 29.4 | 19.6 U | 19.4 U | 19.7 U | 18.9 | 19.8 U | 19.8 U |
| Benzo(b,j,k)fluoranthenes | 3200 | 39.6 U | 38.1 U | 115 | 38.4 U | 37.6 U | 49.2 | 85.1 | 39.2 U | 38.8 U | 39.4 U | 54.5 | 39.6 U | 39.6 U |
| Benzo(g,h,i)perylene | 670 | 19.8 U | 19.1 U | 30.3 | 19.2 U | 18.8 U | 17.2 J | 26.9 | 19.6 U | 19.4 U | 19.7 U | 10.9 J | 19.8 U | 19.8 U |
| Chrysene | 1400 | 19.8 U | 19.1 U | 53.7 | 19.2 U | 18.8 U | 23.4 | 32.4 | 19.6 U | 19.4 U | 19.7 U | 17 J | 19.8 U | 19.8 U |
| Dibenzo(a,h)anthracene | 230 | 5 U | 4.8 U | 12.4 | 4.8 U | 4.7 U | 6 | 8.6 | 4.9 U | 4.9 U | 4.9 U | 4.8 | 5 U | 5 U |
| Fluoranthene | 1700 | 19.8 U | 19.1 U | 52 | 19.2 U | 18.8 U | 36 | 25.2 | 19.6 U | 19.4 U | 19.7 U | 16.5 J | 19.8 U | 19.8 U |
| Fluorene | 540 | 19.8 U | 19.1 U | 7.3 J | 19.2 U | 18.8 U | 12.5 J | 19.9 U | 19.6 U | 19.4 U | 19.7 U | 18.9 U | 19.8 U | 19.8 U |
| Indeno(1,2,3-c,d)pyrene | 600 | 19.8 U | 19.1 U | 28.7 | 19.2 U | 18.8 U | 14.6 J | 21.9 | 19.6 U | 19.4 U | 19.7 U | 10.6 J | 19.8 U | 19.8 U |
| Naphthalene | 2100 | 19.8 U | 19.1 U | 15.9 J | 19.2 U | 18.8 U | 27.9 | 9 J | 19.6 U | 19.4 U | 19.7 U | 8.9 J | 19.8 UJ | 19.8 UJ |
| Phenanthrene | 1500 | 19.8 U | 14.7 J | 43 | 7.7 J | 18.8 U | 38.5 | 21.4 | 5.8 J | 19.4 U | 19.7 U | 15.8 J | 6.1 J | 19.8 U |
| Pyrene | 2600 | 19.8 U | 19.1 U | 79.1 | 6.6 J | 18.8 U | 71.1 | 68.5 | 19.6 U | 19.4 U | 19.7 U | 27.5 | 19.8 U | 19.8 U |
| PCB Aroclors (µg/kg) | | | | | | | • | | | | • | | | |
| Total DMMP PCB Aroclors (U = 0) | 130 | 4 U | 3.9 U | 11.2 J | 3.9 U | 3.8 U | 90.1 J | 23.1 J | 3.7 J | 3.9 U | 4 U | 19.4 J | 4 U | 4 U |

non-detect exceedance detected exceedance

AET-based SQS different from DMMP SL

Table 11
SMS Comparison for Samples with TOC less than 0.5%

| Sample | ID | C-16-A-190223 | C-16-B-190223 | C-17-C-190222 | C-18-A1-190220 | C-18-B1-190220 | C-19-A-190220 | C-19-B-190220 | C-20-A-190219 | C-20-B-190219 | C-21-A-190219 | C-21-B-190219 | C-22-A-190219 | C-22-B-190219 |
|--|------|---------------|---------------|---------------|----------------|----------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|---------------|
| Dep | th | 0 - 2 ft | 2 - 4 ft | 4 - 8 ft | 0 - 2.3 ft | 3.9 - 6.3 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | sqs | | | | | | | | | | | | | |
| Conventional Parameters (%) | | | | | | | | • | • | | | | • | • |
| Total organic carbon | | 0.25 | 0.05 | 0.39 | 0.29 | 0.13 | 0.09 | 0.1 | 0.08 | 0.04 | 0.49 | 0.11 | 0.07 | 0.04 |
| Metals (mg/kg) | | | | | | | | | | | | | | |
| Arsenic | 57 | 3.82 | 2.21 | 2.15 | 3.2 | 3.89 | 1.89 | 2.53 | 1.28 | 1.1 | 4.41 | 2.26 | 1.59 | 1.31 |
| Cadmium | 5.1 | 0.07 J | 0.11 U | 0.04 J | 0.05 J | 0.11 U | 0.1 U | 0.12 U | 0.05 J | 0.03 J | 0.11 U | 0.05 J | 0.1 U | 0.1 U |
| Chromium | 260 | 10.2 | 10.6 | 14.4 | 11.5 | 10.1 | 9.73 | 10.3 | 9.69 | 10.4 | 7.99 | 8.59 | 11.3 | 9.53 |
| Copper | 390 | 14.9 | 10.5 | 21.2 | 16.1 | 13 | 12.7 | 15.2 | 13.9 | 14 | 14.9 | 14.9 | 12.7 | 10.9 |
| Lead | 450 | 2.82 | 1.29 | 2.07 | 2.81 | 1.51 | 1.54 | 1.84 | 1.41 | 1.5 | 1.43 | 1.49 | 1.36 | 1.41 |
| Mercury | 0.41 | 0.0195 J | 0.00813 J | 0.0201 J | 0.0291 U | 0.021 U | 0.0187 U | 0.0204 U | 0.00698 J | 0.00973 J | 0.0112 J | 0.0134 J | 0.00859 J | 0.00788 J |
| Silver | 6.1 | 0.08 J | 0.04 J | 0.07 J | 0.05 J | 0.04 J | 0.04 J | 0.05 J | 0.04 J | 0.04 J | 0.04 J | 0.03 J | 0.03 J | 0.03 J |
| Zinc | 410 | 22.5 | 19.7 | 23.9 | 25.6 | 29.6 | 20.9 | 21.3 | 18.7 | 20.1 | 18 | 20.1 | 19.2 | 17.6 |
| Semivolatile Organics (ug/kg) | | | | | | | | | | | | | | |
| Benzoic acid | 650 | 68.4 J | 98.6 UJ | 32.9 J | 214 J | 60.2 J | 97.7 UJ | 19.6 J | 99.1 UJ | 97.1 UJ | 95.7 UJ | 96.7 UJ | 98.7 UJ | 98.6 UJ |
| Benzyl alcohol | 57 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Hexachlorobutadiene | 11 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 2,4-Dimethylphenol | 29 | 23.9 U | 24.6 U | 23.9 UJ | 24.2 U | 23.6 U | 24.4 UJ | 24.6 UJ | 24.8 UJ | 24.3 UJ | 23.9 UJ | 24.2 UJ | 24.7 UJ | 24.7 UJ |
| 2-Methylphenol (o-Cresol) | 63 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 4-Methylphenol (p-Cresol) | 670 | 4.8 U | 4.9 U | 2 J | 3.1 J | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Pentachlorophenol | 360 | 19.1 UJ | 19.7 UJ | 19.2 UJ | 19.4 UJ | 18.9 UJ | 19.5 UJ | 19.7 UJ | 19.8 UJ | 19.4 UJ | 19.1 UJ | 19.3 UJ | 19.7 UJ | 19.7 UJ |
| Phenol | 420 | 18.3 U | 8.1 U | 7.3 U | 38.7 | 13.4 U | 4.9 U | 5.3 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Semivolatile Organics (ug/kg) | | | | | | | | • | • | | | | • | • |
| 1,2,4-Trichlorobenzene | 31 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 1,2-Dichlorobenzene | 35 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 0.8 J | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| 1,4-Dichlorobenzene | 110 | 4.8 U | 4.9 U | 4.8 UJ | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Hexachlorobenzene | 22 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| bis(2-Ethylhexyl)phthalate | 1300 | 47.8 U | 49.3 U | 29.6 J | 48.4 U | 47.2 U | 48.9 U | 49.2 U | 49.5 U | 48.6 U | 47.9 U | 48.3 U | 49.4 U | 49.3 U |
| Butylbenzyl phthalate | 63 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Diethyl phthalate | 200 | 23.2 U | 19.7 U | 24.6 U | 7.2 J | 9.2 J | 19.5 U | 19.7 U | 35.8 U | 28.9 U | 19.1 U | 19.3 U | 19.7 U | 21.9 U |
| Dimethyl phthalate | 71 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Di-n-butyl phthalate | 1400 | 19.1 U | 19.7 U | 91.1 U | 19.4 U | 18.9 U | 161 | 133 | 36.8 | 22.6 | 17.2 J | 39.8 | 18.8 J | 19.7 U |
| Di-n-octyl phthalate | 6200 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Dibenzofuran | 540 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| n-Nitrosodiphenylamine | 28 | 4.8 U | 4.9 U | 4.8 U | 4.8 U | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Polycyclic Aromatic Hydrocarbons (ug/kg) | | | | | | | | | | | | | | |
| 2-Methylnaphthalene | 670 | 19.1 U | 19.7 U | 6.2 J | 19.4 U | 7.5 J | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 7.3 J | 19.3 U | 19.7 U | 19.7 U |
| Acenaphthene | 500 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Acenaphthylene | 1300 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Anthracene | 960 | 8.8 J | 19.7 UJ | 19.2 UJ | 5.9 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Benzo(a)anthracene | 1300 | 11.9 J | 19.7 U | 19.2 U | 9 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 7 J | 19.3 U | 19.7 U | 19.7 U |
| Benzo(a)pyrene | 1600 | 10.8 J | 19.7 U | 19.2 U | 16.4 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Benzo(b,j,k)fluoranthenes | 3200 | 38.2 U | 39.4 U | 38.3 U | 42.2 | 37.8 U | 39.1 U | 39.3 U | 39.6 U | 38.9 U | 38.3 U | 38.7 U | 39.5 U | 39.5 U |
| Benzo(g,h,i)perylene | 670 | 7.7 J | 19.7 U | 19.2 U | 9.7 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Chrysene | 1400 | 28.8 | 19.7 U | 5.9 J | 18.2 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 14.3 J | 19.3 U | 19.7 U | 19.7 U |
| Dibenzo(a,h)anthracene | 230 | 2.7 J | 4.9 U | 4.8 U | 3.8 J | 4.7 U | 4.9 U | 4.9 U | 5 U | 4.9 U | 4.8 U | 4.8 U | 4.9 U | 4.9 U |
| Fluoranthene | 1700 | 12.3 J | 19.7 U | 4.9 J | 13.9 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 5.8 J | 19.3 U | 19.7 U | 19.7 U |
| Fluorene | 540 | 19.1 U | 19.7 U | 19.2 U | 19.4 U | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Indeno(1,2,3-c,d)pyrene | 600 | 19.1 U | 19.7 U | 19.2 U | 8.2 J | 18.9 U | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Naphthalene | 2100 | 19.1 U | 19.7 U | 8.1 J | 7.9 J | 5.4 J | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 19.1 U | 19.3 U | 19.7 U | 19.7 U |
| Phenanthrene | 1500 | 15.8 J | 19.7 U | 14.6 J | 11.9 J | 6.3 J | 19.5 U | 19.7 U | 19.8 U | 19.4 U | 38.1 | 19.3 U | 19.7 U | 19.7 U |
| Pyrene | 2600 | 23.5 | 19.7 U | 6.2 J | 48.3 | 18.9 U | 19.5 U | 5.5 J | 5.9 J | 19.4 U | 8.1 J | 19.3 U | 19.7 U | 19.7 U |
| PCB Aroclors (μg/kg) | | | | | | | | • | • | | | | • | • |
| Total DMMP PCB Aroclors (U = 0) | 130 | 5.3 J | 4 U | 4 U | 3.9 UJ | 4 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.8 U | 3.9 U | 3.9 U | 4 U |

non-detect exceedance detected exceedance

AET-based SQS different from DMMP SL

Table 11
SMS Comparison for Samples with TOC less than 0.5%

| Sample ID | | C-23-A1-190222 | C-23-B1-190222 | C-24-A-190223 | C-24-B-190223 | C-25-A-190222 | C-25-B-190222 |
|--|------|----------------|----------------|---------------|---------------|---------------|---------------|
| Depth | | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft | 0 - 2 ft | 2 - 4 ft |
| Analyte | sqs | V-210 | 2-410 | 0-210 | 2-410 | 0-210 | 2-410 |
| Conventional Parameters (%) | 543 | | | | | | |
| Total organic carbon | | 0.07 | 0.04 | 0.06 | 0.04 | 0.29 | 0.44 |
| Metals (mg/kg) | | 0.07 | 0.01 | 0.00 | | 0.25 | 3 |
| Arsenic | 57 | 2.41 | 2 | 1.99 | 1.16 | 2.79 | 2.59 |
| Cadmium | 5.1 | 0.04 J | 0.04 J | 0.11 U | 0.1 U | 0.05 J | 0.12 U |
| Chromium | 260 | 10.1 | 9.02 | 11.3 | 9.86 | 15.5 | 13.2 |
| Copper | 390 | 15.1 | 12.8 | 13.4 | 11.2 | 27.7 | 19.4 |
| Lead | 450 | 1.84 | 1.45 | 1.64 | 1.6 | 2.42 | 1.79 |
| Mercury | 0.41 | 0.0232 U | 0.0101 J | 0.0112 J | 0.00818 J | 0.0219 J | 0.0191 J |
| Silver | 6.1 | 0.04 J | 0.04 J | 0.04 J | 0.04 J | 0.07 J | 0.05 J |
| Zinc | 410 | 23.8 | 21.2 | 23 | 22.4 | 73.9 | 20.1 |
| Semivolatile Organics (ug/kg) | | | | | | 10.0 | |
| Benzoic acid | 650 | 15.4 J | 98.6 U | 43.9 J | 25.5 J | 33.6 J | 84.3 J |
| Benzyl alcohol | 57 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Hexachlorobutadiene | 11 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 2,4-Dimethylphenol | 29 | 24.9 UJ | 24.6 UJ | 24.5 U | 24.7 U | 24.7 UJ | 24.2 UJ |
| 2-Methylphenol (o-Cresol) | 63 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 4-Methylphenol (p-Cresol) | 670 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Pentachlorophenol | 360 | 20 UJ | 19.7 UJ | 19.6 UJ | 19.8 UJ | 19.8 UJ | 19.3 UJ |
| Phenol | 420 | 6.8 U | 6.5 U | 10 U | 7.9 U | 14.8 U | 19.5 U |
| Semivolatile Organics (ug/kg) | 120 | 0.0 0 | 0.5 0 | 100 | 7.5 0 | 14.00 | 15.5 0 |
| 1,2,4-Trichlorobenzene | 31 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 1,2-Dichlorobenzene | 35 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| 1,4-Dichlorobenzene | 110 | 5 UJ | 4.9 UJ | 4.9 U | 4.9 U | 4.9 UJ | 4.8 UJ |
| Hexachlorobenzene | 22 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| bis(2-Ethylhexyl)phthalate | 1300 | 49.9 U | 49.3 U | 49.1 U | 49.4 U | 30.4 J | 31.4 J |
| Butylbenzyl phthalate | 63 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Diethyl phthalate | 200 | 30.9 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Dimethyl phthalate | 71 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Di-n-butyl phthalate | 1400 | 87.1 U | 142 U | 19.6 U | 19.8 U | 140 U | 171 U |
| Di-n-octyl phthalate | 6200 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Dibenzofuran | 540 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 5.9 J |
| n-Nitrosodiphenylamine | 28 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Polycyclic Aromatic Hydrocarbons (ug/kg) | | 3 0 | 4.5 0 | 4.5 0 | 4.5 0 | 4.5 0 | 4.0 0 |
| 2-Methylnaphthalene | 670 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 17.9 J |
| Acenaphthene | 500 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Acenaphthylene | 1300 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Anthracene | 960 | 20 UJ | 19.7 UJ | 19.6 UJ | 19.8 UJ | 19.8 UJ | 19.3 UJ |
| Benzo(a)anthracene | 1300 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Benzo(a)pyrene | 1600 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Benzo(b,j,k)fluoranthenes | 3200 | 39.9 U | 39.4 U | 39.3 U | 39.6 U | 39.5 U | 38.7 U |
| Benzo(g,h,i)perylene | 670 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Chrysene | 1400 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Dibenzo(a,h)anthracene | 230 | 5 U | 4.9 U | 4.9 U | 4.9 U | 4.9 U | 4.8 U |
| Fluoranthene | 1700 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Fluorene | 540 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Indeno(1,2,3-c,d)pyrene | 600 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| Naphthalene | 2100 | 20 UJ | 19.7 UJ | 19.6 U | 19.8 U | 19.8 UJ | 5.8 J |
| Phenanthrene | 1500 | 20 U | 19.7 U | 19.6 U | 19.8 U | 6.7 J | 15 J |
| Pyrene | 2600 | 20 U | 19.7 U | 19.6 U | 19.8 U | 19.8 U | 19.3 U |
| PCB Aroclors (µg/kg) | | | 1 .5., 6 | 1 .5.0 0 | | .5.00 | 1 .5.5 6 |
| Total DMMP PCB Aroclors (U = 0) | 130 | 3.9 U | 3.9 U | 3.9 U | 4 U | 3.8 U | 3.9 U |
| | .00 | | 1 2.3 0 | | | 1 2.00 | |

non-detect exceedance
detected exceedance

AET-based SQS different from DMMP SL

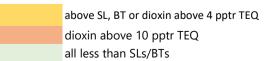
Table 12
Probability of Suitability for Beneficial Use of Non-Native Material

| Section | Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Detected SL/BT Exceedance | Dioxins/furans above 4/10 pptr TEQ | PAH above 2000 ug/kg | Beneficial Use Suitable/Unsuitable | Suitability Probablility | Average suitability probability | Rounded Suitability Probability |
|---------|---------|----------------------------|------------------------|---------------------------------|----------------------------|---------------------------------------|-------------------------|---------------------------------------|-----------------------------|---------------------------------|------------------------------------|
| | 0.4 | Α | 0 to 2 | -49.9 to -51.9 | no | no | no | suitable | 100 | | |
| | C-1 | В | 2 to 4 | -51.9 to -53.9 | no | no | no | suitable | 100 | | |
| | C-2 | А | 0 to 2 | -51.4 to -53.4 | no | no | no | suitable | 100 | 85.71 | |
| Mouth | | А | 0 to 2.7 | -52.5 to -55.2 | Total Chlordane non-detect | no | no | unsuitable | 0 | | 85 |
| | C-3 | В | 2.7 to 5.8 | -55.2 to -58.3 | no | no | no | suitable | 100 | | |
| | C-4 | А | 0 to 2 | -53.6 to -55.6 | no | no | no | suitable | 100 | | |
| | C-5 | А | 0 to 2 | -51.5 to -53.5 | no | no | no | suitable | 100 | | |
| | C-7 | А | 0 to 2 | -50.4 to -52.4 | no | 4.38 | no | unsuitable | 0 | | |
| | 6.0 | А | 0 to 2 | -52.0 to -54.0 | no | 5.00 | no | unsuitable | 0 | | |
| | C-8 | В | 2 to 4 | -54.0 to -56.0 | no | no | no | suitable | 100 | | |
| | | А | 0 to 2 | -49.0 to -51.0 | no | 8.79 | no | unsuitable | 0 | | |
| | C-10 | В | 2 to 4 | -51.0 to -53.0 | Tributyltin | 7.42 | no | unsuitable | 0 | | |
| | | С | 4 to 6 | -53.0 to -55.0 | no | no | no | suitable | 100 | | |
| | C-11 | А | 0 to 2 | -51.6 to -53.6 | Total Chlordane non-detect | 5.92 | no | unsuitable | 0 | | |
| | | А | 0 to 2 | -22.7 to -24.7 | Total PCB Aroclors | 56.2 | no | unsuitable | 0 | | |
| | | В | 2 to 4 | -24.7 to -26.7 | no | 54.5 | no | unsuitable | 0 | | |
| | C-12 | С | 4 to 6 | -26.7 to -28.7 | no | 17.7 | no | unsuitable | 0 | | |
| | | D | 6 to 8 | -28.7 to -30.7 | no | no | no | suitable | 100 | 40.91 | 40 |
| Middle | | Е | 8 to 10 | -30.7 to -32.7 | no | no | no | suitable | 100 | | 40 |
| | | А | 0 to 2 | -39.0 to -41 | no | 5.34 | no | unsuitable | 0 | | |
| | | В | 2 to 4 | -41.0 to -43.0 | no | 7.73 | no | unsuitable | 0 | | |
| | C-13 | С | 4 to 6 | -43.0 to -45.0 | no | 11.88 | no | unsuitable | 0 | | |
| | | D | 6 to 8 | -45.0 to -47.0 | no | 7.64 | no | unsuitable | 0 | | |
| | | E | 8 to 10 | -47.0 to -49.0 | no | no | no | suitable | 100 | | |
| | | А | 0 to 2 | -52.6 to -54.6 | no | no | no | suitable | 100 | | |
| | C-14 | В | 2 to 4 | -54.6 to -56.6 | no | no | no | suitable | 100 | | |
| | | А | 0 to 2 | -45.6 to -47.6 | no | 10.6 | no | unsuitable | 0 | | |
| | C-15 | В | 2 to 4 | -47.6 to -49.6 | no | no | no | suitable | 100 | | |
| | | С | 4 to 6 | -49.6 to -51.6 | no | no | no | suitable | 100 | | |
| | C-16 | А | 0 to 2 | -50.6 to -52.6 | no | no | no | suitable | 100 | | |
| | | А | 0 to 2 | -19.7 to -21.7 | no | no | no | suitable | 100 | | |
| | C-17 | В | 2 to 4 | -21.7 to -23.7 | no | no | no | suitable | 100 | | |
| | | С | 4 to 8 | -23.7 to -25.7 | no | no | no | suitable | 100 | 100 | 100 |
| Head | C-18 | А | 0 to 2.3 | -52.2 to -54.5 | no | no | no | suitable | 100 | | 100 |
| | C-24 | А | 0 to 2 | -51.1 to -53.1 | no | no | no | suitable | 100 | | |
| | 2.2- | A 0 to 2 -51.4 to -53.4 no | no | no | no | suitable | 100 | | | | |
| | C-25 | В | 2 to 4 | -53.4 to -55.4 | no | no | no | suitable | 100 | | |

above SL, BT or dioxin above 4 pptr TEQ dioxin above 10 pptr TEQ all less than SLs/BTs

Table 13
Native Material - Probability of Suitability for Beneficial Use

| Station | Sample ID | Sample Depth (feet) | Sample Elevation (feet MLLW) | Detected SL/BT Exceedance | Dioxins/furans above 4 pptr TEQ | PAH above 2000 ug/kg | Beneficial Use Suitable/Unsuitable | Suitability Probablility | Average suitability probability | Rounded Suitability Probability |
|---------|--------------|------------------------|---------------------------------|------------------------------|------------------------------------|-------------------------|---------------------------------------|-----------------------------|---------------------------------|------------------------------------|
| C-1 | С | 4 to 6 | -53.9 to -55.9 | no | no | no | suitable | 100 | | |
| | В | 2 to 4 | -53.4 to -55.4 | no | no | no | suitable | 100 | | |
| C-2 | С | 4 to 6 | -55.4 to -57.4 | no | no | no | suitable | 100 | | |
| | D | 6 to 8.6 | 57.4 to -60.0 | no | no | no | suitable | 100 | | |
| C-4 | В | 2 to 4 | -55.6 to -57.6 | no | no | no | suitable | 100 | | |
| C-5 | В | 2 to 4 | -53.5 to -55.5 | no | no | no | suitable | 100 | | |
| C-6 | Α | 0 to 2 | -53.9 to -55.9 | no | no | no | suitable | 100 | | |
| C-6 | В | 2 to 4 | -55.9 to -57.9 | no | no | no | suitable | 100 | | |
| C-7 | В | 2 to 4 | -52.4 to -54.4 | Hexachlorobutadiene | no | no | unsuitable | 0 | | |
| C-7 | С | 4 to 6 | -54.4 to -56.4 | no | no | no | suitable | 100 | 96.15 | |
| C-9 | А | 0 to 2 | -53.0 to -55.0 | no | no | no | suitable | 100 | | |
| C-9 | В | 2 to 4 | -55.0 to -57.0 | no | no | no | suitable | 100 | | |
| C-11 | В | 2 to 4 | -53.6 to -55.6 | no | no | no | suitable | 100 | | 95 |
| C-16 | В | 2 to 4 | -52.6 to -54.6 | no | no | no | suitable | 100 | | 33 |
| C-18 | В | 3.9 to 6.3 | -54.5 to -56.9 | no | no | no | suitable | 100 | | |
| C-19 | Α | 0 to 2 | -52.4 to -54.4 | no | no | no | suitable | 100 | | |
| C-19 | В | 2 to 4 | -54.4 to -56.4 | no | no | no | suitable | 100 | | |
| C-20 | Α | 0 to 2 | -51.3 to -53.3 | no | no | no | suitable | 100 | | |
| C-20 | В | 2 to 4 | -53.3 to -55.3 | no | no | no | suitable | 100 | | |
| C-21 | Α | 0 to 2 | -53.7 to -55.7 | no | no | no | suitable | 100 | | |
| C 21 | В | 2 to 4 | -55.7 to -57.7 | no | no | no | suitable | 100 | | |
| C-22 | А | 0 to 2 | -51.0 to -53.0 | no | no | no | suitable | 100 | | |
| C 22 | В | 2 to 4 | -53.0 to -55.0 | no | no | no | suitable | 100 | | |
| C-23 | А | 0 to 2 | -53.7 to -55.7 | no | no | no | suitable | 100 | | |
| C-23 | В | 2 to 4 | -55.7 to -57.7 | no | no | no | suitable | 100 | | |
| C-24 | В | 2 to 4 | -53.1 to -55.1 | no | no | no | suitable | 100 | | |





Site 1



Geotechnical Engineering Design Report

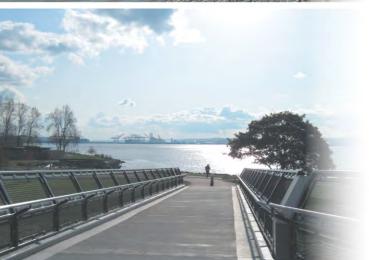
Port of Tacoma
Pier 4 Phase 2
Reconfiguration
Tacoma, Washington



Prepared for

KPFF Consulting Engineers

July 21, 2015 17916-01







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Prepared by

Hart Crowser, Inc.

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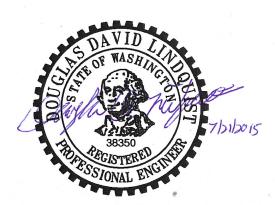
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ATTACHMENT 1

Tsunami Hazard Maps



ACRONYMS AND ABBREVIATIONS

ATD at time of drilling CLE contingency level event CPT cone penetration test CRR cyclic resistance ratio CSR cyclic stress ratio

CDSS cyclic direct simple shear

DE design event

FEM finite element modelling

FHWA Federal Highway Administration

GWT groundwater table

IBC International Building Code **KPFF KPFF Consulting Engineers**

MCE maximum considered earthquake

risk-targeted maximum considered earthquake MCE_R

MKZ modified Kondner and Zelasko

MLLW mean lower low water **OHWL** ordinary high water line OLE operating level event PGA peak ground acceleration PGV peak ground velocity

PSHA probabilistic seismic hazard analysis

SPT standard penetration test USGS **United States Geologic Survey**

weighted average shear wave velocity in the upper 30 meters V_{S30}

WEAP Wave Equation Analysis of Piles



Geotechnical Engineering Design Report

Port of Tacoma Pier 4 Phase 2 Reconfiguration Tacoma, Washington

This geotechnical engineering design report presents our recommendations for design of the Pier 4 Phase 2 Reconfiguration Project on the Blair Waterway in Tacoma, Washington. The Port of Tacoma plans to reconfigure Pier 4 to match the alignment of Pier 3 to the north.

This report contains several sections. The first two pages describe the purpose and scope of our work and our understanding of the project. The main text presents the subsurface conditions, seismic considerations, and our geotechnical engineering findings and conceptual recommendations.

Tables throughout the report and at the end of the text provide data discussed in the text. Figures illustrating project features are at the end of the text, followed by Attachment 1, a tsunami hazard map for Tacoma. The results of field explorations and laboratory tests are in our geotechnical data report (Hart Crowser 2014).

PURPOSE, SCOPE, AND USE OF THIS REPORT

The purpose of our work is to provide KPFF Consulting Engineers (KPFF) and its design and construction consultants with subsurface information, along with our interpretation and geotechnical engineering recommendations to support the design for the Pier 4 Reconfiguration Project.

Our scope of work for this project included:

- Assessing subsurface conditions using explorations, laboratory tests, and historical geotechnical reports and explorations;
- Performing geotechnical and seismic assessment and analysis;
- Providing geotechnical recommendations; and
- Producing this geotechnical engineering design report.

We prepared this report for the exclusive use of KPFF and its design and construction consultants for specific application to the Pier 4 Phase 2 Reconfiguration Project and site location. We completed the work according to generally accepted geotechnical practices in the same or similar localities, related to the nature of the work accomplished, at the time the services were accomplished. We make no other warranty, express or implied.

PROJECT UNDERSTANDING

The project site is along the west shore of the Blair Waterway at the Port of Tacoma in Washington State (Figure 1). The site is occupied by a pile-supported wharf structure and paved shipping container storage area. Figure 2 provides a plan view of the site and includes the project stationing. The paved upland area of the site is generally level, with a surface elevation of approximately 17 feet mean lower low water (MLLW). The ground under the wharf slopes down from the upland area to the bottom of



the Blair Waterway at approximately elevation –50 feet. This under-dock slope is currently inclined at approximately 2 horizontal to 1 vertical.

From historical construction drawings, we know there was a shipping slip (Slip 2) at the north end of Pier 4. The slip was reclaimed by constructing an approximately 36-foot-high select granular fill berm across the mouth of the slip then filling the slip with dredged sediment capped with select fill. The approximate horizontal extent of Slip 2 is shown on Figure 2, which also shows the existing and proposed alignments of Pier 4. To the south, the realignment will require removing the existing wharf structure, cutting back the under-dock slope, installing a new bulkhead, and constructing a new pile-supported wharf structure. To the north, the realignment will require constructing a new wharf structure that extends out from the existing Pier 4 to the outer edge of Pier 3. In addition, a new two-story Operations Building will be located within the upland terminal area.

Elevations provided in this report correspond to vertical datum MLLW, unless noted otherwise.

SUBSURFACE CONDITIONS

We based our interpretation of subsurface conditions on information obtained from new and historical field explorations and laboratory tests on selected soil samples. The new explorations included eight mud rotary borings and four cone penetration test (CPT) probes. Figure 2 shows the approximate location of the new and historical explorations. The results of field explorations and laboratory tests are provided in our geotechnical data report (Hart Crowser 2014). This report should be referred to for specific subsurface information.

The conclusions and analysis in this memorandum are based on subsurface soil and groundwater conditions interpreted from these explorations. The nature and extent of variations between the explorations and current conditions may not become evident until additional explorations are performed or construction begins. If variations are encountered, it will be necessary to reevaluate the conclusions and recommendations in this report.

Soil

We prepared a generalized subsurface profile through the centerline of the proposed pier alignment (Figure 3). The profile is based on our interpretation of historical and new explorations at discrete locations and historical construction drawings. In general, soil conditions are more favorable at the north end of the pier and become less favorable with distance to the south.

The site soils consist of interbedded zones of silt and sand of varying density. Density generally increases with depth; however, there are zones of less dense soil below more dense soil. The soils from the ground surface downward generally consist of the soil units described below.

Loose to medium dense Sand to slightly silty Sand. This soil unit was encountered in explorations in the upland area outside the extent of Slip 2 from the ground surface to a depth of 13 to 30 feet.



Loose to medium dense Sand with layers of Soft Silt. This soil unit was observed underlying the loose Sand to silty Sand in all borings and CPTs located south of the Slip 2 berm. The thickness of this soil unit ranges from approximately 20 to 28 feet.

Medium dense to dense Sand. This soil unit was observed underlying loose to medium dense Sand with layers of soft Silt at the south end of the pier and underlying the Slip 2 berm at the north end of the pier. The thickness of this soil unit ranges from approximately 15 to 45 feet.

Medium dense to very dense silty Sand interbedded with layers of soft to stiff Silt to sandy Silt. This unit was observed underlying medium dense to dense Sand. The explorations terminated in this unit at depths of up to 255 feet below ground surface.

Groundwater

The new and historical upland explorations typically indicate groundwater at elevation 6 to 11 feet MLLW based on observations at time of drilling (ATD). Groundwater levels are representative of the time at which the levels were measured, but they may fluctuate because of seasonal changes, rainfall, temperature, and the tide level of the Blair Waterway.

SEISMIC CONSIDERATIONS

The site is in a seismically active area. In this section, we describe the seismic setting at the project site, identify the seismic basis of design, provide our recommended design response spectra based on our site-specific seismic response analysis, and discuss the seismic hazards at the site.

The seismicity of Western Washington is dominated by the Cascadia Subduction Zone, in which the offshore Juan de Fuca Plate subducts beneath the continental North American Plate (Figure 4). Three types of earthquakes are associated with subduction zones: intraslab subduction, interface subduction, and crustal earthquakes.

Subduction Zone Sources. The offshore Juan de Fuca Plate is subducting below the North American Plate. This causes two distinct types of events. Large magnitude interface subduction earthquakes occur at shallow depths near the Washington coast at the interface between the two plates (e.g., the 1700 earthquake, with magnitude of approximately 9.0). A deeper zone of seismicity is associated with bending and breaking of the Juan de Fuca Plate below the Puget Sound Region, which produces intraslab subduction earthquakes at depths of 40 to 70 kilometers (e.g., the 1949, 1965, and 2001 earthquakes). The intraslab events can produce earthquakes with magnitudes as large as 7.5. Figure 4 depicts the Cascadia Subduction Zone and the various types of earthquakes it can produce.

Crustal Sources. Recent fault trenching and seismic records in the Puget Sound area indicate a distinct shallow zone of crustal seismicity (e.g., Seattle and Tacoma Faults), which may have surficial expressions and can extend 25 to 30 kilometers deep. Figure 5 shows the position of the Puget Sound crustal faults in relation to the project site.



Site Class and IBC Response Spectrum

We performed a downhole shear wave velocity survey to obtain site-specific shear wave velocities for site class determination and to use in our site response analysis and our deformation-based analyses. The survey was conducted in Boring HC12-B5. The results of the survey are in the geotechnical data report (Hart Crowser 2014). The measured profile had a $V_{\rm S30}$ (weighted average shear wave velocity in the upper 30 meters [100 feet]) of 495 feet per second, which corresponds to Site Class E.

However, because the site contains potentially liquefiable soil, it is classified as **Site Class F**. We understand that the period of the proposed pier structure is between 1 and 1.5 seconds. The 2012 International Building Code (IBC; International Code Council 2012) requires a site-specific analysis to determine seismic parameters for Site Class F soils if the period of the structure is greater than 0.5 seconds. In accordance with ASCE 7-05 and 7-10 (Section 21.3), our recommended spectrum will be compared with the code-based Site Class E spectrum. For Pier 4, design is governed by ASCE 61-14 and ASCE 7-05. However, ASCE 7-10 is referenced for comparison and for Operations Building design.

Seismic design of the Operations Building should follow the IBC and ASCE 7-10. With a building period less than 0.5 second, the Operations Building may be designed using the following criteria:

- Latitude 47.273;
- Longitude –122.408;
- Site Class: E;
- Mapped MCE_R spectral response acceleration at short periods, S_S = 1.297 g; and
- Mapped MCE_R spectral response acceleration at 1-second periods, $S_1 = 0.503$ g.

Seismic Basis of Design

As required by ASCE 7 for Site Class F, we performed a site-specific seismic response analysis. We considered four seismic hazard levels in our analysis (OLE, CLE, MCE, and MCE_R, defined below). The basis of design for the 2012 IBC is two-thirds of the hazard associated with the risk-targeted maximum considered earthquake (MCE_R). The IBC event is referred to as the design event (DE). The ASCE Piers and Wharves standard (ASCE 61-14) requires consideration of two additional seismic events: the operating level event (OLE) and the contingency level event (CLE). This standard references the DE from ASCE 7-05 rather than from ASCE 7-10. In ASCE 7-05, the DE is two-thirds of the maximum considered earthquake (MCE), which is a uniform hazard response spectrum, unlike the MCE_R, which is a uniform risk spectrum. For this reason, both the MCE and the MCE_R were evaluated in this geotechnical report.

The OLE has a 50 percent probability of exceedance in 50 years, which corresponds to a return period of 72 years. The CLE has a 10 percent probability of exceedance in 50 years, which corresponds to a return period of 475 years. The MCE has a 2 percent probability of exceedance in 50 years, which corresponds to a return period of 2,475 years.



Seismic Hazard

The seismic hazard for the project site is based on the four seismic hazard levels described above. Response spectra for the 72-year, 475-year, and 2,475-year earthquakes were obtained from the United States Geologic Survey (USGS 2008) for the site location at latitude 47.273 and longitude 122.408. The data are based on probabilistic seismic hazard analysis (PSHA) the USGS performed across the United States. The hazard was retrieved for a V_{S30} of 760 meters per second (2,500 feet per second). This shear wave velocity corresponds to the boundary between Site Classes B and C and is representative of soft rock. Table 1 provides the soft rock target response spectra for the four hazard levels. These spectra are used in ground motion selection for input to the ground response analysis and should not be used as ground surface response spectra for structural analysis.

Table 1 - Soft Rock Target Response Spectra for all Hazard Levels

| Period in seconds | 72-Year Hazard ^a (OLE) in g | 475-Year Hazard ^a (CLE) in g | 2,475-Year Hazard ^a (MCE) in g | MCE _R ª in g |
|----------------------|--|---|---|----------------------------|
| 0 | 0.112 | 0.300 | 0.538 | 0.549 |
| 0.1 | 0.217 | 0.599 | 1.106 | 1.124 |
| 0.2 | 0.242 | 0.663 | 1.223 | 1.252 |
| 0.3 | 0.202 | 0.561 | 1.033 | 1.051 |
| 0.5 | 0.146 | 0.422 | 0.785 | 0.870 |
| 1 | 0.070 | 0.217 | 0.423 | 0.502 |
| 2 | 0.027 | 0.097 | 0.205 | 0.239 |
| 3 | 0.013 | 0.050 | 0.111 | 0.129 |
| 4 | 0.008 | 0.029 | 0.068 | 0.079 |
| 5 | 0.005 | 0.019 | 0.044 | 0.051 |

a. Hazards were obtained from the 2008 USGS deaggregation using V_{S30} of 760 meters per second.

The MCE_R is calculated by multiplying the 2,475-year hazard by maximum component factors and risk coefficients. Table 2 lists the factors used to calculate the MCE_R from the MCE.



Table 2 - Development of MCE_R Soft Rock Target Response Spectrum

| Period in seconds | USGS 2008 2,475-Year Deaggregated Hazard (V _{S30} = 760 m/s) | Risk Coefficients (ASCE 7-10 Method 2) ^a | Maximum Component Factor ^b | MCE _R Response Spectrum in g | Design Response Spectrum in g (2/3 of MCE _R) |
|-------------------------|---|--|---|--|--|
| 0 | 0.538 | 0.929 | 1.1 | 0.549 | 0.366 |
| 0.1 | 1.106 | 0.923 | 1.1 | 1.124 | 0.749 |
| 0.2 | 1.223 | 0.931 | 1.1 | 1.252 | 0.835 |
| 0.3 | 1.033 | 0.926 | 1.1 | 1.051 | 0.701 |
| 0.5 | 0.785 | 0.924 | 1.2 | 0.870 | 0.580 |
| 1 | 0.423 | 0.914 | 1.3 | 0.502 | 0.335 |
| 2 | 0.205 | 0.894 | 1.3 | 0.239 | 0.159 |
| 3 | 0.111 | 0.892 | 1.3 | 0.129 | 0.086 |
| 4 | 0.068 | 0.887 | 1.3 | 0.079 | 0.052 |
| 5 | 0.044 | 0.892 | 1.3 | 0.051 | 0.034 |

a. Risk coefficients were obtained at each period using a MATLAB routine provided to us by Nico Luco of USGS.

Site-Specific Response Spectra

As previously mentioned, because the site contains potentially liquefiable soils, a site-specific ground response analysis is required for the pier structure. The following sections describe the procedure to develop a site-specific response spectrum for the site.

Ground Motion Selection

We selected input ground motions for the site response analyses based on the input motion station's geology, how well the ground motion's response spectrum matched the soft rock target spectrum, and how the ground motion's characteristics (magnitude, mechanism, and distance from the source) fit the earthquake sources that contribute most to the seismic hazard at the site. The 2008 USGS deaggregation data were analyzed to obtain the percent contribution to each hazard level from interface subduction, intraslab subduction, and crustal earthquake sources. We then used these source contributions to select the appropriate number of ground motions from each source. A suite of seven ground motions was selected for each hazard level. For the best fit between our target spectra and the selected ground motions, we performed a least squares error analysis for all the ground motions in our database. The final selected suites generally contain ground motions with the smallest error and the most modest scale factor. Tables 3, 4, and 5 present the three suites of ground motions for the 72-year, 475-year, and MCE_R hazard levels, respectively. The tables include characteristics of the unscaled ground motions, as well as the scale factors we used. Figures 6, 7, and 8 are plots of the scaled ground motions versus the soft rock target spectrum for the 72-year, 475-year, and MCE_R hazard levels, respectively.



b. Maximum component factors are based on ASCE 7-10 and a presentation by Nico Luco at the PEER NGA-West2 Seminar after Shahi and Baker (2013).

Table 3 - Characteristics of Rock Input Ground Motions for the 72-Year Hazard

| Earthquake | Recording Station | M _w | Closest Distance in km | Fault Mechanism | Component | PGA in g (Unscaled) | Scale Factor |
|--------------------------------------|-------------------------------------|----------------|------------------------------|----------------------------------|-----------|------------------------|-----------------|
| 2011 Tohoku, Japan | Karumai | 9.0 | 265ª | Interface Subduction | IWTH07_NS | 0.096 | 1.02 |
| 1965 Puget Sound, Washington | Olympia | 6.7 | 84.9 ^b | Intraslab Subduction | SEA65_266 | 0.203 | 0.46 |
| 2001 Nisqually, Washington | West Seattle Fire Station #29 | 6.8 | 74.8 ^b | Intraslab Subduction | WSF_125 | 0.152 | 0.44 |
| 1985 Coast of Guerrero, Mexico | La Union | 7.6 | 39.8 ^b | Intraslab Subduction | UNI_N00W | 0.047 | 2.12 |
| 2001 Nisqually, Washington | MAR | 6.8 | 77.6 ^b | Intraslab Subduction | MAR_328 | 0.125 | 0.66 |
| 1994 Northridge-01, California | LA - Wonderland Ave | 6.7 | 20.3 | Crustal – Reverse | WON095 | 0.112 | 0.80 |
| 1999 Chi Chi- 06, Taiwan | TCU075 | 6.3 | 26.3 | Crustal – Reverse- Oblique | TCU075_FN | 0.112 | 0.84 |

a. Epicentral distance is given instead of closest distance to fault rupture.

Table 4 - Characteristics of Rock Input Ground Motions for the 475-Year Hazard

| Earthquake | Recording Station | Mw | Closest Distance in km | Fault Mechanism | Component | PGA in g (Unscaled) | Scale Factor |
|---|-----------------------|-----|------------------------------|----------------------------------|-----------|------------------------|-----------------|
| 2010 Chile | Curico | 8.8 | 65.1 | Interface Subduction | CUR_EW | 0.409 | 0.52 |
| 2011 Tohoku, Japan | Yachiyo City Hall | 9.0 | 129 | Interface Subduction | YCY_302 | 0.324 | 0.7 |
| 1949 Western Washington | Olympia | 6.9 | 74.7ª | Intraslab Subduction | OLY49_086 | 0.262 | 0.94 |
| 1965 Puget Sound, Washington | Olympia | 6.7 | 84.9ª | Intraslab Subduction | SEA65_266 | 0.203 | 1.42 |
| 2001 Nisqually, Washington | MAR | 6.8 | 77.6ª | Intraslab Subduction | MAR_328 | 0.125 | 1.86 |
| 1940 Imperial Valley, California | El Centro Array #9 | 7.0 | 6.1 | Crustal – Strike-Slip | I-ELC_180 | 0.313 | 0.66 |
| 1999 Chi- Chi, Taiwan | WNT | 7.6 | 1.8 | Crustal – Reverse- Oblique | WNT_E | 0.956 | 0.36 |

a. Hypocentral distance is given instead of closest distance to fault rupture.



b. Hypocentral distance is given instead of closest distance to fault rupture.

Table 5 - Characteristics of Rock Input Ground Motions for the MCE_R

| Earthquake | Recording Station | M _w | Closest Distance in km | Fault Mechanism | Component | PGA in g (Unscaled) | Scale Factor |
|--|--------------------------|----------------|------------------------------|----------------------------------|-----------|------------------------|-----------------|
| 1985 Valparaiso, Chile | Valparaiso | 7.8 | 129.2ª | Interface Subduction | CHVAL_070 | 0.178 | 2.18 |
| 2010 Chile | SJCH | 8.8 | 87.3 | Interface Subduction | SJCH_090 | 0.472 | 0.94 |
| 2010 Chile | Curico | 8.8 | 65.1 | Interface Subduction | CUR_EW | 0.409 | 1.06 |
| 1949 Western Washington | Olympia | 6.9 | 74.7ª | Intraslab Subduction | OLY49_086 | 0.262 | 1.98 |
| 1965 Puget Sound, Washington | Olympia | 6.7 | 84.9ª | Intraslab Subduction | SEA65_266 | 0.203 | 2.92 |
| 1940 Imperial Valley, California | El Centro Array #9 | 7.0 | 6.1 | Crustal – Strike-Slip | I-ELC_180 | 0.313 | 1.42 |
| 1989 Loma Prieta, California | Saratoga – Aloha Ave. | 6.9 | 8.5 | Crustal – Reverse- Oblique | STG_000 | 0.512 | 1.14 |

a. Hypocentral distance is given instead of closest distance to fault rupture.

Soil Profile

We developed a generalized soil profile based on boring logs, laboratory testing, shear wave velocity testing of Boring HC12-B5, and historical shear wave velocity data. For this boring, laboratory tests included grain size analyses and Atterberg limits. Our subcontractor, Global Geophysics, measured the shear wave velocity within Boring HC12-B5 to a depth of approximately 230 feet using suspension logging equipment. The boring log for exploration HC12-B5, results of the laboratory tests, and shear wave velocity test report are in the geotechnical data report (Hart Crowser 2014). We supplemented shear wave data using results from a seismic cone penetrometer at HC12-P4 as well as historical seismic cone data from a nearby project (CPT-3A).

Our best estimate of shear wave velocity was used as our "V_s base case" for the analysis. Based on regional geology and local experience we assumed a depth to the halfspace (soft rock with shear wave velocity of 2,500 feet per second) of 400 feet for the base case. The soil parameters used in our site response analysis for the base case are shown in Table 6.



Table 6 - Soil Properties used in the "V_S Base Case" Site Response Analysis

| Unit | Soil Type | Thickness in feet | Depth in feet | V _S in fps | Unit Weight in pcf | Soil Model ^a |
|------|---------------------|-------------------|------------------|--------------------------|--------------------------|--|
| 1 | Sand (above GWT) | 9 | 0 to 9 | 287 | 115 | Darendeli (PI = 0, σ' _m = 0.25 atm) |
| 2 | Sand | 19 | 9 to 28 | 342/368 b | 115 | Darendeli (PI = 0, σ' _m = 0.48 atm) |
| 3 | Silt | 11 | 28 to 39 | 443 | 115 | Darendeli (PI = 5, σ' _m = 0.77 atm) |
| 4 | Silty Sand | 9 | 39 to 48 | 540 | 115 | Darendeli (PI= 0, σ' _m = 1 atm) |
| 5 | Sand | 20 | 48 to 68 | 601 | 120 | Darendeli (PI= 0, σ' _m =1 atm) |
| 6 | Sand | 25 | 68 to 93 | 636 | 120 | Darendeli (PI= 0, σ' _m = 1.47 atm) |
| 7 | Silty Sand | 36 | 93 to 129 | 711 | 120 | Darendeli (PI = 0, σ' _m = 2 atm) |
| 8 | Silty Sand | 36 | 129 to 165 | 711 | 120 | Darendeli (PI = 0, σ' _m = 2.6 atm) |
| 9 | Silt | 11 | 165 to 176 | 700 | 120 | Darendeli (PI = 6, σ' _m = 3.3 atm) |
| 10 | Silty Sand | 19 | 176 to 195 | 761 | 120 | Darendeli (PI = 0, σ' _m = 3.3 atm) |
| 11 | Silt | 15 | 195 to 210 | 722 | 120 | Darendeli (PI = 6, σ' _m = 3.8 atm) |
| 12 | Silty Sand | 30 | 210 to 240 | 772 | 120 | Darendeli (PI = 0, σ' _m = 4 atm) |
| 13 | Silt | 15 | 240 to 255 | 772 | 120 | Darendeli (PI = 15, σ' _m = 4 atm) |
| 14 | Sand | 45 | 255 to 300 | 1200 | 125 | Darendeli (PI = 0, σ' _m = 4.8 atm) |
| 15 | Sand | 50 | 300 to 350 | 1600 | 130 | Darendeli (PI = 0, σ' _m = 5.6 atm) |
| 16 | Sand | 50 | 350 to 400 | 2000 | 140 | Darendeli (PI = 0, σ' _m = 6.4 atm) |
| 17 | Halfspace | Infinite | 400 | 2500 | 150 | Visco-Elastic Halfspace |

a. Refers to shear modulus and damping relationship models. Model type was selected considering soil properties of the unit.

Because this was a parametric study, we varied the shear wave velocity to develop our "V_s lower bound," "V_s upper bound," and "V_s deep soft" profiles. These profiles account for variability and uncertainty in the shear wave velocity and in the depth to the halfspace; the profiles, along with shear wave data, are shown on Figure 9. The lower and upper bounds were calculated using -10 and +10 percent of the base case, respectively, at depths for which shear wave data exist, and -20 and +20 percent, respectively, at depths for which the shear wave velocities were assumed. The "V_s deep soft" profile accounts for a slower increase in shear wave velocity and a deeper halfspace.

Seismic Site Response Analysis Methodology

To develop the recommended response spectra for all hazard levels, we performed a site-specific seismic response analysis. Because of the soft, liquefiable soils, we used the one-dimensional, nonlinear dynamic program D-MOD2000 (Matasović and Ordóñez 2009). D-MOD2000 propagates individual input rock ground motions through a one-dimensional soil column to measure the amplification of seismic waves through the soil. The ground motion is then extracted at the surface,



b. Soil Unit 2 was subdivided into two shear wave velocities to refine the profile.

which accounts for any soil amplification. We performed both total stress and effective stress analyses. The effective stress analysis incorporates pore pressure generation models by Dobry et al. (1985) and Vucetic and Dobry (1988) for sands, and by Matasović and Vucetic (1995) for clay. Excess pore pressure development leads to soil softening and accounts for presence of liquefiable soils at the site.

To account for pore pressure generation and liquefaction, we also investigated a response spectral ratio (Kramer et al. 2011). This ratio is a function of spectral period and gives a ratio between the spectral acceleration from an effective stress analysis and the spectral acceleration from a total stress analysis. The ratio was multiplied by the results of our total stress analysis to estimate the results of an effective stress analysis. The ratio depends on the minimum factor of safety against liquefaction of the soil profile. As the minimum factor of safety against liquefaction approaches 1, the ratio has a value close to unity for all periods. At low factors of safety, the ratio indicates de-amplification at short periods, and amplification at longer periods.

To capture the non-linearity of the soil under dynamic loading, D-MOD2000 uses the modified Kondner and Zelasko (MKZ) non-linear soil model (Matasovic and Vucetic 1993). We defined our desired soil models (as shown in Table 6) for each soil unit, and in D-MOD2000 used a two-parameter fit to match as closely as possible the MKZ model to the desired published soil model.

The recommended response spectra are based on calculating the amplification factor (the ratio of the surface output response spectrum to the rock input response spectrum) at various periods. This amplification factor was then applied to the USGS hazards (from Table 1) at selected periods. This was performed for the 72-year, 475-year, and MCE_R hazards and for all four shear wave profiles. We compared the results with the Site Class E code-based response spectra and chose recommended spectra that generally encompass the amplified USGS hazards. We elected to consider a response spectrum lower bound, following ASCE 7-10 guidance that the recommended design response spectra may not be less than 80 percent of the code-defined response spectra.

Results and Recommended Spectra

The results of the site response analysis and an explanation of the derivation of the recommended response spectrum for each hazard are given in the following sections.

72-Year Hazard (OLE)

The lower hazard level generated little pore-pressure; therefore, the D-MOD2000 total stress and the effective stress analysis were essentially equal. Our resulting amplified response spectra were generally at or below 80 percent of the Site Class E code-based response spectrum. The recommended spectrum for the 72-year hazard (OLE) is 80 percent of the code-defined Site Class E spectrum. The results of this analysis and the recommended spectrum are shown and tabulated on Figure 10.

475-Year Hazard (CLE)

The 475-year ground motions produced some excess porewater pressures and even caused liquefaction in the near-surface soils. This generation of pore pressures caused softening of the soil profile and resulted in variations between the total stress and the effective stress analyses. The total



stress analysis resulted in higher spectral accelerations at periods less than approximately 1.5 seconds, was nearly equal to the effective stress analysis between 1.5 and 2.5 seconds, and was generally lower than the effective stress analysis beyond 2.5 seconds. We chose to envelope the amplification factors from the total and effective stress analysis to capture the response from both. We used amplification factors from our total stress analysis from periods of 0 to 2.5 seconds and from the effective stress analysis from periods of 2.5 to 5 seconds.

The resulting spectrum was generally at or below 80 percent of the code-defined Site Class E spectrum, except between periods of 0.75 and 2.5 seconds, where the results slightly exceeded 80 percent of the code spectrum. For this hazard level we recommend following 80 percent of the code-defined spectrum but extending the plateau to the right, to the period where it intersects 85 percent of the code spectrum. The design spectrum then follows 85 percent of the code down to 2.25 seconds, where it linearly transitions back down to 80 percent of the code by 2.5 seconds. The results of the analysis and the recommended spectrum are shown and tabulated on Figure 11.

Risk-Targeted Maximum Considered Earthquake (MCE_R)

Our analysis with the MCE_R ground motions resulted in widespread liquefaction and large increases in porewater pressure. This resulted in significant softening of the soil and produced large differences between the total and the effective stress analysis. The effective stress response spectrum is well below the total stress spectrum from periods of 0 to approximately 3 seconds. Beyond periods of seconds, the effective stress analysis resulted in slightly higher spectral accelerations. For this hazard level, the response spectral ratio (described previously in the section titled "Seismic Site Response Analysis Methodology") was also used to determine our recommended spectrum. Multiplying the total stress analysis by the response spectral ratio resulted in higher spectral accelerations than those of the total stress analysis at periods greater than approximately 1.8 seconds. The total stress response multiplied by the spectral ratio was comparable to the effective stress at periods greater than 4 seconds, but higher than the effective stress at periods between 0.8 and 3.8 seconds.

Based on these results, we chose to envelope the results from the total stress analysis, the effective stress analysis, and the total stress analysis incorporating the response spectral ratio. At any period, the amplification factor was taken as the maximum amplification factor between the three analyses.

The resulting amplified USGS MCE_R spectrum fell slightly below the full code-defined Site Class E response spectrum at periods less than 1.5 seconds. Beyond 1.5 seconds, our results indicate that the response is very close to the code spectrum, varying between slightly below to slightly above, depending on the shear wave profile and the period of interest.

The recommended design response spectrum was taken as 95 percent of the code-defined Site Class E response spectrum through the plateau of the spectrum. The plateau was then extended to the right to the period at which it intersects the full code spectrum. The recommended spectrum then follows the full code spectrum up to a period of 1.75 seconds. To capture some additional amplification that occurred between periods of 2 and 3 seconds, the recommended spectrum exceeds the code spectrum within this range. At 2, 2.5, and 3 seconds, the recommended spectrum is 4 percent, 10



percent, and 4 percent higher than the code, respectively. At 3.5 seconds, the recommended spectrum returns down to the Site Class E spectrum. Between these periods, we used linear interpolation to get the recommended response spectrum (shown and tabulated, along with site response results, on Figure 12).

Maximum Considered Earthquake (MCE)

A site-specific response analysis was not performed for ground motions scaled to the MCE hazard. Instead, the procedures described above for the MCE_R were used to define the recommended MCE response spectrum.

Design Event (DE)

The DE is simply two-thirds of the MCE $_R$ or MCE, depending on the code referenced. ASCE 61-14 references the DE from ASCE 7-05, which defines it as two-thirds of the MCE. The recommended design response spectra for the OLE, CLE, MCE, MCE $_R$, and DE are presented on Figure 13. The MCE and the ASCE 61-14 DE response spectra are shown in Table 7.

| Period in seconds | 2,475-Year Hazard (MCE) in g | DE (2/3 x MCE) in g |
|----------------------|------------------------------------|------------------------|
| 0 | 0.418 | 0.279 |
| 0.184 | 1.045 | 0.697 |
| 0.971 | 1.045 | 0.697 |
| 1 | 1.014 | 0.676 |
| 1.25 | 0.812 | 0.541 |
| 1.5 | 0.676 | 0.451 |
| 1.75 | 0.580 | 0.386 |
| 2 | 0.528 | 0.352 |
| 2.5 | 0.446 | 0.298 |
| 3 | 0.352 | 0.234 |
| 4 | 0.254 | 0.169 |

Liquefaction Potential

Liquefaction is a phenomenon caused by a rapid increase in porewater pressure that reduces the effective stress between soil particles, resulting in the sudden loss of shear strength in the soil. Granular soils that rely on inter-particle friction for strength are susceptible to liquefaction until the excess pore pressures can dissipate. Sand boils and flows observed at the ground surface after an earthquake are the result of excess pore pressures dissipating upward, carrying soil particles with the draining water. In general, loose, saturated sandy soils with low silt and clay contents are the most susceptible to liquefaction. Silty soils with low plasticity are moderately susceptible to liquefaction under relatively higher levels of ground shaking. For any soil type, the soil must be saturated for liquefaction to occur. Liquefaction can cause ground surface settlement and lateral spreading.



We used empirical methods to estimate liquefaction potential based on the standard penetration test (SPT) and the cone penetration test (CPT) data obtained at the site. We used procedures by Idriss and Boulanger (2008) for the SPT and CPT data. For our analysis of the OLE, CLE, DE, and MCE hazard levels we used an earthquake magnitude of 7.0 and peak ground accelerations (PGAs) of 0.269, 0.360, 0.323, and 0.484 g, respectively. ASCE 61-14 does not require consideration of the MCE hazard level for liquefaction evaluation.

Based on our analysis, we estimate that the Slip 2 berm will not liquefy; however, liquefaction could occur in portions of the other soil units from the water table to approximately 80 feet below ground surface. The potential for liquefaction is not constant across the site. Interbedded layers of nonliquefiable soil are present throughout the profile, and the non-liquefiable layers increase in thickness and frequency with depth and from the south to the north end of the pier. In general, we anticipate widespread liquefaction in the soil units between the groundwater table and approximately elevation −30 feet, and limited or localized liquefaction in the soil units below elevation −30 feet.

Some explorations indicate that localized zones of soft or loose liquefiable deposits are present at depths as great as 220 feet below ground surface. However, we limited the depth of potential liquefaction to 80 feet, following guidance in WSDOT Geotechnical Design Manual (WSDOT 2014). WSDOT has adopted an 80-foot limit because simplified procedures for estimating liquefaction potential, such as Idriss and Boulanger, are only calibrated for depths down to approximately 50 to 60 feet, and observations of liquefaction suggest that the effects of liquefaction become less significant as the depth of the liquefiable layer increases. It is also difficult and expensive to mitigate and design against liquefaction at these great depths.

Post-Liquefaction Vertical Settlement

Post-liquefaction settlement occurs because liquefiable soils are redistributed and become denser after an earthquake. The ground surface settlement is not typically uniform across the area, and can result in significant differential settlement.

We estimated liquefaction-induced ground surface settlement using SPT corrections by Idriss and Boulanger (2008) and volumetric strain formulations by Yoshimine et al. (2006), as well as CPT correlations (Cliq 2006) based on procedures by Idriss and Boulanger (2008). We calculated ground surface settlement only from the volumetric strains in the upper 80 feet. This is a reasonable assumption for ground surface settlement, because research has shown that volumetric contractions at depths greater than 60 feet may not manifest as surface settlement (Cetin et al. 2009).

The results of our analysis indicate that liquefaction-induced settlement will be greatest at the south end of the pier and in the upland area. We estimate 4 to 6 inches of settlement may occur at the north end of the site in the Slip 2 fill area. South of the Slip 2 fill, settlement could range between about 12 and 20 inches, with the largest settlement occurring south of station 34+00. These ranges of settlement are for the MCE. Settlement estimates for the DE and CLE are within 1 to 3 inches of the MCE settlement estimates. Assuming the under-dock slope remains stable, the pile-supported wharf



structure is expected to settle only a few inches. This could lead to significant differential settlement between the wharf structure and the adjacent ground surface.

The predicted settlement is based on existing soil conditions; however, the results of our slope stability analysis of the under-dock slope indicate that ground improvement is necessary to mitigate liquefaction and improve slope stability. We expect that settlement in areas of ground improvement will be minimal (e.g., less than a couple of inches); as a result, the differential settlement between the wharf structure and adjacent improved ground will be reduced; however, significant differential settlement could occur between improved and unimproved areas.

Fault Surface Rupture

Pier 4 is approximately 10 miles southeast of the easternmost splay of the east—west Tacoma fault, as mapped by Brocher et al. (2004). Figure 5 is a map of the Tacoma fault and other known faults in the region. The last known rupture of the Tacoma fault occurred approximately 1,000 years ago. Based on current knowledge, the hazard of surface rupture at the site is considered to be very low.

Tsunami Hazard

The tsunami hazard within Puget Sound is controlled by crustal faults. According to the Tacoma tsunami hazard map prepared by the Washington State Department of Natural Resources (2009), a tsunami originating from a Seattle Fault earthquake would likely cause widespread inundation ranging from 0.5 to 2 meters across the project site. In addition, inundation could be 2 to 5 meters in localized areas. Inundation resulting from a Tacoma Fault tsunami would be limited to shoreline areas and would be generally less than 0.5 meter at the site. The tsunami hazard map is included as Attachment 1. Because of the relatively long return periods of these crustal faults, the tsunami hazard during the design life of the structure is low.

GEOTECHNICAL ENGINEERING CONCLUSIONS AND RECOMMENDATIONS

The following section describes our geotechnical engineering analysis, presents the results, and gives our design recommendations. We developed our analysis based on our understanding of the project and on subsurface conditions revealed by historical and recent explorations performed at the site.

Slope Stability

We analyzed slope stability to evaluate the stability of the proposed under-dock slope and pier system under static and seismic load conditions by performing limit equilibrium, Newmark-type sliding block seismic displacement, and deformation-based time history slope stability analyses. The following sections describe each analysis in detail.

Limit Equilibrium Slope Stability Analysis

We analyzed limit equilibrium slope stability at five locations: Stations 26+00, 31+00, 34+00, 38+00, and 39+00. We used the limit equilibrium computer program SLOPE/W, developed by GEO-SLOPE



International Ltd., to analyze the stability of each section. The wharf and slope configurations are based on information and cross-sections of the slope provided by KPFF. The Morgenstern-Price method, which satisfies both moment and force equilibrium, was used in the analysis. Circular slip surfaces were evaluated for three loading cases: static, pseudostatic, and post-earthquake liquefied.

The pseudostatic analysis accounts for inertial earthquake loading by applying a horizontal acceleration to the soil within the slip surface equal to one-half the PGA. The post-earthquake analysis evaluates the static stability of the slope using reduced soil strength to account for effects of liquefaction. We analyzed the pseudostatic stability for the OLE, the DE, and the CLE using a PGA of 0.269, 0.323, and 0.360 g for the OLE, DE, and CLE hazard levels, respectively. The DE acceleration is two-thirds of the MCE acceleration. For our slope stability analyses, we elected to use PGAs calculated as the bedrock PGA multiplied by the Site Class E code-based FPGA factor, which turns out to be somewhat higher than our site-specific PGA. Use of the higher PGA in slope stability analysis was inconsequential to the final design because the deformation-based PLAXIS analysis governed the ground improvement requirements.

The target factors of safety are 1.5 and 1.1 for the static and post-earthquake cases, respectively. A pseudostatic factor of safety less than 1.1 indicates that some level of permanent seismically induced slope displacement is likely to occur.

We analyzed the under-dock slope and calculated the factor of safety with the reinforcing contribution of wharf piles. For our analysis, the piles are modeled as vertical reinforcing elements that contribute additional shear resistance to the critical slip surface. We corresponded with KPFF to select appropriate values of shear contribution from the existing (16.5-inch octagonal concrete) and proposed (24-inch octagonal concrete) piles. KPFF calculated shear contributions of each pile type based on the bending moment capacity of the piles, assuming that piles would fail in bending and not in shear. KPFF provided us tables of shear contribution as a function of distance between plastic hinges for both pile types. The distance between plastic hinges was taken as the distance between the pile cap and the failure surface for every pile. Therefore, each pile along a bent had a different shear contribution. We used an iterative process to identify the appropriate distances between plastic hinges and shear contribution for every pile and loading case. KPFF also provided us with pile tip elevations at each cross-section.

Station 26+00 Slope Stability

We understand that in the northern end of Pier 4, a portion of the existing pier will remain, with new pier structure extending out from the existing pier to the new pier head. Therefore, we analyzed the existing slope with reinforcing contribution from the existing 16.5-inch octagonal concrete piles as part of the wharf that will remain.

Slope stability cross-sections showing geometry, failure surfaces, and factors of safety are on Figure 14. The resulting factors of safety are shown in Table 8. For presentation purposes, we include only figures of the static, CLE, and post-earthquake liquefied analyses. In tables, we present factors of safety for the static, OLE, CLE, and liquefied cases. We present only these cases for all cross-sections.



The CLE controls the pseudostatic cases, and the DE falls in between the OLE and CLE hazard at the PGA for a Site Class E.

Table 8 - Station 26+00 Slope Stability Factors of Safety

| Loading Case | Factor of Safety (No Ground Improvement) |
|-----------------------------|--|
| Static | 1.7 |
| Pseudostatic – OLE | 1.1 |
| Pseudostatic – CLE | 0.9 ^a |
| Post-Earthquake – Liquefied | 1.1 |

a. Further deformation-based analysis was performed to estimate seismic displacements for this case.

The existing soil conditions and factors of safety at Station 26+00 were such that we do not believe ground improvement is necessary in the area of the Slip 2 berm (north of approximately Station 30+00). Stone columns have been attempted at a nearby site in similar fill deposits, but penetration with the stone column probe was not possible due to the relative density of the material. At Pier 4, refusal occurred in the Slip 2 berm fill while we attempted to probe with a CPT. These circumstances indicate that Slip 2 fill is relatively dense and likely will not require liquefaction mitigation.

Station 31+00 Slope Stability

Station 31+00 is approximately the point at which the slope will begin to be cut back, moving south. At this station, only the crest of the slope will be cut back, and only by a small amount. The pile bent at Station 31+00 includes one additional pile between the bulkhead and the farthest upland pony bent piles. The piles at this station are the proposed 24-inch octagonal pre-stressed concrete piles.

Slope stability cross-sections at this location showing geometry, failure surfaces, and factors of safety are shown on Figure 15. Slope stability factors of safety are shown in Table 9.

The section was initially modeled with existing soil conditions. However, the post-earthquake liquefied case was resulting in a factor of safety significantly lower than the 1.1 target factor of safety, and liquefaction had to be mitigated to provide adequate stability. To mitigate liquefaction and prevent slope failure, we selected ground improvement in the form of vibro-replacement stone columns. At approximately Station 31+00 and northward, all the waterside stone columns in the proposed layout would fall below the ordinary high water line (OHWL). Therefore, we investigated the stability of the slope with less or no ground improvement at this location.

The results indicate that less ground improvement could be used at this station than at other stations to achieve factors of safety comparable to those for other stations. Our soil explorations indicate that soil conditions are better at this station than at the sections to the south. We provide further discussion on the ground improvement layout in the Deformation-Based Time History Analysis using PLAXIS and Ground Improvement sections.



Table 9 – Station 31+00 Slope Stability Factors of Safety

| | Factor of Safety | | | |
|-----------------------------|------------------|-------------|--|--|
| Loading Case | Before Ground | With Ground | | |
| | Improvement | Improvement | | |
| Static | 1.9 | 1.9 | | |
| Pseudostatic – OLE | 1.1 | 1.2 | | |
| Pseudostatic – CLE | 1.0 | 1.0ª | | |
| Post-earthquake – liquefied | 0.7 | 1.1 | | |

a. Further deformation-based analysis was performed to estimate seismic displacements for this case.

Stations 34+00, 38+00, and 39+00 Slope Stability

Realigning the wharf structure will require cutting back the under-dock slope south of approximately station 30+00 to 31+00. At stations 34+00, 38+00, and 39+00, the amount of slope cut back will vary; however, the final configuration and geometry will generally be the same at all locations.

Slope stability cross-sections at these stations showing geometry, failure surfaces, and factors of safety are on Figures 16 through 18. Slope stability factors of safety are shown in Table 10. All results presented include reinforcement from the proposed 24-inch octagonal pre-stressed concrete piles.

All three sections were initially modeled with existing soil conditions at each respective location. We found that the post-earthquake liquefied case was resulting in factors of safety significantly lower than the 1.1 target and, therefore, liquefaction had to be mitigated to provide adequate stability. As mentioned above, to mitigate liquefaction and prevent slope failure, we selected vibro-replacement stone columns for ground improvement. We iteratively determined the quantity of stone columns required to attain a factor of safety of 1.1 or greater for the post-earthquake liquefied and the OLE stability analysis. Factors of safety for the DE and CLE pseudostatic cases range from 0.9 to 1.0, which are lower than the target of 1.1. Further deformation-based analyses were performed to estimate seismic displacements caused by the CLE and DE.



Table 10 - Stations 34+00, 38+00, and 39+00 Slope Stability Factors of Safety

| Cross Sastian | | Factor of | of Safety |
|-----------------------|-----------------------------|---------------|-------------|
| Cross-Section Station | Loading Case | Before Ground | With Ground |
| | | Improvement | Improvement |
| | Static | 1.8 | 1.9 |
| 24.00 | Pseudostatic – OLE | 1.1 | 1.1 |
| 34+00 | Pseudostatic – CLE | 0.9 | 1.0ª |
| | Post-Earthquake – Liquefied | 0.6 | 1.3 |
| | Static | 1.8 | 1.9 |
| 20.00 | Pseudostatic – OLE | 1.0 | 1.1 |
| 38+00 | Pseudostatic – CLE | 0.9 | 1.0ª |
| | Post-Earthquake - Liquefied | 0.4 | 1.2 |
| | Static | 1.8 | 1.9 |
| 39+00 | Pseudostatic – OLE | 1.0 | 1.1 |
| | Pseudostatic – CLE | 0.9 | 1.0ª |
| | Post-Earthquake – Liquefied | 0.5 | 1.2 |

a. Further deformation-based analysis was performed to estimate seismic displacements for this case.

Newmark-Type Sliding Block Seismic Displacement Analysis

The factors of safety from the limit equilibrium analysis are below the target of 1.1 for the pseudostatic analyses at the CLE and DE hazard level for all sections analyzed. For this reason, we performed further displacement-based analysis to estimate the amount of slope displacement that may occur during earthquake shaking. As a first approximation of the displacement, a Newmark-type sliding block displacement analysis was performed. A sliding block analysis assumes that the failure mass behaves rigidly, like a sliding block resting on a slope. When the seismic acceleration exceeds the yield acceleration (the acceleration required for the block to slide) the block or failure mass is displaced.

The method chosen for the Newmark-type analysis was developed by Rathje and Saygili (2009) based on the Newmark sliding block analysis. This method is believed to provide more accurate results than the original Newmark analysis. Rathje and Saygili's vector approach uses PGA and peak ground velocity (PGV) to predict the sliding displacement.

Newmark-type analyses assume a rigid sliding block and are therefore only applicable to relatively shallow failure surfaces. These analyses were not developed for deep-seated failures or liquefactioninduced failures, and may not fully encapsulate potential failure modes at Pier 4. In addition, only a single displacement value is provided, with no indication of differential displacement, pile rotation, or other parameters related to slope and structure performance.

The results of the Newmark-based analysis are summarized in Table 11.



Table 11 - Newmark-Based Seismic Displacements

| Cross- Section Stationing | Yield Acceleration in g | Seismic Loading Case | Displacement in Inches |
|---------------------------------|-------------------------------|----------------------------|------------------------|
| | | OLE | Up to 0.8 |
| 26+00 | 0.146 | CLE | Up to 16 |
| | | DE | Up to 15 |
| | | OLE | Up to 0.3 |
| 31+00 | 0.186 | CLE | Up to 8 |
| | | DE | Up to 8 |
| | | OLE | Up to 0.4 |
| 34+00 | 0.174 | CLE | Up to 10 |
| | | DE | Up to 10 |
| | | OLE | Up to 0.5 |
| 38+00 | 0.171 | CLE | Up to 10 |
| | | DE | Up to 10 |
| | | OLE | Up to 0.5 |
| 39+00 | 0.168 | CLE | Up to 11 |
| | | DE | Up to 11 |

The commentary of ASCE 61-14 states that in the presence of soft and/or liquefiable soil layers (both present at Pier 4) more detailed dynamic soil-structure interaction may be necessary. Because of the poor soil conditions at Pier 4, we find it appropriate to use more advanced finite element models to estimate slope displacement. The finite element models can also estimate shear, moment, rotation, and displacement of piles and other structural elements.

ASCE 61-14 requires coupling kinematic and inertial loading unless decoupling can be justified. We found the coupling of kinematic and inertial loading was warranted and chose to use a dynamic timehistory soil-structure interaction model to estimate our pile loads. Coupling kinematic loading with inertial loading is completely independent of coupling liquefaction with strong shaking; the latter is discussed further in the next section.

Deformation-Based Time-History Analysis using PLAXIS

To get a potentially more realistic measure of the seismic slope displacement that may occur at Pier 4 and supplement our design recommendations, we performed time-history analyses using the finite element modelling (FEM) software PLAXIS. PLAXIS can provide a more meaningful evaluation of stability than the traditional limit-equilibrium approaches. The analysis accounts for the dynamic response of soils, soil-structure interaction, and inertial effects from shaking.

We analyzed two representative sections (Stations 31+00 and 38+00) under the OLE, CLE, and DE hazard levels. For each hazard, we chose three representative ground motions from the suite of seven



ground motions obtained for the site-specific seismic response analysis (described in the Site-Specific Response Spectra section). The three ground-motion suites were chosen based on percent contributions from each of the seismic sources to the total hazard. We spectrally matched the ground motions to each respective soft rock target spectrum. Our shear wave profile (Figure 9) assumes a depth to soft rock (shear wave velocity of 2,500 feet per second) of 400 feet, but for a PLAXIS model to extend to that depth is too computationally intensive; instead, the soft rock outcrop ground motions were deconvoluted to an incident motion (i.e., the upward-propagating motion) at an elevation of – 198 feet. The deconvolution was performed using SHAKE2000.

The deconvoluted ground motions were input into the base of the PLAXIS model at elevation - 198 feet. We used a compliant base for the bottom of the PLAXIS model, which allows the wave energy to exit the bottom of the model. This is a realistic representation of the base conditions for these profiles.

Soils were categorized into discrete layers based on average clean sand (N₁)₆₀ values and shear wave velocities. For each ground motion, we ran an analysis that assumed soil liquefaction was decoupled from shaking (i.e., liquefaction initiation and effects were not included) and one that modeled the timing and extent of liquefaction during the earthquake ground motion time-history.

For the decoupled analyses, we modeled the soils using the HSsmall soil model in PLAXIS, which provides reasonable hysteretic damping and an adjustable shear modulus degradation curve based on the Hardin-Drnevich relationship (PLAXIS 2014). For the liquefiable or coupled analysis, layers that we expected to liquefy (based on SPT liquefaction triggering procedures) were modelled using UBCSAND soil model as implemented by PLAXIS. The UBCSAND model parameters for each soil layer were calculated based on SPT correlations for a first-order estimate (Beaty and Byrne 2011; Galavi, Petalas, and Brinkgreve 2013).

We verified the SPT correlations for UBCSAND and the PLAXIS implementation of the model using the SoilTest model in PLAXIS. We have found that the UBCSAND model in PLAXIS is generally well calibrated for an overburden pressure of 1 atmosphere and no shear bias (in-situ shear stresses). The model diverges from standard liquefaction triggering curves at overburden pressures other than 1 atmosphere and when static shear stresses are present. Because of the sloping geometry of the ground beneath the pier, static shear stresses are present in the model. We checked and calibrated all UBCSAND soil regions to the appropriate shear bias and effective overburden pressure.

For the calibration of UBCSAND, we generated a cyclic direct simple shear (CDSS) test in the SoilTest module and calculated the appropriate cyclic resistance ratio (CRR) for each UBCSAND soil layer based on the $(N_1)_{60,CS}$. We used the simplified procedure by Idriss and Boulanger (2008) to estimate CRR. CRR was adjusted for overburden pressure using the K_{α} formulation based on penetration resistance (Boulanger and Idriss 2004). CRR was also adjusted for static shear stresses using K_{α} procedures by Idriss and Boulanger (2003). We calibrated the UBCSAND parameters so that we would achieve liquefaction in the model (ru of approximately 1) after 15 loading cycles with a cyclic stress ratio (CSR) equal to the appropriate CRR of that layer.



Piles were modelled below the ground surface using an elastoplastic embedded pile row in PLAXIS, which models the three-dimensional nature of piles in two dimensions. Above the ground surface, an elastoplastic plate was used to model the piles and was fixed to the embedded pile row at the surface of the slope. The piles were hinged to the deck (modeled as an elastic plate) with an elastoplastic spring. Structural properties (linear and nonlinear stiffness, bending and axial capacity, dimensions, unit weight, and so forth) of each structural element were provided by KPFF along with the geometry of the final pier configuration and pile layout.

PLAXIS Results and Discussion

Historically, in practice, liquefaction has been decoupled from earthquake shaking and inertial loading. However, modelling the liquefaction of the loose and soft soils at Pier 4 in our dynamic model resulted in larger deformations than the model without liquefaction. The model showed that liquefaction and softening of the soil did occur during shaking. [Coupling of liquefaction with shaking is different than coupling of inertial loading with kinematic loading, which is inherent to our soil-structure interaction model in PLAXIS.]

The PLAXIS model shows that mitigating liquefaction through ground improvement in the form of stone columns can significantly reduce the slope deformations and the demands on the structure. With five rows of stone columns in the upland and three to five rows waterside of the bulkhead, the deformations of the slope are deemed reasonable and repairable. The moment demands on the piles were also analyzed. The model shows that with the proposed amount of ground improvement, the piles do not yield, and they remain elastic under all hazard levels. This meets the requirements of ASCE 61-14 for pile performance under the three seismic events we analyzed. We provide more details about our proposed stone column design and layout in the Ground Improvement section, below.

In Table 12 are results from the OLE, CLE, and DE hazard levels for decoupled and coupled/liquefiable analyses. These results are the average of the maximum deformation from three ground motions for each of the hazard levels. Figures 19 through 22 correspond to the cross-section at Station 31+00. Figure 19 shows the full extent of the model geometry with the finite element mesh. Figures 20, 21, and 22 present results of total vector displacements for the OLE, CLE, and DE, respectively. These figures show the displacements from the ground motion that resulted in the maximum deformation and structural demands. ASCE 61-14 requires using for design the ground motion that results in the maximum demands when using a suite of three ground motions.

Figures 23 through 26 correspond to the cross-section at Station 38+00. Figure 23 shows the full extent of the model geometry with the finite element mesh. Figures 24, 25, and 26 present results of total vector displacements for the OLE, CLE, and DE, respectively. The figures show deformations from the ground motion that resulted in the maximum deformation.



| Cross- | Seismic | Maximum Vector Displacement ^a in feet (Average of Three Ground Motions) | | |
|--------------------|--------------|--|--------------------------|--|
| Section Station | Hazard Level | Decoupled | Coupled (Liquefiable) | |
| | OLE | 0.1 | 0.3 | |
| 31+00 | CLE | 0.9 | 2.1 | |
| | DE | 1.7 | 2.6 | |
| | OLE | 0.1 | 0.1 | |
| 38+00 | CLE | 1.3 | 2.0 | |
| | DE | 2.0 | 2.6 | |

a. Average maximum deformations are presented. This deformation could be anywhere in the profile; reference respective figures for the shape and extent of deformations.

Ground Improvement

Based on our liquefaction analysis, a significant portion of the site is susceptible to liquefaction under the level of shaking expected from the OLE, CLE, DE, and MCE. Our slope stability analysis indicates that this liquefaction will result in unacceptable factors of safety and deformations. We recommend installing vibro-replacement stone columns near the proposed bulkhead to mitigate liquefaction and to stabilize the slope.

The design of stone columns for this site is governed by their ability to mitigate liquefaction and sufficiently stiffen the soil to improve the stability of the slope. Three fundamental criteria are normally adopted in stone column design to prevent soil liquefaction and resist slope instability: (1) densification, (2) stress redistribution, and (3) drainage effects.

Densification. The degree of densification is a function of factors including soil type, silt and clay content, plasticity of soils, relative density before densification, vibrator type, stone shape and durability, stone column area, and spacing between columns. Experience has shown that soils with less than 15 percent passing the No. 200 sieve, and with clay content less than 2 percent, usually densify when vibrated. For higher-fines-content soils, the densification effect due to vibration is not significant and the degree of improvement, therefore, is determined by the percentage of soil replaced and displaced by stone columns. We anticipate that some degree of densification can be achieved in the proposed stone column improvement area since the fines content is generally less than 15 percent.

Stress Redistribution. The stress redistribution effect assumes that the relatively high stiffness of the stone column will absorb more shear stresses than the weaker surrounding soils during ground shaking, which reduces the shear stresses applied to the soils. The concept of stress redistribution and reduction in improved soils assumes strain compatibility (i.e., the stone columns and surrounding soil deform equally). Recent research (Rayamajhi et al. 2012) has suggested that strain compatibility may not be an appropriate assumption and has proposed a new relationship to determine the stress reduction in improved ground. This methodology was adopted in our design.



Drainage. Stone columns can be designed to provide a drainage path for the pore pressure to dissipate through during the earthquake, which reduces liquefaction potential.

Recommended Ground Improvement

Based on the densification, stress redistribution, and drainage design criteria described above, we recommend 42-inch-diameter stone columns with 9-foot, center-to-center spacing within rows and 9foot spacing between rows, extending to about elevation -50 feet for the upland areas. For stone columns under the pier, the layout changes to accommodate pile and bent spacing. Figure 27 shows an overview of the proposed stone column layout, and Figures 28 and 29 show details of the layout for different stretches along the pier.

Through refinement and calibration of soil parameters, we were able to meet code standards with fewer stone columns than shown in the 60 percent design report. We recommend five rows of columns on either side of the bulkhead, and installing as many as possible in the upland, on both sides of the bulkhead, before the slope is cut back. To the north (STA 31+00), where soil conditions are better, and stone columns waterside of the bulkhead fall below the current OHWL, we investigated different configurations to minimize the amount of stone columns below the OHWL. The analysis showed that with the more seismically stable soil conditions to the north, three rows of waterside columns will be enough to meet code requirements while reducing displacements and structural demands.

Landside columns should extend north up to the Slip 2 fill area shown on Figure 2 (approximately Station 30+00). Where the bulkhead turns at the intersection of the proposed and the existing bulkhead (approximately Station 31+00), all five rows of the landside stone columns should follow the turn. As mentioned under the Limit Equilibrium Slope Stability Analysis section, ground improvement is not required in the Slip 2 berm.

Although for some projects a rock reservoir is recommended at the top of stone columns, this is not necessary for this project. The columns themselves will have a good capacity above the water table and there is also sand near the ground surface that can act as the reservoir.

Lateral Pile Capacity

Lateral loads are resisted primarily by the horizontal bearing support of soil adjacent to the pile shafts and pile caps. However, the lateral geotechnical resistance of pile caps cannot be included when the pile caps are above the mudline. The lateral capacity of a pile depends on its length, stiffness in the direction of loading, proximity to other piles, and degree of fixity at the head, as well as the engineering properties of the soil providing support to the pile. The design lateral capacity of the vertical piles will depend largely on the piles' allowable lateral deflections.

Development of lateral pile criteria requires the structural engineer to assume the degree of fixity at the pile head. A pile is considered free-headed if the top is free to rotate. If the top of the pile is fixed against rotation by embedment in a pile cap that is sufficient to develop a fixed-end moment, the pile



is considered restrained and fixed-headed. We expect that the piling would be structurally connected to the pile cap and, therefore, fixed to a great degree against rotation until pile hinging occurs.

Recommended LPILE Model Parameters

Tables 13, 14, and 15 summarize our recommended LPILE parameters to be used for the south, central, and Slip 2 berm areas of the pier, respectively. Each soil profile should be used for the station range indicated. Table 16 provides our recommended LPILE parameters to be used for areas with ground improvement. All profiles begin from the upland ground surface at elevation 18 feet.

Upper-bound and lower-bound springs should be used to account for uncertainty in soil parameters, sloping ground, and models. Upper-bound and lower-bound springs can be derived by multiplying the P-Y modulus by factors of 2.0 and 0.3, respectively. Note that lower-bound and upper-bound conditions are independent of any P-multipliers for soil conditions (e.g., liquefied soil) or pile group effects provided in the tables. If an analysis includes lower-bound and liquefied conditions, the lesser of the liquefied P-multiplier and 0.3 should be applied to represent the lower-bound condition.

Table 13 - LPILE Soil Profile, South (Stations 36+30 to 41+80)

| Elevation | | Effective Unit Weight | | Friction P-Multiplier | | P-Y |
|-------------------|-----------|-----------------------|--------|-----------------------|-------------------------------|-----------------------|
| in feet (MLLW) | Soil Type | in pcf | in pci | Angle in degrees | m _p ^(a) | Modulus (k) in pci |
| 18 to 8 | API Sand | 115 | 0.067 | 30 | 1 | 43 |
| 8 to -31 | API Sand | 53 | 0.031 | 30 | 1 [0.1] | 32 |
| −31 to −60 | API Sand | 63 | 0.036 | 35 | 1 [0.35] | 68 |
| -60 and deeper | API Sand | 58 | 0.034 | 32 | 1 | 48 |

a. For liquefied conditions, the P-multiplier provided in [] should be applied in the LPILE analysis.

Table 14 - LPILE Soil Profile, Central (Stations 29+60 to 36+30)

| Elevation in feet | Soil Type | Effective Unit Weight | | Friction | P-Multiplier | P-Y |
|-------------------|-----------|-----------------------|--------|---------------------|------------------------|-----------------------|
| (MLLW) | Soil Type | in pcf | in pci | Angle in degrees | $\mathbf{m}_{n}^{(a)}$ | Modulus (k) in pci |
| 18 to 8 | API Sand | 115 | 0.067 | 30 | 1 | 43 |
| 8 to −26 | API Sand | 53 | 0.031 | 30 | 1 [0.1] | 32 |
| –26 to –65 | API Sand | 63 | 0.036 | 37 | 1 [0.5] | 107 |
| –65 and deeper | API Sand | 63 | 0.036 | 36 | 1 | 93 |

a. For liquefied conditions, the P-multiplier provided in [] should be applied in the LPILE analysis.



Elevation Friction P-Y **Effective Unit Weight P-Multiplier** in feet Soil Type **Angle** Modulus (k) $m_p^{(a)}$ (MLLW) in degrees in pci in pcf in pci 18 to 8 API Sand 125 0.072 36 1 157 8 to -18 **API Sand** 63 0.036 36 1 93 0.036 -18 to -65**API Sand** 63 37 1 [0.5] 107 -65 and deeper **API Sand** 63 0.036 36 1 93

Table 15 - LPILE Soil Profile, Slip 2 Berm (Stations 24+18 to 29+60)

Table 16 - LPILE Soil Profile, Areas with Ground Improvement

| Elevation | | Effective Unit Weight | | Friction | P-Multiplier | P-Y |
|-------------------|-----------|-------------------------|--------|---------------------|----------------|-----------------------|
| in feet (MLLW) | Soil Type | in pcf | in pci | Angle in degrees | m _p | Modulus (k) in pci |
| 18 to 8 | API Sand | 125 | 0.072 | 37 | 1 | 110 |
| 8 to −50 | API Sand | 63 | 0.036 | 37 | 1 | 68 |
| -50 and deeper | API Sand | See appropriate profile | | | | |

Pile Spacing and Group Effects

LPILE results are typically calculated for single piles unaffected by group interactions. Group effects are present for pile spacing of less than 8 pile diameters (center-to-center). The capacity reduction factors in Table 17 should be applied to in-line laterally loaded piles with a center-to-center spacing between 3 and 8 pile diameters (3D and 8D).

Table 17 - LPILE Group Reduction Factors

| | Reduction Factors (P-multipliers) | | | | |
|--------------|-----------------------------------|---------|-------------------------|--|--|
| Pile Spacing | 1st Row | 2nd Row | 3rd and Greater Rows | | |
| 8D | 1.0 | 1.0 | 1.0 | | |
| 6D | 0.95 | 0.9 | 0.8 | | |
| 4D | 0.85 | 0.7 | 0.5 | | |
| 3D | 0.8 | 0.6 | 0.4 | | |

Vertical Pile Capacity

We understand that the proposed wharf will be supported by driven 24-inch, octagonal, pre-stressed concrete piles with compressive working loads of up to 712 kips per pile. The compressive capacity of pile foundations can be achieved through a combination of end-bearing support at the pile tip and side friction between the pile material and the soil along the embedded pile length. There is not a distinct uniform bearing layer at the site; therefore, the piles will achieve much of their capacity from side friction along their length. However, we do expect layers of hard driving over layers of softer driving.



a. For liquefied conditions, the P-multiplier provided in [] should be applied in the LPILE analysis.

We estimated compressive capacity for the 24-inch, octagonal, pre-stressed concrete piles at the site for two representative soil profiles, one at the south end and one at the north end of the pier. We recommend a 100-foot-long transition zone between the north and south profiles. The south profile should be used for the area within 500 feet of the south end of the pier. The north profile should be used north of the transition zone. We estimated pile capacity for two locations: inboard (landside or bulkhead) and outboard (waterside or pier head). The inboard case assumes a ground surface elevation of +14 feet and is representative of the row of piles closest to the bulkhead. The outboard case assumes a ground surface elevation of -55 feet and is representative of the row of piles along the outer edge of the wharf structure.

Our recommended pile capacities were calculated using design equations that have been calibrated to PDA and CAPWAP results for projects at Pier 3 as well as other sites at the Port of Tacoma. Plots of recommended ultimate compressive pile capacities versus elevation are shown on Figures 30 through 33 for piles spaced 3 or more diameters center-to-center. We recommend applying a minimum factor of safety of 2.0 for compression and 3.0 for tension to the ultimate values to obtain allowable working loads for the static load condition. A factor of safety of 2.0 for compression and tension may be used for the kinematic seismic load condition. A factor of safety of 1.0 for compression and tension may be used for the liquefied condition. The weight of the portion of a pile that extends above the ground surface should be treated as a structural load and applied to the pile at the mudline or ground surface. Capacities for the rows of wharf piles between the inboard and outboard rows may be interpolated.

Settlement. The axial load-displacement response of the 24-inch, octagonal, pre-stressed concrete piles can be modelled using side and toe soil springs. We have calculated lower-bound, recommended, and upper-bound soil springs. Table 18 provides side soil springs, and Tables 19 and Table 20 provide toe springs for the south and north profile, respectively. Toe springs provide resistance only in compression. The deflection for each load does not consider elastic compression of the pile above ground.

Table 18 - Axial Side Springs

| Pile Location | Deflection | ir | ot | |
|----------------|------------|-------------|-------------|-------------|
| | in inches | Lower Bound | Recommended | Upper Bound |
| South inboard | 0.0 | 0 | 0 | 0 |
| | ≥ 0.12 | 0.625 | 1.25 | 2.5 |
| South outboard | 0.0 | 0 | 0 | 0 |
| | ≥ 0.12 | 0.7 | 1.4 | 2.8 |
| North inboard | 0.0 | 0 | 0 | 0 |
| | ≥ 0.12 | 0.7 | 1.4 | 2.8 |
| North outboard | 0.0 | 0 | 0 | 0 |
| | ≥ 0.12 | 0.8 | 1.6 | 3.2 |



Table 19 - South Inboard and Outboard Axial Toe Spring

| Deflection | Load in kips | | | | |
|------------|--------------|-------------|-------------|--|--|
| in inches | Lower Bound | Recommended | Upper Bound | | |
| 0.00 | 0 | 0 | 0 | | |
| 0.34 | 25 | 50 | 100 | | |
| 0.44 | 50 | 100 | 200 | | |
| 0.52 | 75 | 150 | 300 | | |
| 0.61 | 100 | 200 | 400 | | |
| 0.73 | 125 | 250 | 500 | | |
| 0.87 | 150 | 300 | 600 | | |
| 1.11 | 175 | 350 | 700 | | |

Table 20 - North Inboard and Outboard Axial Toe Spring

| Deflection | Load in kips | | | | | |
|------------|--------------|-------------|-------------|--|--|--|
| in inches | Lower Bound | Recommended | Upper Bound | | | |
| 0.00 | 0 | 0 | 0 | | | |
| 0.29 | 25 | 50 | 100 | | | |
| 0.43 | 50 | 100 | 200 | | | |
| 0.51 | 75 | 150 | 300 | | | |
| 0.58 | 100 | 200 | 400 | | | |
| 0.64 | 125 | 250 | 500 | | | |
| 0.70 | 150 | 300 | 600 | | | |
| 0.75 | 175 | 350 | 700 | | | |
| 0.82 | 200 | 400 | 800 | | | |
| 0.89 | 225 | 450 | 900 | | | |
| 0.96 | 250 | 500 | 1000 | | | |
| 1.05 | 275 | 550 | 1100 | | | |

Downdrag caused by liquefaction-induced settlement from a seismic event can lead to additional settlement up to the amount that the soil settles.

Pile Drivability Analysis

We performed preliminary wave equation analyses to predict axial pile driving stresses and penetration resistances to achieve the target pile capacities with different hammers. Input parameters were pile information, hammer and driving system, and soil information. For the outboard and inboard piles, we analyzed the behavior of 24-inch, octagonal, prestressed concrete piles driven with APE D62-42 and D80-42 hammers. We assessed the adequacy of the hammer size using the following criteria.



- Driving resistance should be less than approximately 100 blows per foot during hard driving;
- Maximum compressive stress should be less than the allowable stress (0.85 f'c prestress) for concrete; and
- Maximum tensile stress should be less than the allowable stress ($3 \times \sqrt{f'_c}$ + prestress) for concrete, where f'_c and prestress are in psi.

Our driving stress recommendations are those published in Federal Highway Administration (FHWA) publication No. NHI-05-042, "Design and Construction of Driven Pile Foundations" (2006). It may be necessary to select pile material strength based on the driving stresses and allowable values.

Contractor's WEAP Analysis

We recommend requiring the contractor to perform their own Wave Equation Analysis of Piles (WEAP) once the piles, hammer, and driving system have been selected, to confirm the adequacy of the hammer and to estimate driving stresses. Project specifications should be written so that the contractor is responsible for any damage to the piles during installation. In addition, we recommend monitoring selected piles during construction with PDA, and performing CAPWAP to verify adequate pile resistances are achieved.

Preliminary WEAP Analysis

We performed preliminary wave equation analyses using the computer program GRLWEAP to predict axial pile driving stresses and penetration resistances during driving at assumed compressive pile capacities. We performed WEAP analyses for different driving scenarios that represent the pile driving conditions expected during construction. We performed "inspector's chart" analysis of vertical piles.

We modeled two single-acting diesel hammers, APE D62-42 and D80-42. The analysis cases are summarized in Table 21. Input data and results of the WEAP analysis results are shown on Figures 34 through 37 and described in the following sections.

| Table 21 - WEAP Analysis Pile Case Summary |
|--|
|--|

| Pile Location | Length in Feet | Penetration into Bearing Layer in feet | Hammer Type | Figure Number |
|------------------|-------------------|--|----------------|------------------|
| 0 111 | 450 | 00 | APE D62-42 | 34 |
| Outboard | 150 | 80 | APE D80-42 | 35 |
| lab a and | 00 | 00 | APE D62-42 | 36 |
| Inboard | 80 | 80 | APE D80-42 | 37 |

An additional WEAP analysis was completed for an outboard pile with a length of 200 feet and penetration depth of 130 feet. The results of this analysis were nearly identical to the results of the



analysis using a length of 150 feet and penetration depth of 80 feet. This indicates that the results are not particularly sensitive to penetration depth.

Hammer Types. We performed our analyses for two single-acting open-ended diesel hammers that are frequently used in the Puget Sound region for port and harbor construction. The first hammer we considered, the APE D62-42, is manufactured with a 13.7 kip piston (ram), has a nominal maximum stroke of 11.25 feet, and can deliver 154 kip-feet of energy to the hammer cushion and helmet. The second hammer we considered, the APE D80-42, is manufactured with a 17.6 kip piston (ram), has a nominal maximum stroke of 11.25 feet, and can deliver 198 kip-feet of energy to the hammer cushion and helmet. We selected a hammer efficiency of 0.8 for hammers used in a plumb position.

WEAP Results. The results of the WEAP analyses indicate the D62-42 and D80-42 hammers are sufficient for the 24-inch-diameter piles. The results for the outboard 24-inch concrete pile are shown on Figures 34 and 35 for the APE D62-42 and D80-42 hammers, respectively. Results for the inboard 24-inch concrete pile are shown on Figures 36 and 37 for the APE D62-42 and D80-42 hammers, respectively. From the standpoint of pile driving, the results indicate that either of the hammers could be used to achieve the desired ultimate pile capacity of 712 kips. Caution must be taken at low driving resistances, where tensile stresses could exceed allowable limits, and at high driving resistances, where compression stresses could exceed allowable limits. Generally, the tensile stresses are the same between the two hammers, while the D80-42 has higher compressive stresses. However, the D80-42 hammer has an advantage over the D62-42 hammer because it is better able to penetrate through the locally dense soils to reach the design elevation.

Additional Considerations. The output produced by the wave equation analyses depends on the pile, hammer, and soil input parameters. We selected input parameters based on the results of in situ tests, laboratory tests, pile parameters supplied to us by KPFF, and manufacturer-supplied hammer information. Actual field conditions, project requirements, and hammer type and performance may vary from what we have assumed; therefore, the actual drivability and driving stresses may differ from those presented above.

Our analyses did not include possible effects of pile installation such as interruptions to driving and subsequent pile setup. Additionally, the driving stresses computed by the GRLWEAP program do not include stresses that might result from bending or torsion. For best driving performance, it will be important for the contractor to adequately prepare the pile top for driving, use a pile helmet that fits the pile, and maintain the vertical and battered alignment of the hammer, cushions, helmet, and pile for plumb and battered piles, respectively.

Indicator Pile Program

We understand that an indicator pile program is planned for Phase 1 of the Pier 4 project, as shown on the project plans. Experience at the Port of Tacoma has shown us that an indicator pile program is invaluable in determining the required pile lengths. This is especially important for concrete piles, which cannot easily be shortened or lengthened. The indicator piles provide extremely useful information to supplement soil explorations for evaluating pile capacity and drivability.



By careful observation and interpretation of pile installation operations, we believe it is possible to monitor variations in subsurface conditions, estimate the capacity in the field using dynamic pile testing, and optimize pile design and installation criteria. We recommend ordering long enough indicator piles to attain a pile tip elevation of 10 to 20 feet deeper than design to account for possible softer soils than anticipated. The indicator piles should be restruck at the design tip elevation following a minimum set time of 40 hours to evaluate shaft resistance set-up.

Pile Installation and Construction Considerations

Tensile stresses (including bending stresses) may be present in the pile under several circumstances. Times with the greatest risk of damage to the piles from tensile stresses include:

- During handling prior to installation;
- During initial driving; and
- Upon penetrating from an intermediate dense layer into a soft layer.

Tensile stresses during handling may be reduced by using a sufficient number of pickup points. The pile vendor is responsible for the number and placement of the pickup points. We recommend the contractor's structural engineer verify the adequacy of the pickup points.

During initial driving in the upper materials, compressive stress waves may reflect from the pile tip, resulting in a tensile stress wave traveling back up the pile. The contractor can reduce tensile stresses in the piles by using lower driving energies when resistance is low.

A reflected tensile stress wave could also occur when the piles penetrate denser or stiffer materials into underlying looser or softer materials. This condition will likely occur throughout the site in the loose liquefiable sand or soft silt and clay. If the resistance drops unexpectedly as the pile penetrates this layer, large tensile stresses may result. These stresses could exceed the prestress in the piles.

Recommended Monitoring of Pile Installation. Monitoring can often detect unusual soil conditions or installation techniques. We recommend that pile installation include the following minimum monitoring activities:

- Verify adequacy of hammer, cushion, and cap block prior to beginning driving;
- Observe pile handling prior to driving;
- Record the hammer operating characteristics such as fuel setting, stroke, and hammer blows per minute;
- Record the hammer blows per foot of pile penetration;
- Verify capacity using the observed blow count with the S₀ equation (below);
- Monitor movement of adjacent piles or slopes when driving; and
- Provide pile driving analyzer along with CAPWAP analysis for each indicator pile.

Verify Capacity with the S_0 Equation. We recommend verifying the pile capacity using the S_0 equation and the observed blow counts. The S_0 equation provides a method of estimating capacity



from the hammer energy and blow count. It is a simplification of the rational pile formula and is based on the impulse-momentum principles of the hammer/pile system.

The S_o Equation is:

$$Q = \frac{a E_r}{S + S_o}$$

Where:

$$S_o = \left(\frac{aE_r L}{2AE}\right)^{1/2}$$

And:

Q = Ultimate pile capacity in pounds;

 E_r = Rated hammer energy in foot-pounds;

a = Hammer efficiency = assumed value of 0.8 (unless measured);

L = Length of pile in feet;

A = Cross-sectional area of pile in square inches (use annular area for hollow piles, including closed-end steel pipes);

Ε = Modulus of elasticity of pile material in pounds per square inch; and

S = Final set (penetration per blow) in feet.

Both theoretical considerations and pile installation experience indicate that the pile capacity during initial pile driving is typically less than the static pile capacity. This occurs because:

- In granular soils (sand), the vibrations from driving induce excess pore pressures in the nearby soils, reducing the shear strength; and
- In cohesive soils (clay), the soil is remolded during driving; remolded soil strengths are generally less than undisturbed soil strengths.

These strength losses during initial driving are usually regained following installation, rapidly for granular soils (within several days), but more slowly for cohesive soils (weeks to months). Because of this effect, pile resistance derived from initial driving of the pile is considered to underestimate the long-term capacity of the driven piles. We recommended that:

- A minimum safety factor of 2.0 be applied to the ultimate capacity as determined using the pile driving criteria during initial driving.
- If a safety factor of 2.0 is not achieved at the minimum pile tip elevation during initial driving, the pile should be redriven for a short distance following a waiting period. Pile capacity of redriven piles should be evaluated using a factor of safety of 2.5. Restruck piles need to be driven less than



2 feet, with the blow counts in the first 3 inches (normalized to blows per foot) used to estimate the restrike capacity (so capacity is not underestimated).

Bulkhead Design

In the areas where the existing wharf structure will be removed, a new sheet pile bulkhead wall will be constructed at the back of the wharf to support an 8-foot vertical cut at the top of the under-dock slope. To the north, the existing bulkhead will be left in place. The locations of the new and existing bulkheads are shown on Figure 2. We provide recommendations for design of the new bulkhead and analysis of the existing bulkhead in this section.

Lateral Earth Pressures

The lateral pressures acting against a bulkhead depend primarily on:

- Fill material type and degree of compaction immediately adjacent to the wall;
- Surcharges at or behind the wall;
- Flexibility of the wall and the degree of lateral movement the wall undergoes;
- Drainage; and
- Seismic loading considerations.

Lateral loading on the bulkhead can be expected from the soil for both static and seismic loads.

Static Loading. We understand that active conditions will develop behind the new and existing bulkhead walls, which we anticipate will behave as yielding walls. When loaded laterally, the top of a yielding wall will move at least 0.1 percent of its height. Allowable lateral pressures can be estimated using the equivalent fluid pressures in Table 22 for the new and existing bulkhead walls.

Table 22 - Bulkhead Static Lateral Earth Pressures

| | Allowable Equivalent Fluid Weight in pcf | | | | |
|-------------------------|--|------|---------|----------------------|--|
| Condition | New ' | Wall | Existin | ng Wall | |
| | Active Passive ^a | | Active | Passive ^a | |
| Above groundwater table | 35 | 93 | 30 | 140 | |
| Below groundwater table | 16 | 43 | 15 | 70 | |

a. Allowable passive earth pressure includes a factor of safety of 1.5.

The sheet pile wall can act as a barrier to water flow, impounding water behind the bulkhead during low tides. We recommend considering a 5-foot tidal lag across the sheet pile wall. Weep holes could be installed through the wall to reduce the tidal lag.

The equivalent fluid weight does not include any surface or surcharge loading conditions. Any vertical loads behind and adjacent to the bulkhead will impose additional lateral loads on the bulkhead. For uniform surcharge loads, the horizontal pressure on the walls may be calculated as 0.31 and 0.24 times the vertical load at the top of the wall for the new and existing wall, respectively. Other lateral



loads should be incorporated into the bulkhead design case-by-case. Furthermore, we recommend neglecting the passive resistance in the upper 2 feet to account for soil disturbance or erosion.

Lateral loads that are applied longitudinally to the sheet pile bulkhead wall are resisted by friction between the sheet piles and soil along the inboard and outboard sides of the wall. Table 23, at the end of the text, presents the maximum frictional resistance per foot of wall length that can develop under longitudinal loading. The unit resistance is provided at 1-foot increments over the depth of the sheet pile wall. The total resistance for a particular tip elevation should be taken as the sum of the unit resistances down to that elevation. We anticipate the resistances in Table 23 will mobilize at a deflection of approximately 0.12 inch. The soil resistance should be modeled as linear-elastic up to a displacement of 0.12 inch, and as perfectly plastic for displacements greater than 0.12 inch.

Seismic Loading. Lateral loads due to seismic pressure can be computed by applying a rectangular pressure distribution over the height of the bulkhead walls. We performed a Mononobe-Okabe analysis to develop the seismic lateral earth pressures in Table 24. These seismic lateral earth pressures should be added to the active pressures in Table 22.

Table 24 - Bulkhead Seismic Lateral Earth Pressures

| | Uniform Lateral Load in psf | | | |
|---------------|-----------------------------|---------------|--|--|
| Seismic Event | New Wall | Existing Wall | | |
| OLE | 5.2H | 5.0H | | |
| DE | 6.4H | 6.0H | | |
| CLE | 7.4H | 7.0H | | |

Note: H represents the bulkhead height in feet.

Bulkhead Axial Load Transfer Soil Springs

Tables 25 and 26 provide side and toe soil springs for the proposed bulkhead wall consisting of AZ14-700 sheet piles extending from elevation 12.75 to -32.25 feet MLLW (i.e., a 45-foot-long sheet). Toe springs only provide resistance in compression. These springs do not include the elastic compression of the sheet pile.



Table 25 - Axial Bulkhead Side Springs

| Deflection in inches | Load (kips per linear foot of wall) | | | | | |
|----------------------|--|-------------|-------------|--|--|--|
| III IIIOIICS | Lower Bound | Recommended | Upper Bound | | | |
| 0 | 0 | 0 | 0 | | | |
| 0.02 | 8 | 16 | 31 | | | |
| 0.05 | 16 | 32 | 63 | | | |
| 0.1 | 23 | 47 | 93 | | | |
| 0.15 | 27 | 54 | 107 | | | |
| 0.2 | 29 | 57 | 114 | | | |
| 0.25 | 29 | 59 | 117 | | | |
| <u>≥</u> 0.3 | 30 | 60 | 120 | | | |

Table 26 - Axial Bulkhead Toe Springs

| Deflection in inches | Load (kips per linear foot of wall) | | | | | |
|----------------------|--|-------------|-------------|--|--|--|
| III IIIOIICS | Lower Bound | Recommended | Upper Bound | | | |
| 0 | 0.0 | 0.0 | 0 | | | |
| 0.05 | 0.7 | 1.3 | 2.7 | | | |
| 0.1 | 0.8 | 1.6 | 3.3 | | | |
| 0.15 | 0.9 | 1.9 | 3.7 | | | |
| 0.2 | 1.0 | 2.0 | 4.0 | | | |
| 0.25 | 1.1 | 2.2 | 4.3 | | | |
| 0.3 | 1.1 | 2.3 | 4.6 | | | |
| 0.4 | 1.2 | 2.5 | 5.0 | | | |
| 0.5 | 1.3 | 2.7 | 5.3 | | | |
| 0.6 | 1.4 | 2.8 | 5.5 | | | |
| 0.75 | 1.5 | 3.0 | 6.0 | | | |

A combined head spring that also accounts for the elastic compression of the sheet pile may be approximated using a linear-elastic perfectly plastic spring. Values for this simplified head spring are in Table 27.

Table 27 - Simplified Bi-Linear Combined Axial Head Spring

| Deflection in inches | Load in kips per linear for of wall | | | | |
|----------------------|--|-------------|-------------|--|--|
| III IIICIIES | Lower Bound | Recommended | Upper Bound | | |
| 0 | 0 | 0 | 0 | | |
| > 0.2 | 30 | 60 | 120 | | |



Backfill Considerations

We recommend backfilling behind the bulkhead with structural fill. We recommend the following for structural fill:

- When filling above the tidal fluctuation zone, place fill in lifts no greater than 10 inches loose thickness and compact it to a minimum of 95 percent of the modified Proctor maximum dry density (as determined by ASTM D1557 test procedures).
- When filling above the tidal fluctuation zone, control the moisture content of the fill to within 2 percent of the optimum moisture. Optimum moisture is the moisture content corresponding to the maximum Proctor dry density.
- We recommend compaction with a small vibratory plate or self-propelled walk-behind equipment within 2 feet of the wall to minimize potential for overcompaction.
- If small, hand-operated compaction equipment is used to compact structural backfill, fill lifts should not exceed 8 inches of loose thickness.

Bulkhead Settlement

We understand that undesirable post-construction settlement of about 1 to 3 inches has been observed in the soil and pavement adjacent to the pile-supported bulkhead at the Pierce County Terminal and East Blair One Terminal. A transition slab could be installed to mitigate the differential settlement between the at-grade soil and the pile-supported bulkhead. We understand that the Port does not want to incur the expense of a transition slab and would like other alternatives. Alternative mitigation measures, which are not expected to be as effective as a transition slab, include installing short stone columns near the bulkhead and placing select crushed rock (similar to the stone column rock) as backfill adjacent to the bulkhead.

Light Pole Foundations

Based on our experience and on standard practice for similar projects, we recommend deep foundations in the form of 4-foot-diamter drilled shafts to support the light poles at Pier 4. We recommend a minimum embedment depth of 25 feet for the drilled shafts. The vertical capacity is well in excess of the vertical loads; therefore, we do not anticipate that vertical loads will control the design. For lateral design of light pole foundations, we provide generalized LPILE soil parameters that can be used for light poles throughout the site in Table 28.



| Table 28 - LPILE | Soil | Profile | for | Liaht | Pole | Foundations |
|------------------|------|----------|-----|-------|-------|----------------|
| Table 20 Little | - | 1 101110 | 101 | | 1 010 | 1 Odilidations |

| Elevation | Effective Unit Weight | | Friction | D moultinging | D V Madulua | |
|-------------------|-----------------------|--------|----------|------------------|---|---------------------------|
| in feet (MLLW) | Soil Type | in pcf | in pci | Angle in degrees | P-multiplier m _p ^(a) | P-Y Modulus (k) in pci |
| 18 to 8 | API Sand | 115 | 0.067 | 30 | 1 | 43 |
| 8 to -20 | API Sand | 53 | 0.031 | 30 | 1 [0.1] | 32 |

a. For liquefied conditions, the P-multiplier in [] should be applied in the LPILE analysis.

Marine Operations Building Foundations

The existing marine operations building will be demolished and replaced by a similarly sized structure. The precise location of the proposed building has not been determined. If the building is located away from existing soil borings, we will recommend advancing a new boring at the building's location. The recommendations in this section are subject to change when further explorations are carried out in the area of the new proposed building location.

Because the site soils are prone to liquefaction, structures supported on shallow foundations are subject to significant settlement and differential settlement. To reduce differential settlement, the building could be supported on a reinforced concrete mat foundation. Since the proposed building is expected to be lightly loaded, both static and liquefaction-induced differential settlement could be resisted by a reinforced mat foundation. However, the building is expected to settle with the surrounding ground during and after a major earthquake and, as a result, may not be functional following a seismic event.

Mat Foundation

For design and construction of the Marine Operations Building's mat foundation, we recommend:

- Have the mat foundation bear directly on a minimum 2-foot-thick layer of well-compacted structural fill material.
- Use a maximum allowable bearing pressure of 2 kips per square foot for a mat foundation bearing on compacted structural fill at least 1.5 feet below the lowest adjacent grade.
- Use an increase in the allowable soil bearing pressure of up to one-third for loads of short duration, such as those caused by wind or seismic forces.
- Design the mat so it can span a void up to 10 feet in diameter to account for potential seismically induced differential settlement. Additionally, estimate loads from seismically induced differential settlement by assuming that half the magnitude of the total predicted settlement occurs differentially across the building width or length. Our post-liquefaction settlement analysis predicted that as much as 20 inches of settlement could occur at the southern end of Pier 4.



- To estimate lateral spreading loads, use the maximum frictional resistance that can mobilize along the mat foundation over half of the building width. This can be calculated using an unfactored coefficient of friction between the soil and concrete of 0.5.
- For resistance to lateral loads, use an equivalent fluid density to represent the passive resistance of the soil. For a mat foundation poured neat against the native loose to medium dense sand above the groundwater table, we recommend neglecting the upper 2 feet of passive resistance and using an allowable passive equivalent fluid density of 93 pounds per cubic foot in a triangular pressure distribution. A factor of safety of 1.5 has been applied to this value.
- Use an allowable coefficient of friction of 0.35 for a mat foundation poured neat on compacted structural fill for resistance on the base of foundations. A factor of safety of 1.5 has been applied to this value.
- Use a modulus of subgrade reaction based on a 1-foot-by-1-foot square plate $[k_{(1x1)}]$ of 200 pounds per cubic inch. Use the equations below to correct for different foundation sizes and shapes.

Correction for Size

For a square foundation of size B x B:

$$k_{(BxB)} = k_{(1x1)} \frac{(B+1)^2}{4B^2}$$
 for footings where B \le 20 feet

$$k_{(BxB)} = k_{(1x1)} \frac{(B+1)^2}{2B^2}$$
 for footings where B \geq 40 feet

For footings where 20 < B < 40, perform linear interpolation using the two equations above.

Correction for Shape:

For a rectangular foundation of size B x L:

$$k = k_{(BxB)} \frac{(1+0.5\frac{B}{L})}{1.5}$$

Where:

k = modulus of subgrade reaction of rectangular footing;

 $k_{(BxB)}$ = modulus of subgrade reaction of square footing;

 $k_{(1x1)}$ = modulus of subgrade reaction of footing with dimensions of 1 foot by 1 foot;

B =footing width; and

L = footing length.



- Place a capillary break under the building slab. Use a minimum of 6 inches of free-draining granular material with less than 3 percent by weight passing the U.S. No. 200 mesh sieve (based on the minus 3/4-inch fraction) for the capillary break. Above the free-draining material, install a vapor barrier directly below the concrete slab.
- Because of the depth to groundwater, and the fact that this is a fully paved and level site with surface drainage, foundation drains are not required.
- Before concrete is placed for the foundation, make sure subgrade soil are in a very dense, non-yielding condition. Remove any disturbed soil. Also, mud mats may be necessary to protect silty subgrade soil from being disturbed during construction after it is exposed.
- Have a Hart Crowser representative observe exposed subgrades before foundation construction to verify design assumptions about subsurface conditions and subgrade preparation.

Foundation Settlement

When designed and constructed as described above, a relatively stiff mat foundation will have an estimated total static settlement of approximately 1 inch. We estimate that differential static settlement within a relatively stiff mat foundation will be about one-half of the total settlement. We anticipate that the static settlement will be elastic, and will occur as loads are applied. Seismic settlement will occur in addition to static settlements, as described previously.

Utilities

In general, we recommend that utility trench cut design be the contractor's responsibility. For shallow trench excavations less than 4 feet deep, open cutting is not prohibited. Temporary shoring may be necessary if deeper excavation is required for utility placement or if the soils are unstable. The contractor should verify the condition of the side slopes during construction, and lay back trench cuts as necessary to conform to current standards of practice. We can provide additional recommendations as required.

Foundation Support for Underground Civil Structures

The following foundation recommendations cover design and construction of proposed stormwater structures, manholes, catch basins, and similar underground structures:

- Use a maximum allowable bearing pressure of 5 kips per square foot (ksf) for foundations bearing 10 feet below surface grade or deeper.
- Use a maximum allowable bearing pressure of 2 ksf for structures founded above the groundwater table and bearing on soil within the upper 3 feet below existing grade.
- For foundation subgrades below the groundwater table, we anticipate that soft or loose conditions will be encountered when excavations reach planned foundation elevations and may require overexcavation. The need for overexcavation should be determined in the field during construction



by a Hart Crowser representative. Overexcavation could extend up to 3 feet below the design subgrade elevation. A woven geotextile fabric may need be installed over the overexcavated subgrade, followed by free-draining crushed rock or quarry spalls. Quarry spalls should be compacted by thoroughly tamping with the heel of an excavator bucket or using a similar procedure. The geotextile should then be wrapped over the top of the spalls. A minimum of 6 inches of crushed surfacing base course (CSBC) or 1.25-inch-minus gravel should then be placed to backfill up to the required foundation bearing surface (subgrade) elevation. The geotextile over the spalls will separate the spalls from the smaller crushed rock above.

- For foundations above the groundwater table and bearing on soil within the upper 3 feet below existing grade, overexcavation may be required if soft or loose material is encountered during footing excavation. A Hart Crowser field representative should determine the need for and extents of overexcavation. If the overexcavated soil is suitable for recompaction, it can be reused.
- The proposed structures may either consist of precast concrete segments or be cast-in-place. A sand bedding may be required for placement of some precast units. Depending on whether sand bedding is required for installation, we recommend the following for subgrade:
 - Where a layer of sand bedding over the prepared subgrade is required for positioning, leveling, and assembling precast components/segments, the sand should not be more than approximately 3 inches thick.
 - Where cast-in-place concrete is used or sand bedding is not required for placement of precast units, the foundation should be cast or placed directly onto the prepared subgrade.
- An increase in the allowable soil bearing pressure of up to one-third for loads of short duration, such as seismic forces, should be allowed.
- To consider frost penetration, place the base of all footings at least 18 inches below the lowest adjacent finished grade.
- Found structure foundations outside of an imaginary 1H:1V plane (where H is horizontal and V is vertical) projected upward from the bottom edge of any adjacent footings or utility trenches. If structure foundations are founded within the imaginary 1H:1V projection, loads may be transferred through the soil to the lower footing of interest, potentially exceeding the bearing capacity. When structure foundations cannot be founded outside of the 1H:1V projection, consult with Hart Crowser to assess potential foundation design implications.
- Use a modulus of subgrade reaction based on a 1-foot-by-1-foot square plate $[k_{(1x1)}]$ of 100 pounds per cubic inch (pci) in cases in which the water table is within 1.5B of the foundation, where B is the footing width. For cases in which the water table is deeper than 1.5B below the foundation, use a $k_{(1x1)}$ of 200 pci. Use the equations in section Marine Operations Building Foundations to correct for different foundation sizes and shapes.



Foundation Settlement

Assuming proper subgrade preparation, we expect total post-construction settlement to be less than about 1 inch. Elastic settlement from foundation loads on sandy soils should generally occur as the loads are applied. Maximum differential settlement is typically estimated to be one-half of the total settlement.

Utility Bedding and Trench Backfill

For bedding and trench backfill materials, all minimum dry densities recommended are a percentage of the modified Proctor maximum dry density as determined by the ASTM D1557 test procedure. We recommend the following for bedding and trench backfill materials:

- Use at least 6 inches of bedding for all pipe utilities, consisting of well-graded sand and gravel with less than 3 percent material passing the No. 200 sieve based on the minus 3/4-inch fraction. Bedding material should be compacted to a firm non-yielding condition.
- The recommended bedding materials can be used as backfill around the pipe utilities (pipe zone backfill). Extend pipe zone backfill to at least the top of the utility pipe.
- For bedding material beneath catch basins, vaults, and manholes, use 6 inches of imported structural fill (or acceptable on-site material) that consists of well-graded sand and gravel with less than 3 percent material passing the No. 200 sieve based on the minus 3/4-inch fraction. Compact the bedding material to 90 percent.
- Provide a firm, non-yielding, and stable subgrade for excavations for underground structures.
- Evaluate utilities that extend below the water table for the potential to float out of the ground during high groundwater levels.

Deeper utilities may require dewatering well points to obtain a suitable working base. The contractor may elect to place a geotextile fabric at the base of the excavation to help create a suitable working surface.

Structural Fill

Soil placed beneath structures, surrounding utilities, or below paved areas should be considered structural fill. In these fill areas, we recommend the following:

For imported soil to be used as structural fill, use a clean, well-graded sand or sand and gravel with less than 5 percent by weight passing the No. 200 mesh sieve (based on the minus 3/4-inch fraction) for wet-weather grading. Compaction of material containing more than about 5 percent fine material may be difficult if the material is wet or becomes wet during rainy weather. During dry weather grading, the fines content may be increased provided that the soil is compacted near its optimum moisture content.



- For structural fill placed as crushed surfacing base course below pavement and sidewalks, use material that meets the requirements of WSDOT Standard Specification 9-03.9[3].
- Place structural fill only on a dense and non-yielding subgrade.
- Place and compact all structural fill in lifts with a loose thickness no greater than 10 inches. If small, hand-operated compaction equipment is used to compact structural fill, lifts should not exceed 6 inches in loose thickness.
- Control the moisture content of the fill to within 2 percent of the optimum moisture (the moisture content corresponding to the maximum modified Proctor dry density).
- Require compaction of at least 95 percent below all structures, slabs-on-grade, pavement, or sidewalks. The minimum dry densities recommended here are a percentage of the modified Proctor maximum dry density as determined by the ASTM D1557 test procedure.
- If wet subgrade areas are encountered during foundation or pavement section preparation, clean material with a gravel content (material coarser than a US No. 4 sieve) of at least 30 to 35 percent may be necessary.
- Have a Hart Crowser geotechnical engineer or engineering geologist verify the compacted densities of each lift.

Before fill control can begin, the compaction characteristics must be determined from representative samples of the structural and drainage fill. Samples should be obtained as soon as possible. A study of compaction characteristics should include determination of optimum and natural moisture content, maximum dry density, and gradation of the soil.

Use of On-Site Soil as Structural Fill

The suitability of excavated site soil for use as compacted structural fill depends on the gradation and moisture content of the soil when it is placed. As the amount of fines (the portion passing the No. 200 sieve) increases, the soil becomes increasingly sensitive to small changes in moisture content, and adequate compaction becomes more difficult to achieve. Soil containing more than about 5 percent fines cannot be consistently compacted to a dense non-yielding condition when the water content is greater than about 2 percent above or below optimum. To be reusable, soil must also be free of organic and other compressible materials.

Results of our laboratory analysis indicate that the on-site soil likely has a fines content great enough to make it moisture-sensitive when wet. It is possible that the soil could be used as fill during the drier summer construction season, especially if the material can be aerated using dozers or agricultural discs. During periods of wet weather, it will be more difficult to use these materials. Earthwork operations would need to be scheduled for periods of dry weather to keep the moisture content of the material near its optimum level.



Infiltration

We understand that stormwater collected at the site will require some level of treatment prior to discharge. After water has gone through an oil/water separator, biofiltration is a preferred treatment. The near-surface soils in this vicinity are generally silt and sand. We estimate a long-term design infiltration rate for these soils on the order of 0.25 to 2 inches per hour; these rates correspond to sandy loam and sand, respectively, in Stormwater Management Manual for Western Washington (Ecology 2005). We recommend that any infiltration facility have a backup outlet so it will not flood during an intense storm event or if the system becomes clogged. Alternatively, biofiltration could be performed without infiltration.

RECOMMENDATIONS FOR CONTINUING GEOTECHNICAL **SERVICES**

Throughout this report, we have provided recommendations where we believe it is appropriate for Hart Crowser to provide additional geotechnical input to the design and construction process. Many of these recommendations and some additional recommendations are summarized in this section.

Continuing Design and Consultation Services

Before construction begins, we recommend that Hart Crowser:

- Continue to meet with the design team as needed to address geotechnical questions that may arise throughout the remainder of the design process;
- Observe installation and testing of the indicator piles; and
- Review the project plans and specifications to see that the geotechnical engineering recommendations are properly interpreted.

Construction Services

During the construction phase of the project, we recommend retaining Hart Crowser to:

- Review applicable submittals;
- Observe installation of piles and ground improvement;
- Observe shallow foundation subgrade conditions for the Operations Building;
- Observe installation of light pole foundations;
- Consult with the construction team as needed; and
- Respond to other geotechnical engineering considerations that may arise during construction.



REFERENCES

ASCE 2005. Minimum Design Loads for Buildings and Other Structures, ASCE Standard ASCE/SEI 7-05.

ASCE 2010. Minimum Design Loads for Buildings and Other Structures, ASCE Standard ASCE/SEI 7-10.

ASCE 2014. Seismic Design of Piers and Wharves, ASCE Standard ASCE/COPRI 61-14.

Beaty, M.H. and P.M. Byrne 2011. UBCSAND Constitutive Model Version 904aR. Itasca Consulting.

Boulanger, R.W., and I.M. Idriss 2004. State Normalization of penetration resistances and the effect of overburden stress on liquefaction resistance. Proceedings of 11th International Conference on Soil Dynamics and Earthquake Engineering, and 3rd International Conference on Earthquake Engineering. Stallion Press, Vol 2, 484-91.

Brocher, T.M., R.J. Blakely 2004. Interpretation of the Seattle Uplift, Washington, as a Passive-Roof Duplex, Bulletin of the Seismological Society of America, Vol. 94, No. 4, August. 1379–1401.

Cetin, K.O, H.T Bilge, J. Wu, A.M. Kammerer, R.B. Seed 2009. Probabilistic model for the assessment of cyclically induced reconsolidation (volumetric) settlements. Journal of Geotechnical and Geoenvironmental Engineering, Vol. 135, No. 3, March 1, 2009, 387–398.

Cliq 2006. CPT Soil Liquefaction Assessment Software. V.1.3.

Darendeli, M.B. 2001. Development of a New Family of Normalized Modulus Reduction and Material Damping Curves. Doctor of Philosophy Dissertation. The University of Texas at Austin. August 2001.

Dobry, R., W.G. Pierce, R. Dyvik, G.E. Thomas, and R.S. Ladd 1985. "Pore pressure model for cyclic straining of sand." Research Report, Civil Engineering Department, Rensselaer Polytechnic Institute, Troy, New York.

Ecology 2005. Stormwater Management Manual for Western Washington. Publication Numbers 05-10-029 through 05-10-033. Washington State Department of Ecology.

FHWA 2006. Design and Construction of Driven Pile Foundations. No. FHWA NHI-05-042. Volume 1. U.S. Department of Transportation Federal Highway Administration. April 2006.

Galavi, V., A. Petalas, and R.B.J. Brinkgreve 2013. Finite Element Modelling of Seismic Liquefaction in Soils. Geotechnical Engineering Journals of the SEAGS and AGSSEA, Vol. 44 No. 3.

Hart Crowser 2014. Geotechnical Data Report, Port of Tacoma: Pier 4 Reconfiguration, Tacoma, Washington, Prepared for KPFF Consulting Engineers, September 18, 2014, 17916-01

International Code Council 2012. 2012 International Building Code.



Idriss, I.M., and R.W. Boulanger 2003. Estimating K_{α} for use in evaluating cyclic resistance of sloping ground. Proceedings, 8th US-Japan Workshop on Earthquake Resistant Design of Lifeline Facilities and Countermeasures against Liquefaction. Report MCEER-03-0003, MCEER, SUNY Buffalo, NY, pp 449–69.

Idriss, I.M. and R.W. Boulanger 2008. Soil Liquefaction during Earthquakes. EERI Publication MNO-12.

Kramer, S.L., A.J. Hartvigsen, S.S. Sideras, P.T. Ozener 2011. Site response modelling in liquefiable soil deposits. 4th IASPEI/IAEE International Symposium 2011: Effects of Surface Geology on Seismic Motion.

Matasović, N. and G. Ordóñez 2009. D-MOD2000. A computer program for nonlinear seismic response analysis of horizontally layered soil deposits, earthfill dams, and solid waste landfills. V1.03.

Matasovic, N. and M. Vucetic 1993. Cyclic characterization of liquefiable sands. ASCE Journal of Geotechnical and Environmental Engineering, 119(11), 1805–1822.

Matasovic, N. and M. Vucetic 1995. Generalized Cyclic Degradation-Pore Pressure Generation Model for Clays. ASCE Journal of Geotechnical Engineering, Vol. 121, No. 1, 33–42.

PLAXIS 2014. PLAXIS 2D Anniversary Edition. Material Models Manual.

Rathje, E.M. and G. Saygili 2009. Probabilistic based seismic landslide hazard maps: An application in Southern California. Engineering Geology, Vol. 109, Issue 3, 183–194.

Rayamajhi, D., T. V. Nguyen, S. A. Ashford, R. W. Boulanger, J. Lu, A. Elgamal, and L. Shao 2012. Effect of discrete columns on shear stress distribution in liquefiable soil. Geo-Congress 2012: State of the Art and Practice in Geotechnical Engineering, Geotechnical Special Publication No. 225, ASCE Geo-Institute, 1908–1917.

Shahi S.K, and J.W. Baker 2013. NGA-West2 Models for Ground-Motion Directionality. PEER Report 2013/10, May 2013

USGS 2008. U.S. Geological Survey National Seismic Hazard Maps. http://earthquake.usgs.gov/research/hazmaps/

Vucetic, M., and R. Dobry 1988. Cyclic Triaxial Strain-Controlled Testing of Liquefiable Sands. Advanced Triaxial Testing of Soil and Rock, ASTM STP 977, American Society for Testing and Materials, Philadelphia, 475–485.

Washington State Department of Natural Resources 2009. Tsunami Hazard Map of Tacoma, Washington: Model Results for Seattle Fault and Tacoma Fault Earthquake Tsunamis, Open File Report 2009-9.

Washington State Department of Transportation, Geotechnical Design Manual, Publication No. M46-03, November 2010.



WSDOT 2014. Standard Specifications 2014, Publication No. M41-10. Washington State Department of Transportation.

Yoshimine et al. 2006. Flow deformation of liquefied sand under constant shear load and its application to analysis of flow slide in infinite slope. Soil Dynamics and Earthquake Eng. 26, 253-264.

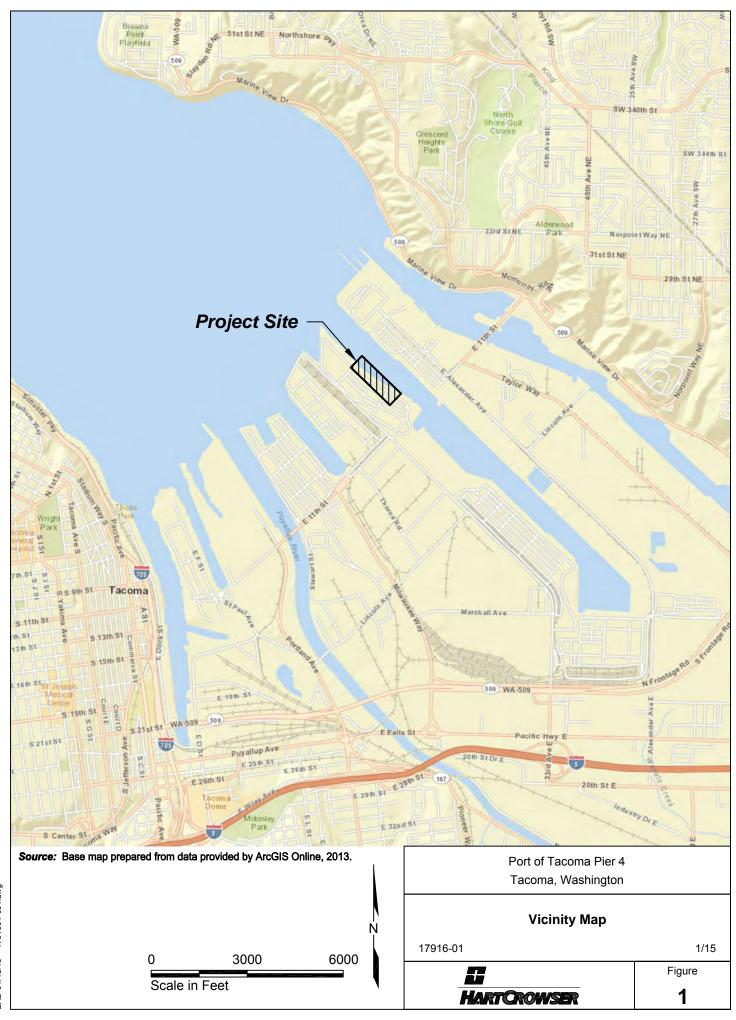
Youd, T.L. et al. Liquefaction Resistance of Soils: Summary Report from the 1996 NCEER and 1998 NCEER/NSF Workshop on Evaluation of Liquefaction Resistance of Soils, ASCE, Journal of Geotechnical & Geoenvironmental Engineering, Vol. 127, October, pp 817-833.

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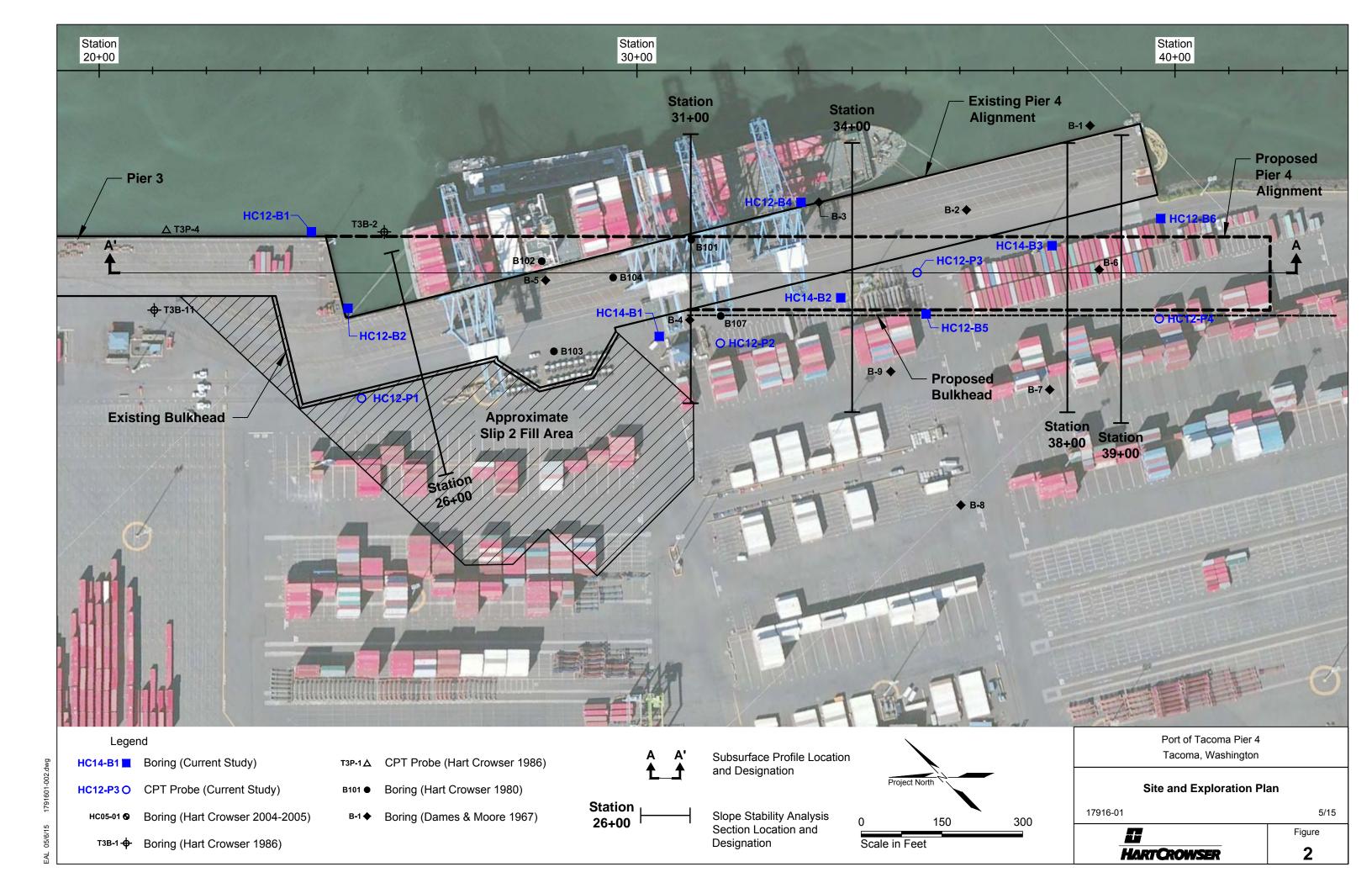


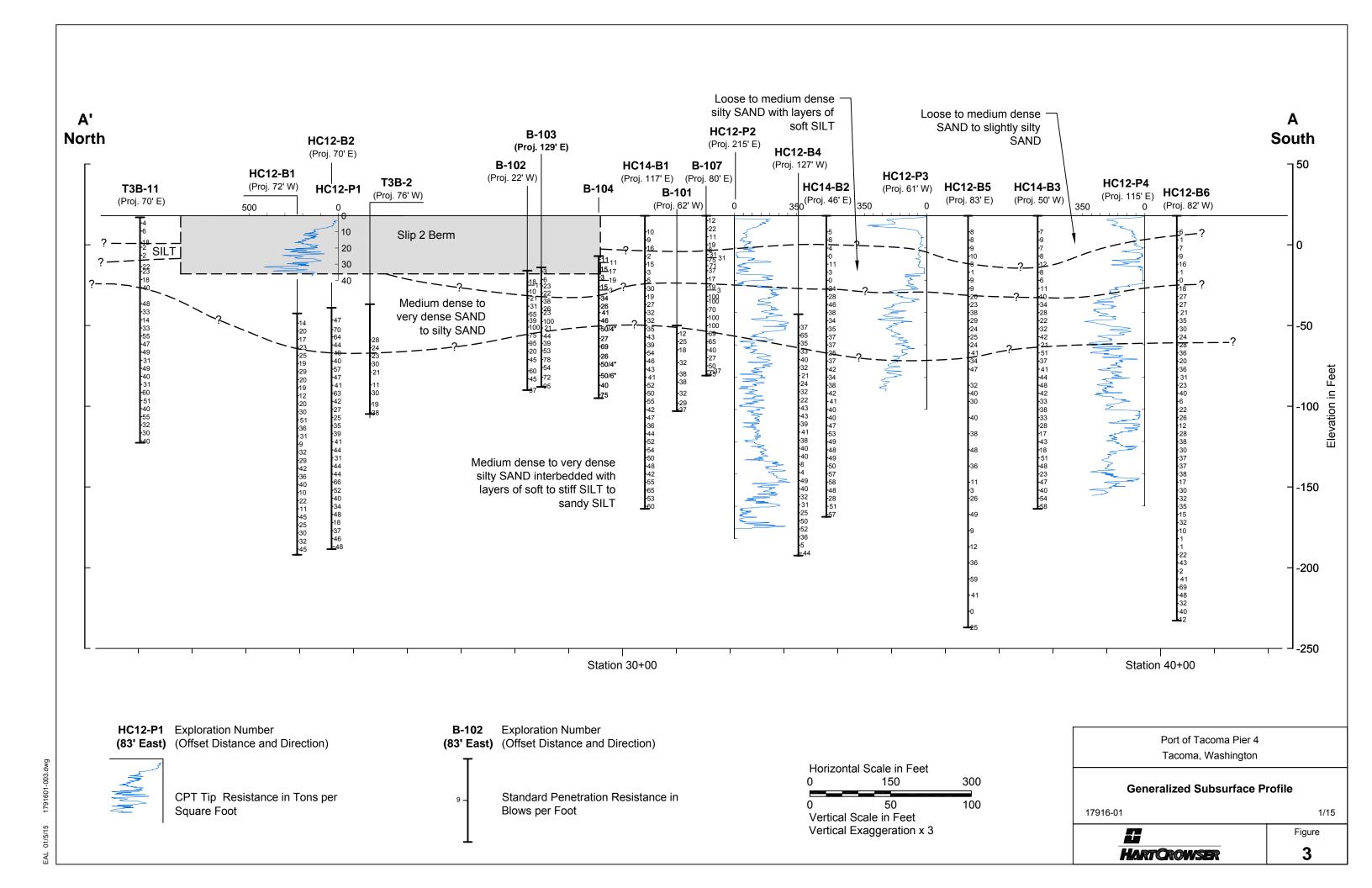
Table 23 - Bulkhead Longitudinal Springs

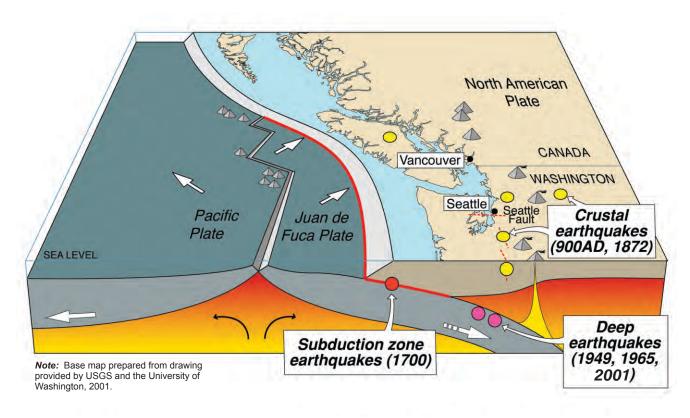
| Table 23 - Bulkile | ad Longitudinal Springs |
|--------------------------------------|---------------------------|
| | Unit Longitudinal |
| Elevation | Resistance |
| in Feet | in Pounds per Lineal Foot |
| 12.75 | 87 |
| 11.75 | 120 |
| 10.75 | 139 |
| 9.75 | 159 |
| 8.75 | 178 |
| 7.75 | 197 |
| 6.75 | 216 |
| 5.75 | 235 |
| 4.75 | 254 |
| 3.75 | 273 |
| 2.75 | 293 |
| 1.75 | 312 |
| 0.75 | 331 |
| -0.25 | 350 |
| -1.25 | 369 |
| -2.25 | 388 |
| -3.25 | 408 |
| -4.25 | 427 |
| -5.25 | 446 |
| -6.25 | 465 |
| -7.25 | 484 |
| -8.25 | 503 |
| -9.25 | 522 |
| -10.25 | 542 |
| -11.25 | 561 |
| -12.25 | 580 |
| -13.25 | 599 |
| -14.25 | 618 |
| -15.25 | 637 |
| -16.25 | 656 |
| -17.25 | 676 |
| -18.25 | 695 |
| -19.25 | 714 |
| -20.25 | 733 |
| -21.25 | 752 |
| -22.25 | 771 |
| -23.25 | 791 |
| -24.25 | 810 |
| -25.25 | 829 |
| -26.25 | 848 |
| -27.25 | 867 |
| -28.25 | 886 |
| | 905 |
| | |
| | 944 |
| -32.25 | 963 |
| -28.25 -29.25 -30.25 -31.25 | 886 905 925 944 |



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| Source | Maximum Magnitude | Not to Scale |
|--------------------------------------|----------------------|--------------|
| Cascadia Subduction Zone - Interface | 9.0 | |
| Cascadia Subduction Zone - Intraslab | 7.5 | |
| Crustal Faults | 7.5 | |

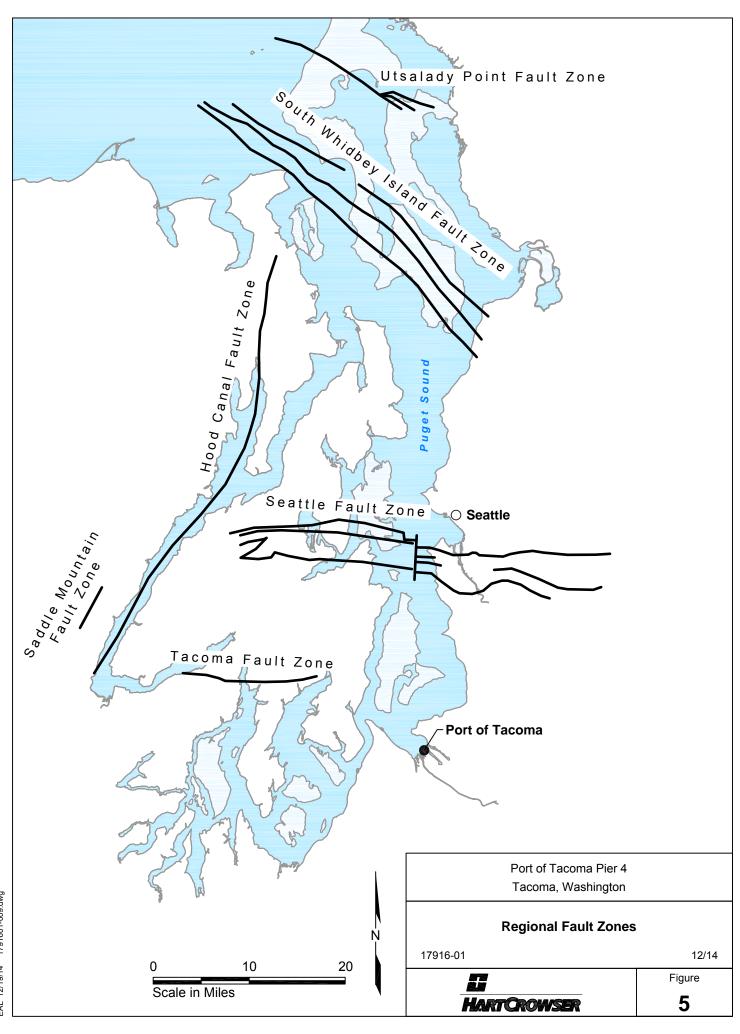
| Port of Tacoma Pier 4 |
|-----------------------|
| Tacoma, Washington |

Cascadia Subduction Zone Earthquake Sources

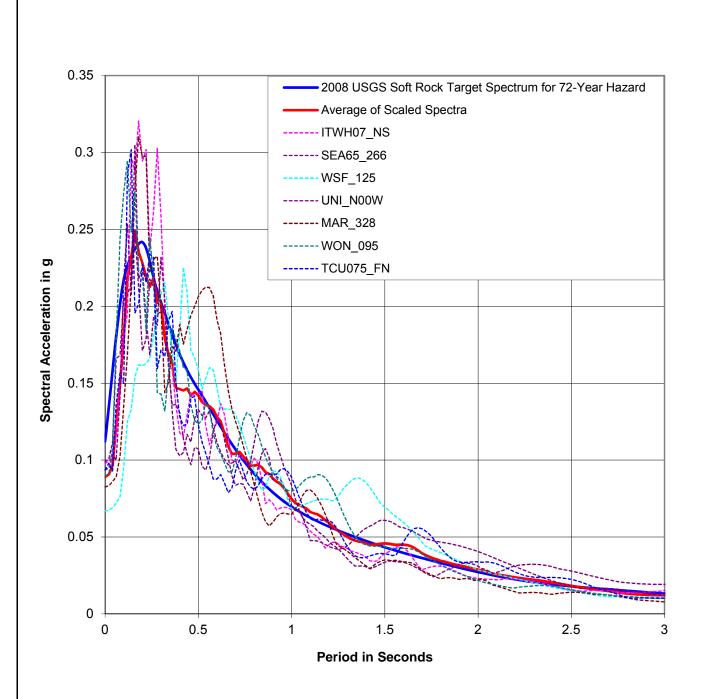
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Figure



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Port of Tacoma Pier 4 Tacoma, Washington

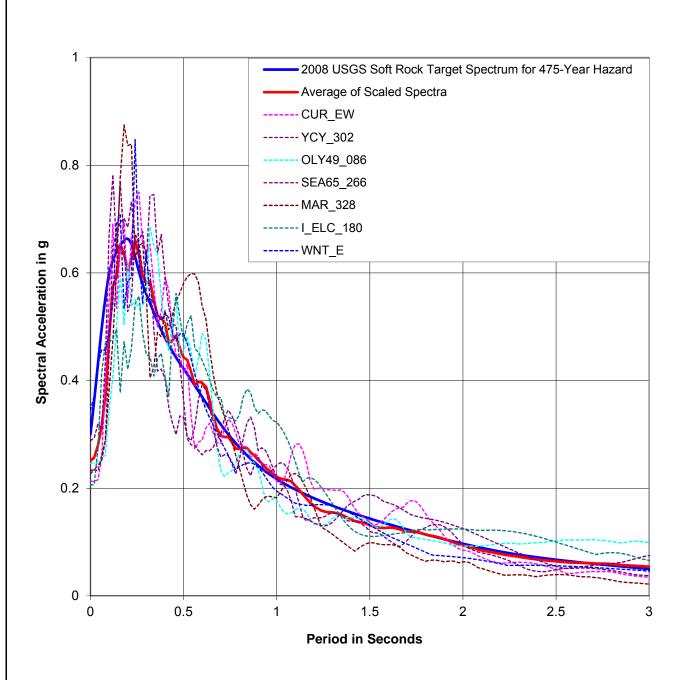
Response Spectra of Scaled Soft Rock Input Ground Motions for 72-Year Hazard

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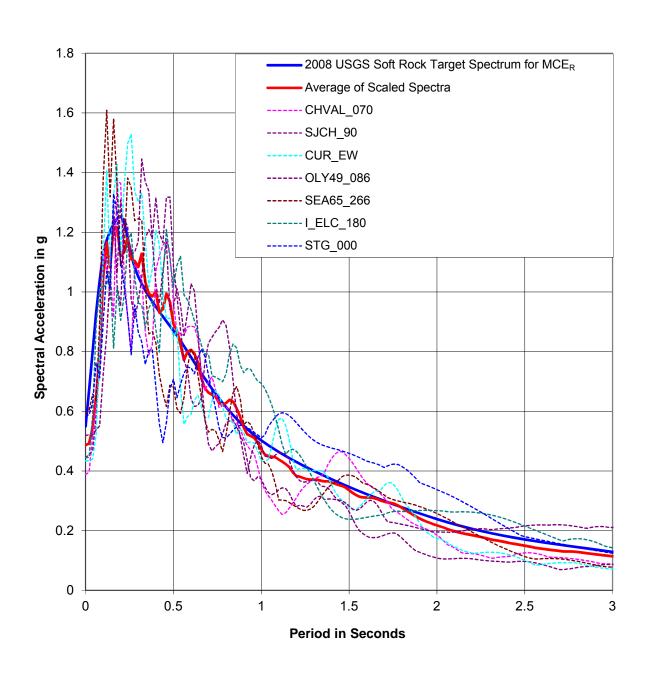
Port of Tacoma Pier 4 Tacoma, Washington

Response Spectra of Scaled Soft Rock Input Ground Motions for 475-Year Hazard

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Figure



Port of Tacoma Pier 4
Tacoma, Washington

Response Spectra of Scaled Soft Rock Input
Ground Motions for MCE_R

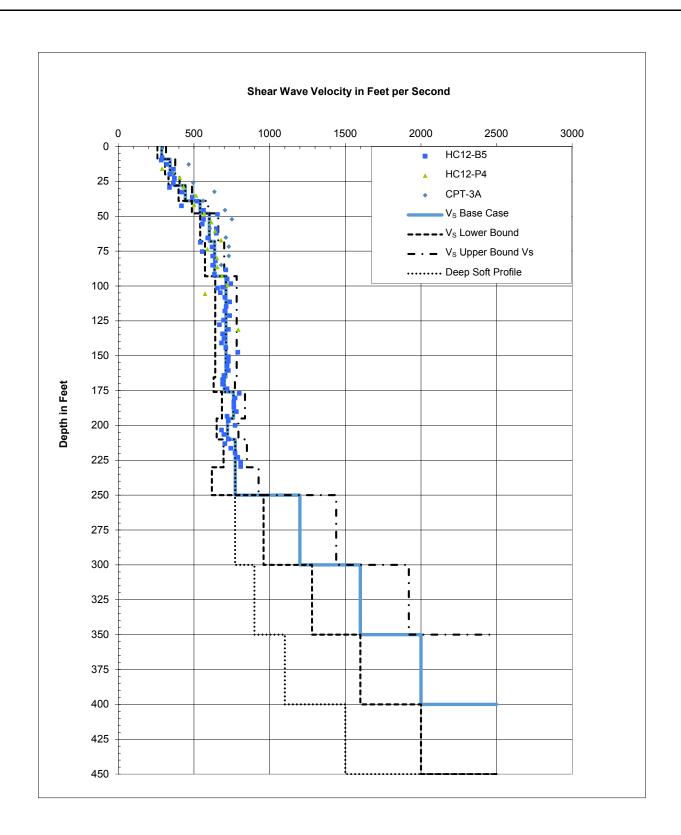
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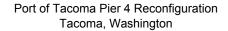
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Figure

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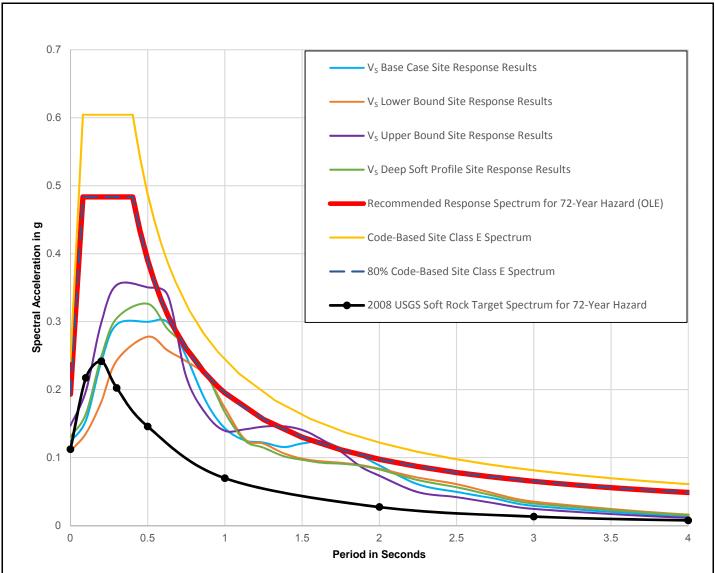


Shear Wave Velocity Profiles

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Recommended Reponse Spectrum Period in Acceleration

| Seconds in g | |
|--------------|-------|
| 0 | 0.193 |
| 0.081 | 0.483 |
| 0.404 | 0.483 |
| 0.5 | 0.390 |
| 0.75 | 0.260 |
| 1 | 0.195 |
| 1.25 | 0.156 |
| 1.5 | 0.130 |
| 1.75 | 0.111 |
| 2 | 0.098 |
| 2.5 | 0.078 |
| 3 | 0.065 |
| 4 | 0.049 |

Note:

Reference Figure 9 for details on different shear wave velocity (V_{S}) profiles.

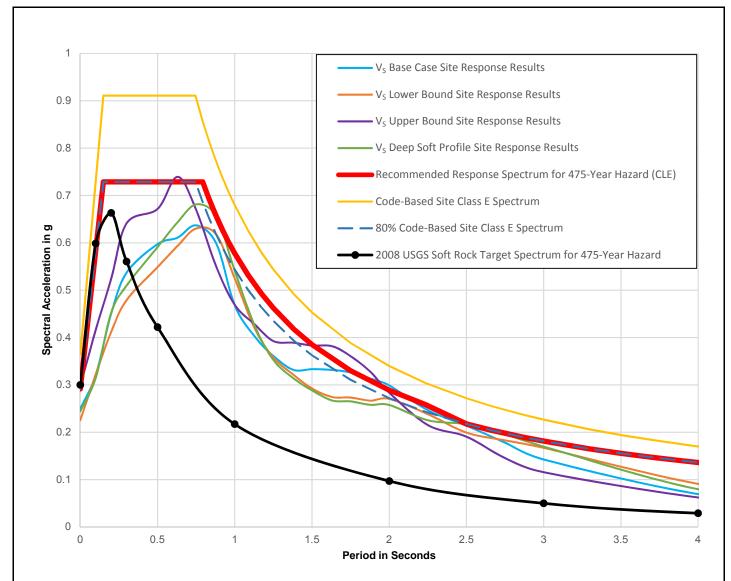
Port of Tacoma Pier 4 Tacoma, WA

Site Response Results and Recommended Response Spectrum for 72-Year Hazard

17916-01 7/14

HARTCROWSER

Figure



Recommended Reponse Spectrum Period in Acceleration

| Seconds | in g |
|---------|-------|
| 0 | 0.292 |
| 0.149 | 0.729 |
| 0.793 | 0.729 |
| 1 | 0.578 |
| 1.25 | 0.462 |
| 1.5 | 0.385 |
| 1.75 | 0.330 |
| 2 | 0.289 |
| 2.5 | 0.217 |
| 3 | 0.181 |
| 4 | 0.136 |

Note:

Reference Figure 9 for details on different shear wave velocity (V_S) profiles.

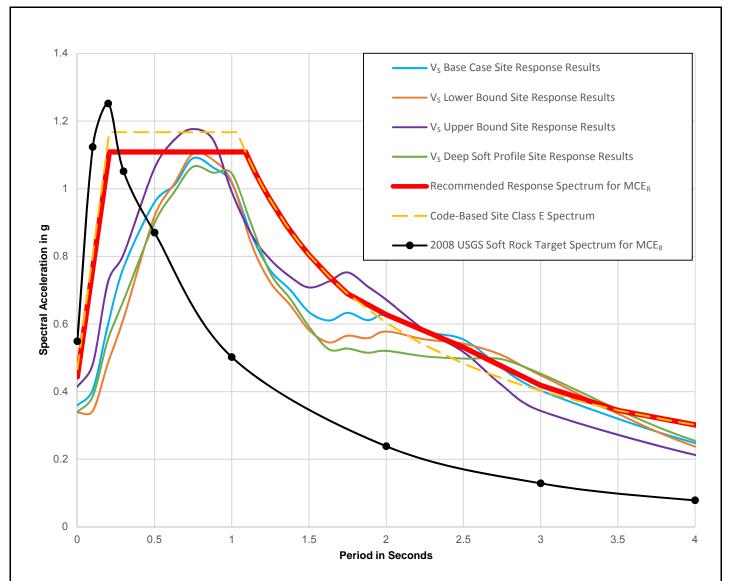
Port of Tacoma Pier 4 Tacoma, WA

Site Response Results and Recommended Response Spectrum for 475-Year Hazard

17916-01 7/14



Figure



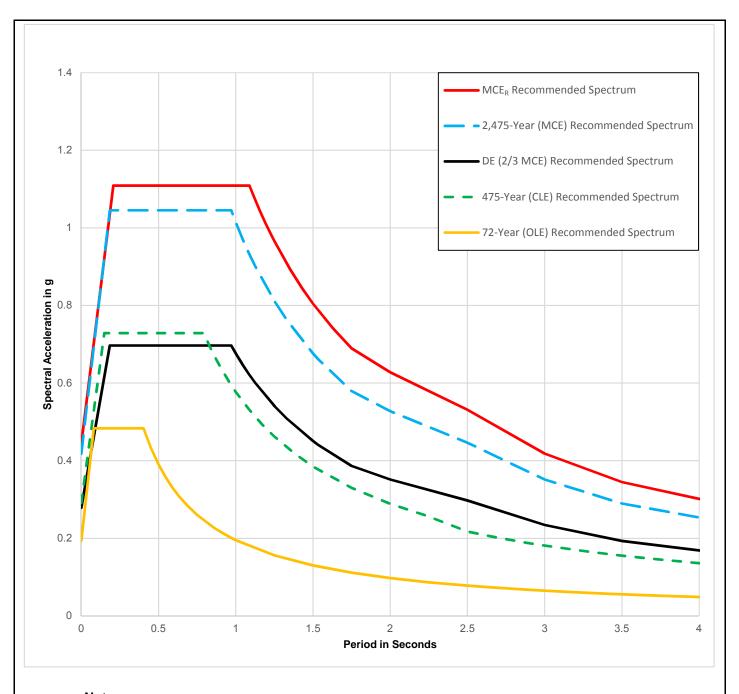
Recommended Reponse Spectrum Period in Acceleration

| Seconds | in g |
|---------|-------|
| 0 | 0.444 |
| 0.207 | 1.109 |
| 1.089 | 1.109 |
| 1.25 | 0.966 |
| 1.5 | 0.805 |
| 1.75 | 0.690 |
| 2 | 0.628 |
| 2.5 | 0.531 |
| 3 | 0.418 |
| 4 | 0.302 |
| | |

Note:

Reference Figure 9 for details on different shear wave velocity $(V_{\rm S})$ profiles.

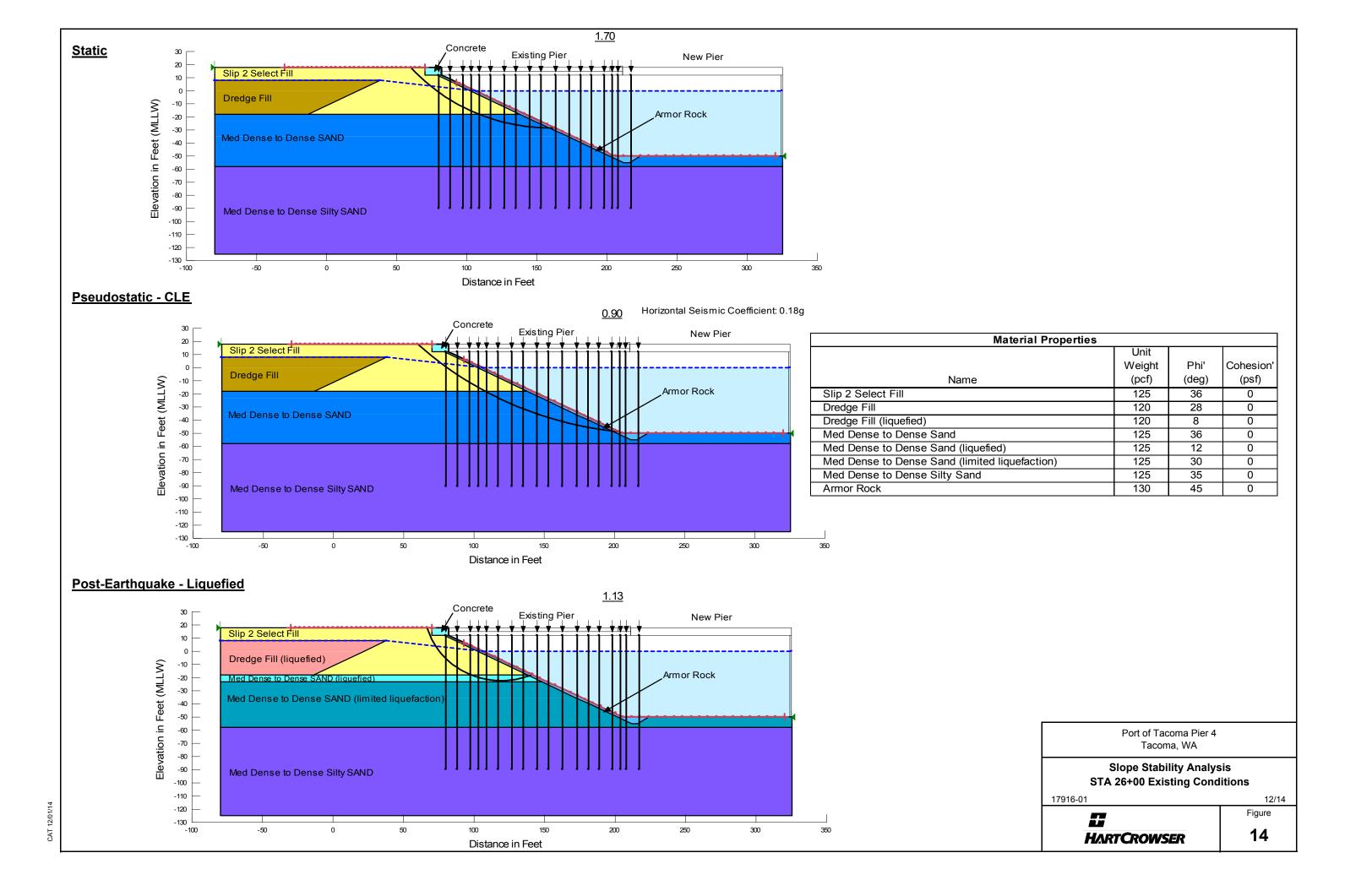
| Port of Tacoma Pier 4 Tacoma, WA | | |
|--|--------|--|
| Site Response Results and Recommended Response Spectrum for MCE _R | | |
| 17916-01 | 8/14 | |
| <i>=</i> | Figure | |
| HART CROWSER | 12 | |

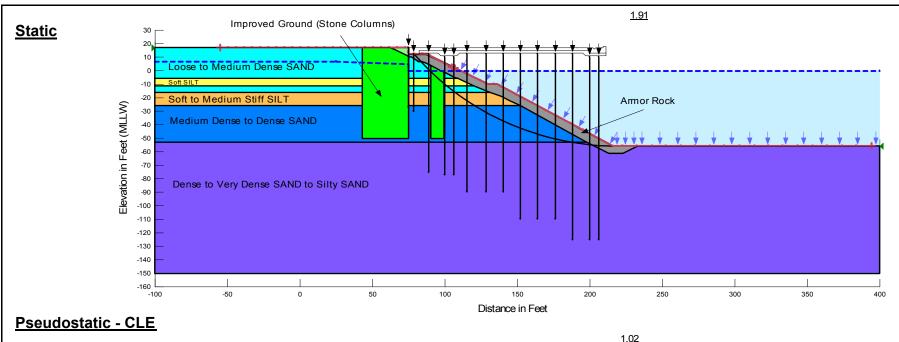


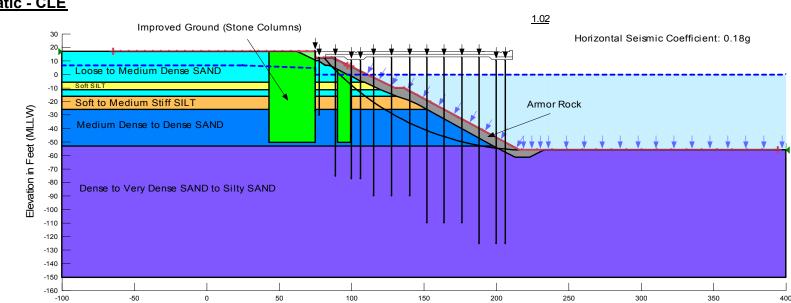
Notes:

- a. The design earthquake (DE) is 2/3 of the MCE based on ASCE 61-14 and ASCE 7-05.
- **b.** For the MCE recommended response spectrum we used the same spectral shape as calculated from the MCE_R site response analysis.
- **c.** Reference Figures 10 to 12 for results of site response analysis and recommended spectra for individual hazards.

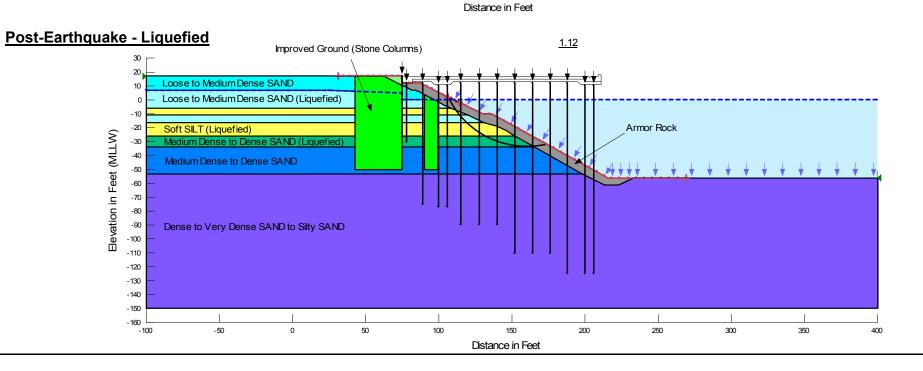
| oonse Spectra |
|---------------|
| 8/1 |
| Figure |
| 13 |
| |







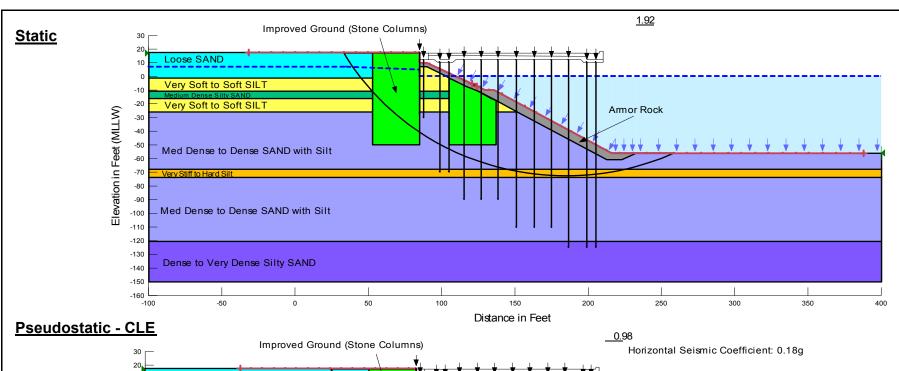
| Material Properties | | | |
|--------------------------------------|--------|-------|-----------|
| | Unit | | |
| | Weight | Phi' | Cohesion' |
| Name | (pcf) | (deg) | (psf) |
| Loose to Med Dense SAND | 120 | 32 | 0 |
| Loose to Med Dense SAND (liquefied) | 120 | 8 | 0 |
| Soft SILT | 110 | 26 | 0 |
| Soft to Med Stiff SILT | 110 | 28 | 0 |
| Soft SILT (liquefied) | 110 | 5 | 0 |
| Med Dense to Dense SAND | 125 | 34 | 0 |
| Med Dense to Dense SAND (liquefied) | 125 | 12 | 0 |
| Dense to V. Dense SAND to Silty SAND | 130 | 36 | 0 |
| Armor Rock | 130 | 45 | 0 |
| Improved Ground (stone columns) | 121 | 37 | 0 |

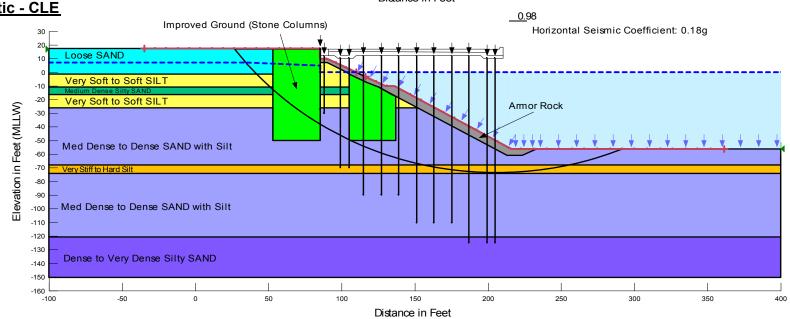


Port of Tacoma Pier 4 Tacoma, WA

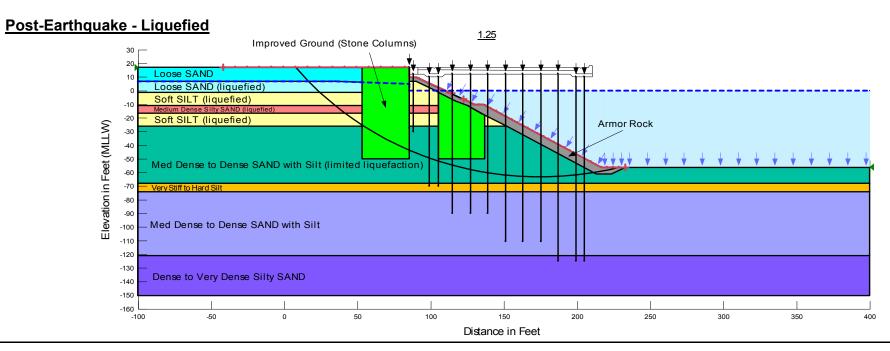
Slope Stability Analysis
STA 31+00 with Ground Improvement
17916-01 12

III HARTCROWSER Figure





| Material Properties | | | |
|--|--------|-------|-----------|
| | Unit | | |
| | Weight | Phi' | Cohesion' |
| Name | (pcf) | (deg) | (psf) |
| Loose SAND | 120 | 30 | 0 |
| Loose SAND (liquefied) | 120 | 6 | 0 |
| V. Soft to Soft SILT | 110 | 26 | 0 |
| Soft SILT (liquefied) | 110 | 5 | 0 |
| Med Dense Silty SAND | 125 | 32 | 0 |
| Med Dense Silty SAND (liquefied) | 125 | 8 | 0 |
| Med Dense to Dense SAND with SILT | 125 | 35 | 0 |
| Med Dense to Dense SAND with SILT (limited liquefaction) | 125 | 20 | 0 |
| V. Stiff to Hard SILT | 115 | 30 | 0 |
| Dense to V. Dense SAND with Silt | 130 | 35 | 0 |
| Armor Rock | 130 | 45 | 0 |
| Improved Ground (stone columns) | 121 | 37 | 0 |



CAT 12/01/14

Port of Tacoma Pier 4 Tacoma, WA

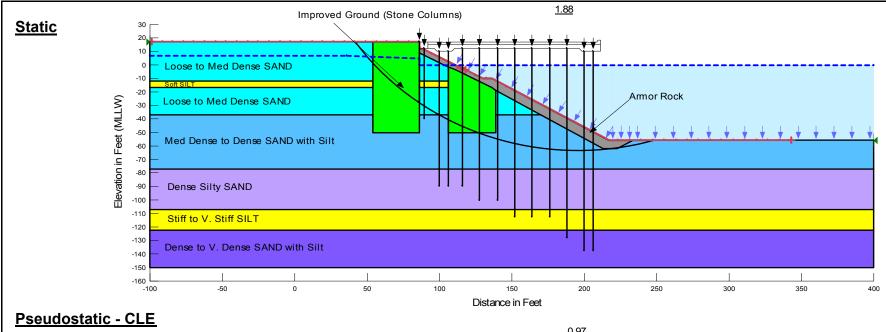
Slope Stability Analysis
STA 34+00 with Ground Improvement

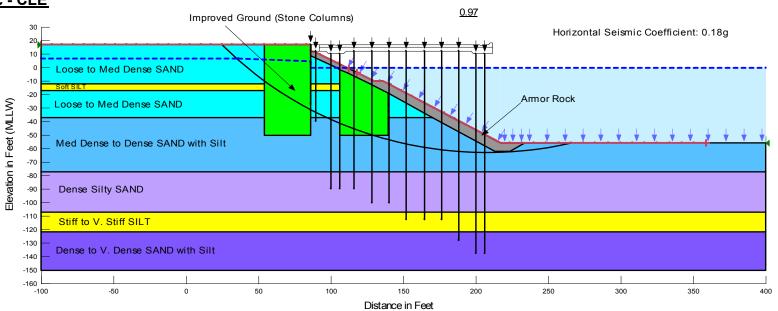
17916-01

Figure

12/14

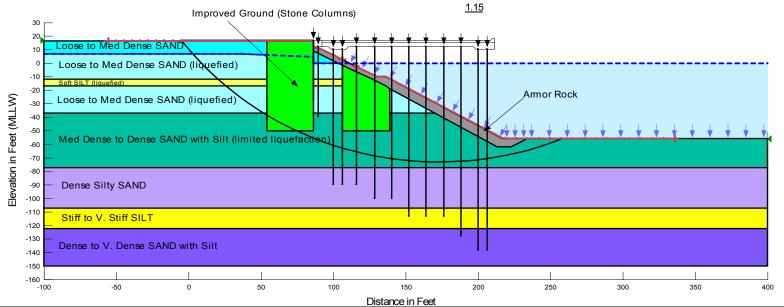
HARTCROWSER





| Material Properties | | | |
|--|--------|-------|-----------|
| | Unit | | |
| | Weight | Phi' | Cohesion' |
| Name | (pcf) | (deg) | (psf) |
| Loose to Med. Dense SAND | 120 | 31 | 0 |
| Loose to Med. Dense SAND (liquefied) | 120 | 5 | 0 |
| Soft SILT | 110 | 24 | 0 |
| Soft SILT (liquefied) | 110 | 4 | 0 |
| Med Dense to Dense SAND with Silt | 125 | 34 | 0 |
| Med Dense to Dense SAND with Silt (limited liquefaction) | 125 | 20 | 0 |
| Dense Silty SAND | 125 | 34 | 0 |
| Stiff to V. Stiff | 115 | 28 | 0 |
| Dense to V. Dense SAND with Silt | 130 | 35 | 0 |
| Armor Rock | 130 | 45 | 0 |
| Improved Ground (stone columns) | 121 | 37 | 0 |

Post-Earthquake - Liquefied



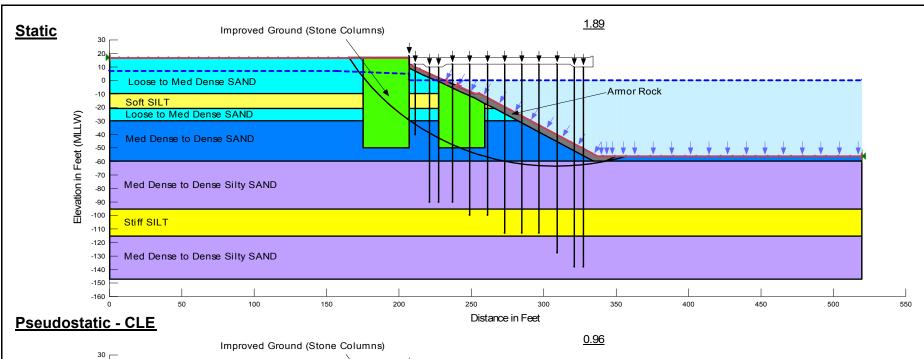
Port of Tacoma Pier 4
Tacoma, WA

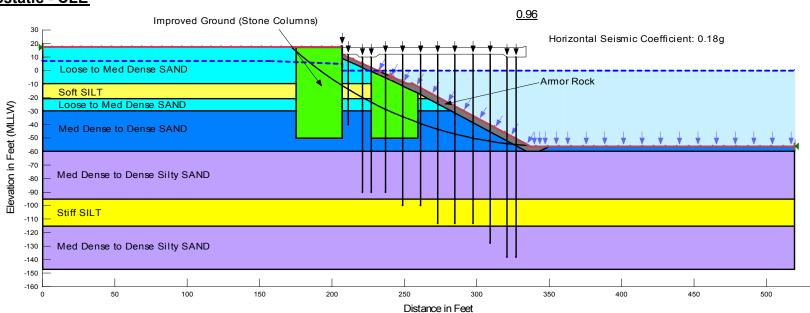
Slope Stability Analysis STA 38+00 with Ground Improvement

17916-01

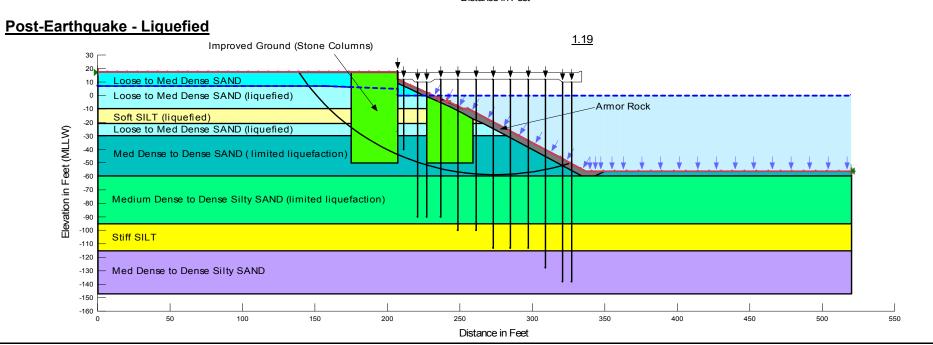
Figure

HART CROWSER





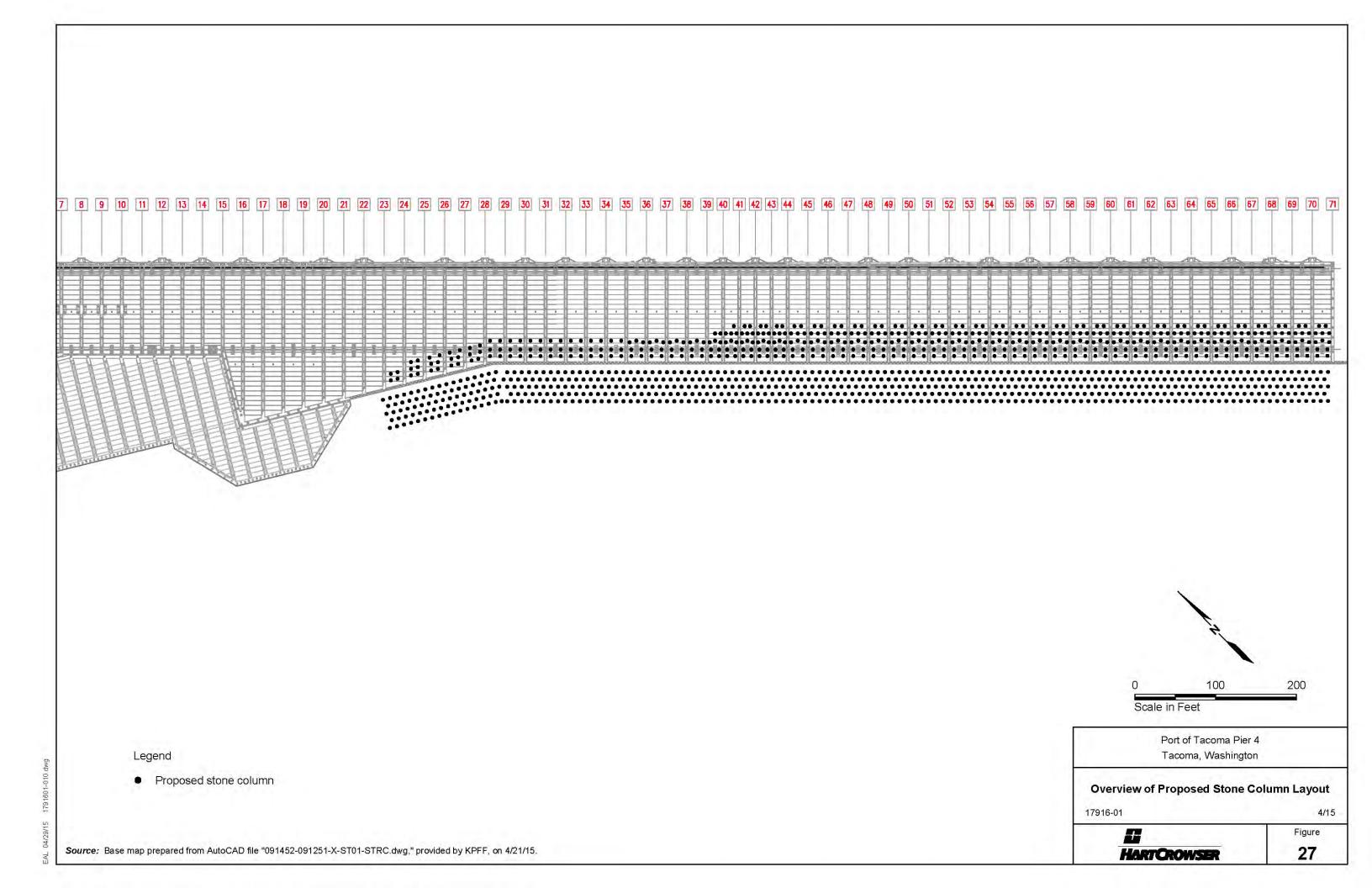
| Material Properties | | | |
|--|----------------|-------|-----------|
| | Unit Weight | Phi' | Cohesion' |
| Name | (pcf) | (deg) | (psf) |
| Loose to Med. Dense SAND | 120 | 31 | 0 |
| Loose to Med. Dense SAND (liquefied) | 120 | 6 | 0 |
| Soft SILT | 110 | 24 | 0 |
| Soft SILT (liquefied) | 110 | 4 | 0 |
| Med Dense to Dense SAND | 125 | 34 | 0 |
| Med Dense to Dense SAND (limited liquefaction) | 125 | 19 | 0 |
| Med Dense to Dense Silty SAND | 125 | 34 | 0 |
| Med Dense to Dense Silty SAND (limited liquefaction) | 125 | 24 | 0 |
| Armor Rock | 130 | 45 | 0 |
| Improved Ground (stone columns) | 121 | 37 | 0 |

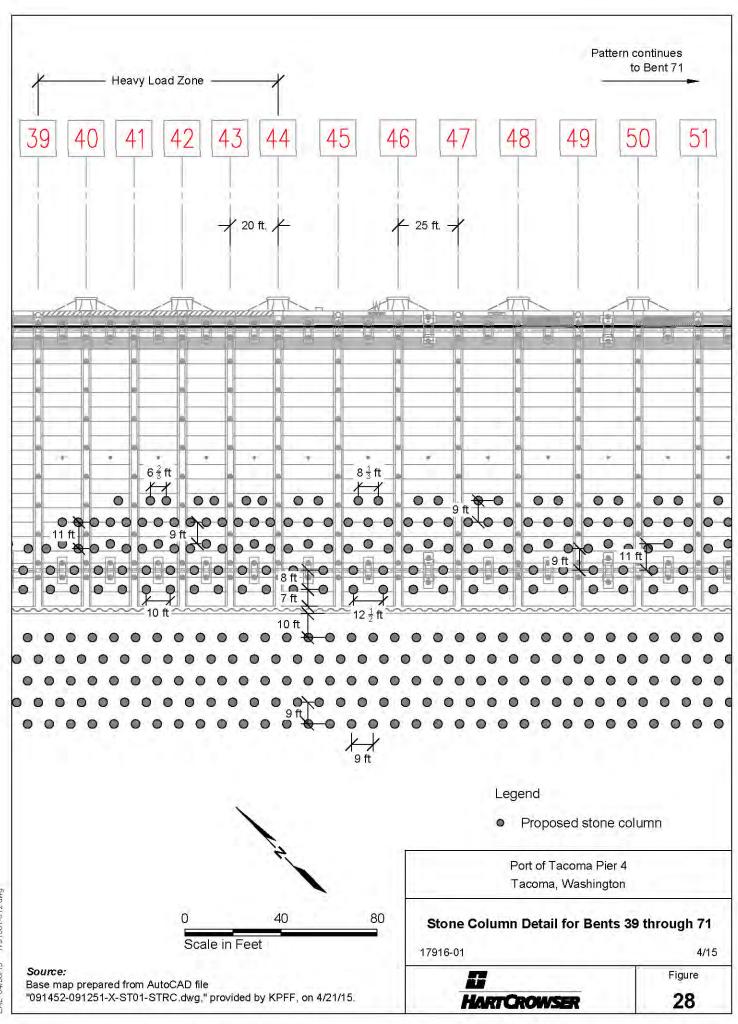


Port of Tacoma Pier 4 Tacoma, WA

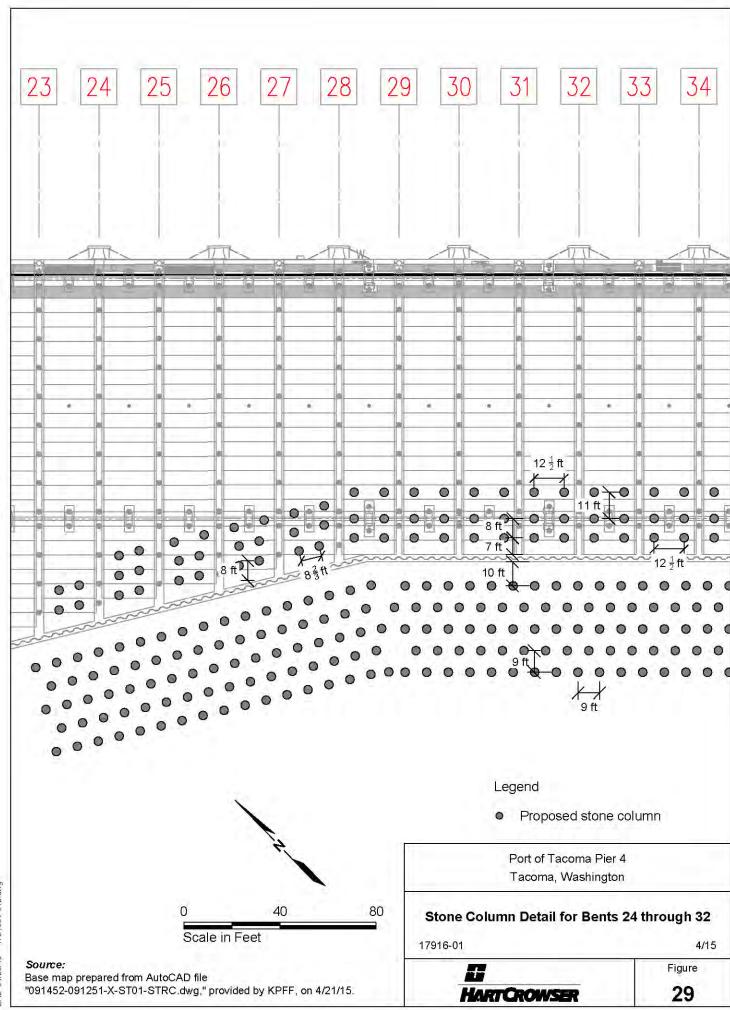
Slope Stability Analysis
STA 39+00 with Ground Improvement
17916-01 12/14

II HARTCROWSER Figure

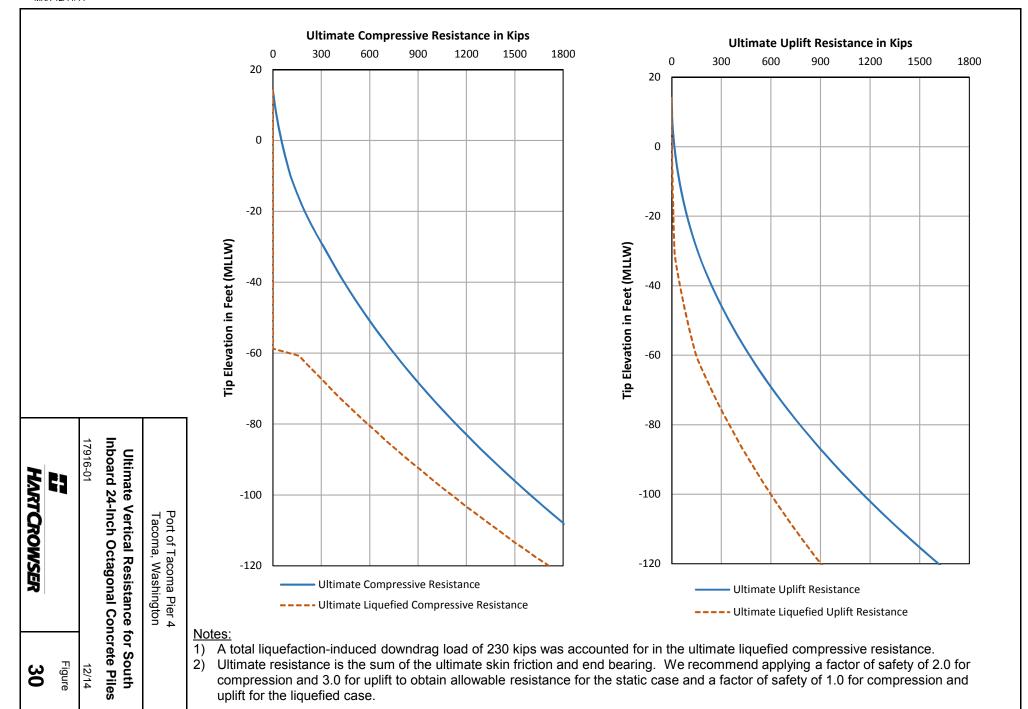


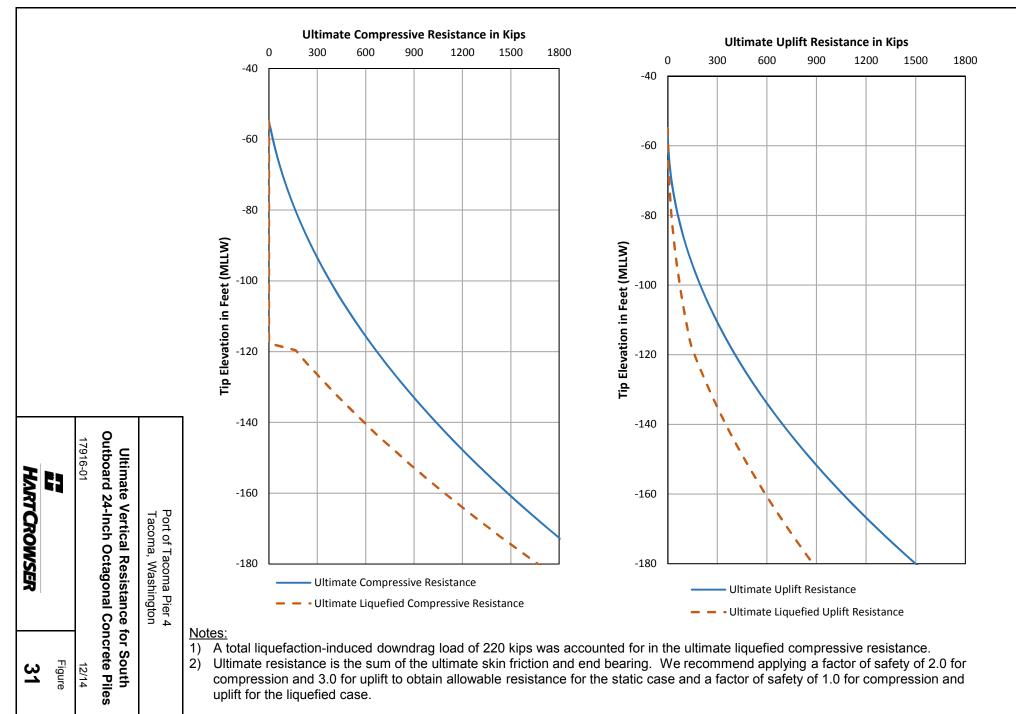


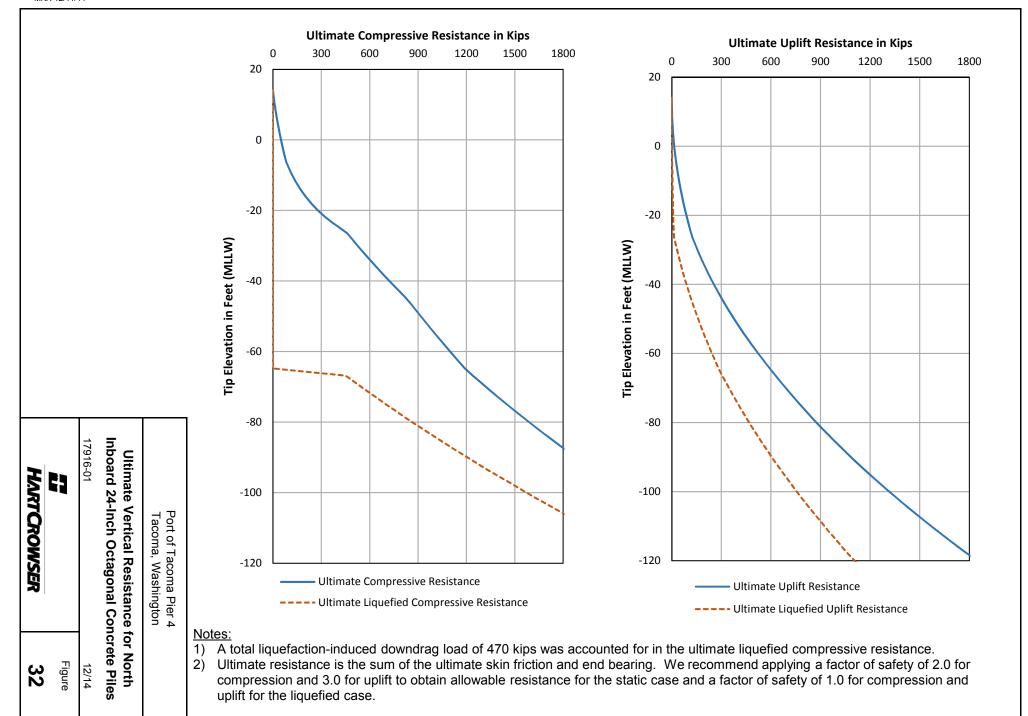
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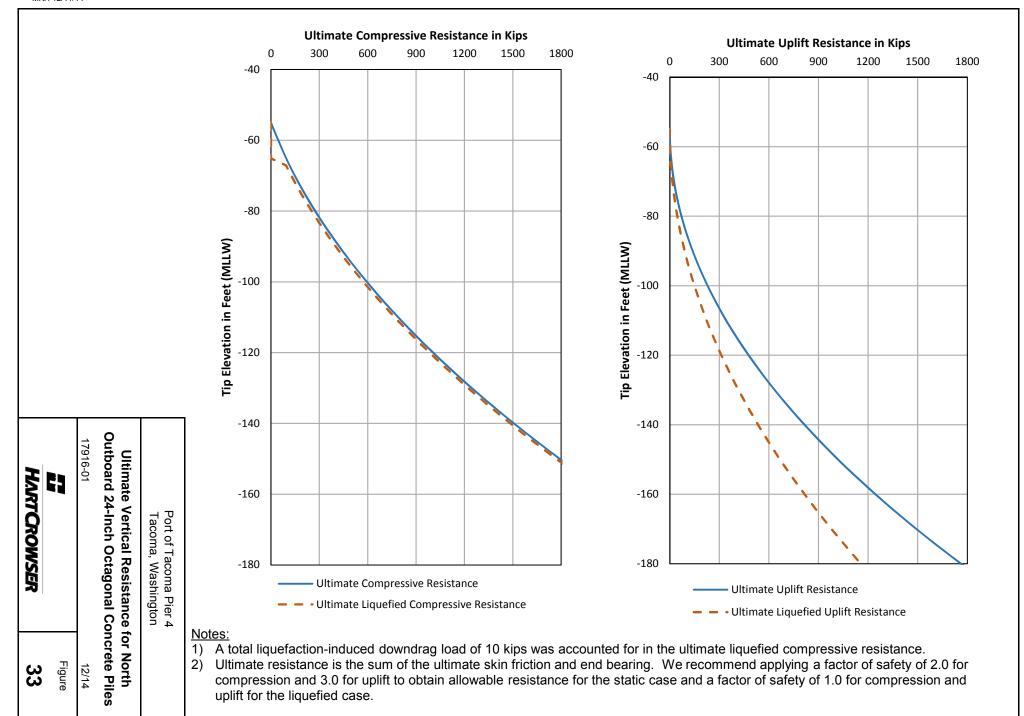


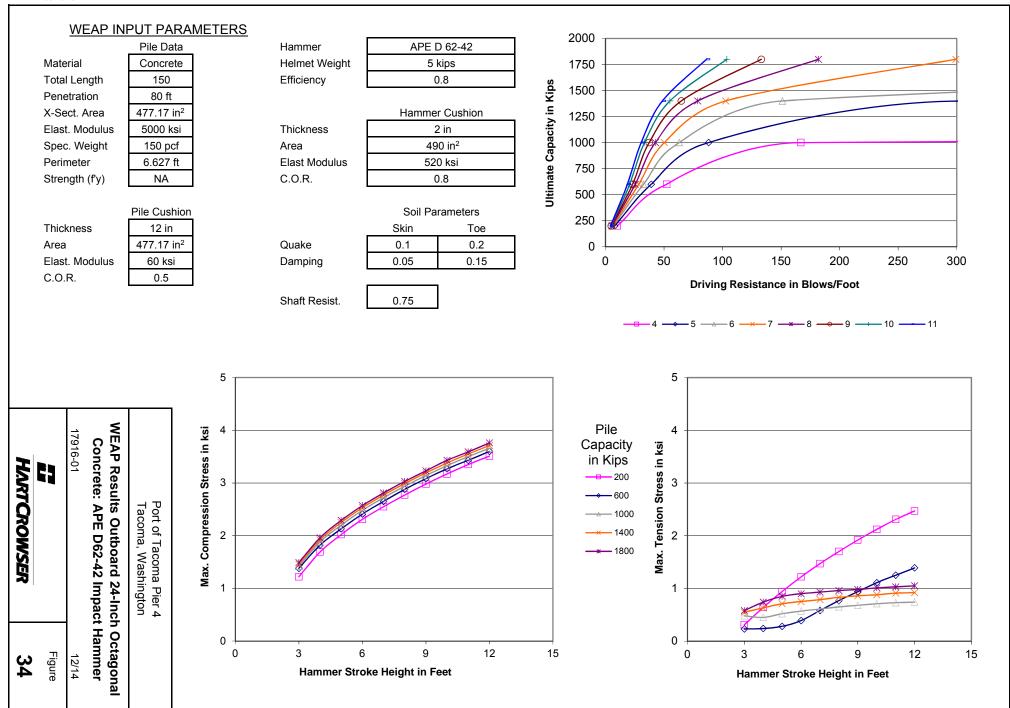
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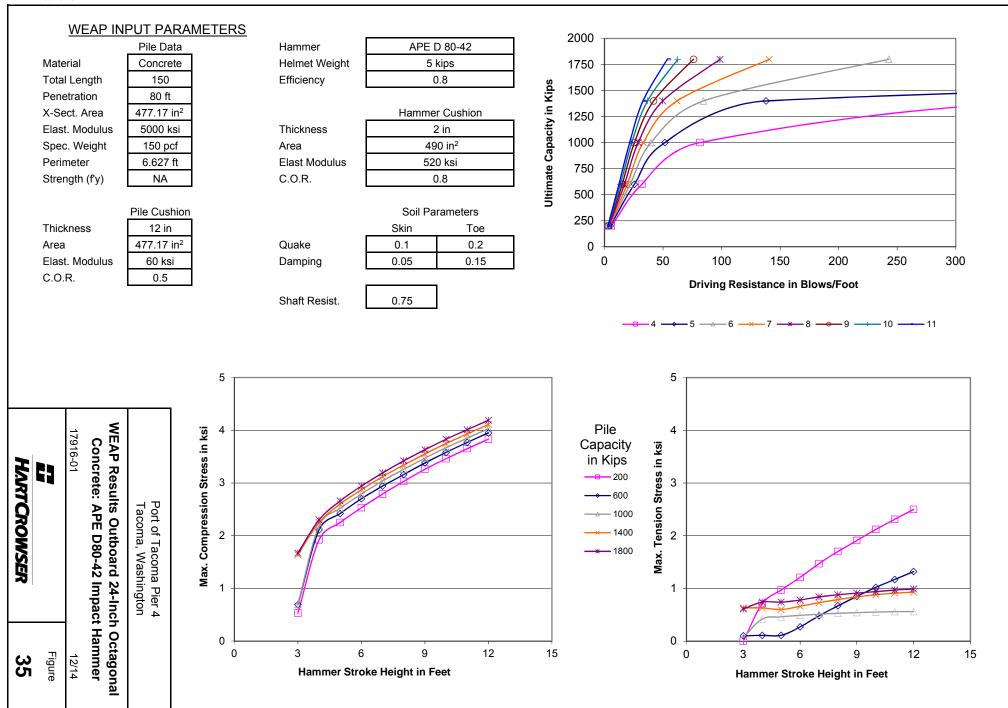


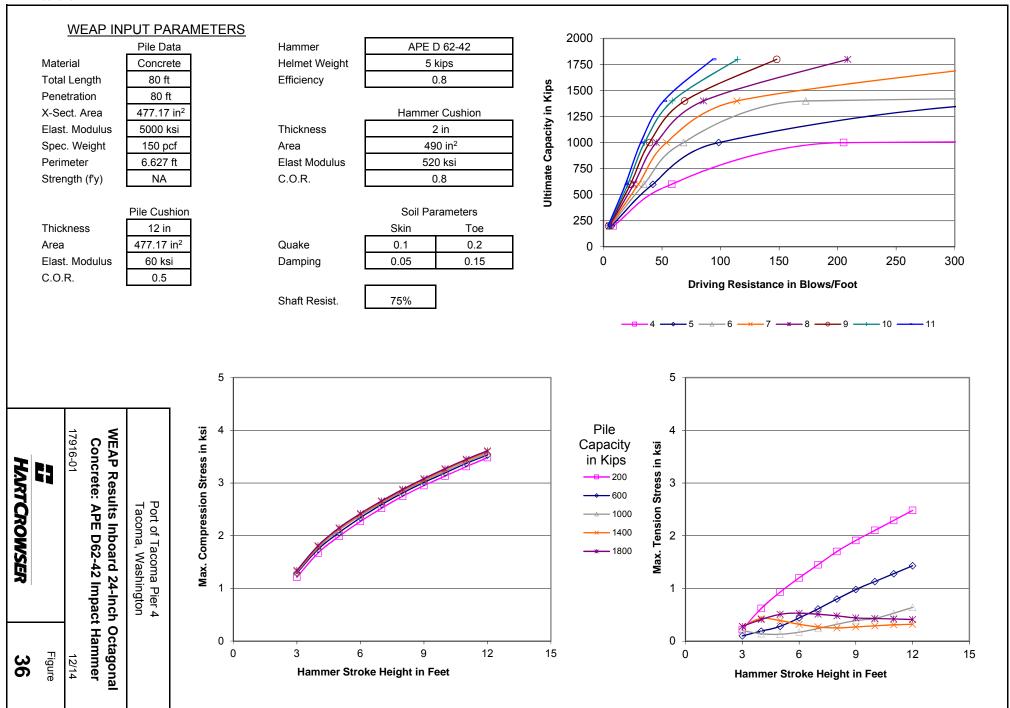


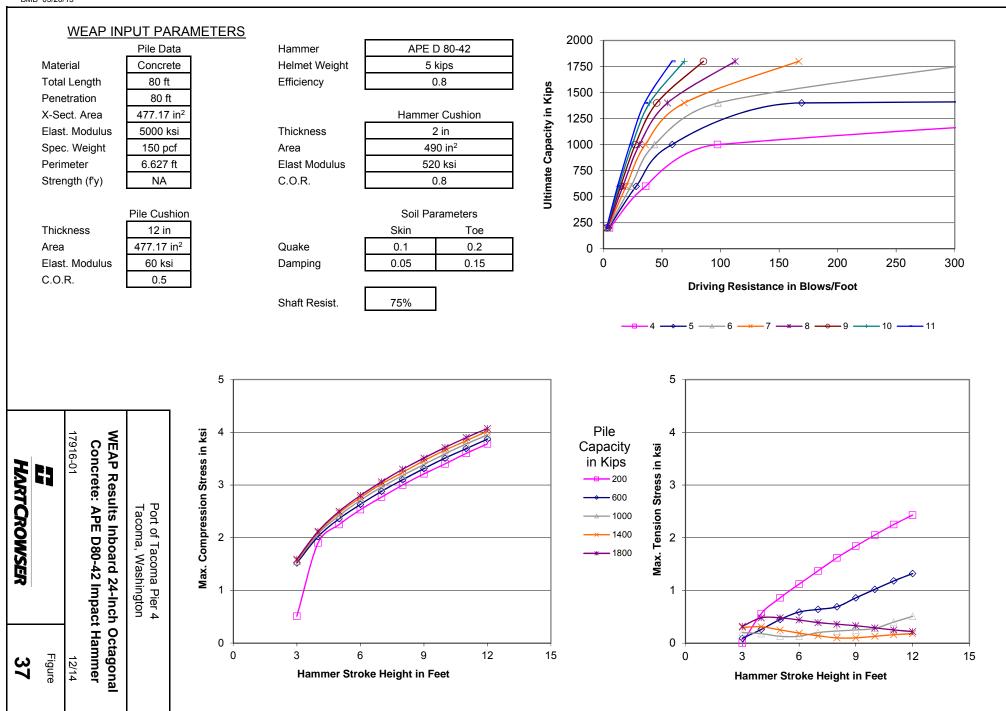






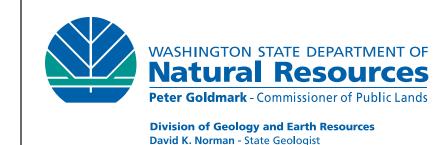






ATTACHMENT 1 Tsunami Hazard Maps



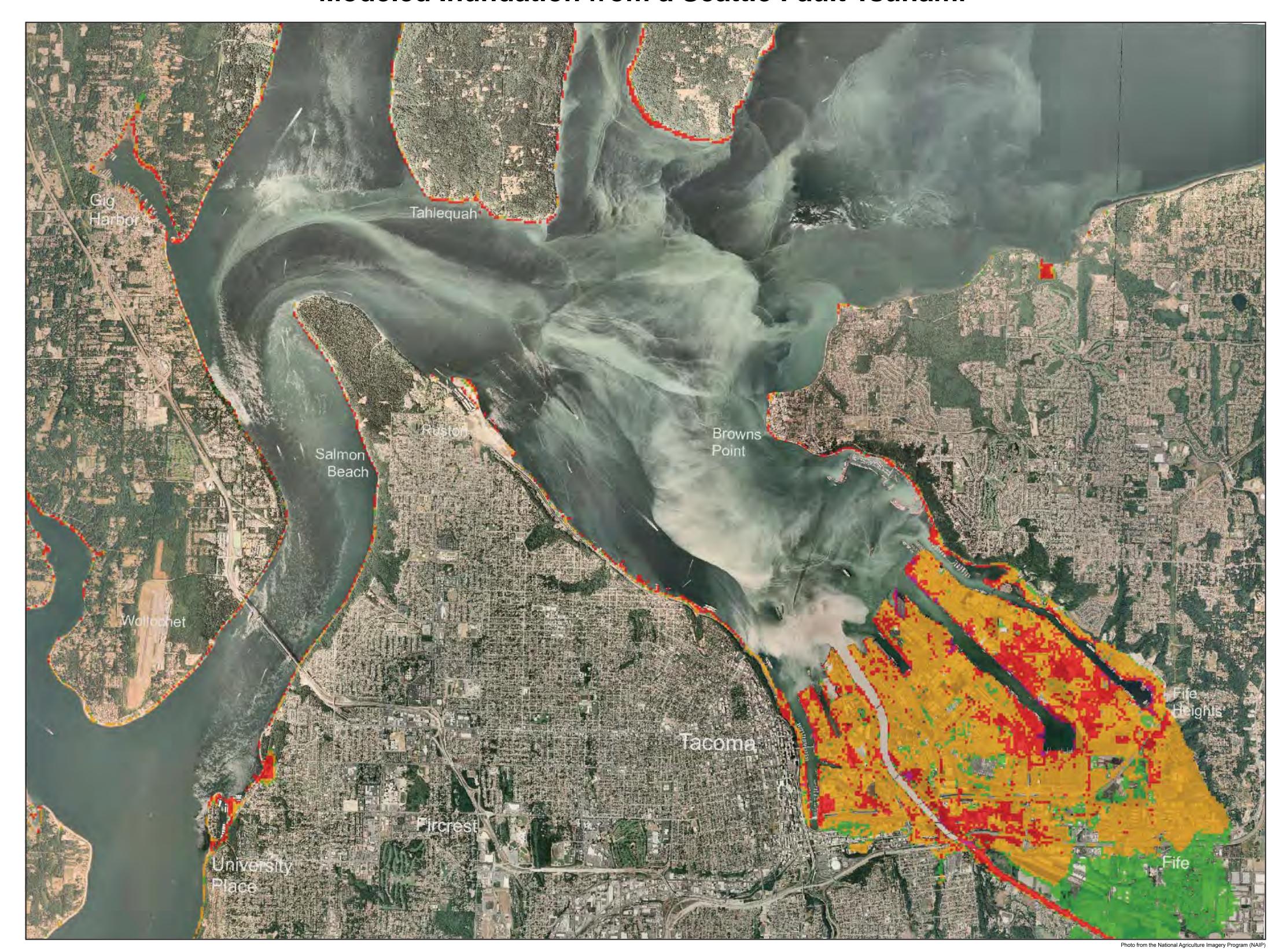


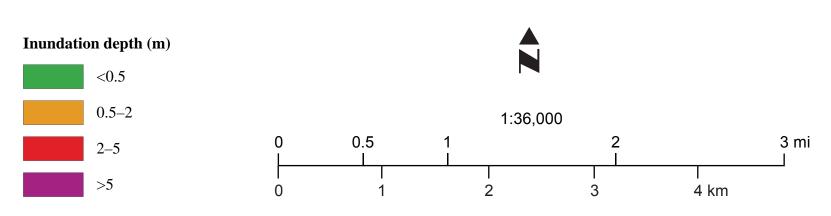


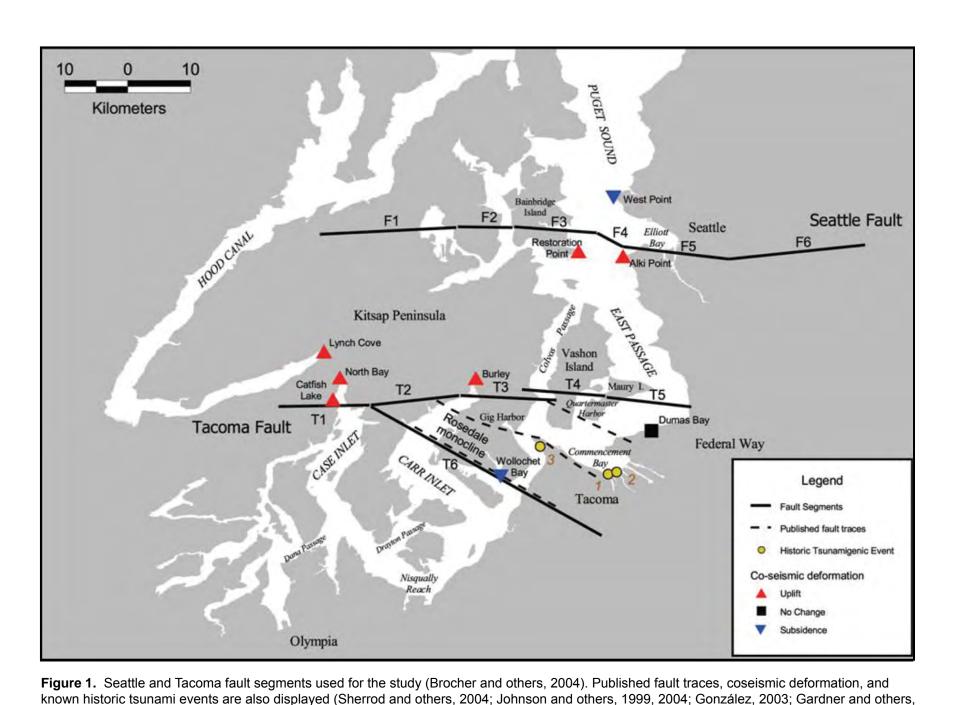
Tsunami Hazard Map of Tacoma, Washington: Model Results for Seattle Fault and Tacoma Fault Earthquake Tsunamis

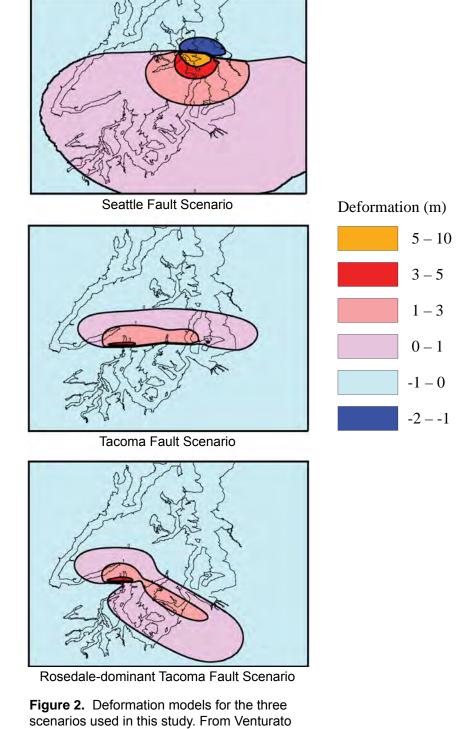
Timothy J. Walsh¹, Diego Arcas², Angie J. Venturato², Vasily V. Titov², Harold O. Mofjeld², Chris C. Chamberlin², and Frank I. González² ¹Washington Division of Geology and Earth Resources, PO Box 47007, Olympia, WA 98504-47007; tim.walsh@dnr.wa.gov ²NOAA Center for Tsunami Research, NOAA/PMEL-UW/JISAO, 7600 Sand Point Way NE, Seattle, WA 981²

Modeled Inundation from a Seattle Fault Tsunami

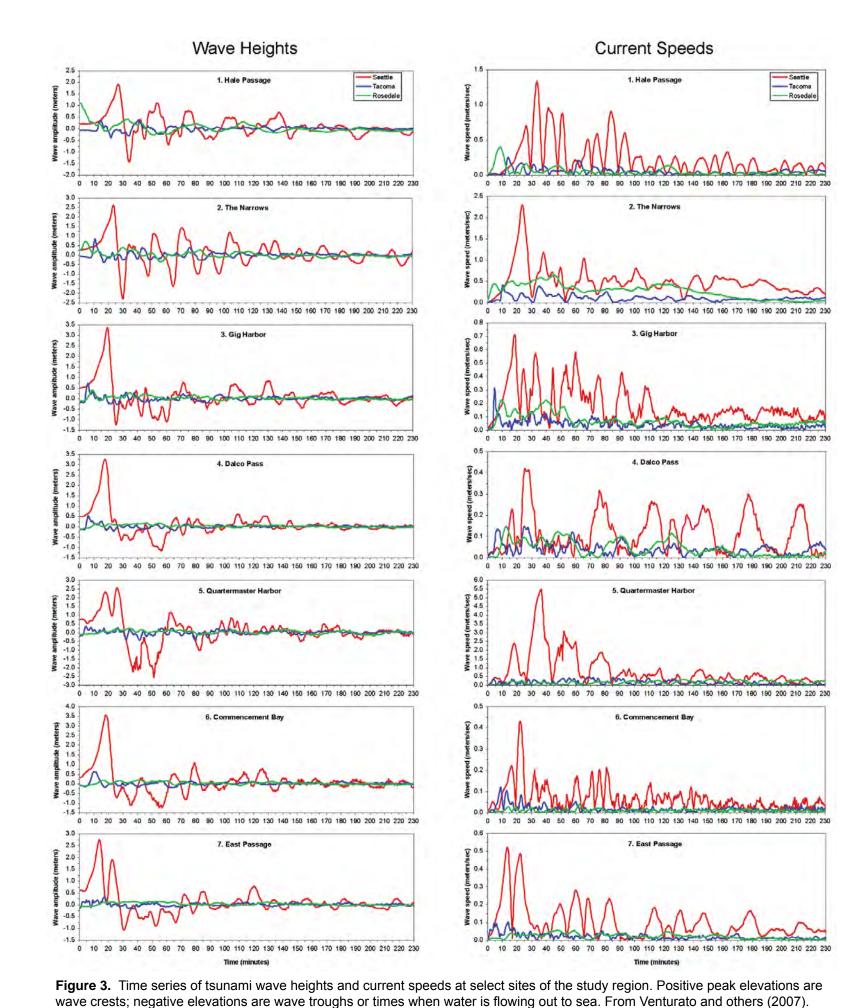




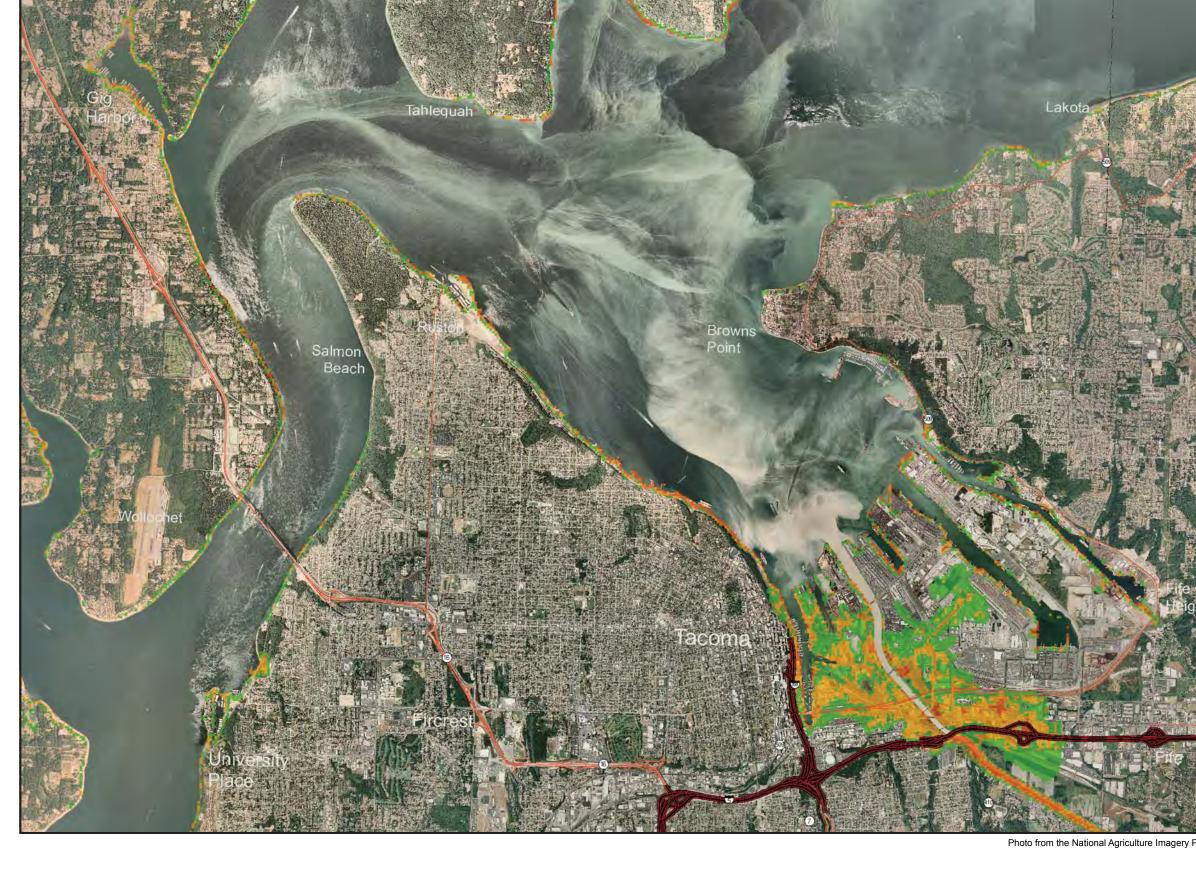




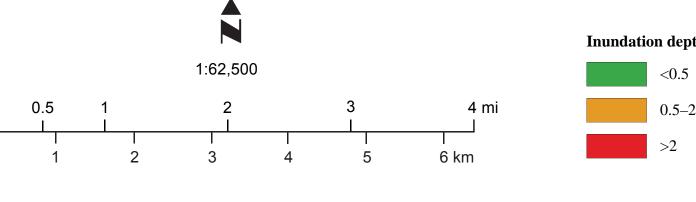
and others (2007).



Note that at all locations, the Seattle fault tsunami is much larger.



Suggested citation: Walsh, T. J.; Arcas, Diego; Venturato, A. J.; Titov, V. V.; Mofjeld, H. O.; Chamberlin, C. C.; González, F. I., 2009, Tsunami hazard map of Tacoma, Washington—Model results for Seattle fault and Tacoma fault earthquake tsunamis: Washington Division of Geology and Earth Resources Open File Report 2009-9, 1 sheet, scales 1:36,000 and 1:62,500. [http://www.dnr.wa.gov/ Publications/ger_ofr2009-9_tacoma_tsunami.pdf]



Modeled Inundation from a Tacoma Fault (left) and a Tacoma-Rosedale Fault (right) Tsunami

Numerical modeling of tsunamis generated by earthquakes on the Seattle fault and the Tacoma fault show that Tacoma would be subjected to larger and more damaging waves from a Seattle fault earthquake, even though the Seattle fault is considerably more distant. This is because the Seattle fault traverses Puget Sound in much deeper water and can therefore displace more water.

event would be beyond the scope of this study. The results show that a repeat of the Seattle fault earthquake of about A.D. 935 would generate inundation depths of more than 2 m in much of the Puyallup delta. Although the Port of Tacoma either Tacoma fault scenario because it displaces much more water. This scenario is therefore shown at a has experienced substantial dredging and filling, there is still natural ground along the main stem of the Puyallup River in Fife and in Hylebos Waterway. Both of these channels have significant areas with modeled inundation depths of more than 5 m for a Seattle fault event and more than 4 m from a Tacoma fault event. These models will provide useful guidance for paleoseismology investigations of A.D. 935 tsunami deposits and perhaps also tsunami deposits from the last Tacoma fault earthquake, which was also about 1000 years ago but is less well

In 1995, Congress directed the National Oceanic and Atmospheric Administration (NOAA) to develop a plan to protect the West Coast from tsunamis generated locally. A panel of representatives from NOAA, the Federal Emergency Management Agency (FEMA), the U.S. Geological Survey (USGS) and the five Pacific Coast states wrote the plan and submitted it to Congress, which created the National Tsunami Hazard Mitigation Program (NTHMP) in October of 1996. The NTHMP is designed to reduce the impact

There have been no investigations that have identified paleotsunami deposits in the Tacoma area. Model of tsunamis through warning guidance, hazard assessment, and mitigation. A key component of the Division, as a contribution of the NTHMP. These maps are produced using computer models of earthquake-generated tsunamis from nearby seismic sources. The modeling for this map was done by the NOAA Center for Tsunami Research (NCTR) at NOAA's Pacific Marine Environmental Laboratory in Seattle.

THE SEATTLE FAULT

Vancouver (1798) noted that the fault-uplifted bedrock wavecut platform at Restoration Point (Fig. 1, Location 1) on Bainbridge Island "did not possess that beautiful variety of landscape, being an almost impenetrable wilderness of lofty trees" that characterized the rest of his explorations in Puget Sound. identified the marine fossils found there. He also described the Newcastle Hills, part of the hanging wall 900–930 event, suggesting that significant earthquakes have occurred on the fault that had different and of the fault, as a "postglacial eruption". Daneš and others (1965) interpreted the large gravity and magnetic anomalies through central Puget Sound and the associated abrupt change in the sedimentary section thickness as an active fault with about 11 km of displacement. Rogers (1970) collected additional horizontally, although high-resolution multibeam data (Gardner and others, 2001) is available for Comgravity and magnetic data across the structure and named it the Seattle–Bremerton fault. Gower (1978) mencement Bay. demonstrated that the uplift at Restoration Point was Holocene in age and Bucknam and others (1992) showed that the uplift produced 7 m of uplift on the fault about 1000 years ago. In 1996, the first of a series of lidar (light detection and ranging) surveys was flown on Bainbridge Island. This and subsequent

At the Port of Tacoma, the diurnal range (the difference in height between mean higher high water and lidar missions have enabled scientists to accurately locate the fault in a number of places and dig trenches mean lower low water) is about 12 ft (http://www.tidesandcurrents.noaa.gov, accessed March 23, 2009). (Bucknam and others, 1999; Nelson and others, 2002). At about the same time, the U.S. Geological Survey began several large-scale geophysical studies. An aeromagnetic study of Puget Sound (Blakely and others, 1999, 2002) enabled more accurate location of the fault along its entire length. Seismic studies, such as SHIPS (Seismic Hazards Investigations in Puget Sound), and other geophysical studies in ACKNOWLEDGMENTS Puget Sound have greatly increased our understanding of the fault at depth (Pratt and others, 1997; Johnson and others, 1999; ten Brink and others, 2002). There also is substantial evidence that earthquakes on the Seattle fault can generate tsunamis. Atwater and Moore (1992) showed that tsunamis inundated part of Whidbey Island and West Point about 1000 years ago, and Jacoby and others (1992) showed that a tree in the tsunami deposit at West Point died in the same season of the same year as a drowned forest carried into Lake Washington by a huge landslide

and Johnson, 2001). THE TACOMA FAULT

Dane's and others (1965) interpreted the large gravity and magnetic anomalies south of the Seattle fault as **REFERENCES** an active fault as well, although less so than the Seattle fault. Rogers (1970) collected additional gravity and magnetic data across the structure and named it the Tacoma–Gig Harbor fault. Brocher and others (2001) refined its location on the basis of gravity, aeromagnetics, and seismic tomography and renamed it the Tacoma fault. Lidar imagery enabled Sherrod and others (2004) to locate and trench the fault, demonstrating that it ruptured about 1,000 years ago. Johnson and others (2004) proposed structural models for the Tacoma fault that either put surface displacement along the main trace of the fault or partitioning some slip along the Rosedale monocline. No paleotsunami deposits have been attributed to the Tacoma fault.

from Mercer Island, strongly implicating the large A.D. ~935 earthquake on the Seattle fault. A

discontinuous sand layer along Snohomish delta distributaries—Ebey Slough, Steamboat Slough, Union

Slough, and Snohomish River—was also probably deposited by the tsunami from this event (Bourgeois

The model of Titov and Synolakis (1998), also known as the Method of Splitting Tsunami (MOST) model duplex: Seismological Society of America Bulletin, v. 94, no. 4, p. 1379-1401. (Titov and González, 1997) was used by NCTR modelers. It uses a grid of topographic and bathymetric

Brocher, T. M.; Parsons, T. E.; Blakely, R. J.; Christensen, N. I.; Fisher, M. A.; Wells, R. E.; SHIPS Working Group, elevations and calculates a wave elevation and velocity at each gridpoint at specified time intervals to simulate the generation, propagation, and inundation of tsunamis in the Tacoma area. simulates the ~1100 yr B.P. event as a credible worst-case scenario of magnitude 7.3. Details of the Seattle fault scenario are given in Titov and others (2003) and Walsh and others (2003c). Two deformation models for the Tacoma fault were used in the tsunami simulations, following Johnson and others (2004). The fault parameters (Figs. 1 and 2) were derived in a workshop convened by Walsh and

attended by T. M. Brocher, T. L. Pratt, B. L. Sherrod, and C. S. Weaver of the USGS and Diego Arcas, F.

Daneš, Z. F.; Bonno, M.; Brau, J. E.; Gilham, W. D.; Hoffman, T. F.; Johansen, D.; Jones, M. H.; Malfait, Bruce; . González, H. O. Mofjeld, V. V. Titov, and A. J. Venturato of NOAA. Details of the Tacoma fault models are given in Venturato and others (2007). These scenarios were modeled separately, although Brocher and others (2004) and Sherrod and others (2004) suggest that the two faults may have ruptured at the same time. If both ruptures were part of the same event, however, reproducing the kinematics of the combined The Seattle fault, which traverses much deeper water, produces significantly more inundation than

The computed tsunami inundation is shown on the map in three color-coded depth ranges for the Tacoma fault scenarios: 0–0.5 m, 0.5–2 m, and greater than 2 m. These depth ranges were chosen because they are approximately knee-high or less, knee-high to head-high, and more than head-high. The model for the Seattle fault additionally shows a >5 m inundation depth. Figure 3 shows wave heights and arrival times for all three scenarios at key locations throughout the map area. The limit of tsunami inundation is the landward edge of the green zone. In previous maps, we have shown only the edge of inundation. Figure 4 also shows current velocities in two zones—less than or greater than 1.5 m/sec (~3 mi/hr), which is the current speed at which it would be difficult to stand.

Initial flooding in the Tacoma area occurs 15 to 20 minutes after tsunami generation for both the Seattle and Rosedale scenarios and about 5 minutes after generation for the Tacoma fault scenario (Fig. 3;

data that show significant depth of flow and velocity may be useful to select appropriate areas of study. hazard assessment for tsunamis is delineation of areas subject to tsunami inundation. This map is part

The map of fill at the Port of Tacoma (Fig. 5) shows areas where tsunami deposits would not be accessof a series of tsunami inundation maps produced by the Washington Department of Natural Resources, sible and areas, such as the mouth of Hylebos Waterway or along the Puyallup River, that may be suitable Division of Geology and Earth Resources, in cooperation with the Washington Emergency Management for paleoseismic studies. Distinguishing the source of a paleotsunami deposit would be difficult, though, because the last major earthquake on each fault was at approximately the same time.

LIMITATIONS OF THE MAP

Computed velocities locally exceed 30 m/sec (~60 mi/hr).

Because the nature of the tsunami depends on the initial deformation of the earthquake, which is poorly understood, the largest source of uncertainty is the input earthquake. The earthquake scenarios used in this modeling were selected to honor the paleoseismic constraints, but the next Seattle or Tacoma fault Geographic features now known to be associated with the Seattle fault have been noted for many years. earthquake may be substantially different from these. Sherrod and others (2000) show that an uplift event at Restoration Point predating the A.D. 900–930 event was smaller. Trenching of subsidiary structures to the Seattle fault that are thought to be coseimic with the main fault trace (Nelson and others, 2002) indicates that there were at least two earthquakes in the 1500 years before the A.D. 900–930 event. These, Kimball (1897) also noted the uplifted wavecut platform at Restoration Point, measured the uplift, and however, did not produce prominent uplifted wavecut platforms similar to the one made by the A.D. smaller uplifts in central Puget Sound. Another significant limitation is that the resolution of the modeling is no greater or more accurate than the bathymetric and topographic data used. This can be up to 50 m The model runs do not include the influences of changes in tides and are referred to mean high water.

> The tide stage and tidal currents can amplify or reduce the impact of a tsunami on a specific community. This means that, while the modeling can be a useful tool to guide evacuation planning, it is not of sufficient resolution to be useful for land-use planning.

This project was supported by the National Tsunami Hazards Mitigation Program (NTHMP) in coopera-

Whidbey Island (Walsh and others, 2005).

tion with the Washington Emergency Management Division (WAEMD). Information about NTHMP is available at http://nthmp.tsunami.gov/. During the study, NCTR maintained close communication with WAEMD and the Washington Department of Natural Resources (WADNR), and upon completion of the study, a suite of model-derived mapping products were delivered to both agencies in the form of electronic files and, where appropriate, hard-copy representations. This map is part of a series of tsunami hazard maps for Washington State. Maps completed to date are the southern Washington coast (Walsh and others, 2000), Port Angeles (Walsh and others, 2002a), Port Townsend (Walsh and others, 2002b), Neah Bay (Walsh and others, 2003a), Quileute area (Walsh and others, 2003b), Seattle (Walsh and others, 2003c), Bellingham (Walsh and others, 2004), and Anacortes-

Atwater, B. F.; Moore, A. L., 1992, A tsunami about 1000 years ago in Puget Sound, Washington: Science, v. 258,

Blakely, R. J.; Wells, R. E.; Weaver, C. S., 1999, Puget Sound aeromagnetic maps and data: U.S. Geological Survey Open-File Report 99-514, version 1.0. [http://pubs.usgs.gov/of/1999/of99-514/] Blakely, R. J.; Wells, R. E.; Weaver, C. S.; Johnson, S. Y., 2002, Location, structure, and seismicity of the Seattle fault zone, Washington—Evidence from aeromagnetic anomalies, geologic mapping, and seismic-reflection data: Geological Society of America Bulletin, v. 114, no. 2, p. 169-177. Bourgeois, Joanne; Johnson, S. Y., 2001, Geologic evidence of earthquakes at the Snohomish delta, Washington, in the past 1200 yr: Geological Society of America Bulletin, v. 113, no. 4, p. 482-494.

Brocher, T. M.; Blakely, R. J.; Wells, R. E., 2004, Interpretation of the Seattle uplift, Washington, as a passive-roof

2001, Upper crustal structure in Puget Lowland, Washington—Results from the 1998 Seismic Hazards Investigations in Puget Sound: Journal of Geophysical Research, v. 106, no. B7, p. 13,541-13,564. In this MOST model study, the tsunami generated by a Seattle fault deformation model (Figs. 1 and 2)

Bucknam, R. C.; Hemphill-Haley, Eileen; Leopold, E. B., 1992, Abrupt uplift within the past 1700 years at southern Puget Sound, Washington: Science, v. 258, no. 5088, p. 1611-1614. Bucknam, R. C.; Sherrod, B. L.; Elfendahl, G. W., 1999, A fault scarp of probable Holocene age in the Seattle fault zone, Bainbridge Island, Washington [abstract]: Seismological Research Letters, v. 70, no. 2, p. 233.

Masten, J.; Teague, G. O., 1965, Geophysical investigation of the southern Puget Sound area, Washington: Journal of Geophysical Research, v. 70, no. 22, p. 5573-5580. Gardner, J. V.; van den Ameele, E. J.; Gelfenbaum, Guy; Barnhardt, W. A.; Lee, H. J.; Palmer, S. P., 2001, Mapping

southern Puget Sound delta fronts after the 2001 Nisqually earthquake. In Gardner, J. V.; van den Ameele, E. J.;

Dartnell, Peter, Multibeam mapping of the major deltas of southern Puget Sound, Washington: U.S. Geological

González, F. I., compiler, 2003, Puget Sound tsunami sources—2002 workshop report: NOAA/Pacific Marine Environmental Laboratory Contribution No. 2526, 36 p. Gower, H. D., 1978, Tectonic map of the Puget Sound region, Washington, showing locations of faults, principal folds, and large-scale Quaternary deformation: U.S. Geological Survey Open-File Report 78-426, 22 p., 1 plate,

Survey Open-File Report 01-266, 1 v. [http://geopubs.wr.usgs.gov/open-file/of01-266/]

Hart-Crowser and Associates, Inc., 1974, Geology of the Port of Tacoma: Hart-Crowser and Associates, Inc. [Seattle,

Jacoby, G. C.; Williams, P. L.; Buckley, B. M., 1992, Tree ring correlation between prehistoric landslides and abrupt tectonic events in Seattle, Washington: Science, v. 258, no. 5088, p. 1621-1623. Johnson, S. Y.; Blakely, R. J.; Stephenson, W. J.; Dadisman, S. V.; Fisher, M. A., 2004, Active shortening of the Cascadia forearc and implications for seismic hazards of the Puget Lowland: Tectonics, v. 23, TC1011, doi:10.1029/2003TC001507, 2004, 27 p. Johnson, S. Y.; Dadisman, S. V.; Childs, J. R.; Stanley, W. D., 1999, Active tectonics of the Seattle fault and central

Puget Sound, Washington—Implications for earthquake hazards: Geological Society of America Bulletin, v. 111, no. 7, p. 1042-1053, 1 plate.

Kimball, J. P., 1897, Physiographic geology of the Puget Sound basin [in 2 parts]: American Geologist, v. 19, no. 4, p. 225-237 [part 1]; v. 19, no. 5, p. 304-322 [part 2]. Nelson, A. R.; Johnson, S. Y.; Wells, R. E.; Pezzopane, S. K.; Kelsey, H. M.; Sherrod, B. L.; Bradley, L.-A.; Koehler, R. D., III; Bucknam, R. C.; Haugerud, R. A.; Laprade, W. T., 2002, Field and laboratory data from an earthquake history study of the Toe Jam Hill fault, Bainbridge Island, Washington: U.S. Geological Survey Open-File Report

Pratt, T. L.; Johnson, S. Y.; Potter, C. J.; Stephenson, W. J.; Finn, C. A., 1997, Seismic reflection images beneath Puget Sound, western Washington State—The Puget Lowland thrust sheet hypothesis: Journal of Geophysical Research, v. 102, no. B12, p. 27,469-27,489.

Rogers, W. P., 1970, A geological and geophysical study of the central Puget Sound lowland: University of Washington Doctor of Philosophy thesis, 123 p., 9 plates. Sherrod, B. L.; Brocher, T. M.; Weaver, C. S.; Bucknam, R. C.; Blakely, R. J.; Kelsey, H. M.; Nelson, A. R.; Haugerud, Ralph, 2004, Holocene fault scarps near Tacoma, Washington, USA: Geology, v. 32, no. 1, p. 9-12. Sherrod, B. L.; Bucknam, R. C.; Leopold, E. B., 2000, Holocene relative sea level changes along the Seattle fault at

Restoration Point, Washington: Quaternary Research, v. 54, no. 3, p. 384-393.

1927, 11 p. [http://www.pmel.noaa.gov/pubs/PDF/tito1927/tito1927.pdf]

ten Brink, U. S.; Molzer, P. C.; Fisher, M. A.; Blakely, R. J.; Bucknam, R. C.; Parsons, T. E.; Crosson, R. S.; Creager, K. C., 2002, Subsurface geometry and evolution of the Seattle fault zone and the Seattle basin, Washington: Seismological Society of America Bulletin, v. 92, no. 5, p. 1737-1753. Titov, V. V.; González, F. I., 1997, Implementation and testing of the method of splitting tsunami (MOST) model: NOAA Technical Memorandum ERL PMEL-112; NOAA Pacific Marine Environmental Laboratory Contribution

Titov, V. V.; González, F. I.; Mofjeld, H. O.; Venturato, A. J., 2003, NOAA TIME Seattle tsunami mapping project—Procedures, data sources, and products: NOAA Technical Memorandum OAR PMEL-124, 21 p. [http://www.pmel.noaa.gov/pubs/PDF/tito2572/tito2572.pdf] Titov, V. V.; Synolakis, C. E., 1998, Numerical modeling of tidal wave runup: Journal of Waterway, Port, Coastal and Ocean Engineering, v. 124, no. 4, p. 157–171.

Vancouver, George, 1798, repr. 1992, A voyage of discovery to the north Pacific Ocean, and round the world; in which the coast of north-west American has been carefully examined and accurately surveyed—Undertaken by

His Majesty's command, principally with a view to ascertain the existence of any navigable communication

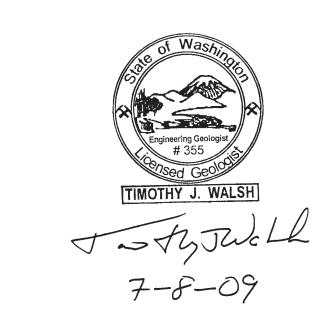
between the north Pacific and north Atlantic Oceans; and performed in the years 1790, 1791, 1792, 1793, 1794, and 1795: G. G. and J. Robinson [London], 3 v. Venturato, A. J.; Arcas, Diego; Titov, V. V.; Mofjeld, H. O.; Chamberlin, C. C.; González, F. I., 2007, Tacoma, Washington, tsunami hazard mapping project—Modeling tsunami inundation from Tacoma and Seattle fault earthquakes: National Oceanic and Atmospheric Administration, Pacific Marine Environmental Laboratory Technical Memorandum OAR-PMEL-132, 23 p. [http://www.pmel.noaa.gov/pubs/PDF/vent2981/vent2981.pdf] Walsh, T. J.; Caruthers, C. G.; Heinitz, A. C.; Myers, E. P., III; Baptista, A. M.; Erdakos, G. B.; Kamphaus, R. A., 2000, Tsunami hazard map of the southern Washington coast—Modeled tsunami inundation from a Cascadia

subduction zone earthquake: Washington Division of Geology and Earth Resources Geologic Map GM-49, 1 sheet, scale 1:100,000, with 12 p. text. [http://www.dnr.wa.gov/Publications/ger_gm49_tsunami_hazard_ Walsh, T. J.; Myers, E. P., III; Baptista, A. M., 2002a, Tsunami inundation map of the Port Angeles, Washington area: Washington Division of Geology and Earth Resources Open File Report 2002-1, 1 sheet, scale 1:24,000. [http://www.dnr.wa.gov/Publications/ger_ofr2002-1_tsunami_hazard_portangeles.pdf] Walsh, T. J.; Myers, E. P., III; Baptista, A. M., 2002b, Tsunami inundation map of the Port Townsend, Washington area: Washington Division of Geology and Earth Resources Open File Report 2002-2, 1 sheet, scale 1:24,000. [http://www.dnr.wa.gov/Publications/ger_ofr2002-2_tsunami_hazard_porttownsend.pdf]

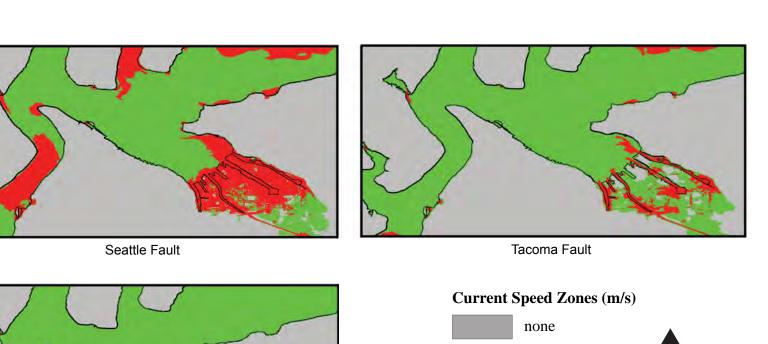
Walsh, T. J.; Myers, E. P., III; Baptista, A. M., 2003a, Tsunami inundation map of the Neah Bay, Washington, area: Washington Division of Geology and Earth Resources Open File Report 2003-2, 1 sheet, scale 1:24,000. [http://www.dnr.wa.gov/Publications/ger_ofr2003-2_tsunami_hazard_neahbay.pdf] Walsh, T. J.: Myers, E. P., III: Baptista, A. M., 2003b, Tsunami inundation map of the Ouileute, Washington, area: Washington Division of Geology and Earth Resources Open File Report 2003-1, 1 sheet, scale 1:24,000. [http://www.dnr.wa.gov/Publications/ger_ofr2003-1_tsunami_hazard_quileute.pdf] Walsh, T. J.; Titov, V. V.; Venturato, A. J.; Mofjeld, H. O.; González, F. I., 2003c, Tsunami hazard map of the Elliott

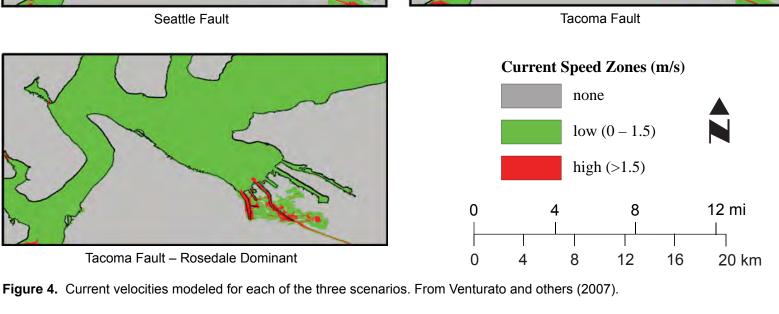
Bay area, Seattle, Washington—Modeled tsunami inundation from a Seattle fault earthquake: Washington Division of Geology and Earth Resources Open File Report 2003-14, 1 sheet, scale 1:50,000. [http://www.dnr.wa.gov/Publications/ger_ofr2003-14_tsunami_hazard_elliottbay.pdf] Walsh, T. J.; Titov, V. V.; Venturato, A. J.; Mofjeld, H. O.; González, F. I., 2004, Tsunami hazard map of the Bellingham area, Washington—Modeled tsunami inundation from a Cascadia subduction zone earthquake: Washington Division of Geology and Earth Resources Open File Report 2004-15, 1 sheet, scale 1:50,000.

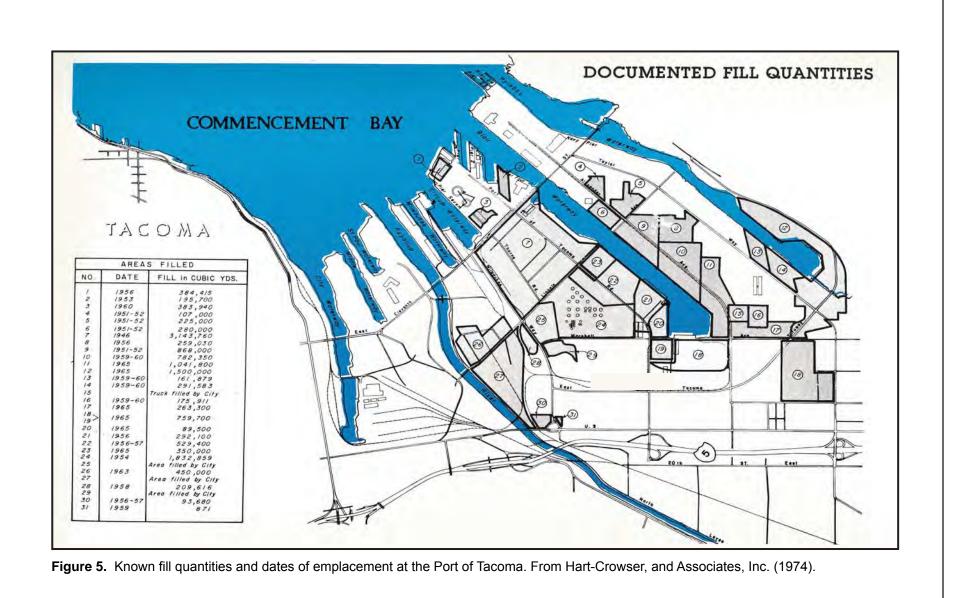
[http://www.dnr.wa.gov/Publications/ger_ofr2004-15_tsunami_hazard_bellingham.pdf] Walsh, T. J.; Titov, V. V.; Venturato, A. J.; Mofjeld, H. O.; González, F. I., 2005, Tsunami hazard map of the Anacortes-Whidbey Island area, Washington—Modeled tsunami inundation from a Cascadia subduction zone earthquake: Washington Division of Geology and Earth Resources Open File Report 2005-1, 1 sheet, scale 1:62,500. [http://www.dnr.wa.gov/Publications/ger_ofr2005-1_tsunami_hazard_anacortes_whidbey.pdf]



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http://www.dnr.wa.gov/AboutDNR/Divisions/GER/

2001). From Venturato and others (2007).

FINAL REPORT
GEOTECHNICAL ENGINEERING SERVICES
WUT WHARF EXTENSION
PORT OF TACOMA
TACOMA, WASHINGTON

SEPTEMBER 1, 2009

FOR PORT OF TACOMA AND BERGERABAM



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REPORT GEOTECHNICAL ENGINEERING SERVICES WUT WHARF EXTENSION PORT OF TACOMA TACOMA, WASHINGTON FOR PORT OF TACOMA AND BERGERABAM

INTRODUCTION

This report presents the results of our subsurface investigation and review and provides geotechnical recommendations in support of final design of the Washington United Terminal (WUT) Wharf Extension project located in the Port of Tacoma (Port), Tacoma, Washington. The project site is located on the west side of the Blair-Hylebos Peninsula, as shown on the Vicinity Map, Figure 1. The purpose of our geotechnical services is to evaluate soil and groundwater conditions at the project site and conduct engineering testing and analyses as a basis for providing geotechnical seismic design criteria and recommendations for the proposed wharf extension.

We have provided two preliminary memoranda for this project dated May 30 and July 10, 2008, a 30% Design Report dated August 15, 2008 and a 95% Design Report dated May 5, 2009. The geotechnical recommendations provided in this report supersede our previous recommendations.

RELEVANT ENGINEERING STUDIES

Several geotechnical engineering studies for wharf structures on the Blair Waterway, recent and on-going, are relevant to the geotechnical aspects of this project. The recent and ongoing studies along the East Blair Peninsula are particularly relevant to this project.

We recently provided geotechnical engineering services for the East Blair One Wharf (EB1 or EBOW) and the East Blair Two Wharf (EB2). These projects are located across the Blair Waterway from the subject 600-foot wharf extension. The East Blair One Wharf was recently constructed and the East Blair Two Wharf project is currently on hold in the design phase. The geotechnical recommendations provided in this report consider GeoEngineers' experience at EB1 and EB2, and also consider results of laboratory testing conducted to evaluate dynamic soil behavior for studies at nearby projects. Below is a list of relevant engineering studies we reviewed in preparing this report, including a preliminary geotechnical assessment we performed as the initial element of service for this project.

- **1.** Dames & Moore, Report of Soils Investigation, Proposed Pier Blair Waterway, Tacoma, Washington, March 5, 1970 (existing Blair Dock).
- **2.** GeoEngineers, Inc., Report, Geotechnical Engineering Services, West Blair Terminal Development, Port of Tacoma, Washington, March 28, 1994 (existing WUT Terminal).
- **3.** GeoEngineers, Inc., Report Addendum, Supplemental Geotechnical Engineering Services, Hyundai Marine Terminal, Port of Tacoma, Washington, September 10, 1997 (existing WUT Terminal).
- **4.** GeoEngineers, Inc., Report, Geotechnical Engineering Services, Proposed Hyundai Container Terminal, Port of Tacoma, Washington, December 18, 1997 (existing WUT Terminal).

- **5.** GeoEngineers, Inc., Report, Geotechnical Engineering Services, East Blair One Wharf, Port of Tacoma, Tacoma, Washington, April 23, 2007 (EBOW).
- **6.** GeoEngineers, Inc., Memorandum, Hyundai Wharf Extension Conceptual Design Task 1, February 14, 2008 (subject WUT Wharf Extension project).
- **7.** GeoEngineers, Inc., 30% Design Report, Geotechnical Engineering Services, Blair-Hylebos Peninsula, YTTI Terminal Redevelopment, Port of Tacoma, Tacoma, Washington," dated February 29, 2008 (EB2).

We have also reviewed select pile driving records from the Blair Dock, existing WUT Terminal and EB1.

PROJECT UNDERSTANDING AND BACKGROUND

GENERAL

In general, the project consists of extending the existing WUT Wharf 600 feet to the south. The wharf extension will require demolition of the northernmost 600 feet of the existing Blair Dock. In addition to the wharf extension, improvements will be made to the existing WUT Wharf and Blair Dock. The proposed site improvements are shown on the Conceptual Site Plan in Figure 2, and are discussed in more detail below.

600-Foot Wharf Extension

The wharf extension will be constructed using prestressed concrete piles, reinforced concrete deck panels, reinforced concrete pile caps and a steel sheet pile bulkhead. Current plans address a pile layout similar to the existing WUT wharf, except for the configuration of the K and K/L line piles; the existing wharf includes L-line batter piles to the west of the inboard crane rail. The proposed pile layout for the wharf extension does not include batter piles.

The dredge slope beneath the wharf extension will be a compound slope inclined at 2H:1V (horizontal:vertical) and 1.75H:1V and will extend to the current dredge depth of the Blair Waterway, Elevation -50 feet (Elevations presented in this report are relative to mean lower low water [MLLW]). The break-in-slope is located at Elevation -10 feet. The Port is planning a future dredge depth of Elevation -55 feet for the Blair Waterway. Our analyses and recommendations presented in this report assume the future dredge depth of Elevation -55 feet. A schematic cross section showing pile layout, dredge slope geometry and riprap details is provided on Figure 3.

In accordance with recent wharf designs and construction in the Port of Tacoma, the 600-foot wharf extension is being designed using performance-based methodology. This methodology focuses on the effects of ground improvement on slope and wharf deformation and stress during a design level earthquake. Stone columns have been selected as the ground improvement technique for this project. A unique aspect of this project relative to recent wharf improvements in the Port is that stone column installation on the proposed dredge slope can be completed from land prior to dredging.

Our earlier studies for this project assessed multiple stone column configurations, mainly: 1) stone columns upland of the dredge slope only and 2) stone columns on the dredge slope in addition to the upland (composite configuration). Our earlier assessments of stone column ground improvement are detailed in our 30% Design Report. This Final Report addresses the composite stone column configuration that was selected by the design team.

Existing WUT Wharf Improvements

The existing WUT Wharf currently operates with four cranes, but has infrastructure to support seven cranes. Two new cranes recently arrived, which may operate on the existing wharf until the subject 600-foot extension is complete. New storm tie downs will be constructed within approximately the southernmost 500 feet of the existing wharf.

In addition to new storm tie-downs, the toe slope at the existing front face of the WUT Wharf may be dredged from Elevation -50 feet to Elevation -55 feet in the future. Geotechnical information regarding dredging below the existing WUT Wharf is provided under a separate cover in our February 14, 2008 memorandum. Geotechnical issues related to dredging for the existing WUT Wharf are not discussed in this report.

Blair Dock Improvements

The existing Blair Dock is a roll on/roll off (RO/RO) facility used for unloading automobiles and other break-bulk cargos. The Port intends to continue using the remaining portion of the Blair Dock as a RO/RO facility after demolition of its northernmost 600 feet. New mooring features are proposed at the north and south ends of the remaining Blair Dock, as shown on Figure 2.

Additional improvements at the Blair Dock will include future dredging. Significant dredging may be needed to the south of the existing dock. Geotechnical issues associated with dredging along the remaining portions of the Blair Dock are not addressed in this report.

WHARF SEISMIC DESIGN APPROACH

The seismic design for the wharf extension has been completed using a performance-based approach in general accordance with California State Land Commission, Marine Oil Terminal Engineering and Maintenance Standards [MOTEMS]. Two design earthquake levels were considered, an operating level earthquake (OLE) and a contingency level earthquake (CLE). The OLE is defined as a seismic event with a 50 percent probability of exceedance in 50 years (72-year return period). The CLE is defined as a seismic event with a 10 percent probability of exceedance in 50 years (475-year return period).

In addition to MOTEMS guidelines, the CLE design spectrum for the wharf is compared with 80 percent of a 2006 International Building Code (IBC) design earthquake generalized spectrum. The IBC design earthquake is defined as 2/3 of a maximum considered earthquake (MCE), an event with a 2 percent probability of exceedance in 50 years (2,475-year return period). The comparison to 80 percent of the generalized design spectrum is recommended by the IBC as a basis for forming a lower bound on spectral accelerations developed using site specific response analyses.

SCOPE OF GEOTECHNICAL SERVICES

Our geotechnical scope of services for this project is presented in our April 10, 2008 signed agreement with BERGER/ABAM Engineers. Our geotechnical scope of services includes the following:

EXPLORATIONS

1. Advancing three cone penetration test (CPT) soundings to explore subsurface conditions in the area of the proposed wharf extension. CPT soundings were extended to depths of about 200 feet

- below existing ground surface (bgs). Shear wave velocity data were collected in two of the CPT soundings.
- **2.** Drilling four geotechnical borings in the area of the proposed wharf extension. Borings were drilled to depths of about 150 feet bgs.

LABORATORY TESTING

Laboratory tests were conducted on selected samples from the borings to evaluate the engineering properties of the materials encountered. Tests included:

- 1. Moisture content and dry density tests
- **2.** Grain-size analysis
- 3. Percent passing U.S. No. 200 sieve

ENGINEERING STUDIES

Our engineering studies included the following:

- 1. Developing summary logs of the explorations and cross sections illustrating our interpretation of subsurface conditions for use in design.
- **2.** Providing recommendations for precast concrete pile foundation support of the proposed new wharf, including ultimate downward and uplift capacities and settlement estimates.
- 3. Developing soil parameters for LPILE lateral pile load analysis.
- **4.** Providing geotechnical recommendations for sheet pile bulkhead design.

GEOTECHNICAL SEISMIC STUDIES

Geotechnical seismic studies are a critical part of developing an understanding of soil liquefaction potential and the seismic shaking risk to the proposed dredge slope and wharf. We also use geotechnical seismic studies to provide preliminary estimates of the most effective locations for stone column ground improvements. We completed the following seismic design analyses:

- **1.** Developing seismic design criteria, including recommended response spectra for the OLE, CLE and MCE events.
- **2.** Providing recommendations for subsurface profile type and seismic lateral earth pressures for the design seismic events.
- **3.** Evaluating liquefaction potential and strength loss of soils during seismic events.
- **4.** Evaluating the proposed dredge slope stability and the extent of lateral spreading anticipated under the design seismic events using pseudo-static and Newmark methods.

FINITE ELEMENT ANALYSES

The purpose of our finite element analyses is to augment the geotechnical seismic studies by refining the predicted performance of the new wharf/slope (deformation and stresses) under the design earthquakes per MOTEMS. We performed our finite element analyses using the computer program PLAXIS V8, a program developed by PLAXIS b.v. in the Netherlands. We completed the following finite element analyses:

- 1. Estimating wharf/slope movements under both the OLE and CLE events using two options for stone column layout and two wharf pile configurations.
- 2. Estimating maximum pile moment and shear associated with the estimated wharf/slope movements.

SITE CONDITIONS

SURFACE CONDITIONS

The site surface is generally level and covered by asphalt concrete. The ground surface varies approximately between Elevation 19 and 20 feet. The site is bordered to the north by the existing WUT Wharf, to the east by the Blair Waterway, to the south by the southern portion of the Blair Dock and to the west by paved WUT property.

GEOLOGIC HISTORY

The Port is situated on the delta formed at the mouth of the Puyallup River as it enters Commencement Bay. Prior to human modification, this delta consisted of a tidal marsh extending to a front located approximately between present-day Lincoln Avenue and 11th Street and a tidal flat, exposed only during the lowest tides, which extended approximately to the line formed by the seaward ends of the present-day peninsulas.

Based on the "Geology of the Port of Tacoma" report (Hart Crowser and Associates, undated), the general model of delta progradation begins with deposition of a series of clayey and silty deep-water beds known as prodelta deposits. These beds are overlain by a thick series of inclined sandy delta-front deposits known as foreset beds. Silt layers and lenses are often present within the delta-front deposits, representing periods of low-energy deposition. The foreset beds are in turn overlain by silty and clayey shallow water beds called delta plain deposits or topset beds. Generally, sand deposits indicate a rapid rate of delta progradation; silt characterizes a period of little or no delta progradation. In the Puyallup River Delta, the interbedded silt and sand deposits suggest a highly variable rate of progradation.

Since the founding of Tacoma and development of the Port, fill has been placed over most of the natural ground surface in the Port area to create usable land. The properties of the fill vary greatly depending on the source and type of fill as well as the method of placement. It appears that much of the fill in the Port was placed without any engineering design or inspection.

SUBSURFACE EXPLORATIONS

Site subsurface conditions were explored by drilling four borings and advancing three CPT soundings. We also reviewed subsurface exploration logs from studies completed for the existing WUT Wharf and Blair Dock

The drilled borings were extended to depths of about 150 feet bgs, and the CPT soundings were extended to depths of about 200 feet bgs. Shear wave velocity data were collected in two of the CPT soundings. Approximate locations of subsurface explorations are shown on Figure 4.

The following sections of this report provide brief descriptions of the materials encountered in our explorations. Summary exploration logs, shear wave velocity data and descriptions of our field exploration and laboratory testing programs are presented in Appendix A.

SUBSURFACE CONDITIONS

General

Based on our explorations, subsurface conditions at the project site include a surficial layer of fill, which is in turn underlain by native alluvial soils that typically comprise alternating layers of silt and sand. The soil descriptions presented in this section characterize the predominant soil units encountered. The sand units include occasional to frequent interbeds of silt and vice versa.

Based on an assessment of the physical and engineering properties of the site soils, we characterize the materials encountered in our explorations into seven general units: 1) fill, 2) upper silt, 3) upper sand, 4) middle sand, 5) middle silt, 6) lower sand and 7) lower silt. A generalized profile illustrating our interpretation of subsurface conditions is presented in Figure 5. A brief description of each of the soil units is provided below.

Fill

Underlying the asphalt concrete, our explorations encountered about 5 to 8 inches of fine to coarse gravel with sand. We interpret this material as pavement base course. Beneath the base course, our explorations encountered medium dense silty fine to medium sand with trace gravel and organics, grading to loose/medium stiff silty sand/sandy silt. At our exploration locations, we interpret the fill unit to extend to between 10 and 13 feet bgs.

It is possible that debris, cobbles and boulders are present within the fill unit.

Native Soils

We interpret all soils encountered below the fill be deltaic Puyallup River alluvium deposits to the full depths explored, approximately 200 feet bgs (Elevation -180 feet MLLW). As illustrated on the subsurface profiles and exploration logs, the stratigraphy is complex. The following is a generalized summary of the native soil units present in our explorations.

Upper Silt – Underlying the fill, the upper silt unit generally comprises soft silt with occasional sand and organics, present between about 10 and 20 feet bgs (Elevation +10 and 0 feet). This unit also contains occasional soft organic silt and very loose silty sand layers.

Upper Sand – Underlying the upper silt, the upper sand unit generally comprises medium dense silty sand with layers of very soft to very stiff sandy silt. At our exploration locations, this unit is generally present between about 20 and 50 feet bgs (Elevation 0 and -30 feet). This unit also includes layers of medium dense sand with silt. We subdivide this unit into three additional layers when considering geotechnical design parameters.

Middle Sand – Underlying the upper sand, the middle sand unit generally comprises medium dense to dense silty fine to medium sand and fine to medium sand with silt. At our exploration locations, this unit is generally present between about 50 and 85 feet bgs (Elevation -30 and -65 feet).

Middle Silt – Underlying the middle sand, the middle silt unit generally comprises alternating layers of very stiff/medium dense sandy silt/silty sand and very soft silt. At our exploration locations, this unit is generally present between about 85 and 140 feet bgs (Elevation -65 and -120 feet). We subdivided this unit into two additional layers when considering geotechnical design parameters.

Lower Sand – Underlying the middle silt, we interpret the lower sand unit to generally comprise medium dense to dense silty sand. At our exploration locations, this unit is generally present between about 140 and 160 feet bgs (Elevation -120 and -140 feet).

Lower Silt – Underlying the lower sand, we interpret the lower silt unit to generally comprise medium stiff to very stiff sandy silt. At our exploration locations, this unit is generally present between about 160 and 200 feet bgs (Elevation -140 and -180 feet).

Groundwater

Groundwater was generally encountered between 7.5 and 10 feet bgs (Elevation 11.5 and 9 feet) in our explorations. Groundwater elevations are expected to vary with season, tidal fluctuations and other factors.

SELECTED ENGINEERING PROPERTIES OF SOIL UNITS

Based on the subsurface conditions encountered in our explorations, shear wave velocity data, laboratory test results and our experience with similar projects in the Port, we selected representative engineering properties of the soil units. By comparison with extensive laboratory testing performed for nearby projects in the Port, we generally consider the fine-grained materials encountered in our explorations to be non-plastic or to have low plasticity. Table 1 provides the soil properties used in the majority of the analyses described in this report. The properties provided in Table 1 should not be used in structural design or any other type of design without first referencing the section of this report (such as "static axial pile capacity") pertaining to that design element.

Table 1. Selected Engineering Properties of Soil Units

| | | | | Soil Shear Strength Properties | | | | | |
|-------------|------------------------|-------------------------|-------------------------|--------------------------------|-------------------|--------------------------|-------------------------------|--------------------------|-------------------------------|
| | | Total | Effective | St | tatic | C | LE | C | LE |
| Soil Unit | Depth (feet bgs) | Unit Weight (pcf) | Unit Weight (pcf) | Friction Angle (°) | Cohesion (psf) | Friction Angle (°) | Residual Strength (psf) | Friction Angle (°) | Residual Strength (psf) |
| Fill | 0-10 | 125 | 63 | 36 | 0 | 36 | 0 | 36 | 0 |
| Upper Silt | 10-20 | 110 | 48 | 27 | 0 | 25 | 0 | 0 | 50 |
| Upper Sand | 20-30 | 120 | 58 | 33 | 0 | 33 | 0 | 33 | 0 |
| | 30-40 | 120 | 58 | 27 | 0 | 27 | 0 | 9 | 0 |
| | 40-50 | 120 | 58 | 33 | 0 | 33 | 0 | 33 | 0 |
| Middle Sand | 50-85 | 125 | 63 | 36 | 0 | 36 | 0 | 31 | 0 |
| Middle Silt | 85-110 | 125 | 63 | 30 | 0 | 27 | 0 | 25 | 0 |
| | 110-140 | 125 | 63 | 30 | 0 | 27 | 0 | 25 | 0 |
| Lower Sand | 140-160 | 125 | 63 | 36 | 0 | 36 | 0 | 36 | 0 |
| Lower Silt | 160-200 | 125 | 63 | 35 | 0 | 35 | 0 | 35 | 0 |

SEISMIC DESIGN CONSIDERATIONS

SEISMICITY

Earthquake Source Zones

The Puget Sound Lowland is located near the convergent tectonic plate boundary known as the Cascadia Subduction Zone (CSZ). The CSZ is an approximately 650-mile-long thrust fault that extends along the

Pacific Coast from mid-Vancouver Island to Northern California, where the westward advancing North American Plate is overriding the subducting Juan de Fuca Plate. The fault surfaces approximately 50 to 75 miles off the Washington coast. The interaction of these two plates results in two potential seismic source zones within the CSZ: 1) a Benioff source zone and 2) an interplate source zone. A third seismic source zone, referred to as the shallow crustal source zone, is associated with the north-south compression resulting from northerly movement of the Sierra Nevada block of the North American Plate.

Benioff Source Zone. Benioff source zone earthquakes are also referred to as intraplate, intraslab or deep subcrustal earthquakes. Benioff zone earthquakes within the CSZ occur within the subducting Juan de Fuca Plate between depths of 20 and 50 miles and typically have no large aftershocks. Extensive faulting results as the Juan de Fuca Plate is forced below the North American Plate and into the upper mantle.

Damaging Benioff source zone earthquakes occur in Western Washington every 30 years or so. The Benioff source zone within the CSZ is characterized as being capable of generating earthquakes up to magnitude 7.5. The 1949 Olympia (magnitude [M] = 7.1), the 1965 Seattle (M = 6.5) and the 2001 Nisqually (M = 6.8) earthquakes are considered to be Benioff zone earthquakes. The recurrence interval for large earthquakes originating from the Benioff source zone is believed to be shorter than shallow crustal and interplate source zone earthquakes. The deep focal depth of Benioff source zone earthquakes tends to dampen the shaking intensity, when compared to shallow crustal earthquakes of similar magnitude.

Interplate Source Zone. Interplate source zone earthquakes within the CSZ result from rupture of all or a portion of the convergent boundary between the subducting Juan de Fuca Plate and the overriding North American Plate. Interplate source zones within the CSZ are considered to be capable of generating earthquakes of M = 8 to M = 9. Interplate source zone earthquakes on the CSZ have not been instrumentally recorded; however, through the geologic record and historical records of tsunamis in Japan, it is believed that the most recent interplate CSZ event occurred in the year 1700 (Atwater, 1996 and Satake et al., 1996). Recurrence intervals for CSZ interplate earthquakes are thought to be on the order of 400 to 600 years. Paleogeologic evidence suggests that five to seven interplate earthquakes may have occurred along the CSZ over the last 3,500 years at irregular intervals.

Shallow Crustal Source Zone. The shallow crustal source zone is used to characterize shallow crustal earthquake activity within the North American Plate. Shallow crustal earthquakes typically occur at depths ranging from 3 to 20 miles. The shallow crustal source zone is characterized as being capable of generating earthquakes up to about magnitude 7.5. Large shallow crustal earthquakes are typically followed by a sequence of aftershocks.

The largest known earthquakes associated with the shallow crustal source zone in Western Washington include an event on the Seattle Fault in about A.D. 900 and the 1872 North Cascades earthquake. The Seattle Fault event was believed to be magnitude 7 or greater (Johnson et al., 1999), and the 1872 North Cascades earthquake is estimated to have been between magnitudes 6.8 and 7.4. The location of the 1872 North Cascades earthquake is uncertain; however, recent research suggests that the earthquake's intensity center was near the south end of Lake Chelan (Bakun et al., 2002).

Representative Design Earthquake Types and Sources

To assess the potential contribution of each of the regional earthquake source zones to the seismic hazard at the project site, we reviewed the 2002 United States Geological Survey (USGS) probabilistic seismic hazard deaggregations for the OLE, CLE and MCE events with periods less than or equal to 1 second. Based on the results of the deaggregation, the project site is strongly influenced by shallow crustal and

Benioff earthquakes of small- to moderate-size magnitudes (about 6.2 to 6.7). Large crustal (Seattle fault) and interplate zone earthquakes each compose less than 15 percent of the total seismic hazard at the project site, for the OLE, CLE and MCE events. Table 2 below presents the earthquake type, magnitude and their associated contribution to the seismic hazard at the project site.

Table 2. Summary of Seismic Hazard Deaggregation for Period ≤ 1 second

| | Charac | teristic Mag | nitude | | ontribution t Seismic Haz | |
|--|--------|--------------|--------|-----|------------------------------|-----|
| Earthquake Type | OLE | CLE | MCE | OLE | CLE | MCE |
| Benioff | 6.6 | 6.7 | 6.9 | 44 | 46 | 38 |
| Interplate | 8.3 | 9.0 | 9.0 | 12 | 11 | 15 |
| Shallow Crustal | 6.3 | 6.4 | 6.6 | 40 | 37 | 40 |
| Large Shallow Crustal (Seattle Fault) | 6.8 | 6.9 | 7.2 | 4 | 6 | 7 |

SITE-SPECIFIC SEISMIC RESPONSE ANALYSES

GENERAL

Site-specific seismic response analyses were required because of the presence of liquefiable soils at the site, per MOTEMS and ASCE 7-05 guidelines. We completed seismic response analyses to develop design spectra for the OLE, CLE and MCE events. The results from the OLE and CLE site-specific response analyses presented in this section were used by the structural engineer in the structural analysis of the wharf, and used for input to our finite element analyses discussed below. Site seismic response analyses for the OLE and CLE events were completed in general accordance with MOTEMS guidelines. Site seismic response analysis for the MCE event was completed in general accordance with the IBC/ASCE 7-05 procedure.

USGS SEISMIC HAZARD VALUES

The USGS has developed probabilistic seismic hazard maps that present peak ground acceleration (PGA) and spectral accelerations at periods of 0.1, 0.2, 1 and 2 seconds for earthquakes corresponding to the return period of 72-years, 475-years and 2,475-years (Frankel, et al., 1996, 2002). The USGS seismic hazard values are for rock outcrop sites and do not include site effects such as soil amplification/damping. The USGS probabilistic rock outcrop seismic hazard values for the three earthquake levels for the project site are as shown in the following table.

Table 3. USGS Seismic Hazard Values at Rock Outcrop

| Peak Ground Acceleration/Spectral Acceleration (g) | | | | | | | |
|--|------------------------|-------------------------|---------------------------|--|--|--|--|
| Period (seconds) | 72-year Event (OLE) | 475-year Event (CLE) | 2,475-year Event (MCE) | | | | |
| PGA | 0.122 | 0.311 | 0.548 | | | | |
| 0.1 | 0.229 | 0.600 | 1.070 | | | | |
| 0.2 | 0.264 | 0.684 | 1.211 | | | | |
| 1.0 | 0.081 | 0.228 | 0.416 | | | | |
| 2.0 | 0.035 | 0.102 | 0.194 | | | | |

SELECTION OF EARTHQUAKE ACCELERATION TIME HISTORIES FOR SITE RESPONSE ANALYSIS

Seven earthquake time histories that are representative of the site seismic hazard were selected for use in development of the design spectra for the OLE, CLE and MCE events. Based on the deaggregation presented in Table 2, we selected two shallow crustal events, three Benioff events and two interplate events as representative earthquake acceleration time histories. The selected earthquake acceleration time history events are presented below in Table 4.

Table 4. Selected Earthquake Acceleration Time Histories for OLE, CLE and MCE

| Earthquake, Year | Recording Station | Magnitude | Earthquake Type |
|--------------------|---------------------------|-----------|-----------------|
| San Fernando, 1971 | Cedar Springs Allen Ranch | 6.6 | Shallow Crustal |
| Northridge, 1994 | LA Wonderland Ave | 6.7 | Shallow Crustal |
| Nisqually, 2001 | University of Puget Sound | 6.8 | Benioff |
| Nisqually, 2001 | Green Mountain | 6.8 | Benioff |
| El Salvador, 2001 | Santiago De Maria | 7.6 | Benioff |
| Michoacan, 1985 | La Union, Mexico | 8.1 | Interplate |
| Tokachi-Oki, 2003 | Iwamizawa, Japan | 8.3 | Interplate |

SCALING OF EARTHQUAKE ACCELERATION TIME HISTORIES

Each of the acceleration time histories from the earthquake events shown in Table 4 were scaled such that the average response spectrum approximates the USGS seismic hazard values summarized in Table 3, over the period range of significance to the structure. The period range of significance of the proposed wharf is estimated to be between 0.5 and 1.5 seconds. The results of our scaled rock outcrop response spectra are provided in Figures 6 through 8. The scaled earthquake acceleration time histories are used as input time histories in site seismic response analysis, as summarized below.

ANALYSIS METHODOLOGY

The site seismic response was computed using the computer program D-MOD2000, a one-dimensional, nonlinear geotechnical ground response analysis program developed by GeoMotions, LLC. The engineering behavior of the site soils during a seismic event was modeled with nonlinear shear modulus reduction and damping relationships that account for the excess pore water pressure generated from earthquake loadings.

SOIL MODEL

A soil model profile defined by shear wave velocities, shear stress-strain relationships, damping-shear strain relationships and unit weights was developed for input to D-MOD2000. The shear wave velocities of the soil within the explored depth (about 200 feet bgs) were obtained from the CPT shear wave velocity measurements.

Measured shear wave velocities for the upper 200 feet of soil profile range from about 450 to 1,000 feet per second. Shear wave velocity was assumed to increase linearly from 1,000 feet per second at a depth of 200 feet to 1,500 feet per second at the transition between alluvial and glacially consolidated soils (modeled as bedrock). Based on our review of regional geology, this transition was assumed at a depth of 650 feet. We assumed the very dense glacially consolidated soils below 650 feet have shear wave

velocities of 2,500 feet per second, based on measured values in similar glacial soils in the Puget Sound region. Figure 9 presents the shear wave velocity profile used in our analysis.

In order to capture the nonlinear dynamic soil response during a seismic loading, we used the Modified Kondner and Zelasko (MKZ) nonlinear stress strain model (Matasovic and Vucetic, 1993) using the fitting parameters developed by Matasovic (1993) for the Wildlife Site in California. In addition, the soil model incorporates reduced shear wave velocities to reflect the buildup of excess pore pressure during seismic shaking.

RESPONSE SPECTRA

Response spectra with 5 percent critical damping were developed for the site by propagating the scaled earthquake acceleration time histories developed for the OLE, CLE and MCE events through the soil profile using D-MOD2000. Figures 10 through 12 present the 5 percent damped response spectra at the ground surface for each of the seven earthquake acceleration time histories chosen for the OLE, CLE and MCE events. Figure 13 presents our recommended OLE and CLE response spectra for use in structural analyses using a MOTEMS based design. For comparison purposes, Figure 13 also shows 80 percent of the design IBC generalized spectrum (i.e., 2/3 MCE S_a values for Site Class E x 80 percent).

LIQUEFACTION ANALYSES

GENERAL

Soil liquefaction refers to the condition by which vibration or shaking of the ground, usually from earthquake forces, results in the development of excess pore pressures in saturated soils with subsequent loss of strength. In general, soils that are susceptible to liquefaction at this site include very loose to medium dense, clean to silty sands and non-plastic silts that are below the water table.

Soil liquefaction may result in slope instability and downslope soil movement. This movement may exert lateral forces on the wharf piles embedded within the dredge slope. If the downslope movement is sufficiently large, structural damage to the piles and other portions of the structure can occur.

ANALYSIS METHODOLOGY

The evaluation of liquefaction potential is complex and dependent on numerous parameters, including soil type, grain-size distribution, soil density, depth to groundwater, in-situ static ground stresses, earthquake-induced ground stresses and excess pore water pressure generated during seismic shaking. A key ground stress parameter for evaluating liquefaction potential is the cyclic shear stress ratio, which is defined as the ratio of the cyclic shear stress to the effective overburden stress.

Typically, the liquefaction potential of a site is evaluated by comparing the cyclic shear stress ratio induced by an earthquake with the cyclic shear stress ratio required to cause soil liquefaction (i.e., the cyclic resistance ratio of the soil). This ratio can be considered as representing a factor of safety (FS) against liquefaction. If this FS is less than 1.0, the soil will likely liquefy, resulting in a significant loss in shear strength. We consider this condition to be fully liquefiable (FL). If the FS is greater than about 1.5, we expect essentially no loss in shear strength will occur. We designate this condition as non-liquefiable (NL). For an FS between 1.0 and about 1.5, there will be some development of excess pore pressure, but the soil will likely undergo only a partial loss of shear strength. Therefore, we designate this condition as marginally liquefiable (ML).

We evaluated liquefaction potential of the site soils for the OLE and CLE events using subsurface data and information obtained from the CPTs and borings, and the scaled earthquake acceleration time histories previously discussed. We evaluated liquefaction potential using three simplified methods, Youd et al (1997), Seed et al (2003) and Idriss and Boulanger (2004). We also used the computer program D-MOD2000 to calculate excess pore water pressure generated by seismic shaking during the design earthquake time histories and compared the results to that of the simplified methods. Based on our analyses, we characterized the liquefaction potential of the site soils using the criteria below:

- 1. 0 to 70 feet bgs If the simplified methods indicate FS less than 1, we consider the soils fully liquefiable.
- 2. 0 to 200 feet bgs If the calculated excess pore water pressure is less than 10 percent of the effective vertical confining pressure, we consider the soils non-liquefiable.
- 3. 0 to 200 feet bgs If the calculated excess pore water pressure is between 10 and 50 percent of the effective vertical confining pressure, we consider the soils marginally liquefiable.

ANALYSES RESULTS

The results of our analyses for the OLE and CLE events are presented in Table 5 below.

Table 5. Summary of Liquefaction Analyses Results

| | Depth | Liquefaction | n Potential ¹ |
|-------------|------------|--------------|--------------------------|
| Soil Unit | (feet bgs) | OLE | CLE |
| Fill | 0-10 | NL (Above W | /ater Table) |
| Upper Silt | 10-20 | ML | FL |
| Upper Sand | 20-30 | NL | NL |
| | 30-40 | NL | FL |
| | 40-50 | NL | NL |
| Middle Sand | 50-85 | NL | ML |
| Middle Silt | 85-110 | ML | ML |
| | 110-140 | ML | ML |
| Lower Sand | 140-160 | NL | NL |
| Lower Silt | 160-200 | NL | NL |

Note:

¹ NL: Non-Liquefiable; ML: Marginally Liquefiable; FL: Fully Liquefiable

SLOPE STABILITY AND NEWMARK ANALYSES

GENERAL

Slope stability and Newmark analyses were completed to identify potential critical failure surfaces for the dredge slope and to estimate permanent deformation of the identified critical failure surfaces under seismic conditions. Slope stability and Newmark analyses were also completed to provide preliminary estimates of the effects of different ground improvement (stone column) layouts. Our analyses were completed for the OLE and CLE events. The soil shear strength parameters used in our slope stability analyses are included in Table 1.

We completed our slope stability analyses using the computer program SLOPE/W (GEO-SLOPE International, Ltd., 2005). SLOPE/W evaluates the stability of numerous trial failure surfaces using vertical slice limit-equilibrium methods. This method compares the ratio of forces driving slope

movement with forces resisting slope movement for each trial failure surface, and presents the result as the FS. The program then sorts the trial failure surfaces and identifies the surface with the lowest FS, or the "critical" failure surface. Also computed is the yield acceleration, which is defined as the ground acceleration that will cause a failure surface to start yielding or moving (i.e., FS = 1.0). The yield acceleration values calculated for the critical failure surfaces are used to estimate permanent slope movement under various earthquake time histories using the Newmark analysis method.

We completed our Newmark analyses using the computer program developed by Jibson and Jibson of USGS (Open File Report 03-005) using the rigorous rigid block method. The earthquake time histories calculated at the ground surface in our site seismic response analysis were used in our Newmark analyses.

ANALYSIS METHODOLOGY

The analyses of slope stability, magnitude of soil movement (Newmark), and effect of ground improvement involves an iterative process. In general, our analyses were performed as follows:

- 1. Perform static slope stability analyses to generate three critical failure surfaces (shallow, intermediate and deep) and obtain an associated FS, assuming no ground improvement and the reduced soil shear strengths associated with the OLE and CLE events.
- 2. Determine the yield acceleration value for critical failure surfaces with calculated factors of safety greater than 1.0 by varying the pseudo-static seismic coefficient (using SLOPE/W) to account for earthquake ground motions.
- **3.** Perform Newmark analyses to estimate the potential magnitude of movement of the soil mass above the critical failure surfaces without ground improvement.
- **4.** Perform iterative static slope stability analyses using different ground improvement configurations to identify the most effective location for ground improvement, with respect to slope stability.
- **5.** Perform Newmark analyses to estimate the potential magnitude of movement of the soil mass above the critical failure surfaces with the selected ground improvement layout.
- **6.** Perform static slope stability analyses (with static soil shear strength parameters) with the selected ground improvement layout.

ANALYSIS RESULTS

The results of our initial slope stability analyses (unimproved ground and the reduced soil shear strengths associated with the CLE event) are illustrated on Figures 14, 15 and 16 for the shallow, intermediate and deep failure surfaces, respectively. The results of our Newmark analyses for unimproved ground conditions are provided below in Table 6. These results indicate that significant slope movement would occur under the CLE event without ground improvement. Newmark analyses were not performed for the shallow failure surface because the FS was less than 1 before applying a pseudo-static acceleration coefficient.

Table 6. Summary of Newmark Analysis Results - Unimproved Soil Profile

| | Slope Mov Intermediate F (incl | ailure Surface | Slope Moveme Seated Failui (inche | re Surface |
|----------------------------|--------------------------------------|----------------|---|------------|
| Earthquake Time Histories | OLE | CLE | OLE | CLE |
| San Fernando | 2.8-5.8 | 40-60 | 1.0-2.4 | 22-42 |
| Northridge | 1.5-5.0 | 19-31 | 0.5-2.8 | 9-20 |
| Nisqually (U of PS) | 10.1-14.3 | 165-208 | 3.6-5.9 | 98-129 |
| Nisqually (Green Mountain) | 0.87-0.94 | 5-6 | 0.3-0.5 | 2.6-2.7 |
| El Salvador | 4.3-8.2 | 11-70 | 1.7-4.2 | 12-22 |
| Michoacan | 8.4-25.9 | 29-99 | 3.4-12.3 | 19-46 |
| Tokachi-oki | 36.6-40.5 | 279-283 | 17.4-15.0 | 158-160 |

The results of our slope stability analyses with improved ground conditions are shown on Figures 17 through 19. The ground improvement zone shown on these figures is 50 feet wide by 50 feet deep. We assigned an internal friction angle of 36 degrees for the ground improvement zone. The results of our Newmark analyses for improved ground conditions are provided below in Table 7.

Table 7. Summary of Newmark Analysis Results - With Ground Improvement

| | Intermediate F | vement for Failure Surface hes) | Slope Movem Seated Failu (inch | ıre Surface |
|----------------------------|----------------|---------------------------------------|--------------------------------------|-------------|
| Earthquake Time Histories | OLE | CLE | OLE | CLE |
| San Fernando | 0 | 0-0.8 | 0 | 2.2-4.5 |
| Northridge | 0 | 0-0.6 | 0-0.08 | 0.9-3.9 |
| Nisqually (U of PS) | 0 | 0.35-0.43 | 0 | 7.5-12.8 |
| Nisqually (Green Mountain) | 0 | 0 | 0 | 0.08-0.16 |
| El Salvador | 0 | 0-0.79 | 0 | 0.4-2.3 |
| Michoacan | 0 | 0 | 0-0.04 | 0.2-1.5 |
| Tokachi-oki | 0 | 0 | 0 | 5.75-5.83 |

By comparison of Tables 6 and 7, it is evident that our analyses suggest ground improvement would significantly limit downslope movement due to an OLE or CLE event. However, the Newmark approach is a simplified method of analysis and does not include the effects of initial shear stresses nor does it account for downslope movement for ground motions less than the critical yield acceleration. Also, soil-pile interaction during an earthquake is not considered. Accordingly, the calculated slope movements shown above should be considered estimates, to be used to provide insight regarding the potential for significant earthquake-related slope instability. A more detailed approach of predicting slope deformation and wharf performance is presented in our finite element analyses, as discussed in the following section.

We also performed static slope stability analyses for improved ground conditions using static soil parameters (no reduction in shear strength). These analyses indicate an FS greater than 1.5 for the shallow, intermediate and deep failure surfaces.

FINITE ELEMENT ANALYSES

GENERAL

Based on our slope stability and Newmark analysis results and stone column installation considerations, we identified a target zone for stone column ground improvement of 50-feet-wide by 50-feet-deep. Considering the slope stability and Newmark analyses results, we completed time history deformation analysis using PLAXIS to optimize the location and depth of the stone column zones with respect to the performance of the wharf and slope. A summary of our finite element analyses is provided below. A detailed discussion of our analysis, methodology and replacement ratio selection is provided in Appendix B.

30% DESIGN

During 30% design we completed finite element analyses for the OLE and CLE events considering two options for ground improvement layout. Option 1 consisted of three rows of stone columns on the landside of the bulkhead and two rows of stone columns on the dredge slope between pile bents. Option 2 consisted of four rows of stone columns on the landside of the bulkhead and no stone columns on the dredge slope. Our 30% design analyses utilized 3-foot-diameter stone columns, with tip Elevation -30 feet, and did not include L-line piles.

Our 30% design analyses results predicted about 4 to 5 inches less horizontal wharf deck deformation for Option 1 than Option 2. Our analyses also suggested that a plastic hinge would likely develop in the K-line piles during a CLE event with the Option 2 ground improvement layout. Based on the results of these analyses, an Option 1 type ground improvement layout was selected by the design team.

FINAL DESIGN

Finite element analyses performed for 95% design included modifying the PLAXIS model to include L-line piles and varying stone column configurations within an Option 1 layout to assess potential benefits. Additional finite elements analyses were not required for final design. Our 95% design configuration included L-line piles and 3.5-foot-diameter stone columns. We analyzed two stone column configurations with the same volume but different replacement ratios (A_r =6% and A_r =9%) on the slope. The larger replacement ratio (A_r =9%) with the same volume of stone was achieved by shifting the stone columns toward the bulkhead, condensing the layout. As such, the A_r =9% configuration is over a smaller improved ground area than the A_r =6% configuration. A schematic illustration of the wharf, soil profile and loading conditions used in our finite element model is provided on Figure 20. The two stone column configurations analyzed are shown on Figure 21.

The results of our finite element analyses are provided below on Tables 8 and 9. As evident by comparison of Tables 8 and 9, our analyses predict about 1 inch less horizontal wharf deck deformation for A_r =9% than A_r =6% as a result of a CLE event. Our analyses also suggest that shear and moment on the piles is about 5 percent to 10 percent less for A_r =9%.

Table 8. PLAXIS OUTPUT - Slope A_r=6%

| | | OI | LE | | CLE | | | | |
|--|---|--|---|---|---|---|---|---|--|
| | San Fernando | | Nisqually | | San Fernando | | EL Salvador | | |
| Pile Row | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | |
| Α | 165 | 27 | 187 | 42 | 332 | 58 | 340 | 55 | |
| В | 148 | 13 | 170 | 17 | 313 | 25 | 333 | 22 | |
| С | 140 | 18 | 159 | 19 | 314 | 26 | 321 | 25 | |
| D | 118 | 28 | 133 | 34 | 265 | 39 | 252 | 49 | |
| Е | 157 | 25 | 175 | 29 | 315 | 34 | 286 | 34 | |
| F | 181 | 26 | 199 | 30 | 336 | 34 | 303 | 36 | |
| G | 202 | 19 | 219 | 20 | 294 | 71 | 261 | 72 | |
| Н | 191 | 20 | 205 | 22 | 355 | 92 | 356 | 104 | |
| J | 167 | 25 | 162 | 27 | 384 | 70 | 388 | 78 | |
| K | 237 | 22 | 248 | 21 | 350 | 39 | 354 | 35 | |
| L | 245 | 35 | 275 | 34 | 452 | 73 | 476 | 71 | |
| AZ37-700 | 80 | 7 | 89 | 6 | 154 | 8 | 159 | 9 | |
| Pile Capacity | 675 | 250 | 675 | 250 | 675 | 250 | 675 | 250 | |
| Wharf Deck Horizontal Deformation at the End of Earthquake (in.) | 3 | | 4 | | 11 | | 14 | | |

Table 9. PLAXIS OUTPUT - Slope $A_r \! = \! 9\%$

| | OLE | | | | CLE | | | | |
|----------|---|--|---|---|---|---|---|---|--|
| | San Fernando | | Nisqually | | San Fernando | | EL Salvador | | |
| Pile Row | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear during EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | |
| Α | 168 | 30 | 191 | 39 | 325 | 58 | 333 | 52 | |
| В | 151 | 13 | 173 | 13 | 306 | 24 | 327 | 21 | |
| С | 144 | 17 | 163 | 18 | 306 | 25 | 315 | 25 | |
| D | 119 | 28 | 135 | 32 | 254 | 39 | 244 | 50 | |
| Е | 158 | 11 | 177 | 27 | 301 | 31 | 276 | 35 | |
| F | 180 | 26 | 199 | 31 | 315 | 35 | 294 | 36 | |
| G | 200 | 30 | 217 | 18 | 263 | 72 | 272 | 73 | |
| Н | 182 | 18 | 199 | 20 | 324 | 95 | 376 | 109 | |

Table 9. PLAXIS OUTPUT - Slope A_r=9% (Continued)

| | OLE | | | | CLE | | | | |
|--|---|--------------------------------------|---|--|---|---|---|--------------------------------------|--|
| | San Fernando | | Nisqually | | San Fernando | | EL Salvador | | |
| Pile Row | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | Estimated Max Moment During EQ (kip-ft) | Estimated Max Shear During EQ (kips) | |
| J | 177 | 14 | 177 | 18 | 351 | 71 | 351 | 62 | |
| К | 232 | 22 | 247 | 22 | 343 | 25 | 369 | 23 | |
| L | 235 | 38 | 265 | 36 | 428 | 70 | 455 | 67 | |
| AZ37-700 | 77 | 7 | 64 | 7 | 146 | 14 | 152 | 9 | |
| Pile Capacity | 675 | 250 | 675 | 250 | 675 | 250 | 675 | 250 | |
| Wharf Deck Horizontal Deformation at the End of Earthquake (in.) | 3 | | 4 | | 10 | | 13 | | |

CONCLUSIONS AND RECOMMENDATIONS

GENERAL

Based on the results of our subsurface exploration and analyses, it is our opinion that the proposed development is feasible from a geotechnical standpoint. To reduce the potential for excessive deformation of the wharf and slope, we recommend that stone columns be installed on the slope prior to dredging.

Our explorations encountered a layer of relatively dense sand (middle sand) extending between approximately Elevation -30 and -65 feet (50 and 85 feet bgs). This dense soil unit is shallower and thicker than in explorations at nearby wharf sites. Accordingly, we recommend that stone columns extend down to the top of the middle sand layer with a minimum tip elevation of -30 feet.

The results of our finite element analyses indicate acceptable wharf and slope deformation and pile stresses under the design level earthquakes while utilizing stone columns that are considerably shorter than used in recent nearby wharf designs. Details and results of our finite element analyses are provided in Appendix B.

Based on the subsurface conditions encountered in our explorations and recent observation of pile installation at the EB1 site, we anticipate the proposed 24-inch-octagonal concrete piles can be driven to the proposed tip elevations (shown on Figure 3) using conventional diesel hammer driving methods. We anticipate slow pile penetration rates when driving through dense sand layers and in the improved ground zone. Predrilling may be necessary in the upper 30 feet to expedite pile installation in the improved ground zone (pile gridlines J, K and L only). The following sections of this report provide additional pile driving considerations.

In the following sections we provide recommendations for axial pile capacity, LPILE parameters and lateral pressures acting on the sheet pile bulkhead. These recommendations are appropriate for structural

analyses under static conditions or when using pseudo-static analyses, and do not include reduced soil shear strengths as a result of seismic shaking.

CONSTRUCTION SEQUENCING

In order to limit risk of slope instability and potential damage to structures, we recommend the following general construction sequencing order:

- 1. Ground Improvement
- **2.** Dredging and Wharf Demolition
- 3. Riprap Placement
- **4.** Pile Driving and Sheet Pile Installation
- 5. Wharf Deck Construction
- **6.** Upland Improvements

Installation of stone columns and driving piles is expected to cause some permanent slope movement. The amount of movement will depend on the effort required to complete the work and local soil and groundwater conditions. Based on lessons learned from nearby projects, considerable wharf movement (approximately 4 to 6 inches at EB1) should be expected if stone columns are installed after pile driving and during wharf deck/bulkhead construction.

We recommend that stone columns be installed prior to dredging and wharf construction, as described in the sequencing order above. Project construction contract documents should specifically state that ground improvement must be completed before beginning pile or bulkhead installation.

GROUND IMPROVEMENT

Configuration Alternatives

The selection of a ground improvement alternative should consider several things, including slope/wharf seismic performance, constructability and cost. From a geotechnical standpoint, we recommend the A_r =9%. As described in the "Finite Element Analyses – Final Design" section of this report, this configuration provides better seismic performance to the wharf and slope without additional stone column installation volume.

Stone Column Construction Recommendations

We recommend that stone columns be constructed using bottom-feed vibro-replacement construction techniques. Stone columns should be approximately 3.5 feet in diameter. We recommend that an approximately 6-inch-thick blanket of crushed rock be placed over the stone column improvement area, continuous with the top of the completed stone columns. The top of the crushed rock blanket should be at the elevation of the bottom of the pavement base course section. During liquefaction, this blanket of crushed rock will allow for dissipation of excess pore pressure, reducing the potential for disturbance of the pavement section.

Crushed rock for stone column construction and the crushed rock blanket should be hard, durable, washed and crushed rock with no organics or other deleterious material, and a maximum size of about 2 inches. Stone column aggregate should be in general accordance with the recommendations of "Shoulder Ballast"

described in WSDOT Specification 9-03.9(2). Minor variations in the gradation should be allowed to accommodate local rock sources, the contractor's equipment and the installation method.

Stone Column Cleanup

Based on our experience, the site surface is heavily disturbed after stone column installation. Between stone wasted on the ground and underlying soils brought to the surface through the column, we have observed excess material on the ground on the order of 20 to 30 percent of the neat stone column volume. This can raise site grades by feet. We do not anticipate that the matrix of wasted stone and returned underlying silty soils will be a suitable source for structural fill on this project.

We recommend that the contract document specifically state that it is the contractor's responsibility to restore site grades and expose the tops of the stone columns before placement of the rock blanket. We also recommend that the contractor submit a work plan that addresses their proposed methods for limiting disturbance to the subgrade during stone column installation, to be approved by the engineer.

PILE INSTALLATION CONSIDERATIONS

General

We anticipate the proposed 24-inch-octagonal concrete piles can be driven to the proposed tip elevations shown on Figure 3 using conventional diesel hammer driving methods. We anticipate slow penetration times when driving through dense sand layers and also where piles are driven within the stone column improved ground zone.

To assess possible pile driving conditions on this site, we reviewed select pile driving records from nearby projects. Select pile driving records from the existing WUT Wharf and Blair Dock are provided as Appendices C and D, respectively. To further assess potential driving conditions we performed preliminary Wave Equation Analyses of Pile Driving (WEAP), as discussed below.

Pile Driving in Improved Ground

As shown on Figure 21, pile rows K, J and L are located within or in proximity to the proposed improved ground zone. Accurate survey control of the pile grid, placement of the pile, and vertical control (plumbness) of the pile will be necessary to limit occurrences of piles potentially being obstructed by stone columns. It will also be necessary to maintain accurate survey control, placement and plumbness of the stone columns during installation.

We anticipate driving times for piles in the improved ground zone will be slow relative to driving piles outside of the improved ground zone. We anticipate predrilling in the upper 30 feet might be necessary to expedite pile installation in the improved ground zone. We recommend that the contractor submit a separate unit price for driving piles in the improved ground zone.

WEAP Analyses

We used the computer program GRLWEAP to evaluate pile driving conditions and perform preliminary pile drivability analyses. For our analyses, we selected the same hammer (Berminghammer B6505) used for construction of the EB1 Wharf, which has an energy rating of approximately 205,000 ft-lbs.

In general, the results of our preliminary analyses suggest that the selected hammer is capable of driving the piles to their design tip elevations (shown on Figure 3) without exceeding the acceptable stresses in the pile. However, it may be necessary to reduce the hammer stroke when entering and/or exiting dense sand layers and/or the improved ground zone. Our preliminary analyses also indicate this hammer should be capable of proving the design axial pile capacity. We recommend that a Berminghammer B6505 or equivalent be specified for this project. More specific WEAP analyses should be performed on the specific hammer submitted by the contractor prior to acceptance for use on this project.

Indicator Pile Program

To assess the pile driving conditions and confirm design pile capacities, we recommend that an indicator pile program be performed using full-length piles. Based on recent discussions, it is the design team's recommendation to the Port that an indicator pile program is not cost effective prior to construction. Instead, the indicator piles should consist of select initial production piles installed at the start of foundation construction.

We recommend that the indicator piles be spread along the length of the wharf and be spread from east to west to account for potential variations in driving conditions. The indicator pile program should consist of four to six piles, and include both driving and redriving. If possible, we recommend waiting up to one week before performing redrives in order to assess pile setup capacities.

The indicator pile program should include dynamic pile testing using a Pile Driving Analyzer (PDA) and wave equation analyses. We recommend CAse Pile Wave Analysis Program (CAPWAP) analysis be performed by a qualified consultant specializing in dynamic pile testing and use of the wave equation. We recommend that PDA testing and CAPWAP analysis be performed for initial indicator pile driving and for redriving.

STATIC AXIAL PILE CAPACITY

600-foot Wharf Extension

Our recommendations for axial pile capacity are based on 24-inch-octagonal prestressed concrete piles with embedment lengths and pile locations/groupings as shown on Figure 3. Figures 22 through 25 present our recommendations for allowable axial pile load versus pile head deformation for static conditions. The pile head deformation estimates provided on Figures 22 through 25 do not include elastic compression/elongation for the portion of the pile between mudline and the wharf deck.

Figures 22 through 25 are appropriate for use in static pile capacity analyses and/or seismic pile capacity analyses using pseudo-static seismic coefficients, and are not appropriate for structural analyses that utilize an earthquake time-history approach.

Existing WUT Wharf – Storm Tie-downs

Estimates for allowable uplift capacity of existing 24-inch-diameter hollow concrete piles on the existing WUT Wharf are provided below. These piles will be used to provide uplift resistance for storm tie-downs for the new cranes.

We reviewed exploration logs and pile driving records pertaining to the southernmost 500 feet of the existing WUT Wharf. Based on our review, it is our opinion that an allowable design uplift capacity of 250 kips is appropriate for individual piles in all rows except Row D. We recommend an allowable

design pile uplift capacity of 200 kips for Row D piles. In most cases, greater allowable uplift capacities are available.

Existing Blair Dock - Mooring and Breasting Dolphins

We have reviewed geotechnical borings provided in the Blair Dock Report for information on subsurface conditions in the vicinity of the proposed dolphins. The approximate locations of the proposed mooring and breasting dolphins are provided on Figure 2. Our recommendations for ultimate axial static pile capacity versus pile embedment depth are provided on Figures 26 through 28. These recommendations are for 24-inch-diameter octagonal concrete piles and assume the mudline elevations for each pile shown on the figures. Appropriate safety factors should be applied (typically 2 for side friction and 3 for end bearing) to establish allowable pile capacities. We are available to provide recommendations for allowable axial pile capacity versus pile head deformation upon request.

SOIL PARAMETERS FOR LPILE ANALYSES

Our recommendations for LPILE parameters to be used in static lateral pile analyses are provided in Table 10. These parameters are based on our experience and on published sources. Based on the riprap thicknesses proposed under current plans (shown on Figure 3) we do not recommend assuming lateral resistance will develop in the riprap layer. For piles spaced at least three pile diameters center-to-center, no reduction for pile group action needs to be made.

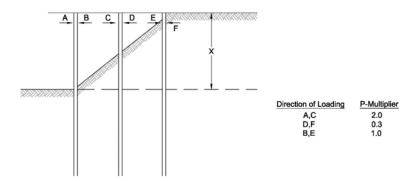
Table 10. Recommended Static LPILE Parameters for Level Ground Conditions

| Soil Layer | Depth (feet bgs) | Average Blow Counts (N) | Effective Unit Weight (pcf) | K (pci) | Friction Angle | LPILE Soil Type |
|-------------|---------------------|-------------------------------|-----------------------------------|------------|-------------------|-----------------|
| Fill | 0-10 | 16 | 120 | 27-40 | 36 | Sand (Reese) |
| Upper Silt | 10-20 | 4 | 46 | 4-20 | 27 | Sand (Reese) |
| Upper Sand | 20-30 | 16 | 56 | 18-30 | 33 | Sand (Reese) |
| | 30-40 | 16 | 56 | 18-30 | 27 | Sand (Reese) |
| | 40-50 | 16 | 56 | 18-30 | 33 | Sand (Reese) |
| Middle Sand | 50-85 | 33 | 61 | 33-40 | 36 | Sand (Reese) |
| Middle Silt | 85-110 | 18 | 51 | 16-30 | 30 | Sand (Reese) |
| | 110-140 | 18 | 51 | 16-30 | 30 | Sand (Reese) |
| Lower Sand | 140-160 | 37 | 56 | 37-40 | 36 | Sand (Reese) |
| Lower Silt | 160-200 | 37 | 56 | 37-40 | 35 | Sand (Reese) |

Application of Static LPILE Parameters on Sloping Ground

To account for the increases and reductions in lateral pile resistance due to sloping ground, we recommend that P-multipliers be applied to the LPILE parameters in Table 10. The illustration below provides the appropriate P-multiplier to be used for specific cases of directional lateral loading (A-F) of wharf piles along the slope. P-multipliers need only be applied for analyses of soil layers located within the dimension "X" shown below.

Key to use of P-Multiplier on Sloping Ground



BULKHEAD AND SHEET PILE WALLS

General

Based on the soils encountered in our explorations and considering ground improvement we recommend the following parameters be used for the structural design of the sheet pile wall:

Soil Parameters

- Unsubmerged unit weight = 120 pounds per cubic foot (pcf)
- Submerged unit weight = 56 pcf
- Friction Angle = 32 degrees
- Wall Friction = 11 degrees

Static Earth Pressure Coefficients

- $K_a = 0.284$
- $K_p = 4.74$
- $K_p = 1.35$ (for 2H:1V slope)

Seismic Earth Pressure Coefficients

- $K_{ae} = 0.382$
- $K_{pe} = 4.21$
- $K_{pe} = 1.1$ (for 2H:1V slope)

Discussion of Design Parameter Assumptions

The design parameters provided above do not include the effects of hydrostatic pressure or surcharge loads. Base friction on below-grade elements supported by piles should be neglected since full contact with the underlying soil cannot be assured. Seismic pressures assume a pseudo-static horizontal

acceleration coefficient of about 0.15g. The passive earth pressure coefficients provided above are unfactored.

Sheet Pile Wall Return

A new sheet pile wall return will be used at the south end of the wharf extension. For calculating the frictional resistance of the sheet pile wall return, we recommend using an at-rest equivalent fluid density of 27 pcf and the following ultimate friction factors. Based on our experience, significant movement is required to mobilize all of the frictional resistance in a longitudinal wall due to the deformation that occurs at the interlocks.

- 0.62 for soil/soil contact
- 0.25 for soil/steel sheet pile contact

Differential Head

Differential head conditions created by tides and groundwater behind the bulkhead or sheet pile wall should be considered in design. Based on site groundwater levels and tidal fluctuations, we recommend an 8-foot differential head, with tide level at Elevation 0 feet and groundwater behind the wall at Elevation 8 feet MLLW for static conditions. For seismic conditions, we recommend a 4-foot differential head, with tide level at Elevation 4 feet MLLW and groundwater behind the wall at Elevation 8 feet MLLW.

The above recommendations consider site groundwater levels, sheet pile wall permeability, our experience monitoring groundwater levels behind sheet pile wall bulkheads and design of similar sheet pile wall bulkheads in the Port.

DREDGING AND SLOPE ARMORING

General

It is our understanding that the design composite slope and armoring configuration shown on Figure 3 was selected by the Port. Based on this configuration, we anticipate shallow sloughing could occur in steeper portions of the slope during dredging. These areas include the 1.75H:1V portion of the slope and the toe of the slope. However, the dredge slope should stabilize after the rock blanket is placed. Our scope for evaluating stability of the selected slope armoring does not include consideration of localized forces imparted by vessels, including bow thrusters or prop wash.

Our slope stability/Newmark analyses and finite element analyses were completed utilizing the design composite slope and armoring configuration, as shown in Figure 3. These analyses suggest the slope will be stable under static conditions and experience some deformation under an OLE or CLE event. Specific estimates of seismic slope deformation are provided in Appendix B.

Transition Slope Area

The proposed slope geometry in the transition area between the WUT extension and the Blair Dock (shown on Figure 2) is typically 1.5H:1V (horizontal:vertical) and 1H:1V in select areas. The proposed slope geometry is similar to the slope inclinations in the existing transition area between the WUT and the Blair Dock. These slope inclinations are equal to or greater than the estimated internal angle of friction for the soils. Accordingly, temporary cohesion of the soil will need to be relied upon during dredging.

To reduce the potential for short-term slope instability, we recommend that transition slopes be covered with rock immediately following dredging.

Following construction of the new transition area slopes as described above, we do not believe the potential for long-term slope instability and sloughing will be any greater than presently exists in the current slope transition area. However, over the short term there may be increased risk for slope instability and sloughing, mainly within about 20 feet of the top of slope in the new transition area if not immediately armored.

LIMITATIONS

We have prepared this report for use by BergerABAM and the Port of Tacoma for the WUT Wharf Extension project.

Within the limitations of scope, schedule and budget, our services have been executed in accordance with generally accepted practices in the field of geotechnical engineering in this area at the time this report was prepared. No warranty or other conditions express or implied should be understood.

Please refer to Appendix E "Report Limitations and Guidelines for Use" for additional information pertaining to use of this report.

REFERENCES

- 2002 USGS Probabilistic Seismic Hazard Deaggregations. http://eqint.cr.usgs.gov/deaggint/2002/ index.php.
- ASCE. 2005. "ASCE/SEI 7-05, Minimum Design Loads for Buildings and Other Structures," American Society of Civil Engineers.
- Atwater, B. 1996. "Coastal Evidence for Great Earthquakes in Western Washington." Assessing Earthquake Hazards and Reducing Risk in the Pacific Northwest, U.S. Geological Survey Professional Paper 1560, Vol. 1: pp. 77-90.
- Bakun, W.H., Haugerud, R.A., Hopper, M.G., and Ludwin, R.S. 2002. "The December 1872 Washington State Earthquake." Bulletin of the Seismological Society of America, Vol. 92, No. 8, pp. 3239-3258.
- Bergado, D.T., Anderson, L.R., Miura, N., and Balasubramaniam, A.S. 1966. "Soft Ground Improvement in Lowland and Other Environments." ASCE Press.
- Cetin, et al. 2004. "Standard Penetration Test-based Probabilistic and Deterministic Assessment of Seismic Soil Liquefaction Potential." Journal of Geotechnical and Geoenvironmental Engineering, Vol. 130, No. 12, December 1, 2004, pp. 1314-1340.
- Dames & Moore. March 5, 1970. Report of Soils Investigation Proposed Pier Blair Waterway, Tacoma, Washington for Port of Tacoma.
- Electric Power Research Institute (EPRI). 1993. "Guidelines for Site Specific Ground Motions." Palo Alto, California, Electric Power Research Institute, November, TR-102293.

- Frankel, A.D.; Petersen, M.D.; Mueller, C.S.; Haller, K.M.; Wheeler, R.L.; Leyendecker, E.V.; Wesson, R.L.; Harmsen, S.C.; Cramer, C.H.; Perkins, D.M.; and, Rukstales, K.S. 2002. Documentation for the 2002 Update of the National Seismic Hazard Maps. U.S. Geological Survey Open-File Report 02-420.
- GeoEngineers, Inc. December 18, 1997. Report Geotechnical Engineering Services Proposed Hyundai Container Terminal Port of Tacoma, Washington for Port of Tacoma.
- GeoMotions, LLC. 2007. "D-MOD2000, A Computer Program for Seismic Response Analysis of Horizontally Layered Soil Deposit, Earthfill Dams, and Solid Waste Landfills," Version 1.1.0.
- GEO-SLOPE International, Ltd. (2005). "Slope/W" Version 6.17.
- Greenwood, D.A. (1991. "Load Tests on Stone Columns." In Deep Found Improvements; Design, Construction and Testing. ASTM STP 1089. 148-171 pp.
- Hart Crowser & Assosciates, Inc. undated; *Geology of the Port of Tacoma*, Prepared in cooperation with the Port of Tacoma, 40 p.
- I.M. Idriss and R.W. Boulanger. 2004 . "Invited Paper, Semi-Empirical Procedures for Evaluating Liquefaction Potential During Earthquakes," Proceedings of the 11th ICSDEE & 3rd ICEGE, pp 32-56.
- International Code Council (2006). "2006 International Building Code."
- Jibson, R.W. and Jibson, M.W. 2005. "Slope Performance During an Earthquake", Java Programs for using Newmark's method and simplified decoupled analysis to model slope performance during earthquakes, U.S. Geological Survey Open-File Report 03-005.
- Johnson, S.Y., et al. 1999. "Active Tectonics of the Seattle Fault and Central Puget Sound, Washington: Implications for Earthquake Hazards," GSA Bulletin, Vol. 111, No. 7, pp. 1042-1053.
- Matasovic, J. 1993. "Analysis of Seismic Records Obtained on November 24, 1987, at the Wildlife Liquefaction Array," Master Thesis, Civil Engineering Department, University of California, Los Angeles, California.
- Matasovic, N. and Vucetic, M. 1993. "Cyclic Characterization of Liquefiable Sands," ASCE Journal of Geotechnical Engineering, Vol. 119, No. 11, pp. 1805-1822.
- Moss, R.E. 2003. "CPT-Based Probabilistic Assessment of Seismic Soil Liquefaction Initiation," PhD Thesis, University of California, Berkeley.
- Palmer, S.P., Perkins, W.J., and Grant, W.P. 2003; *Liquefaction Susceptibility of the Greater Tacoma Urban Area, Pierce and King Counties, Washington*. Washington Division of Geology and Earth Resources Geologic Map GM-51, 11p., 1 plate, scale 1:30,000.
- Ritter, D.F., Kochel, R.C., and Miller, J.R. 2002. *Process Geomorphology, 4th Edition:* McGraw Hill pp. 264-269.
- Satake, Kenji, et al. 1996. "Time and Size of a Giant Earthquake in Cascadia Inferred from Japanese Tsunami Records of January 1700," Nature, Vol. 379, pp. 247-248.

- Seed, R.B. and Harder, R.B. 1990. "SPT-Based Analysis of Cyclic Pore Pressure Generation and Undrained Residual Strength." H.B. Seed Memorial Symposium, Berkeley, CA., BiTech Publishing, Ltd., v. 2, 351-376 pp.
- Seed, R.B., Cetin, K.O., Moss, R.E.S., Kammerer, A.M., Wu, J., Pestana, J.M., Riemer, M.F., Sancio, R.B., Bray, J.D., Kayen, R.E. and Faris, A. 2003. "Recent Advances in Soil Liquefaction Engineering: A Unified and Consistent Framework." Earthquake Engineering Research Center, Report No. EERC 2003-06, College of Engineering, University of California, Berkeley.
- Smith, M. 1977. *Geologic Map of the City of Tacoma, Pierce County, Washington:* Washington Division of Geology and Earth Resources Open-file Report 77-9, 1 sheet, scale 1:24,000.
- Troost, K.G.; Booth, D.B.; Borden, R.K., in press, *Geologic Map of the Tacoma North 7.5-minute Quadrangle, Washington:* U.S. Geological Survey Miscellaneous Field Studies Map, scale 1:24,000.
- Youd, T.L., Idriss, I.M., Andrus R.D., Arango, I., Castro, G., Christian, J.T., Dobry, R., Finn, W.D.L., Harder, L.F. Jr., Hynes, M.E., Ishihara, K., Koester, J.P., Liao, S.S.C., Marcuson, W.F. III., Martin, G.R., Mitchell, J.K., Moriwaki, Y., Power, M.S., Robertson, P.K., Seed, R.B., and Stokoe, K.H. II. 1997. "Summary Paper, Proceeding of the NCEER Workshop on Evaluation of Liquefaction Resistance of Soils." NCEER-97-0022.



Vicinity Map

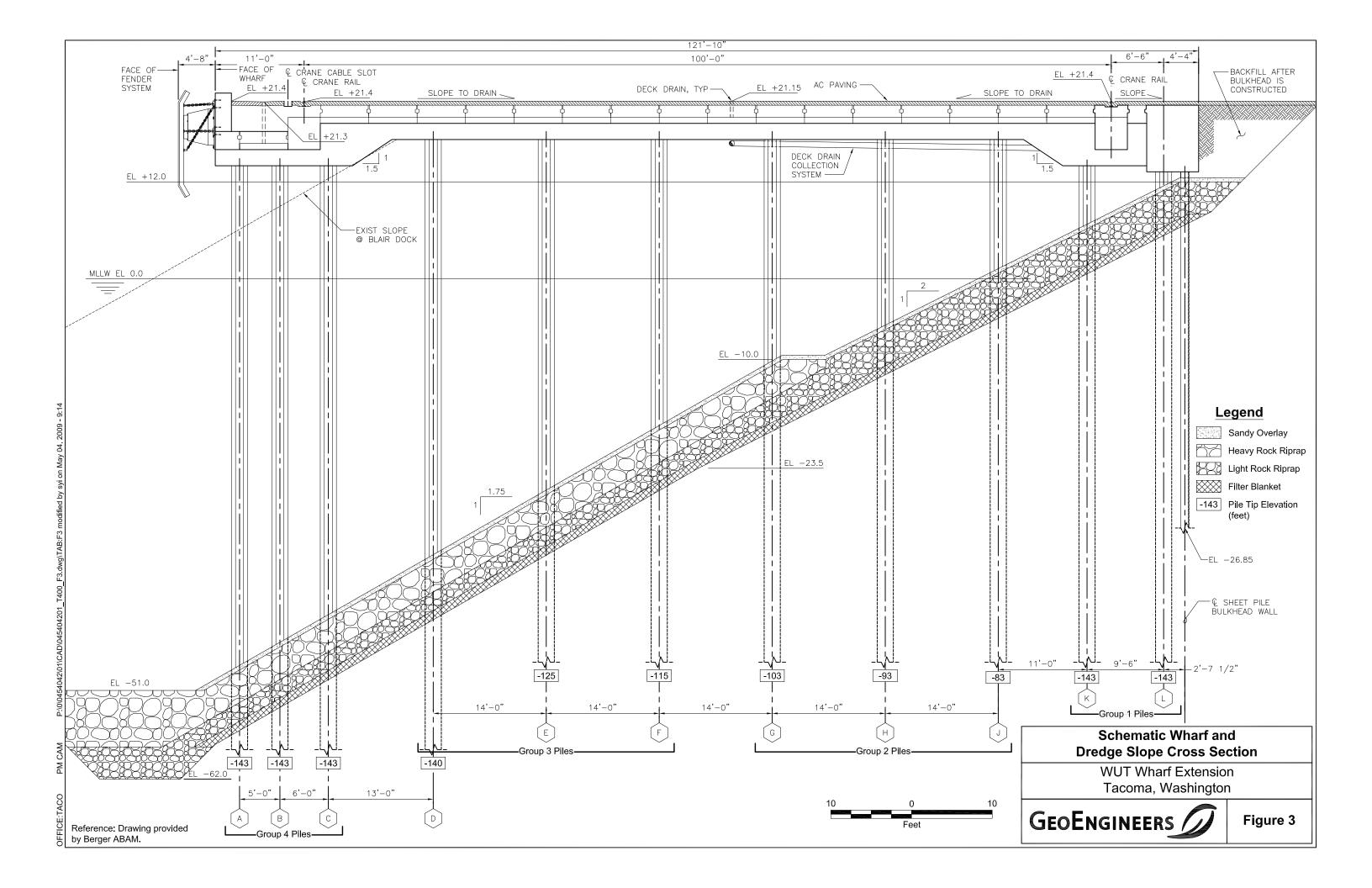
WUT Wharf Extension Tacoma, Washington

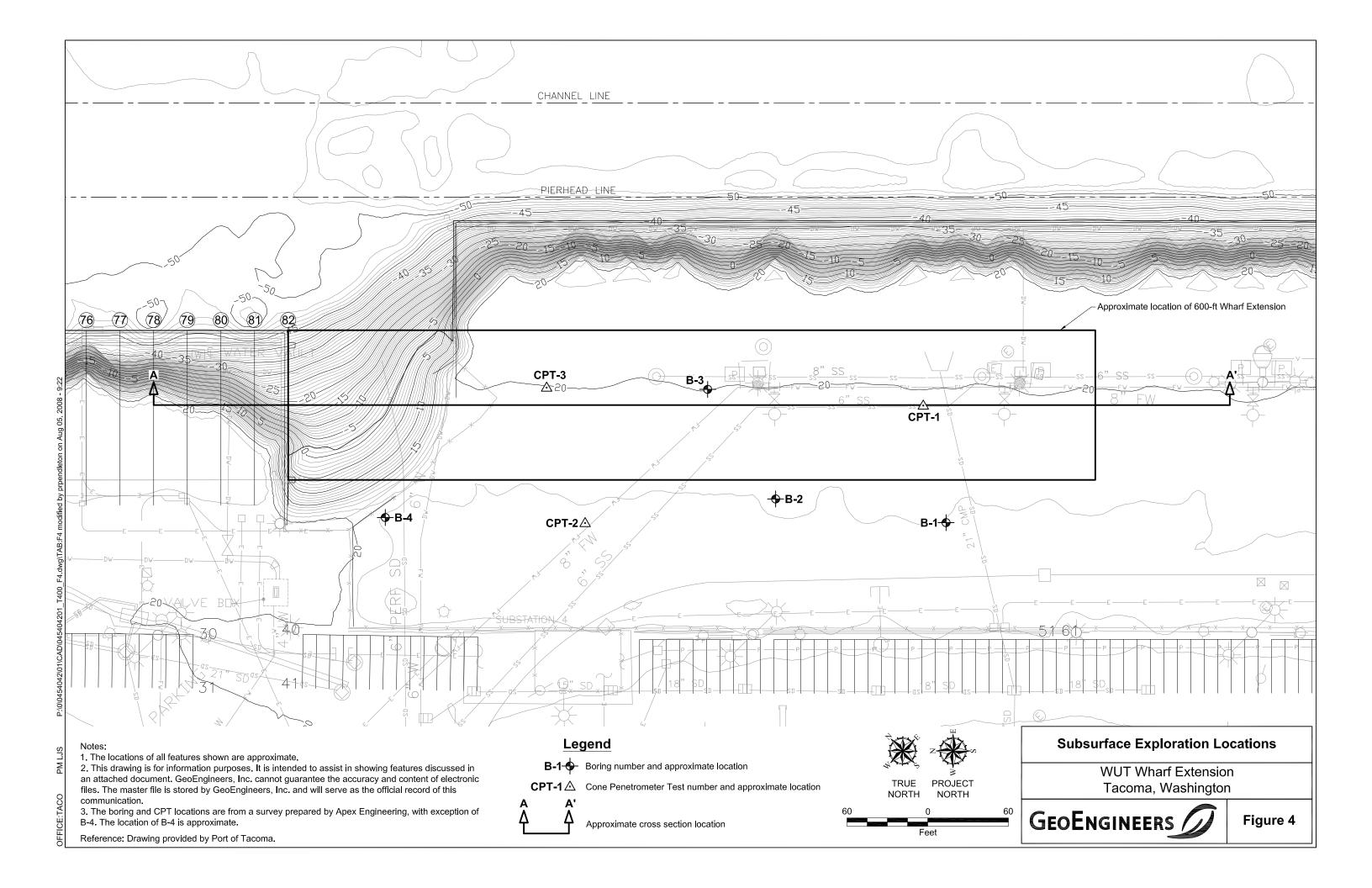


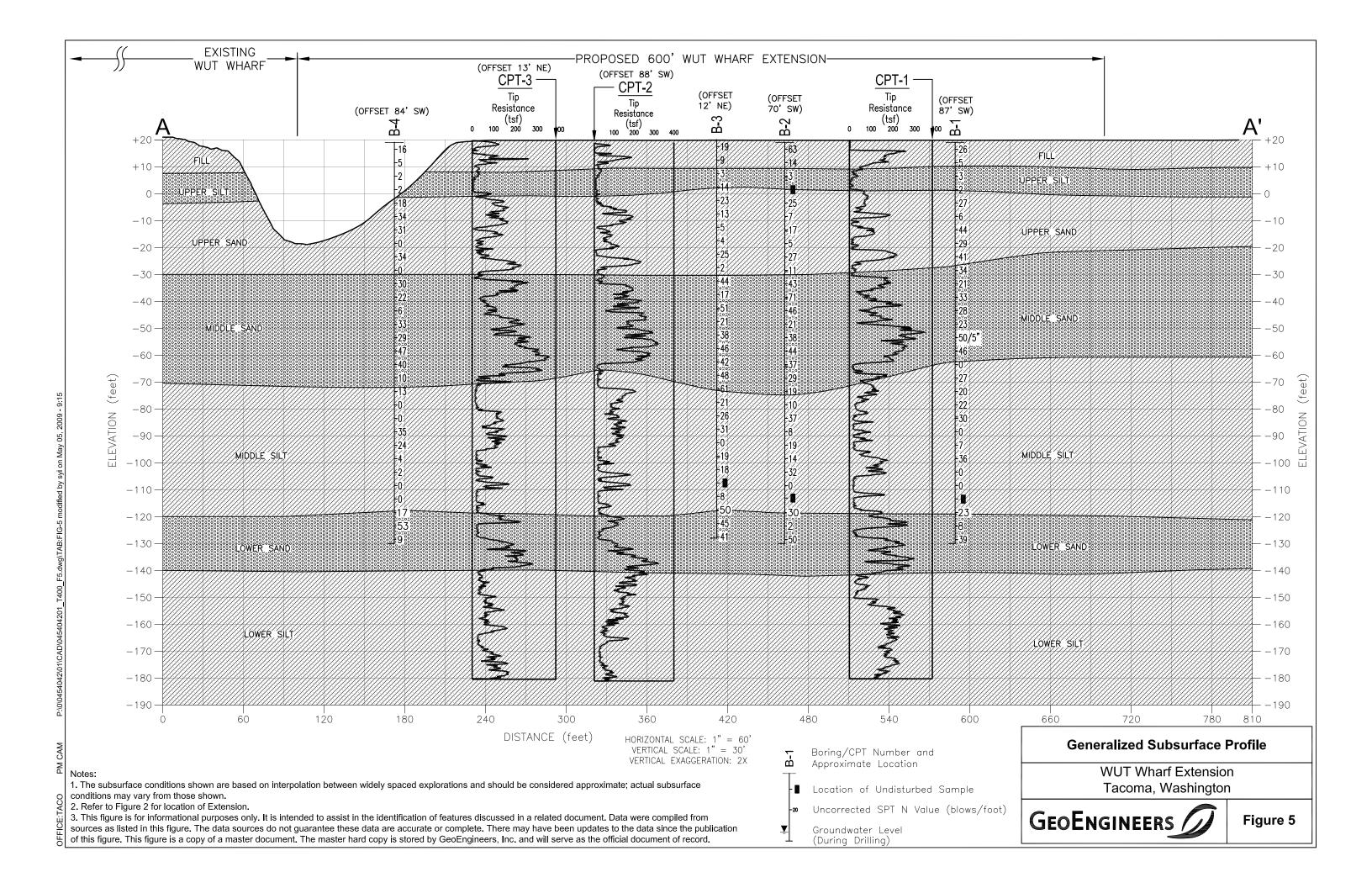
Figure 1

OFFICE:TACO

Reference: Base drawing provided by Port of Tacoma.

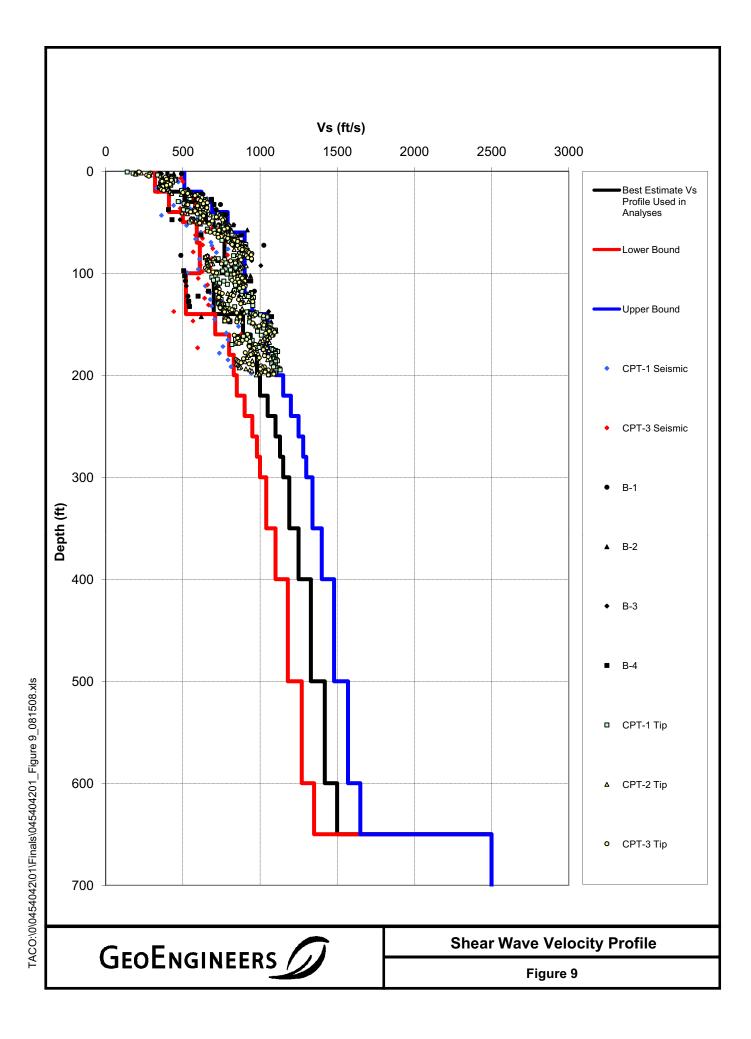


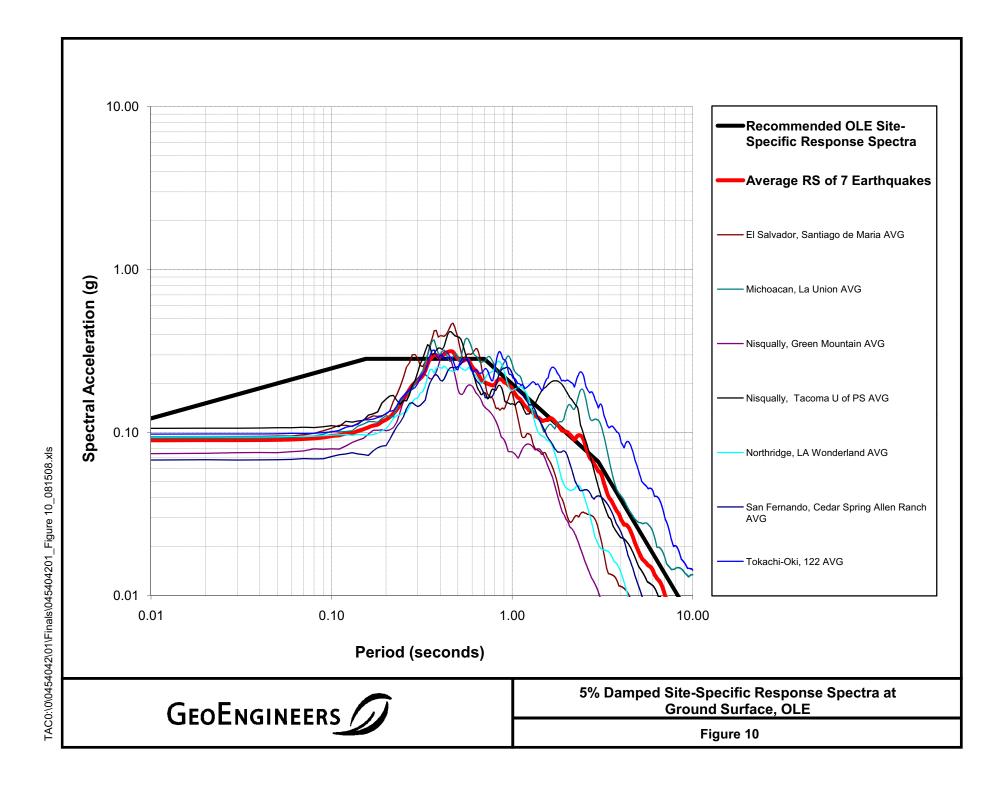


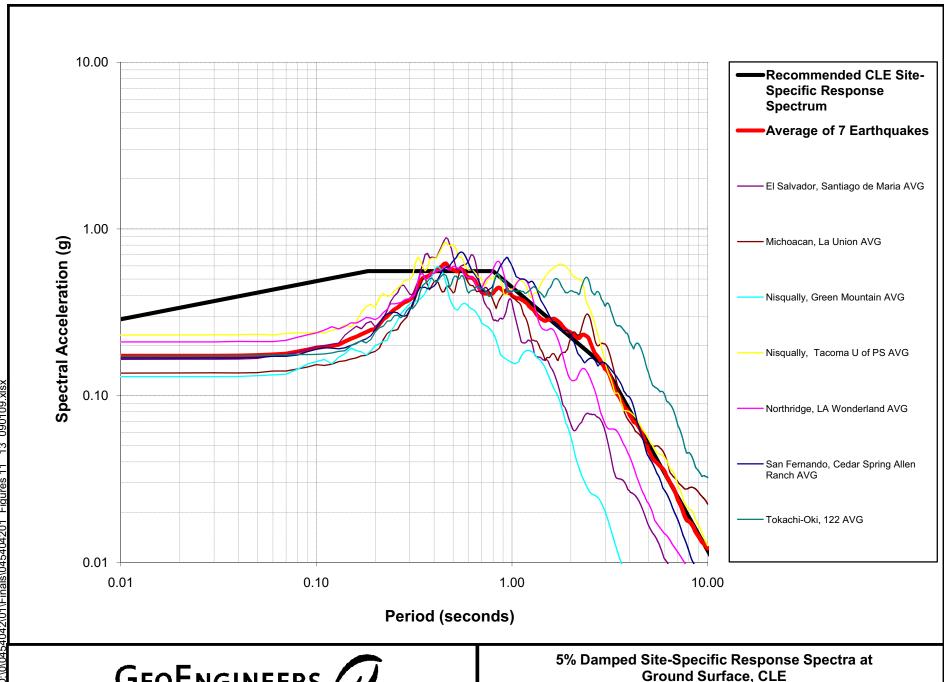


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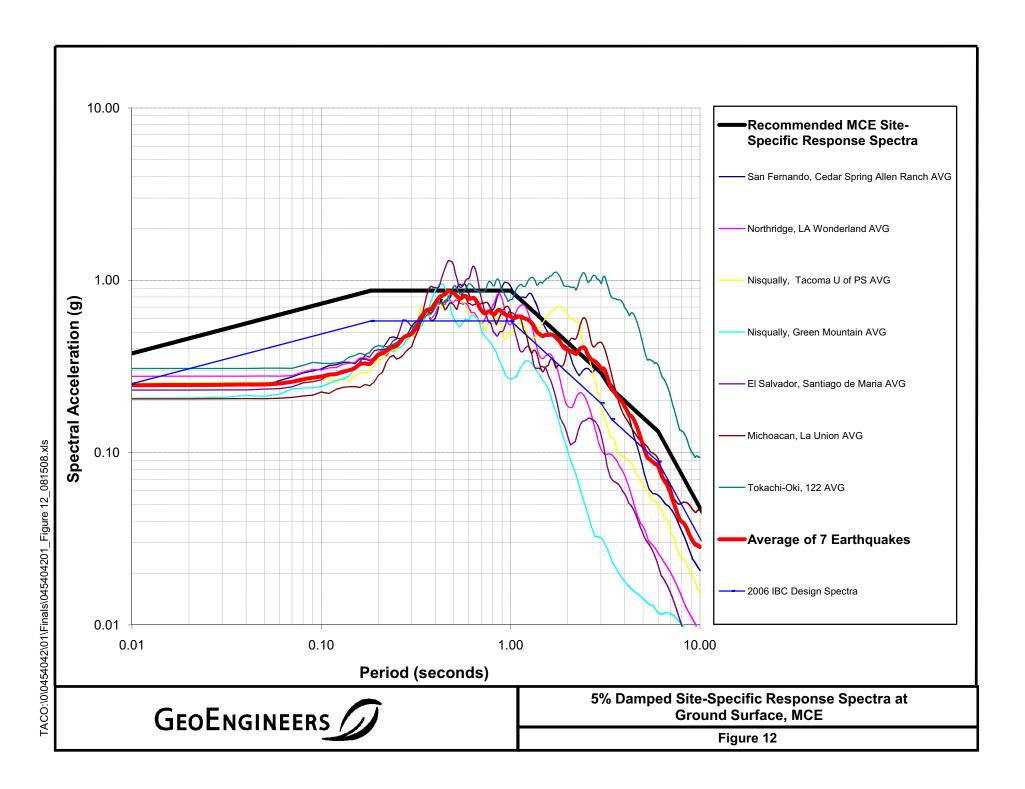


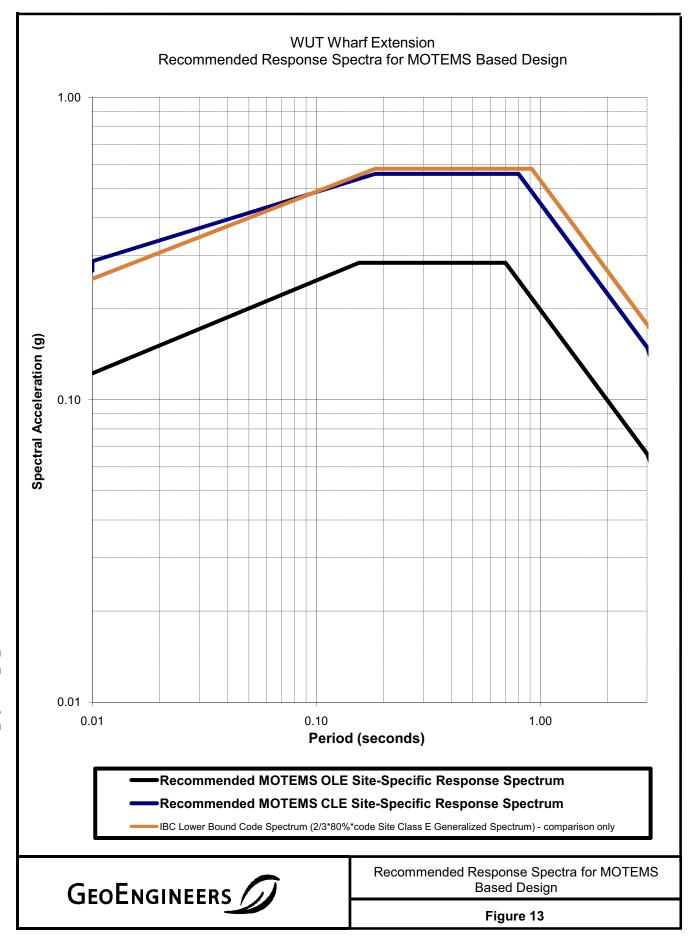


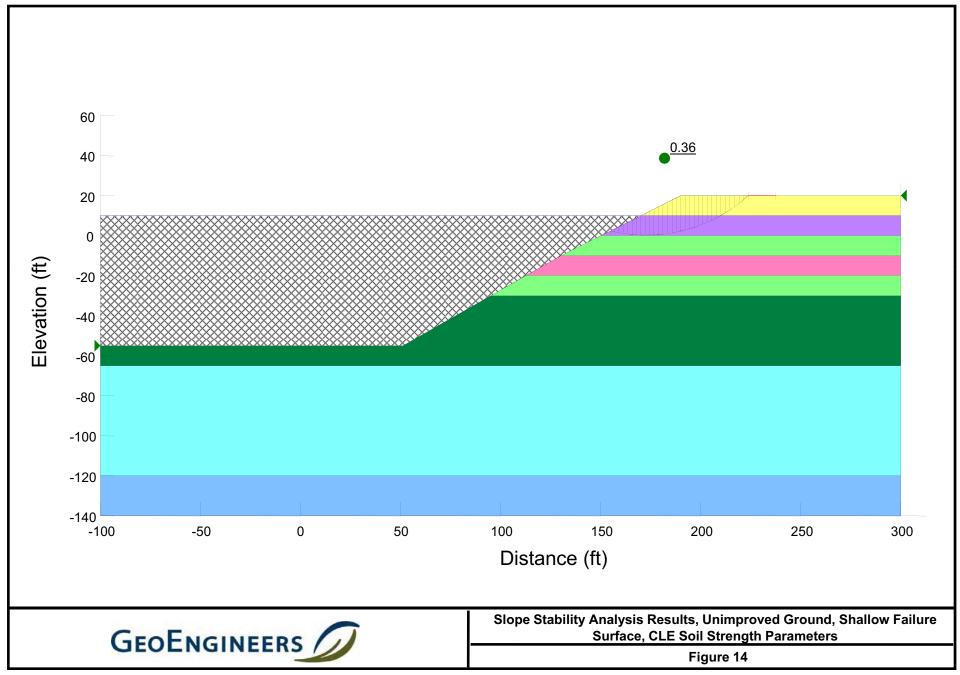
GEOENGINEERS /

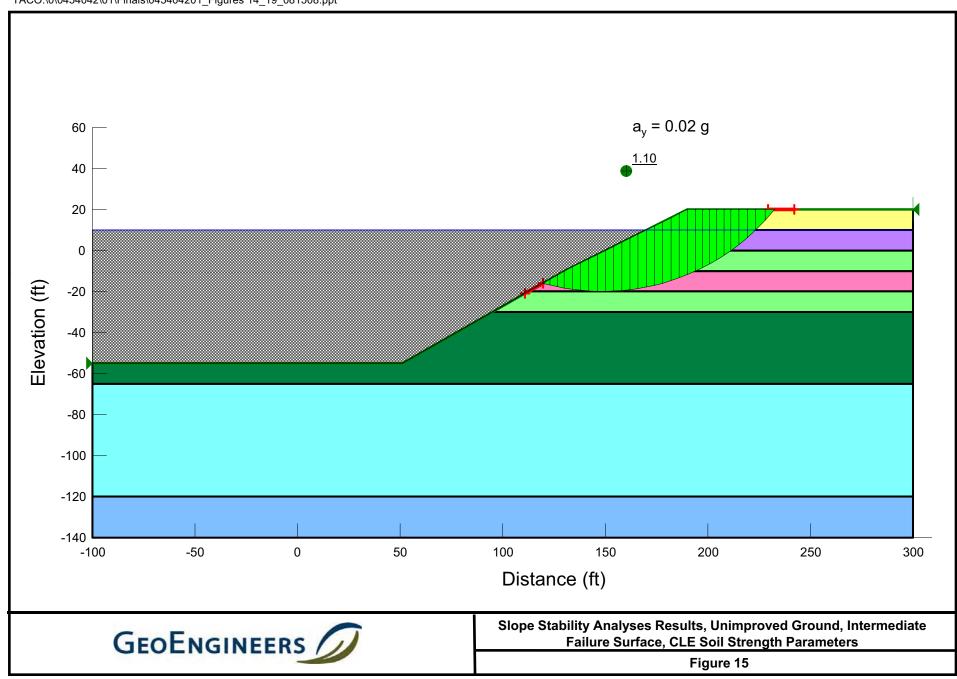
Ground Surface, CLE

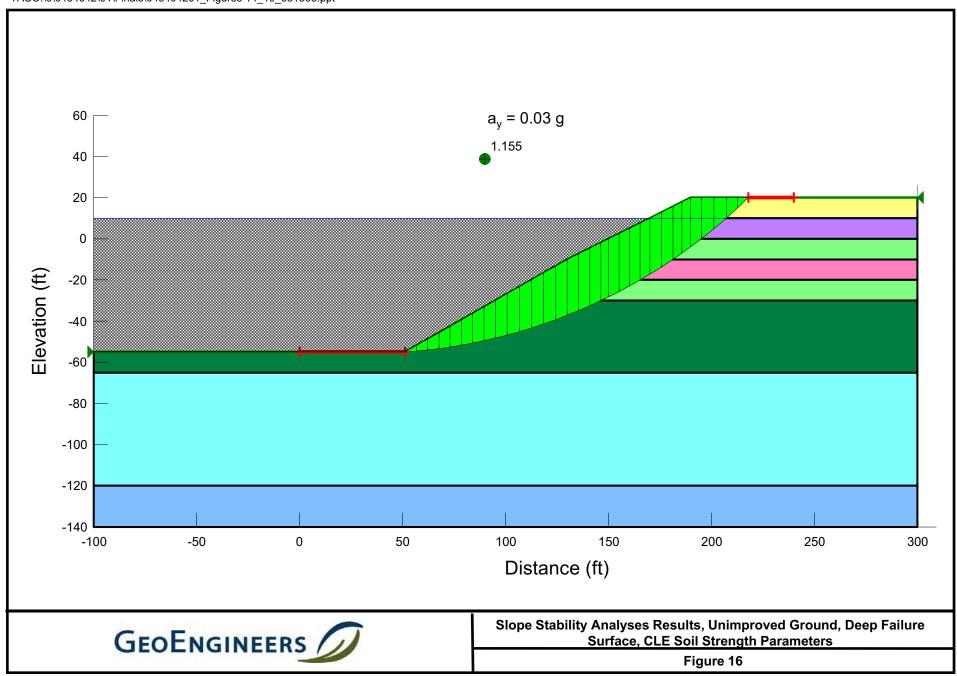
Figure 11

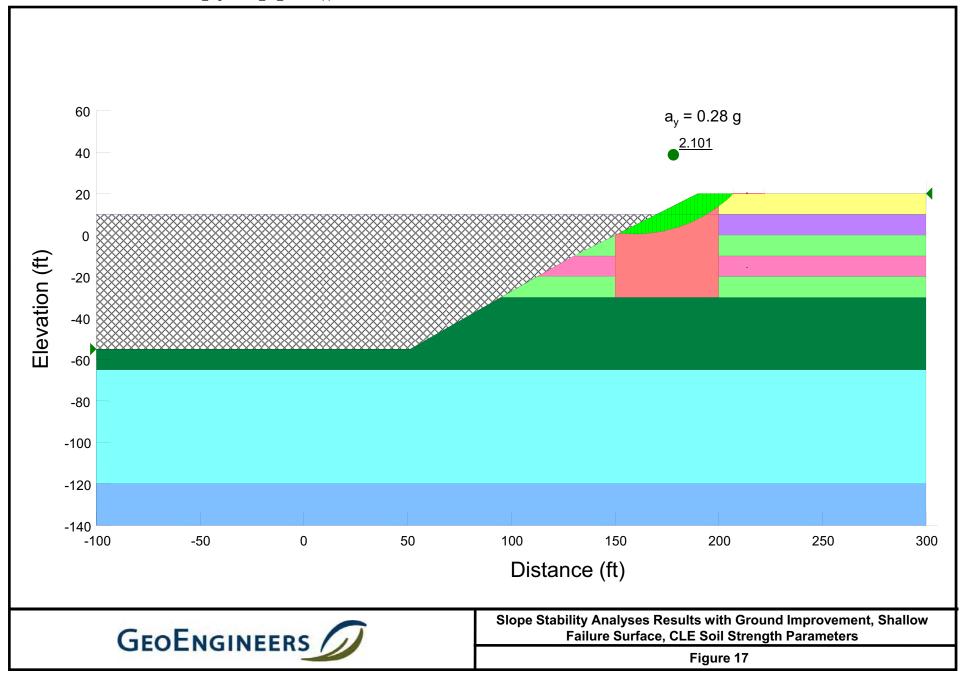


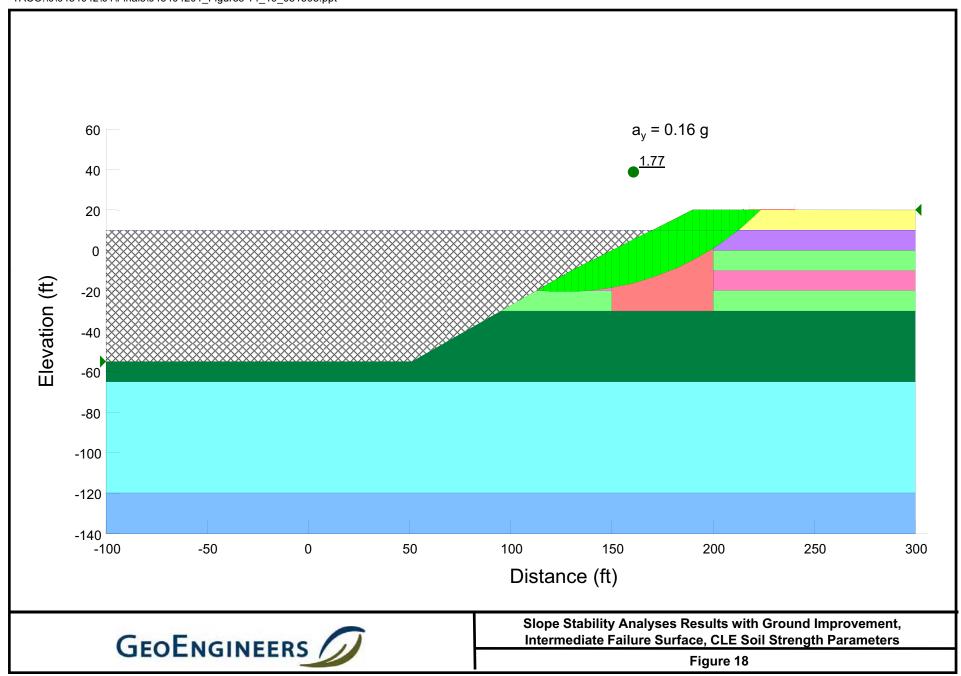


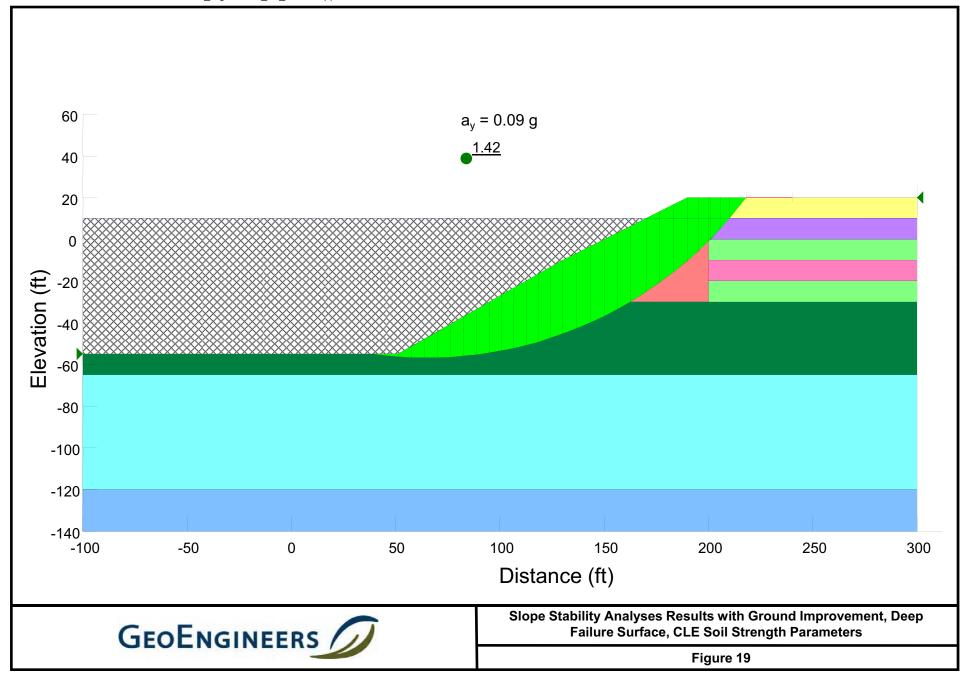


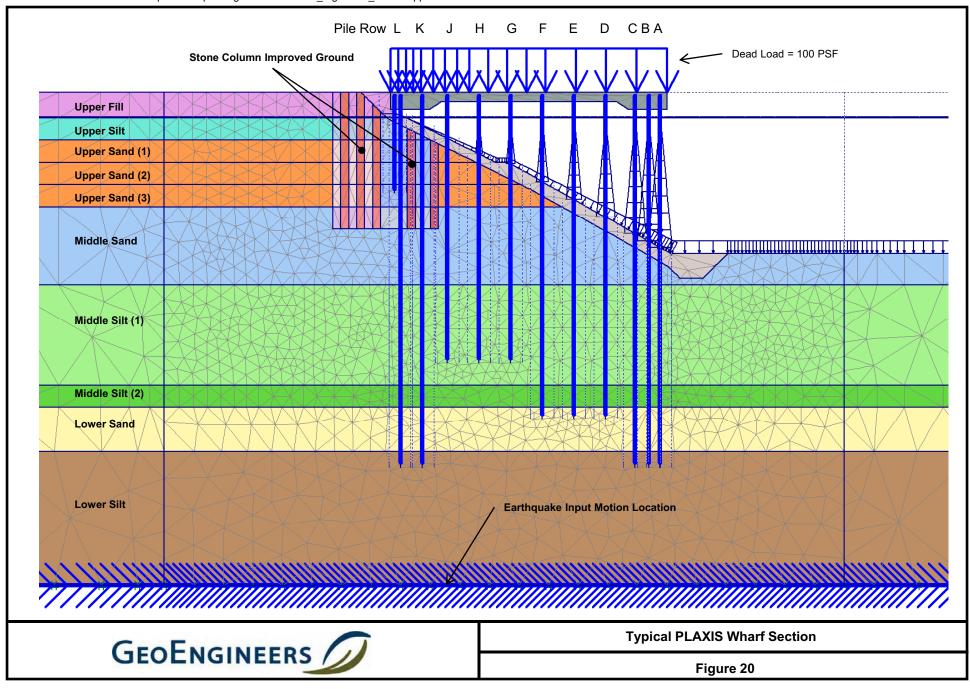






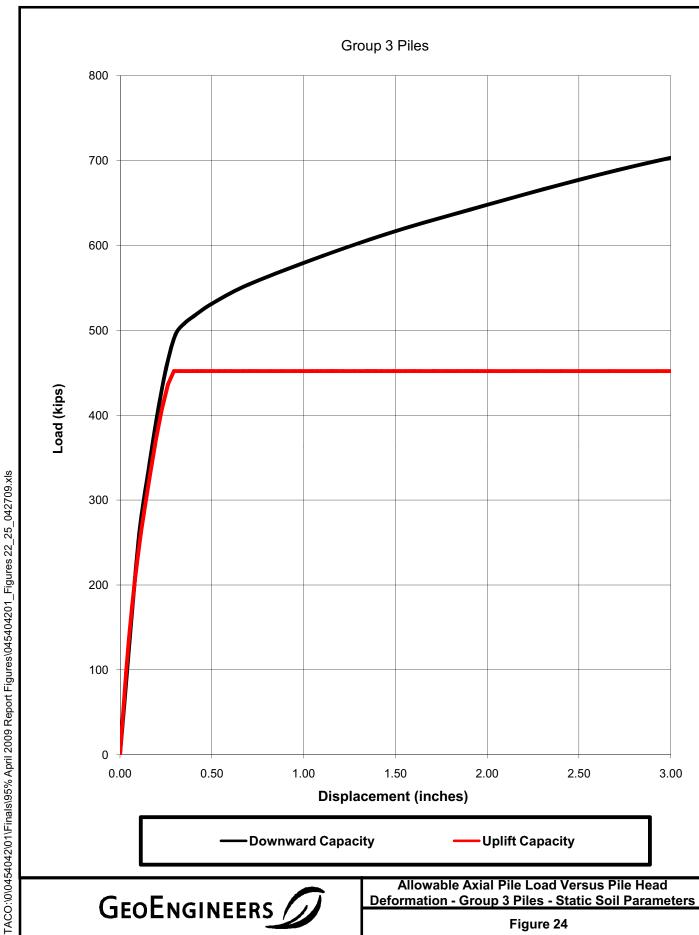






Deformation - Group 2 Piles - Static Soil Parameters

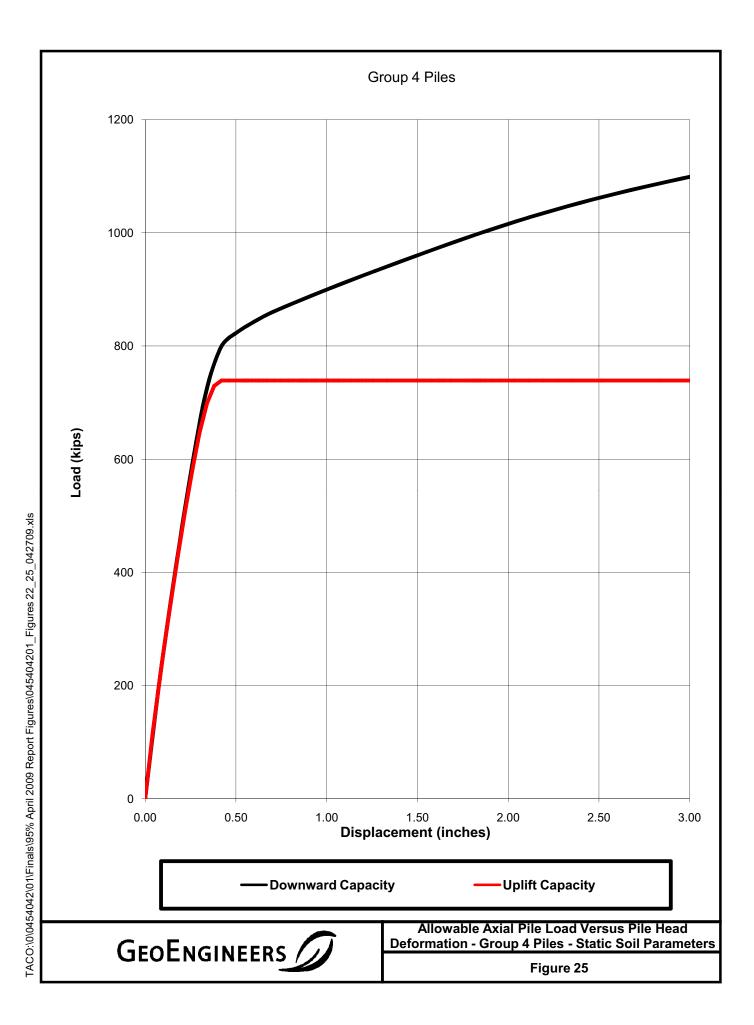
Figure 23

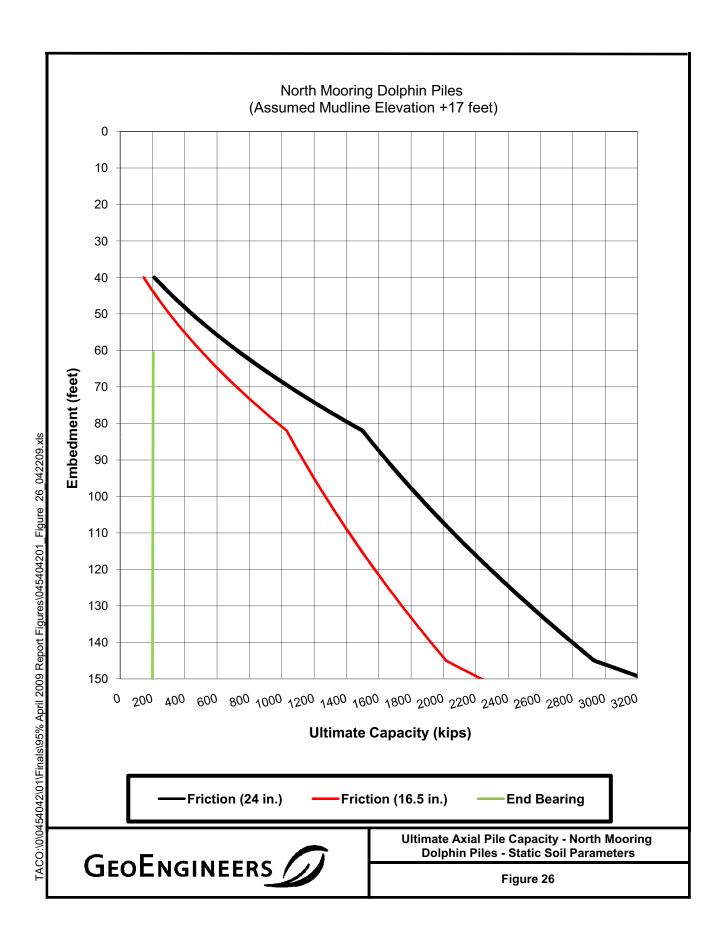


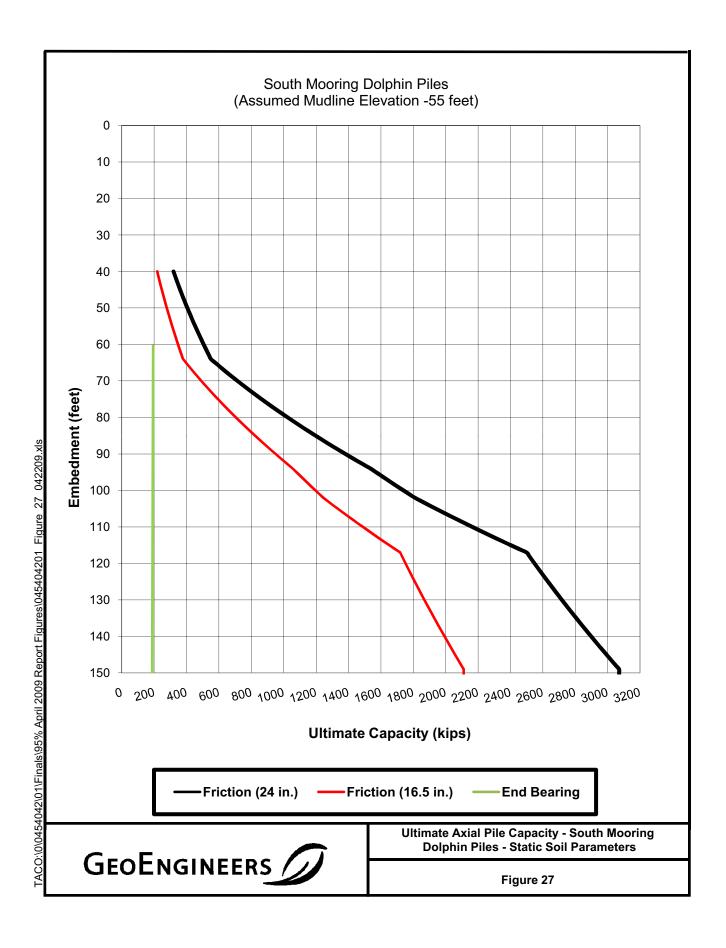
GEOENGINEERS /

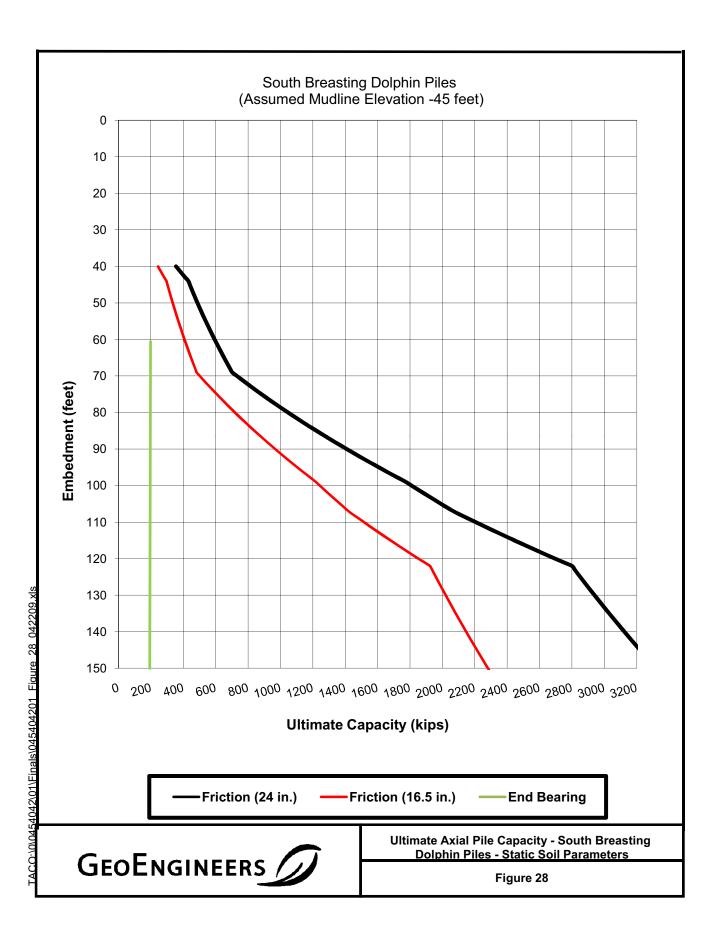
Deformation - Group 3 Piles - Static Soil Parameters

Figure 24











APPENDIX A SUBSURFACE EXPLORATIONS AND LABORATORY TESTING

APPENDIX A SUBSURFACE EXPLORATIONS AND LABORATORY TESTING

GENERAL

We explored subsurface conditions at the site by advancing four borings and three CPT soundings. Our representative located the explorations in the field using measurements from existing site features; all of our explorations except B-4 were located by Apex Engineering's survey. A key to the symbols used on the boring logs is included as Figure A-1. The boring logs are included as Figures A-2 through A-5. The CPT logs and respective Shear Wave Velocity Plots are included as Figures A-6 through A-10.

SOIL BORINGS

The borings were advanced by Holocene Drilling using a truck-mounted drill rig under subcontract to GeoEngineers. The soil borings were advanced to a depth of about 150 feet bgs. Hollow-stem auger drilling methods were generally used to advance the borings to the groundwater table so that water level measurements could be made. Mud rotary methods were used to advance the borings below groundwater.

Disturbed soil samples were obtained from the borings using a 1.375-inch inside-diameter split-spoon SPT sampler driven into the soil using a 140-pound hammer free-falling a distance of 30 inches. The number of blows required to drive the sampler the last 12 inches or other indicated distance is recorded on the logs as the blow count. Relatively undisturbed samples were obtained at selected intervals using either a Shelby tube sampler or a Dames and Moore ring sampler.

Our representative continuously monitored the borings, maintained a log of the subsurface conditions, and observed sample attempts, generally at 5-foot-depth intervals. The soils encountered were visually classified in general accordance with the system described in Figure A-1, American Society for Testing and Materials (ASTM) D 2488.

WASTE DISPOSAL AND BORING COMPLETION

Cuttings generated from the borings were contained and characterized for disposal in accordance with the Port of Tacoma's established investigative waste disposal procedures. Borings were backfilled in accordance with applicable regulations.

CPT Soundings

CPT soundings were advanced by Northwest Cone Exploration Inc. using a truck-mounted hydraulically operated cone penetrometer under subcontract to GeoEngineers, Inc. The CPT soundings were advanced to depths of about 200 feet bgs; shear wave velocity data was collected in two of the soundings. The CPT sounding involves pushing an instrumented probe into the ground and recording soil friction, tip resistance and dynamic pore pressure using electronic methods. Soil samples are not obtained during CPT soundings. Soil types are interpreted based on empirical relationships between measured CPT parameters described above. Because it provides a continuous interpretation of subsurface data, the CPT method generally provides more detail regarding soil layering than conventional drilling and sampling methods.

LABORATORY TESTING

General

Soil samples obtained from the borings were transported to GeoEngineers' laboratory for further review. Representative soil samples were selected for laboratory tests to evaluate the pertinent geotechnical engineering characteristics of the site soils and to confirm or modify our field classification. The following paragraphs provide a description of the tests performed. It should be noted that the samples tested included a small amount of bentonite drilling fluid, which likely influences the percent passing and grain-size analysis results by increasing the fines content. However, it is difficult to quantify the influence of the drilling fluid on the test results.

Moisture Content and Dry Density

The moisture content and/or density of selected samples was determined in general accordance with ASTM Test Methods D 2216 and D 2937, respectively. The test results are used to aid in soil classification and correlation with other pertinent engineering soil properties. The test results are presented on the boring logs.

Percent Passing U.S. No. 200 Sieve (%F)

Selected samples were "washed" through the U.S. No. 200-mesh sieve to estimate the relative percentages of coarse and fine-grained particles in the soil. The percent passing value represents the percentage by weight of the sample finer than the U.S. No. 200 sieve (fines). This test was conducted to check field descriptions and to estimate the fines content for analysis purposes. The tests were conducted in general accordance with ASTM D 1140, and the test results are shown on the boring logs.

Grain-Size Analyses

Grain-size analyses were performed on selected samples in general accordance with ASTM Test Method D 422. This test method describes the quantitative determination of the distribution of particle sizes in soils. The results of the tests were used to check field soil classifications. Figures A-11 and A-12 present the results of the grain-size analyses.

SOIL CLASSIFICATION CHART

| М | AJOR DIVISION | ONS | SYMI | BOLS | TYPICAL | |
|---|--|----------------------------------|-------|--------|---|--|
| IVI | AJON DIVISI | J143 | | LETTER | DESCRIPTIONS | |
| | GRAVEL | CLEAN GRAVELS | | 1 | WELL-GRADED GRAVELS, GRAVEL - SAND MIXTURES | |
| | AND GRAVELLY SOILS | (LITTLE OR NO FINES) | | GP | POORLY-GRADED GRAVELS, GRAVEL - SAND MIXTURES | |
| COARSE GRAINED SOILS | MORE THAN 50% OF COARSE | GRAVELS WITH FINES | | GM | SILTY GRAVELS, GRAVEL - SAND - SILT MIXTURES | |
| GOILO | FRACTION RETAINED ON NO. 4 SIEVE | (APPRECIABLE AMOUNT OF FINES) | | GC | CLAYEY GRAVELS, GRAVEL - SAND - CLAY MIXTURES | |
| MORE THAN 50% | SAND | CLEAN SANDS | | SW | WELL-GRADED SANDS, SAND-GRAVEL MIXTURES | |
| RETAINED ON NO. 200 SIEVE | AND SANDY SOILS | (LITTLE OR NO FINES) | | SP | POORLY-GRADED SANDS, SAND-GRAVEL MIXTURES | |
| | MORE THAN 50% OF COARSE FRACTION | SANDS WITH FINES | | SM | SILTY SANDS, SAND - SILT MIXTURES | |
| | PASSING NO. 4 SIEVE | (APPRECIABLE AMOUNT OF FINES) | | sc | CLAYEY SANDS, SAND - CLAY MIXTURES | |
| | | | | ML | INORGANIC SILTS, ROCK FLOUR, CLAYEY SILTS WITH SLIGHT PLASTICITY | |
| FINE GRAINED | SILTS AND CLAYS | LIQUID LIMIT LESS THAN 50 | | CL | INORGANIC CLAYS OF LOW TO MEDIUM PLASTICITY, GRAVELLY CLAYS, SANDY CLAYS, SILTY CLAYS LEAN CLAYS | |
| SOILS | | | | OL | ORGANIC SILTS AND ORGANIC SILTY CLAYS OF LOW PLASTICITY | |
| MORE THAN 50% PASSING NO. 200 SIEVE | | | | МН | INORGANIC SILTS, MICACEOUS OR DIATOMACEOUS SILTY SOILS | |
| | SILTS AND CLAYS | LIQUID LIMIT GREATER THAN 50 | | СН | INORGANIC CLAYS OF HIGH PLASTICITY | |
| | | | Huh | ОН | ORGANIC CLAYS AND SILTS OF MEDIUM TO HIGH PLASTICITY | |
| Hi | GHLY ORGANIC S | SOILS | 3.8.F | PT | PEAT, HUMUS, SWAMP SOILS WITH HIGH ORGANIC CONTENTS | |

NOTE: Multiple symbols are used to indicate borderline or dual soil classifications

Sampler Symbol Descriptions

(SPT)

| | 2.4-inch I.D. split barrel |
|---|----------------------------|
| | Standard Penetration Test |
| П | Shelby tube |

Shelby to

Direct-Push

Bulk or grab

Blowcount is recorded for driven samplers as the number of blows required to advance sampler 12 inches (or distance noted). See exploration log for hammer weight and drop.

A "P" indicates sampler pushed using the weight of the drill rig. $\,$

ADDITIONAL MATERIAL SYMBOLS

| SYM | BOLS | TYPICAL |
|-------|--------|--------------------------------|
| GRAPH | LETTER | DESCRIPTIONS |
| = | СС | Cement Concrete |
| | AC | Asphalt Concrete |
| 33 | CR | Crushed Rock/ Quarry Spalls |
| | TS | Topsoil/ Forest Duff/Sod |

 \leq

Measured groundwater level in exploration, well, or piezometer



Groundwater observed at time of exploration

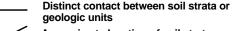


Perched water observed at time of exploration



Measured free product in well or piezometer

Graphic Log Contact





Approximate location of soil strata change within a geologic soil unit

Material Description Contact

Distinct contact between soil strata or geologic units

Approximate location of soil strata change within a geologic soil unit

Laboratory / Field Tests

Percent fines %F Atterberg limits ΑL CA Chemical analysis CP Laboratory compaction test CS Consolidation test DS **Direct shear** HA Hydrometer analysis Moisture content MC Moisture content and dry density MD OC Organic content PΜ Permeability or hydraulic conductivity PP Pocket penetrometer SA Sieve analysis ΤX Triaxial compression UC Unconfined compression VS Vane shear

Sheen Classification

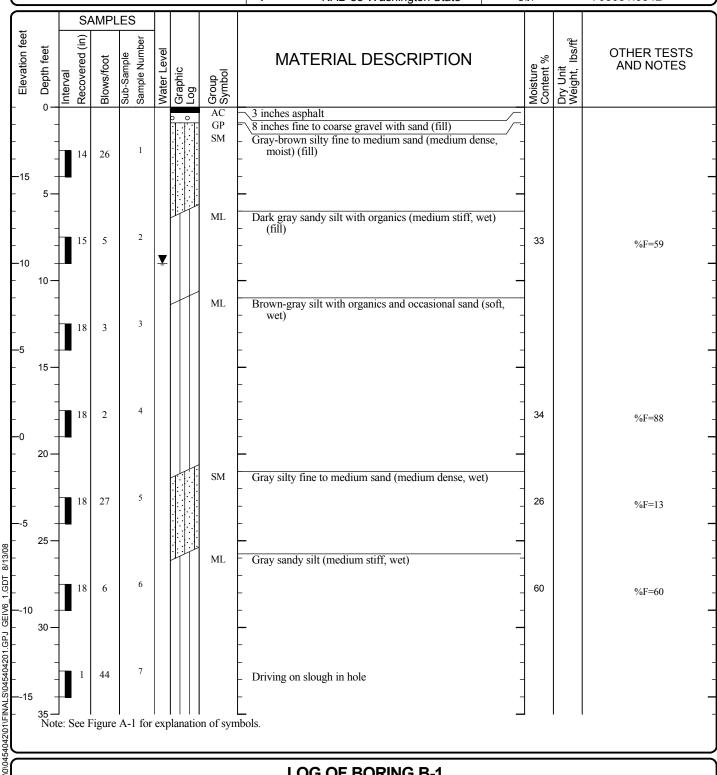
NS No Visible Sheen SS Slight Sheen MS Moderate Sheen HS Heavy Sheen NT Not Tested

NOTE: The reader must refer to the discussion in the report text and the logs of explorations for a proper understanding of subsurface conditions. Descriptions on the logs apply only at the specific exploration locations and at the time the explorations were made; they are not warranted to be representative of subsurface conditions at other locations or times.

KEY TO EXPLORATION LOGS



| Date(s) Drilled | 04/12/08 | Logged By | | | CAM |
|------------------------|----------|---------------------------|-------------------------|-------------------------------|-----------------------------|
| Drilling Contractor | Holocene | Drilling Method | | | SPT and D&M |
| Auger Data | N/A | Hammer Data | | | Diedrich D-120 |
| Total Depth (ft) | 149 | Surface Elevation (ft) | 19 | Groundwater Elevation (ft) | 10 |
| Vertical Datum | MLLW | Datum/ System | NAD 83 Washington State | Easting(x): Northing(y): | 1172233.5031 708051.3542 |

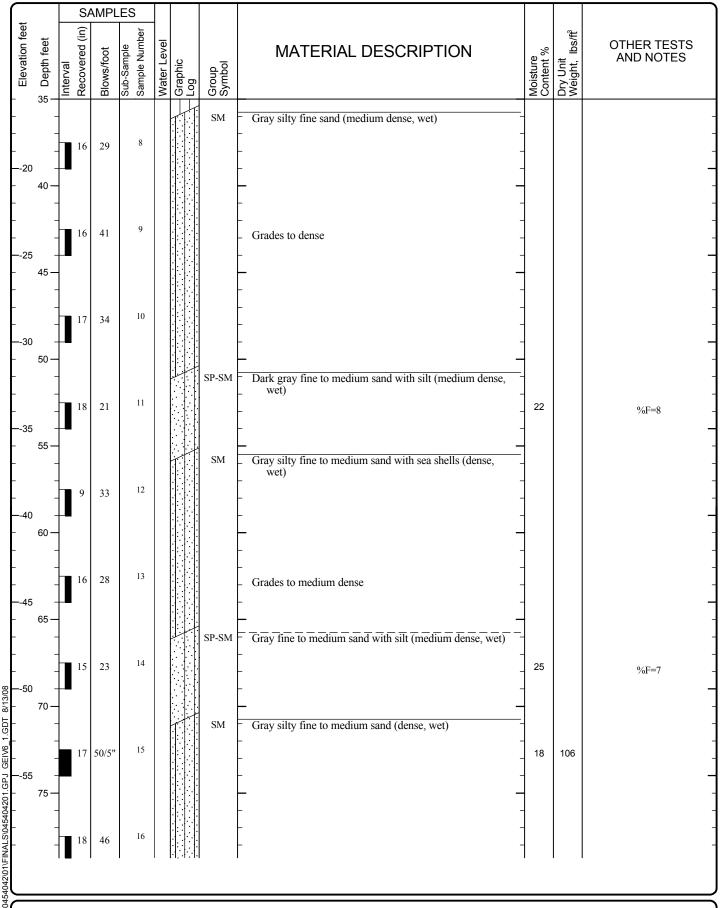


LOG OF BORING B-1



WUT Wharf Expansion Project: Project Location: Tacoma, Washington Project Number: 0454-042-01

Figure A-2 Sheet 1 of 4

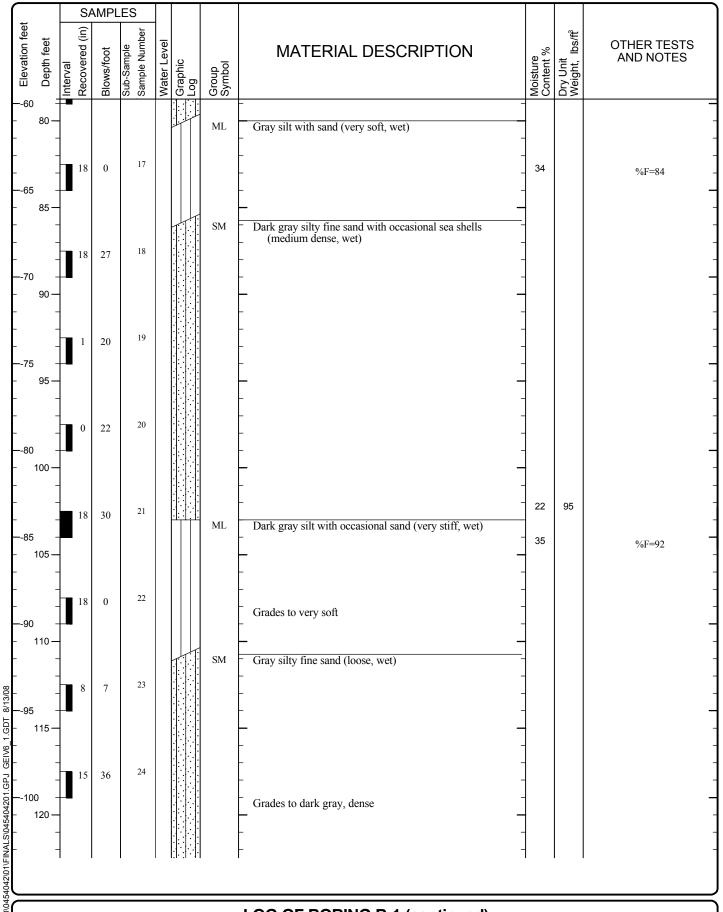


LOG OF BORING B-1 (continued)



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

Project Number: 0454-042-01 Figure A-2 Sheet 2 of 4



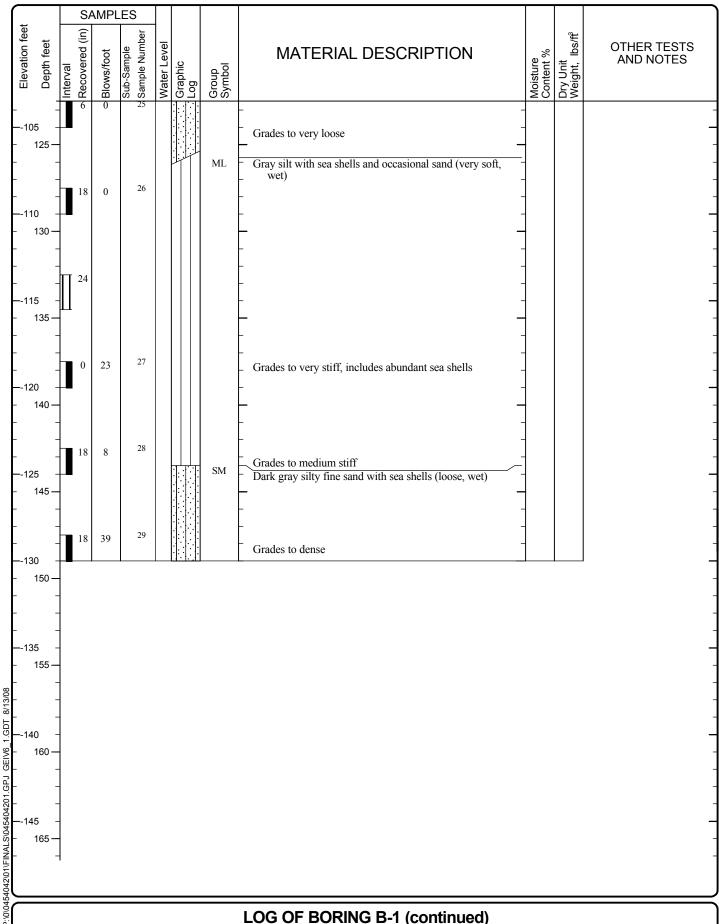
LOG OF BORING B-1 (continued)



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

Project Number: 0454-042-01

Figure A-2 Sheet 3 of 4



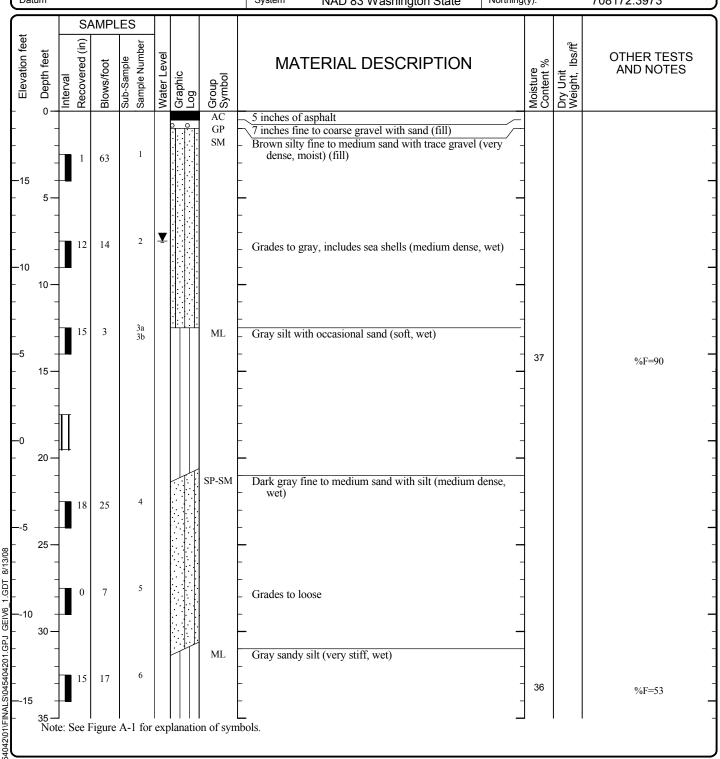
LOG OF BORING B-1 (continued)



WUT Wharf Expansion Project: Project Location: Tacoma, Washington

Project Number: 0454-042-01 Figure A-2 Sheet 4 of 4

| Date(s) Drilled | 04/16/08 | Logged By | ASB | Checked By | CAM |
|------------------------|-----------------|---------------------------|-------------------------|-------------------------------|-----------------------------|
| Drilling Contractor | Holocene | Drilling Method | HSA and Mud Rotary | Sampling Methods | SPT and D&M |
| Auger Data | 6-inch diameter | Hammer Data | er 140 lb Automatic | | Diedrich D-120 |
| Total Depth (ft) | 149 | Surface Elevation (ft) | 19 | Groundwater Elevation (ft) | 11.5 |
| Vertical Datum | MLLW | Datum/ System | NAD 83 Washington State | Easting(x): Northing(y): | 1172068.4443 708172.3973 |



LOG OF BORING B-2

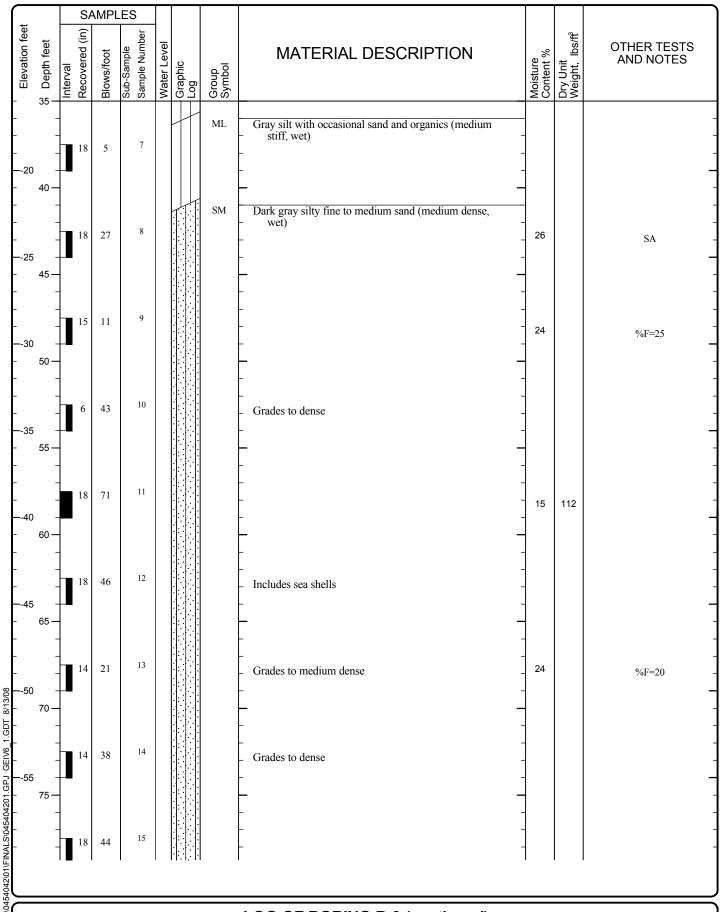
Project Number:



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

0454-042-01

Figure A-3 Sheet 1 of 4



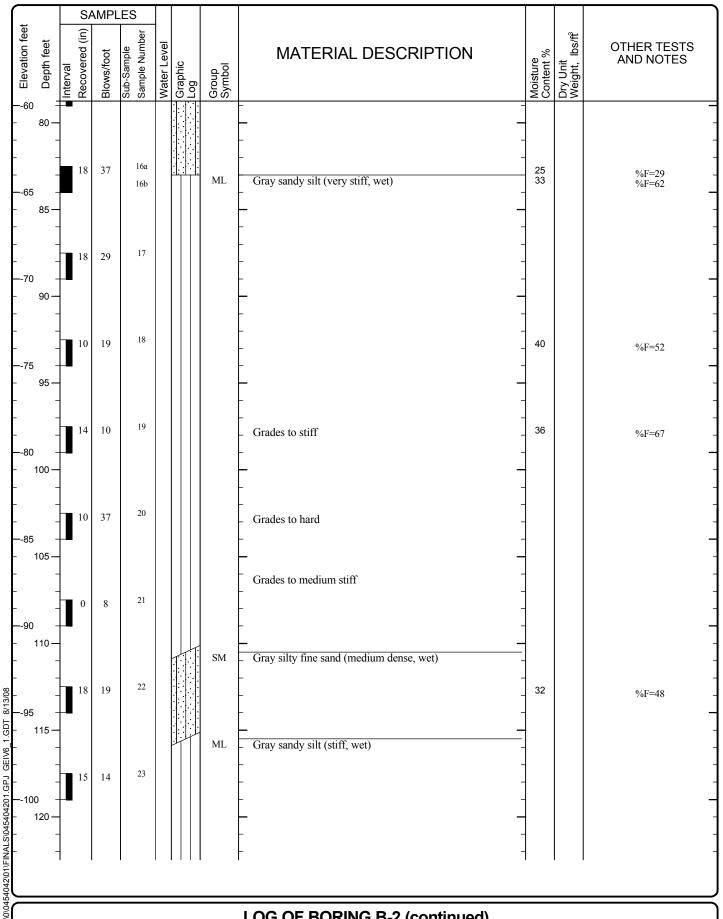
LOG OF BORING B-2 (continued)



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

Project Number: 0454-042-01

Figure A-3 Sheet 2 of 4

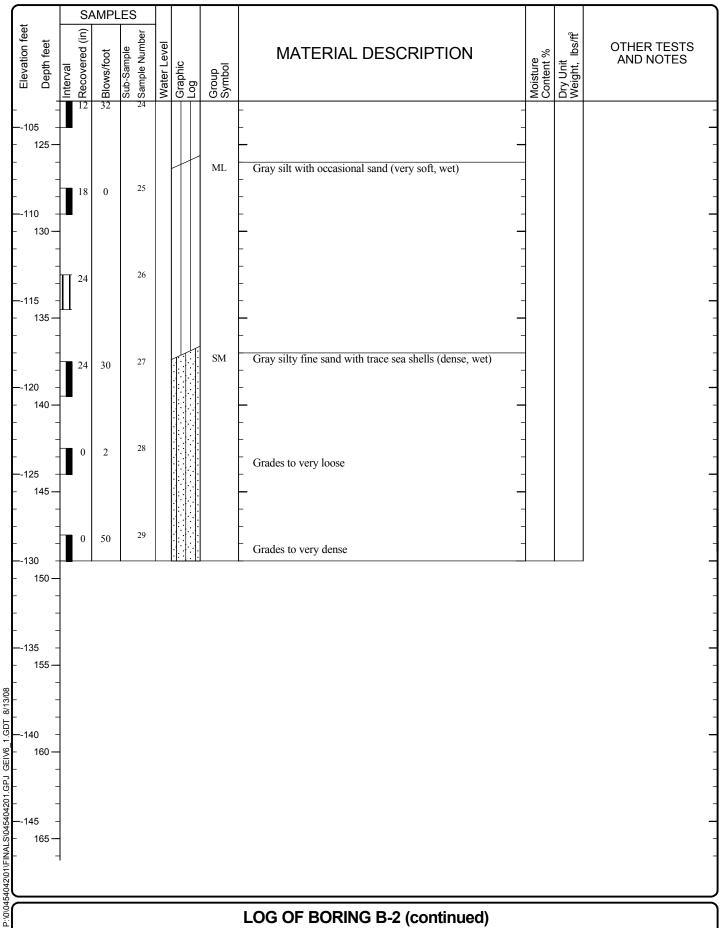


LOG OF BORING B-2 (continued)



WUT Wharf Expansion Project: Project Location: Tacoma, Washington

Figure A-3 Project Number: 0454-042-01 Sheet 3 of 4

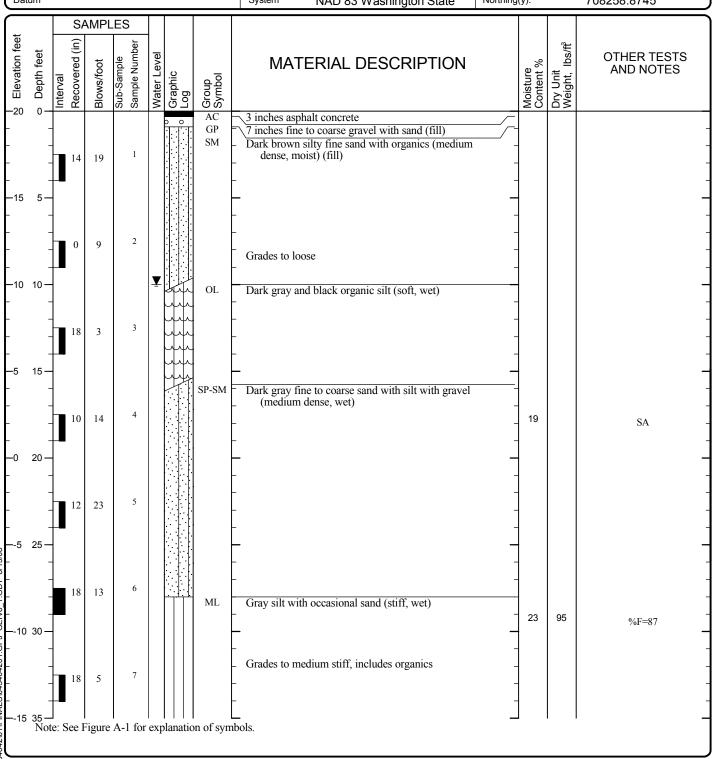




WUT Wharf Expansion Project: Project Location: Tacoma, Washington

Figure A-3 Sheet 4 of 4 Project Number: 0454-042-01

| Date(s) Drilled | 04/15/08 | 1 ===================================== | | Checked By | CAM |
|------------------------|-----------------|---|-------------------------|-------------------------------|----------------------------|
| Drilling Contractor | Holocene | Drilling Method | HSA and Mud Rotary | Sampling Methods | SPT and D&M |
| Auger Data | 6-inch diameter | Hammer Data | 140 IO AHIOMAIIC | | Diedrich D-120 |
| Total Depth (ft) | 149 | Surface Elevation (ft) | 20 | Groundwater Elevation (ft) | 10 |
| Vertical Datum | MLLW | Datum/ System | NAD 83 Washington State | Easting(x): Northing(y): | 112094.1761 708258.8745 |



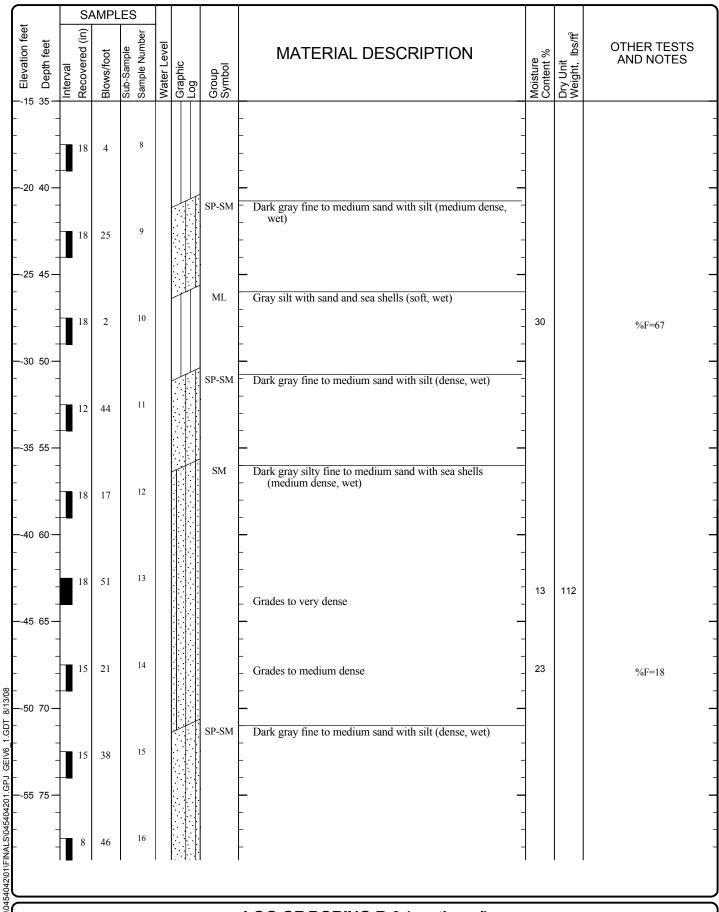
LOG OF BORING B-3



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

Project Number: 0454-042-01

Figure A-4 Sheet 1 of 4



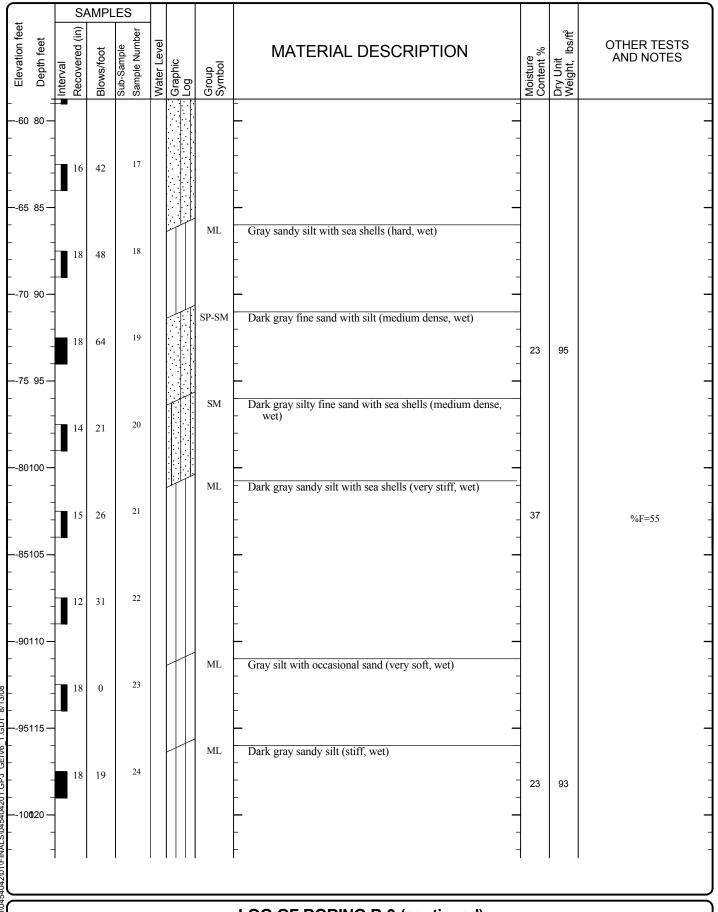
LOG OF BORING B-3 (continued)



Project: WUT Wharf Expansion
Project Location: Tacoma, Washington

Project Number: 0454-042-01

Figure A-4 Sheet 2 of 4



LOG OF BORING B-3 (continued)

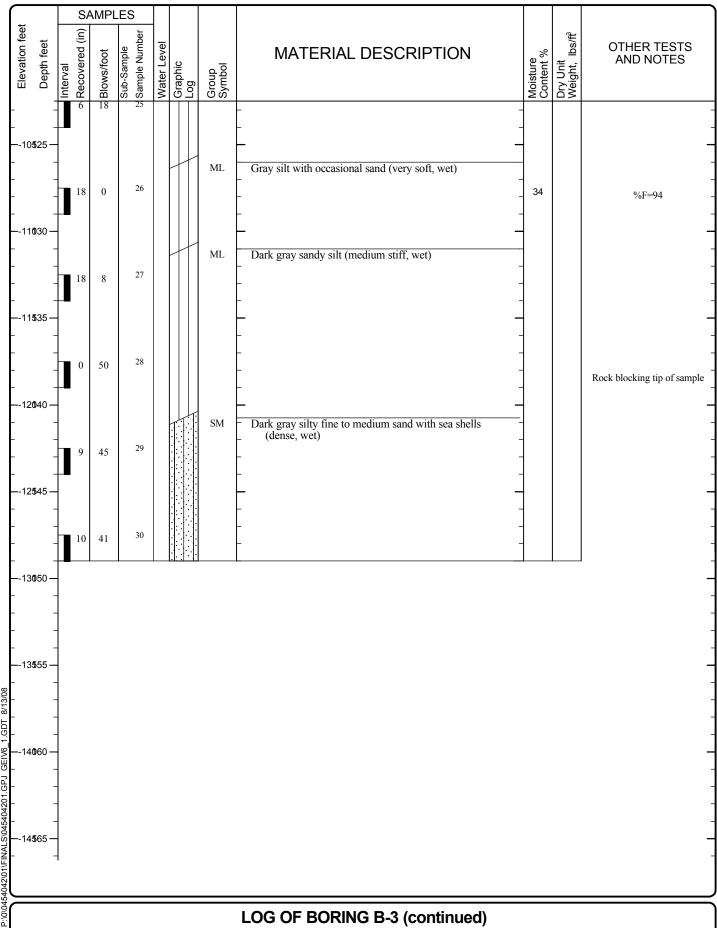
Project Number:



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

0454-042-01

Figure A-4 Sheet 3 of 4



Project Number:

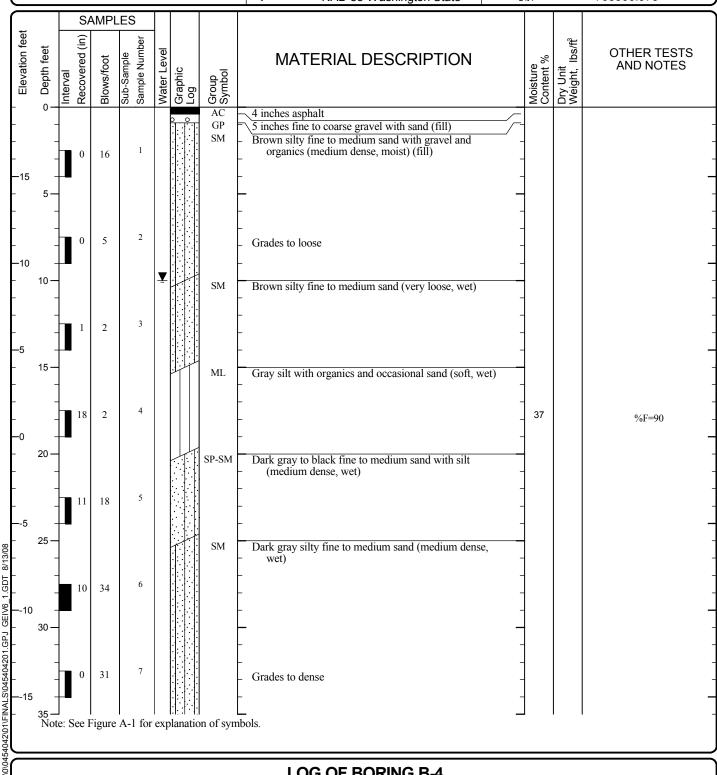


WUT Wharf Expansion Project: Project Location: Tacoma, Washington

0454-042-01

Figure A-4 Sheet 4 of 4

| Date(s) Drilled | 04/24/08 | Logged By | ASB | Checked By | CAM |
|------------------------|-----------------|---------------------------|-------------------------|-------------------------------|----------------------------|
| Drilling Contractor | Holocene | Drilling Method | | | SPT and D&M |
| Auger Data | 6-inch diameter | Hammer Data | 140 lb Automatic | Drilling Equipment | Diedrich D-120 |
| Total Depth (ft) | 149 | Surface Elevation (ft) | 19 | Groundwater Elevation (ft) | 9 |
| Vertical Datum | MLLW | Datum/ System | NAD 83 Washington State | Easting(x): Northing(y): | 1171854.6208 708360.975 |



LOG OF BORING B-4

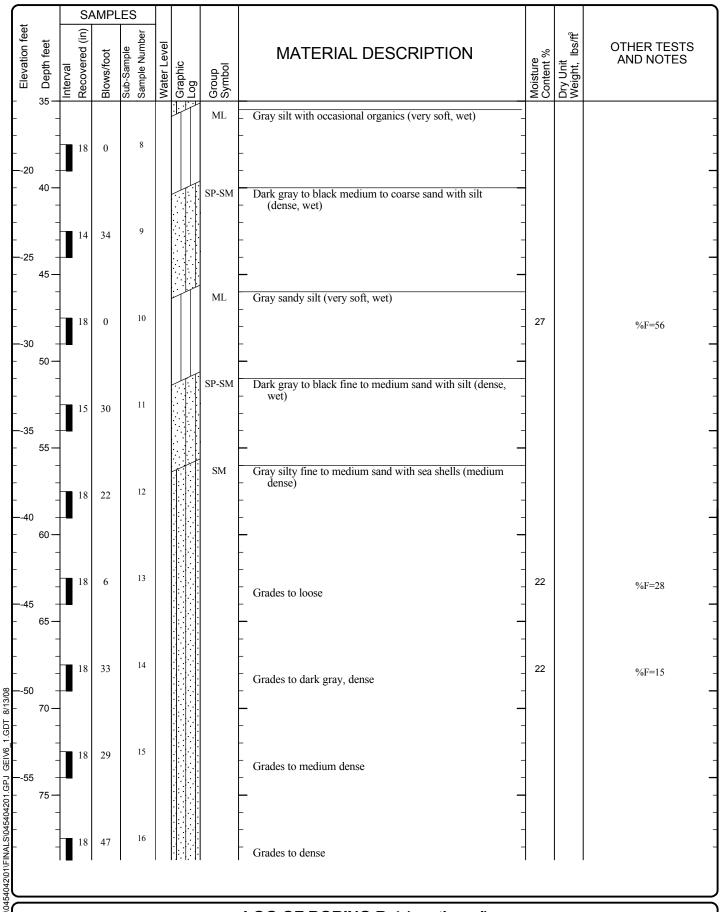
Project Number:



WUT Wharf Expansion Project: Project Location: Tacoma, Washington

0454-042-01

Figure A-5 Sheet 1 of 4



LOG OF BORING B-4 (continued)

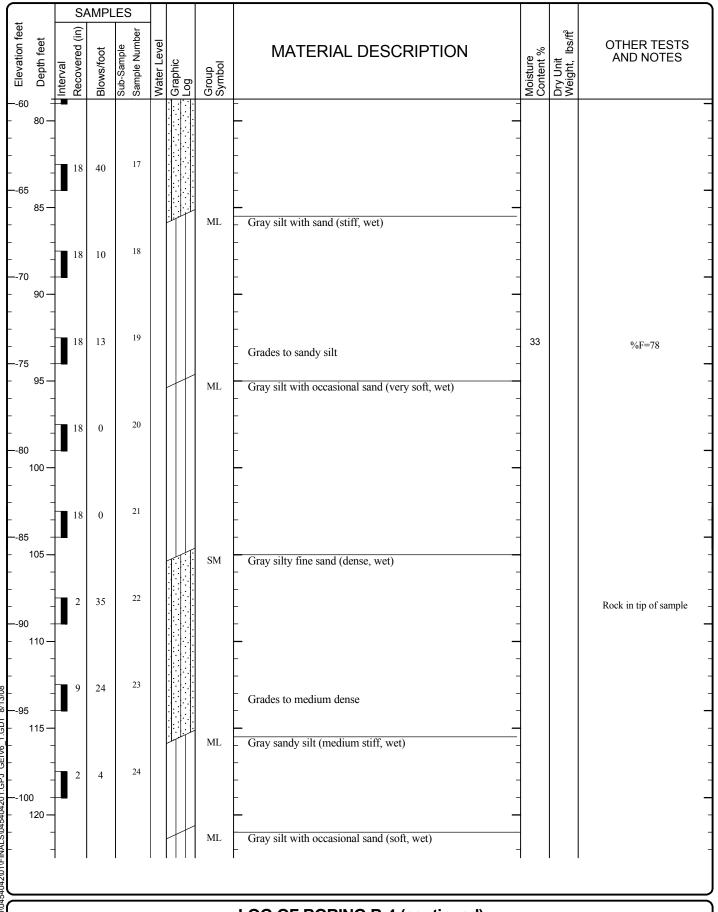
Project Number:



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

0454-042-01

Figure A-5 Sheet 2 of 4



LOG OF BORING B-4 (continued)

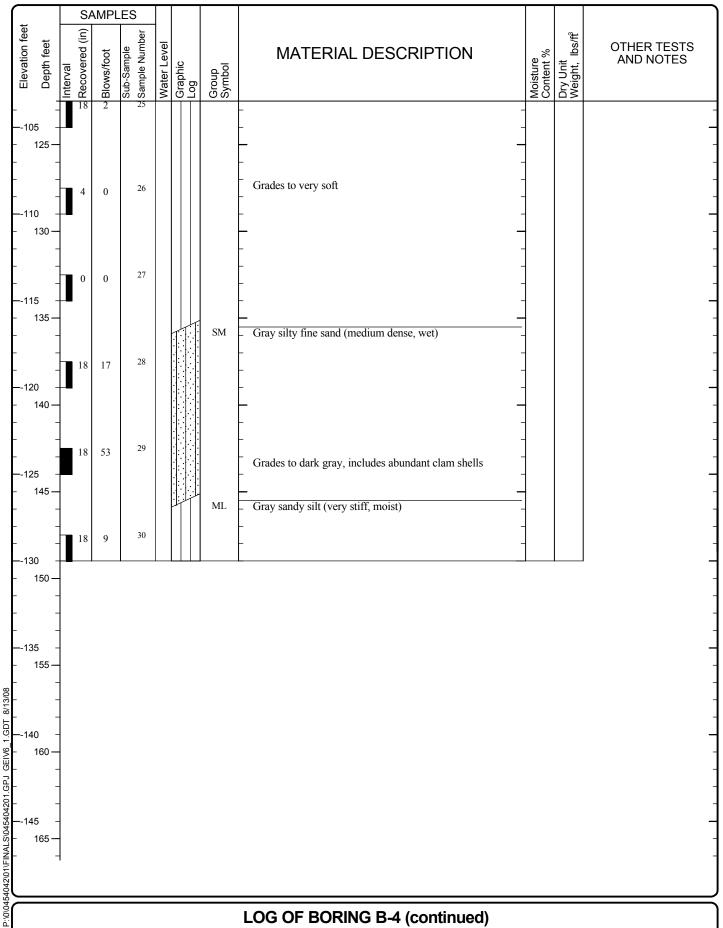
Project Number:



Project: WUT Wharf Expansion Project Location: Tacoma, Washington

0454-042-01

Figure A-5 Sheet 3 of 4





WUT Wharf Expansion Project: Project Location: Tacoma, Washington

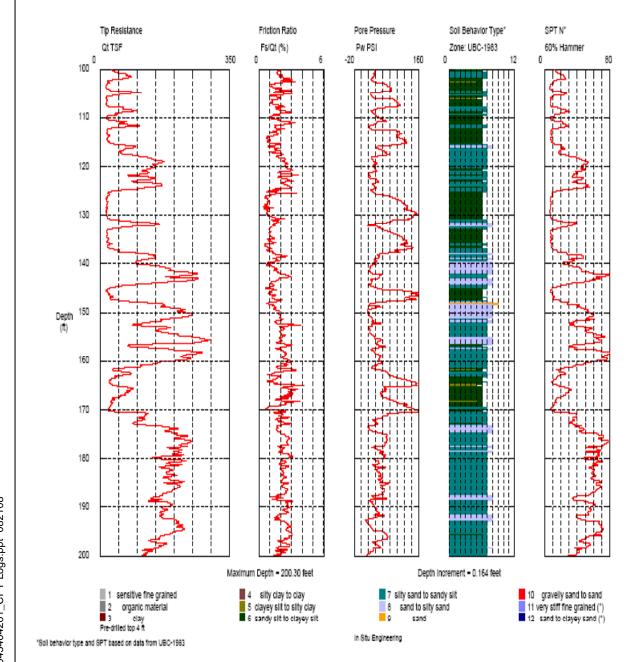
Project Number: 0454-042-01 Figure A-5 Sheet 4 of 4

WUT Wharf Extension Tacoma, Washington



GeoEngineers

Operator: Dafni Sounding: CPT-1 Cone Used: DSG1029 CPT Date/Time: 4/15/2008 10:20:56 AM Location: Hyundai Terminai Expansion Job Number: 0454-042-01



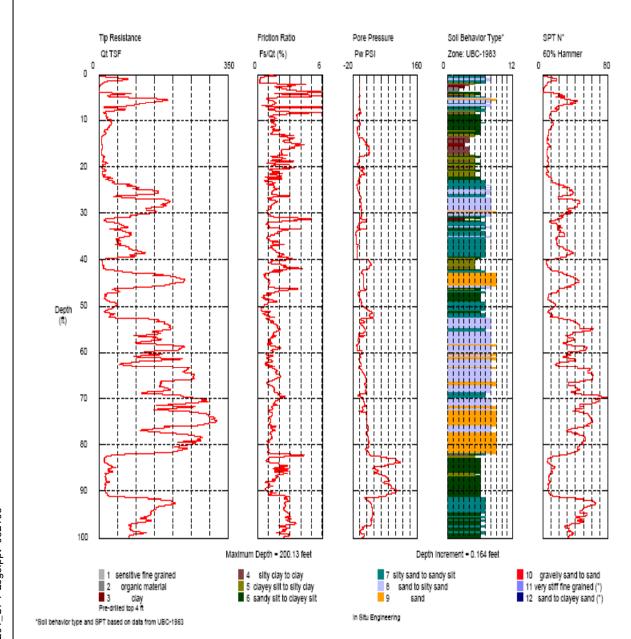
CPT-1 (page 2 of 2)

WUT Wharf Extension Tacoma, Washington





CPT Date/Time: 4/17/2008 9:40:48 AM Location: Hyundal Terminal Expansion Job Number: 0454-042-01



CPT-2 (page 1 of 2)

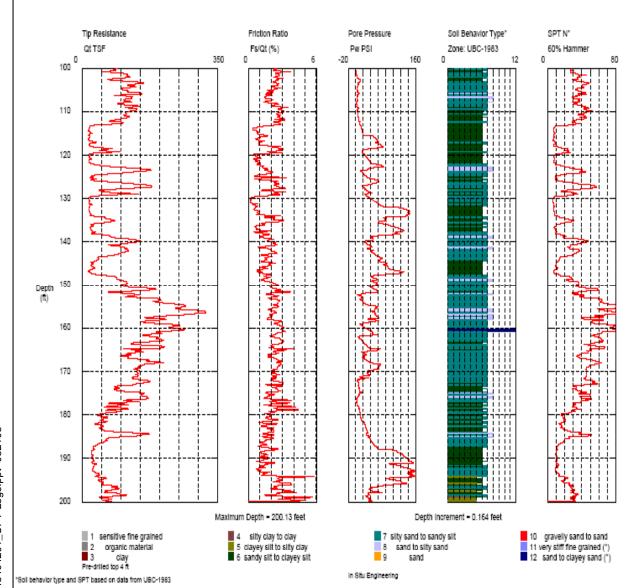
WUT Wharf Extension Tacoma, Washington



GeoEngineers



CPT Date/Time: 4/17/2008 9:40:48 AM Location: Hyundal Terminal Expansion Job Number: 0454-042-01



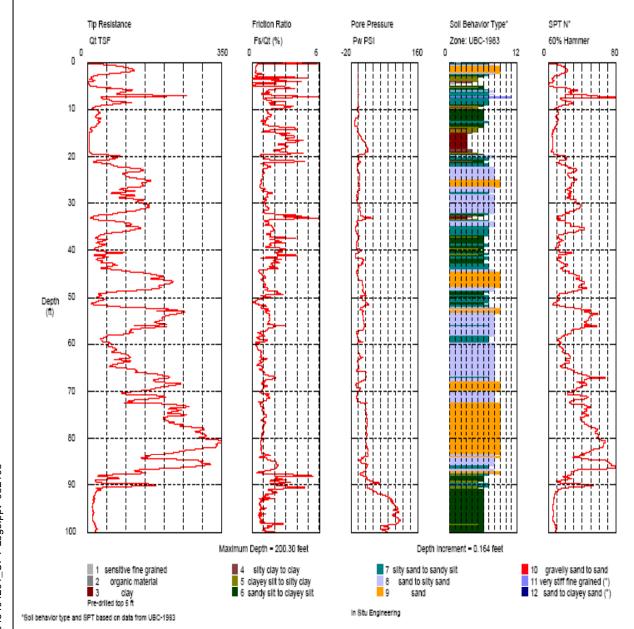
CPT-2 (page 2 of 2)

WUT Wharf Extension Tacoma, Washington



GeoEngineers

Operator: Dafni Sounding: CPT-3 Cone Used: DSG1029 CPT Date/Time: 4/16/2008 9:22:14 AM Location: Hyundal Terminal Expansion Job Number: 0454-042-01

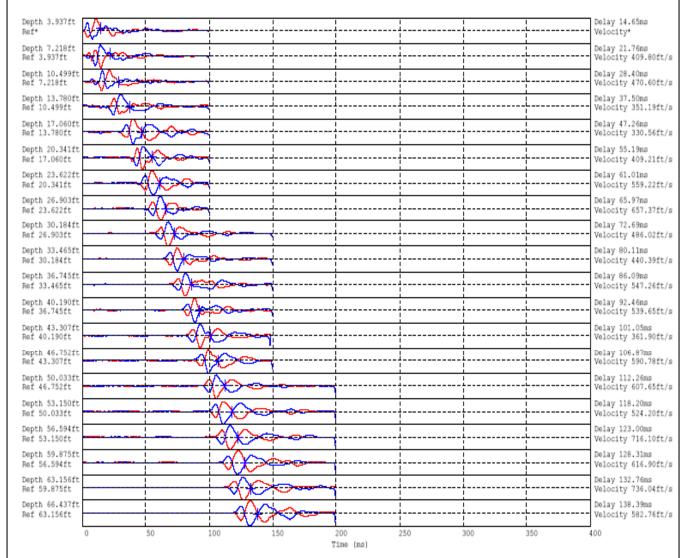


CPT-3 (page 1 of 2)

WUT Wharf Extension Tacoma, Washington



GeoEngineers Operator: Dafni CPT Date/Time: 4/16/2008 9:22:14 AM Sounding: CPT-3 Location: Hyundai Terminal Expansion Cone Used: DSG1029 Job Number: 0454-042-01 Tip Resistance Friction Ratio Pore Pressure Soll Behavior Type" SPT N" Qt TSF Fs/Qt (%) PW PSI Zone: UBC-1983 60% Hammer 350 160 80 100 110 120 130 140 150 Depth (ft) 160 170 180 TACO:\0\0454042\01\Finals\045404201_CPT Logs.ppt 082108 190 200 Maximum Depth - 200.30 feet Depth Increment = 0.164 feet 10 gravelly sand to sand 11 very stiff fine grained (") 1 sensitive fine grained 4 slity clay to clay 7 slity sand to sandy slit 5 clayey slit to slity clay 6 sandy slit to clayey slit organic material 8 sand to slity sand 3 12 sand to clayey sand (*) 3 clay Pre-drilled top 5 ft sand in Situ Engineering "Soil behavior type and SPT based on data from UBC-1983 **CPT-3 (page 2 of 2) WUT Wharf Extension** Tacoma, Washington GEOENGINEERS



Hammer to Rod String Distance 0.85(m)
* = Not Determined

in Situ Engineering

Shear Wave Velocity Plots CPT-1 (page 1 of 3)

WUT Wharf Extension Tacoma, Washington



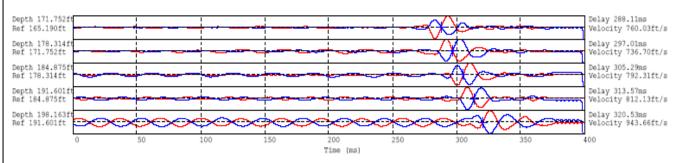
Hammer to Rod String Distance 0.85(m) * = Not Determined

in Situ Engineering

Shear Wave Velocity Plots CPT-1 (page 2 of 3)

WUT Wharf Extension Tacoma, Washington





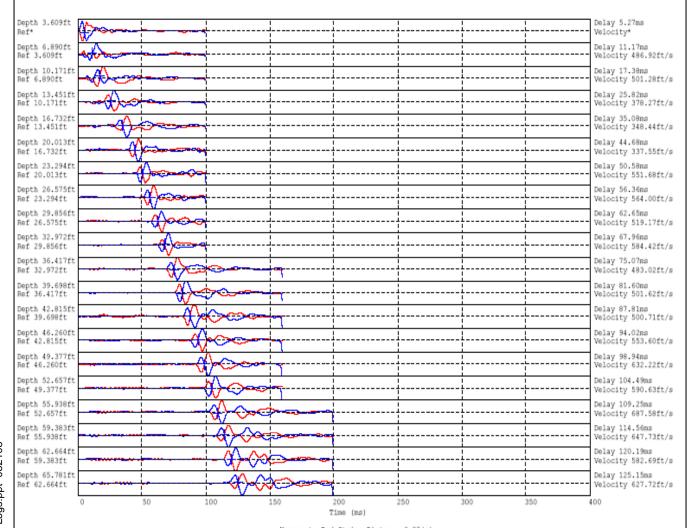
Hammer to Rod String Distance 0.85 (m)
* = Not Determined

in Situ Engineering

Shear Wave Velocity Plots CPT-1 (page 3 of 3)

WUT Wharf Extension Tacoma, Washington





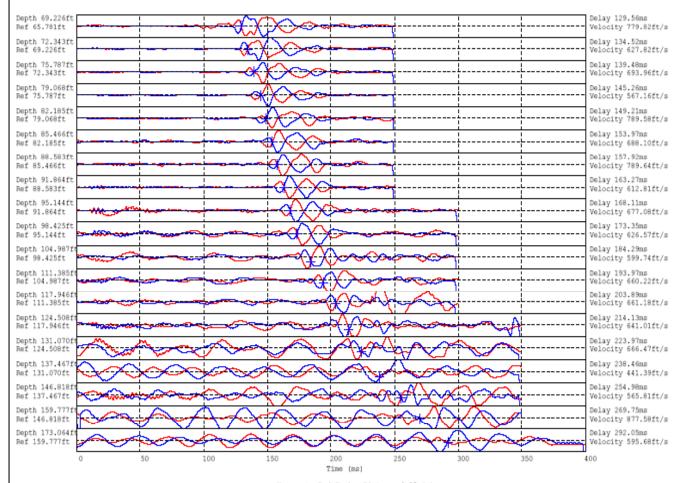
Hammer to Rod String Distance 0.85(m) * = Not Determined

in Situ Engineering

Shear Wave Velocity Plots CPT-3 (page 1 of 2)

WUT Wharf Extension Tacoma, Washington





Hammer to Rod String Distance 0.85 (m)
* = Not Determined

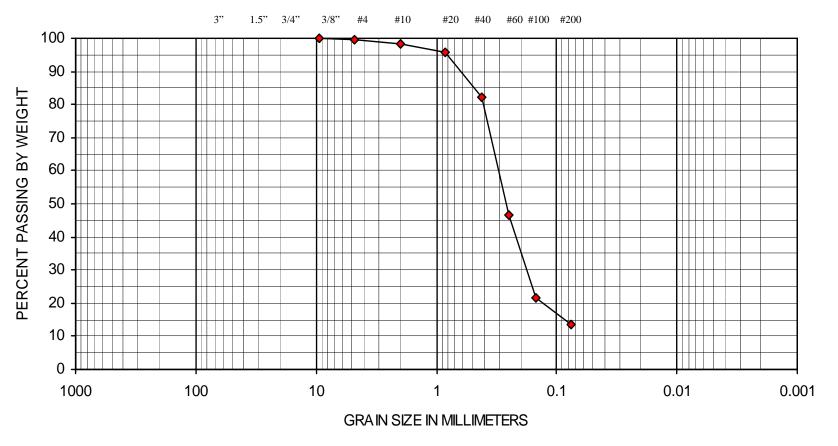
in Situ Engineering

Shear Wave Velocity Plots CPT-3 (page 2 of 2)

WUT Wharf Extension Tacoma, Washington



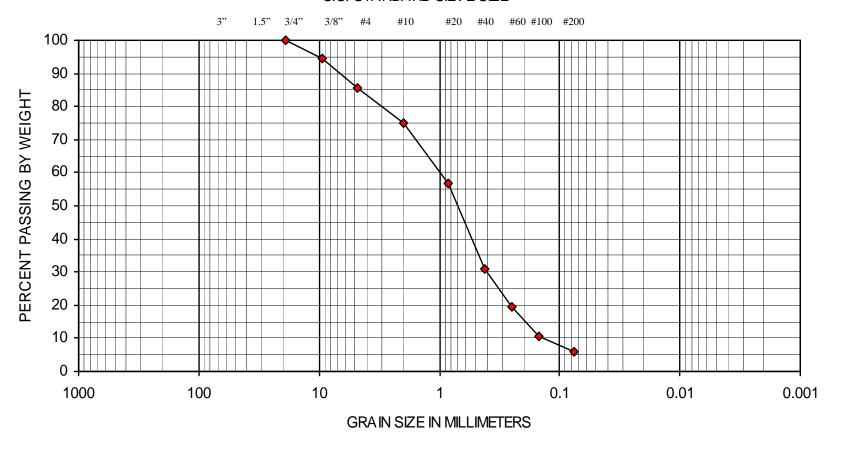
U.S. STANDARD SIEVE SIZE



| CODDIES | GRA | VEL | SAND | | | SILT OR CLAY |
|---------|--------|------|--------|--------|------|--------------|
| COBBLES | COARSE | FINE | COARSE | MEDIUM | FINE | SILT OR CLAT |

| SYMBOL | EXPLORATION NUMBER | DEPTH (ft) | MOISTURE (%) | SOIL CLASSIFICATION |
|----------|-----------------------|---------------|-----------------|--------------------------------|
| • | B-2 | 42.5 | 26 | Silty fine to medium sand (SM) |
| | | | | |

U.S. STANDARD SIEVE SIZE



| CODDIES | GRA | VEL | SAND | | | SILT OR CLAY |
|---------|--------|------|--------|--------|------|--------------|
| COBBLES | COARSE | FINE | COARSE | MEDIUM | FINE | SILT OR CLAT |

| SYMBOL | EXPLORATION NUMBER | DEPTH (ft) | MOISTURE (%) | SOIL CLASSIFICATION |
|----------|-----------------------|---------------|-----------------|--|
| ♦ | B-3 | 17.5 | 19 | Fine to coarse sand with silt and gravel (SP-SM) |
| | | | | |



APPENDIX B FINITE ELEMENT ANALYSES

APPENDIX B FINITE ELEMENT ANALYSES

INTRODUCTION

To gain an understanding of soil/structure interaction and to better understand the potential benefits of stone column ground improvement, we modeled and analyzed the soil and wharf/slope using PLAXIS V8 with the dynamic module. PLAXIS is a 2D plane strain dynamic finite element program that can analyze the soil response and seismic soil-structure interaction in time domain. Dynamic stress and deformation of soil and structure/foundations subjected to dynamic loads such as earthquake loads can be calculated. Output from the program includes soil and structure deformation, moments and shear along each pile and other information such as soil strain and plastic points within the soil mass. Preliminary finite element analyses where completed for the 30% design level. The PLAXIS analyses were refined and updated at the 95% design level. No additional finite element analyses were performed to complete the final design.

PLAXIS 2D Mesh Generation

The design cross section for the proposed wharf structure and soil profile is defined based on the slope configuration, pile layout and deck dimensions developed by BergerABAM. Figure 20 shows the typical finite element mesh and cross section used in our analyses. Discrete soil zones are delineated within the mesh to represent the soil profile. Each element is assigned a set of soil/structure strength and stiffness properties. Piles are modeled as a plate with equivalent pile strength and stiffness properties in proportion to the pile spacing.

SOIL INPUT PARAMETERS

General

Pertinent soil properties required by PLAXIS include density, friction angle, cohesion and modulus of stiffness. Pertinent soil properties used in our model are summarized in Tables B-1 through B-3.

Table B-1. Soil Parameters Used in PLAXIS Modeling - Static

| Soil Layer | Depth (feet bgs) | Total Unit Weight (pcf) | Friction Angle (degrees) | Modulus of Stiffness, E (ksf) | Poisson's Ratio, v |
|-----------------|---------------------|-------------------------------|--------------------------------|-------------------------------------|-----------------------|
| Upper Fill | 0-10 | 125 | 36 | 600 | 0.3 |
| Upper Silt | 10-20 | 110 | 27 | 100 | 0.3 |
| Upper Sand (1) | 20-30 | 120 | 33 | 500 | 0.3 |
| Upper Sand (2) | 30-40 | 120 | 27 | 500 | 0.3 |
| Upper Sand (3) | 40-50 | 120 | 33 | 500 | 0.3 |
| Middle Sand | 50-85 | 125 | 36 | 1,000 | 0.3 |
| Middle Silt (1) | 85-110 | 115 | 30 | 400 | 0.3 |
| Middle Silt (2) | 110-140 | 115 | 30 | 400 | 0.3 |
| Lower Sand | 140-160 | 125 | 36 | 1,200 | 0.3 |
| Lower Silt | 160-200 | 115 | 35 | 600 | 0.3 |

Table B-1. Soil Parameters Used in PLAXIS Modeling – Static (Continued)

| Soil Layer | Depth (feet bgs) | Total Unit Weight (pcf) | Friction Angle (degrees) | Modulus of Stiffness, E (ksf) | Poisson's Ratio, v |
|-------------------|---------------------|-------------------------------|--------------------------------|-------------------------------------|-----------------------|
| Riprap | - | 140 | 45 | 3,000 | 0.3 |
| Deck | - | 150 | - | 4.50E+05 | 0.3 |
| Improved Soil (1) | - | 125 | 33 | 130 | 0.3 |
| Improved Soil (2) | - | 125 | 36 | 560 | 0.3 |
| Improved Soil (3) | - | 125 | 35 | 540 | 0.3 |
| Improved Soil (4) | - | 125 | 38 | 1,080 | 0.3 |
| Improved Soil (5) | - | 125 | 37 | 1,040 | 0.3 |
| Stone Column (1) | - | 130 | 40 | 2,300 | 0.3 |
| Stone Column (2) | - | 128 | 38 | 1,570 | 0.3 |
| Stone Column (3) | - | 130 | 41 | 2,610 | 0.3 |
| Stone Column (4) | - | 130 | 39 | 1,950 | 0.3 |

Table B-2. Soil Parameters Used in PLAXIS Modeling - OLE

| Soil Layer | Depth (feet bgs) | Total Unit Weight (pcf) | Friction Angle (degrees) | Modulus of Stiffness, E (ksf) | Poisson's Ratio, v |
|-------------------|---------------------|-------------------------------|--------------------------------|--|-----------------------|
| Upper Fill | 0-10 | 125 | 36 | 2,025 | 0.35 |
| Upper Silt | 10-20 | 110 | 25 | 1,750 | 0.35 |
| Upper Sand (1) | 20-30 | 120 | 33 | 3,500 | 0.35 |
| Upper Sand (2) | 30-40 | 120 | 27 | 3,500 | 0.35 |
| Upper Sand (3) | 40-50 | 120 | 33 | 3,500 | 0.35 |
| Middle Sand | 50-85 | 125 | 36 | 4,425 | 0.35 |
| Middle Silt (1) | 85-110 | 115 | 27 | 4,100 | 0.35 |
| Middle Silt (2) | 110-140 | 115 | 27 | 7,550 | 0.35 |
| Lower Sand | 140-160 | 125 | 36 | 9,950 | 0.35 |
| Lower Silt | 160-200 | 115 | 35 | 9,950 | 0.35 |
| Riprap | - | 140 | 45, c=100 psf | 4,000 | 0.35 |
| Deck | - | 150 | - | 4.50E+05 | 0.35 |
| Improved Soil (1) | - | 125 | 33 | 2,230 | 0.35 |
| Improved Soil (2) | - | 125 | 36 | 3,920 | 0.35 |
| Improved Soil (3) | - | 125 | 35 | 3,780 | 0.35 |
| Improved Soil (4) | - | 125 | 38 | 4,780 | 0.35 |
| Improved Soil (5) | - | 125 | 37 | 4,600 | 0.35 |

Table B-2. Soil Parameters Used in PLAXIS Modeling – OLE (Continued)

| Soil Layer | Depth (feet bgs) | Total Unit Weight (pcf) | Friction Angle (degrees) | Modulus of Stiffness, E (ksf) | Poisson's Ratio, v |
|------------------|---------------------|-------------------------------|--------------------------------|--|-----------------------|
| Stone Column (1) | - | 130 | 40 | 4,340 | 0.35 |
| Stone Column (2) | - | 128 | 38 | 4,060 | 0.35 |
| Stone Column (3) | - | 130 | 41 | 4,860 | 0.35 |
| Stone Column (4) | - | 130 | 39 | 4,700 | 0.35 |

Table B-3. Soil Parameters Used in PLAXIS Modeling - CLE

| Soil Layer | Depth (ft bgs) | Total Unit Weight (pcf) | Friction Angle (degrees) | Modulus of Stiffness, E (ksf) | Poisson's Ratio, v |
|-------------------|-------------------|-------------------------------|--------------------------------|-------------------------------------|-----------------------|
| Upper Fill | 0-10 | 125 | 36 | 1,600 | 0.35 |
| Upper Silt | 10-20 | 110 | 6 | 875 | 0.35 |
| Upper Sand (1) | 20-30 | 120 | 33 | 2,450 | 0.35 |
| Upper Sand (2) | 30-40 | 120 | 12 | 2,050 | 0.35 |
| Upper Sand (3) | 40-50 | 120 | 33 | 2,050 | 0.35 |
| Middle Sand | 50-85 | 125 | 31 | 3,150 | 0.35 |
| Middle Silt (1) | 85-110 | 115 | 25 | 2,250 | 0.35 |
| Middle Silt (2) | 110-140 | 115 | 25 | 2,250 | 0.35 |
| Lower Sand | 140-160 | 125 | 36 | 6,300 | 0.35 |
| Lower Silt | 160-200 | 115 | 35 | 6,750 | 0.35 |
| Riprap | - | 140 | 45, c=100 psf | 4,000 | 0.35 |
| Deck | - | 150 | - | 4.50E+05 | 0.35 |
| Improved Soil (1) | - | 125 | 33 | 1,115 | 0.35 |
| Improved Soil (2) | - | 125 | 36 | 2,450 | 0.35 |
| Improved Soil (3) | - | 125 | 35 | 2,360 | 0.35 |
| Improved Soil (4) | - | 125 | 37 | 3,280 | 0.35 |
| Improved Soil (3) | - | 125 | 33 | 2,550 | 0.35 |
| Stone Column (1) | - | 130 | 40 | 3,440 | 0.35 |
| Stone Column (2) | - | 128 | 38 | 2,970 | 0.35 |
| Stone Column (3) | - | 130 | 41 | 4,020 | 0.35 |
| Stone Column (4) | - | 130 | 39 | 3,680 | 0.35 |

In-Situ Soil

Soil input parameters for the in-situ soil are divided into three categories: non-liquefied, marginally liquefied and liquefied. Strength parameters for the non-liquefied case were developed from correlations between SPT (blow counts), CPT results, and laboratory results with data pertaining to strength and modulus reported in literature. Strength input parameters for liquefied conditions were calculated based on SPT blow counts with the procedure presented by Stark and Mesri (1992). Strength parameters for

marginally liquefied conditions were reduced from the non-liquefied conditions based on the amount of excess pore water pressure generated during earthquake loadings as calculated from the 1-D site specific response analyses. The stress-strain behavior of soils under small strain loading conditions such as earthquakes is generally non-linear and depends on strain levels. Therefore, soils modulus values were derived using shear wave velocity measurements from the seismic CPTs and modulus reduction curves developed by EPRI (1993) based on the strain levels from the 1-D site response analyses.

Improved Soil

Based on our slope stability and Newmark analysis, ground improvements are required to increase overall slope stability and reduce slope deformation under the design earthquake conditions. Details of our slope stability and Newmark analysis are discussed in the body of this report. Increasing soil relative density is a key factor to control slope deformation and reduce soil liquefaction during the design earthquakes. For this project, stone column improvement was selected to increase soil relative density because it has proven results for improvement in the site soil conditions relative to other methods (compaction grouting, jet grouting, etc).

A key issue in the deformation analysis is selection of appropriate soil strength and stiffness parameters for input to PLAXIS. Stone columns provide an increase in shear strength. They can also increase the stiffness of the surrounding soil by densification during stone column installation (Bergado et al., 1996). The clean crushed stone also provides drainage paths during earthquake loadings to prevent or reduce the generation of excess pore water pressure which can lead to liquefaction.

The improvement factors for the in-situ soils as a result of stone column installation were evaluated using the chart presented by Greenwood (1991). The chart provides increased N values versus initial N values for various stone column replacement ratios. For PLAXIS modeling, the weighted average soil strength properties were used for the improved ground zone, which includes the stone columns and the densified in-situ soils as presented below:

 $\phi_{improved ground zone} = (\phi_{sc} * A_{sc} + \phi_{ds} * A_{ds}) / A_T$

where:

\$\phi_{improved ground zone}\$ = weighted average friction angle of stone column and densified in-situ soil

 ϕ_{sc} = average friction angle of stone column (~50° - crushed stone)

 A_{sc} = cross section area of stone column (typically 3.5-foot diameter)

 ϕ_{ds} = friction angle of densified in-situ soils between stone columns

 A_{ds} = cross section area of densified in-situ soil in between stone columns

 A_T = cross section area between stone columns, center-center

The resulting average friction angle of the improved ground zone conservatively ranges from 33 to 38 degrees, depending on the spacing of the stone columns and the initial density of the soil. Closer spacing results in a higher replacement ratio (A_r) , density, friction angle and modulus of the soil. Improved soil properties used in our analyses are provided in Tables B-1 through B-3.

EARTHQUAKE TIME HISTORIES FOR PLAXIS MODELING

Earthquake loading was modeled by applying the design earthquake time histories at the base of the PLAXIS mesh. For this project, the time histories from our 1-D nonlinear site response analysis were used as input at the base (Elevation -200 feet) of the PLAXIS mesh. Two earthquake time histories (one representing the shallow crustal earthquake and the other representing the Benioff earthquake) were selected for use in PLAXIS modeling under both design earthquake levels (OLE and CLE). The earthquake time histories were further scaled prior to being used as input such that the response spectra of the selected earthquakes matched the recommended response spectra developed in our site-response analysis. Table B-4 presents the selected earthquake time histories for both the OLE and CLE events.

Table B-4. Selected Earthquake Acceleration Time Histories for PLAXIS Modeling

| Earthquake Level | Earthquake, Year | Recording Station |
|---------------------|---------------------|---------------------------|
| OLE | San Fernando, 1971 | Cedar Springs Allen Ranch |
| | Nisqually, 2001 | University of Puget Sound |
| CLE | San Fernando, 1971 | Cedar Springs Allen Ranch |
| | El Salvador, 2001 | Santiago De Maria |

PLAXIS MODELING OF STRUCTURES

The foundation system supporting the wharf structure consists of 24-inch-diameter pre-stressed concrete piles that are modeled using a plate element in PLAXIS. Because PLAXIS is a 2-dimensional plane strain program, the plate extends into and out of the page infinitely. The strength and modulus of the plate is in proportion to the properties of an individual pile and the pile spacing. An interface element is used to connect the structural element to the soil matrix. A coefficient of 0.80 was used as the interface coefficient between piles and the soil for this project. Table B-5 summarizes the structural properties provided by BergerABAM used in PLAXIS. Included in these properties are values for the plastic moment M_p in the pile. If the pile bends excessively such that the calculated moment in the pile is greater than M_p , the PLAXIS program will limit the lateral capacity of that pile so that it cannot provide any further resistance to soil movement.

Table B-5. Structural Properties by BergerABAM

| Pre-stressed Pile | M _p | 675 kip-ft |
|------------------------|---------------------------|----------------------------|
| | Moment at Inertia | 9,000 in. ⁴ |
| | Cross-sectional Area | 452 in. ² |
| | Modulus of Elasticity (E) | 5,700 Ksi |
| | Shear Capacity | 250 kips |
| | Structural Damping | 10% |
| Sheet Pile (AZ 37-700) | M_p | 287 k-ft/ft |
| | Cross-sectional Area | 10.68 in. ² /ft |
| | Modulus of Elasticity (E) | 29,000 Ksi |
| | Structural Damping | 10% |

PLAXIS RESULTS

General

In our 30% Design Report, we recommended a stone column replacement ratio of 6 percent on the slope for an Option 1 layout. Because of changes in the pile layout and calibration of the model, additional PLAXIS analyses were completed for 95% design with the stone column spacing condensed to achieve a replacement ratio of 9 percent on the slope. This change resulted in better performance of the structure, particularly for CLE level events.

The ground improvement layouts analyzed are shown on Figure 21. Specific results of our analyses with respect to wharf deformation and stress are provided in Tables 8 and 9.

OLE Results

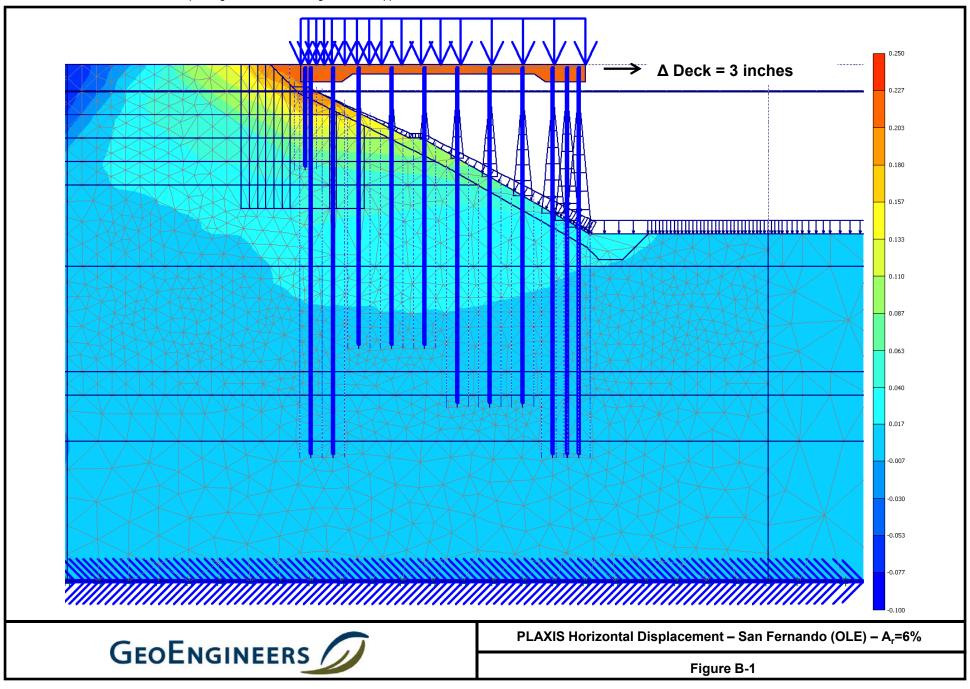
Our PLAXIS results indicate that the forces acting on the piles during an OLE event do not exceed the capacity of the piles. Figures B-1 through B-4 illustrate horizontal wharf and slope deformation after two OLE events with two different A_r options. The deformation of the wharf deck at the end of the OLE event was estimated to be about 3 to 4 inches.

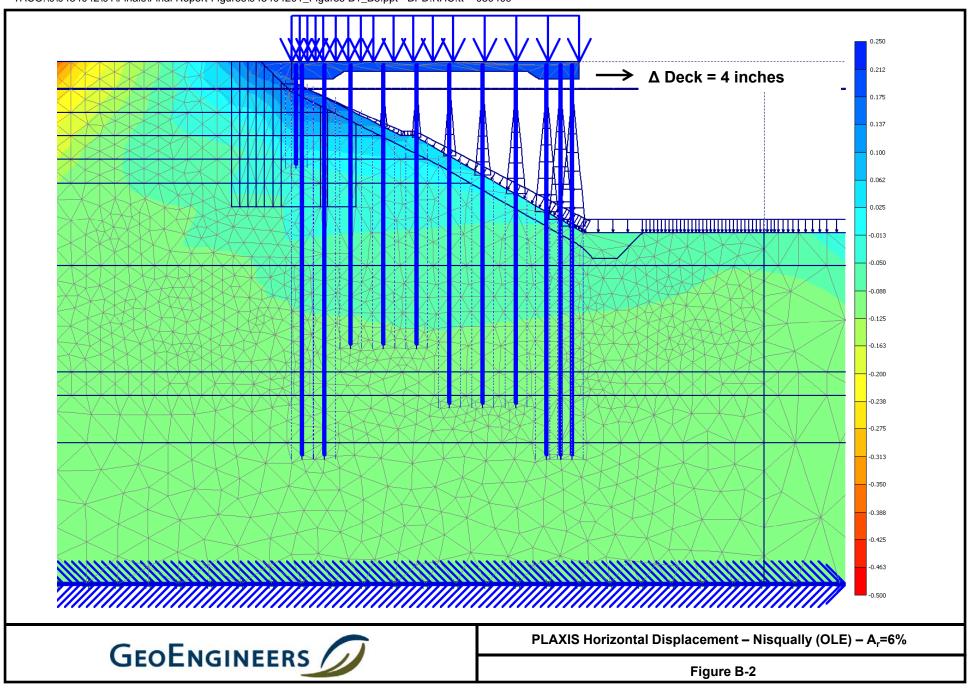
The maximum pile shear force during the OLE event was estimated to range between 11 and 39 kips. The maximum pile shear is well below the allowable pile shear capacity of 250 kips. The maximum pile shear forces were found at mudline. The maximum pile moment during the OLE event was estimated to range between 119 and 265 kip-ft, which is well below the allowable moment capacity of 675 kip-ft. The maximum moments were found at the pile-deck connection.

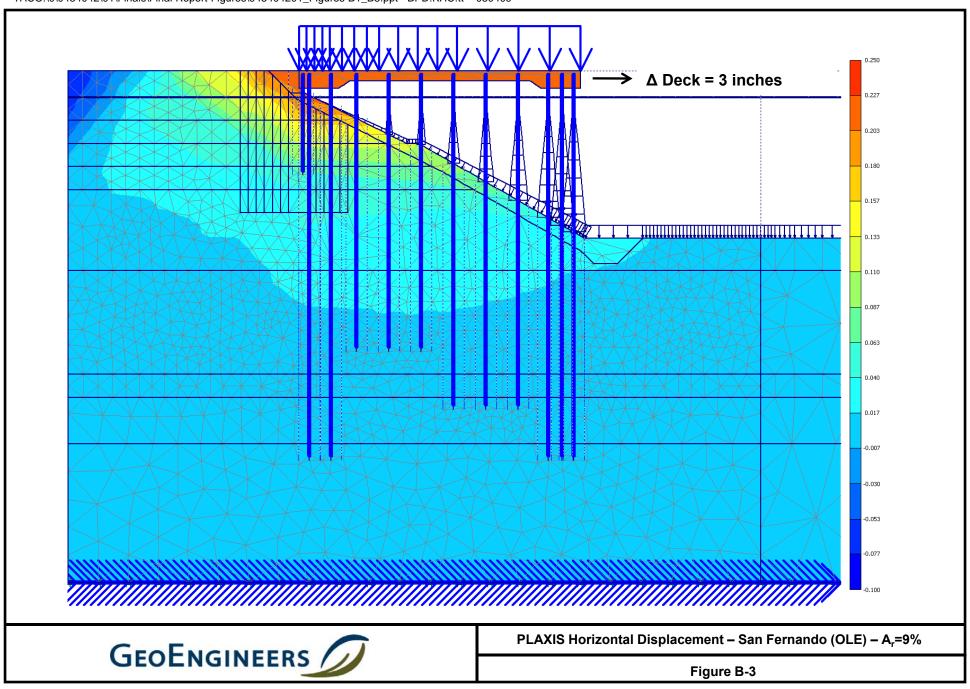
CLE Results

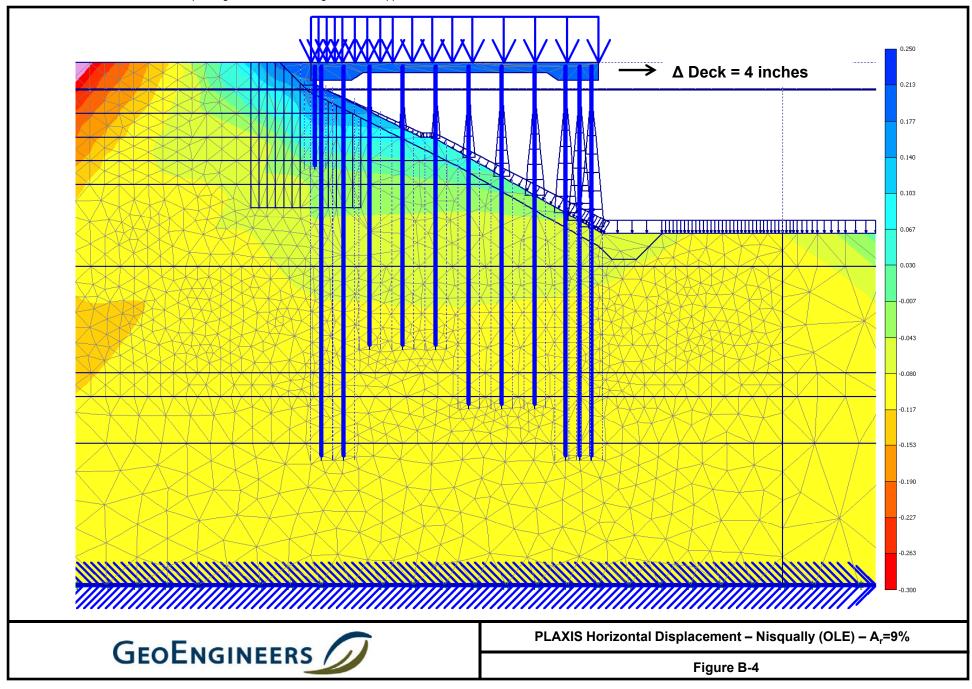
Our PLAXIS results indicate that the forces acting on the piles during the CLE event do not exceed the capacity of the piles. Figures B-5 through B-8 illustrate the horizontal wharf and slope deformation after two different CLE events with two A_r options. The results indicate that the estimated deformation of the wharf deck at the end of a CLE event is about 10 to 14 inches (the lower value for San Fernando and the larger value for El Salvador).

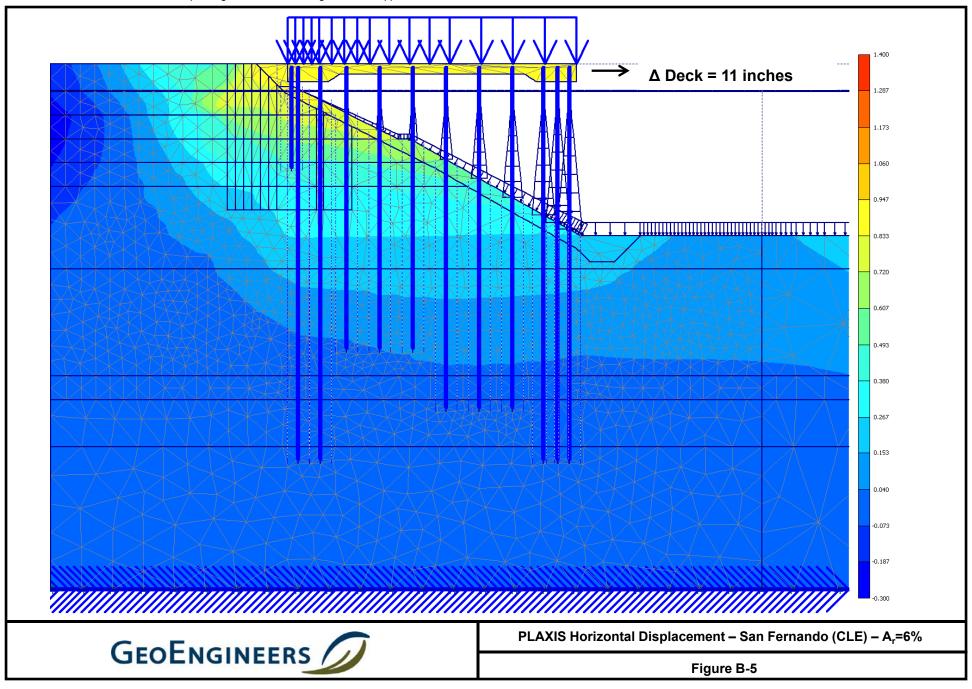
The maximum pile shear force during a CLE event was estimated to range between 24 and 109 kips. The maximum pile shear force is well below the allowable pile shear capacity of 250 kips. The maximum pile shear forces were found at mudline. The maximum pile moment during a CLE event was estimated to range between 244 and 455 kip-ft, which is below the moment capacity of the piles at 675 kips. The maximum moments were found at the pile-deck connection. The model did not calculate a plastic moment in any of the piles during CLE event.

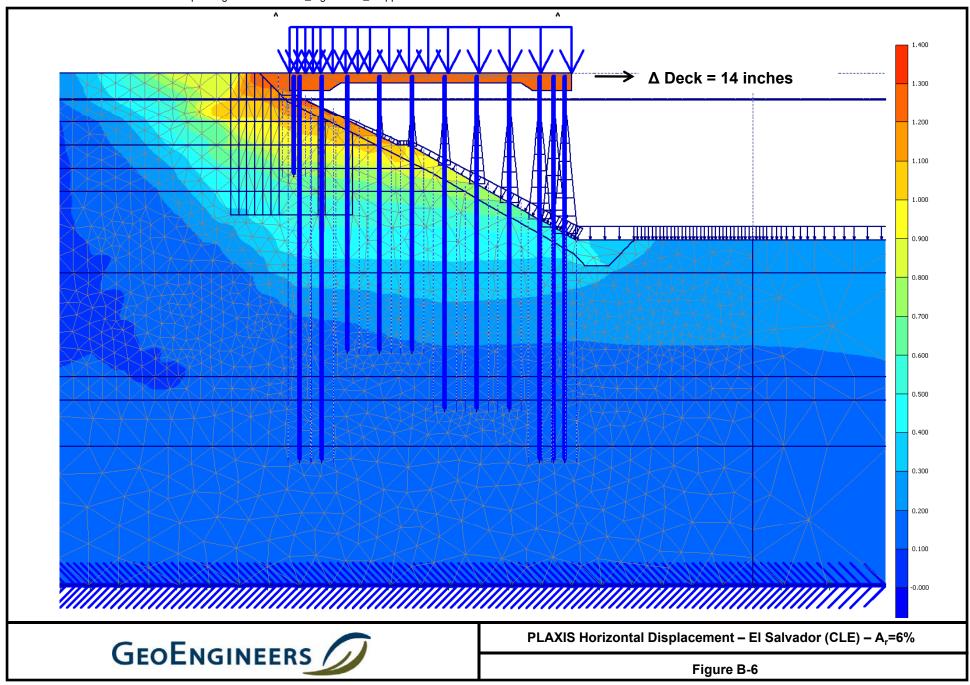


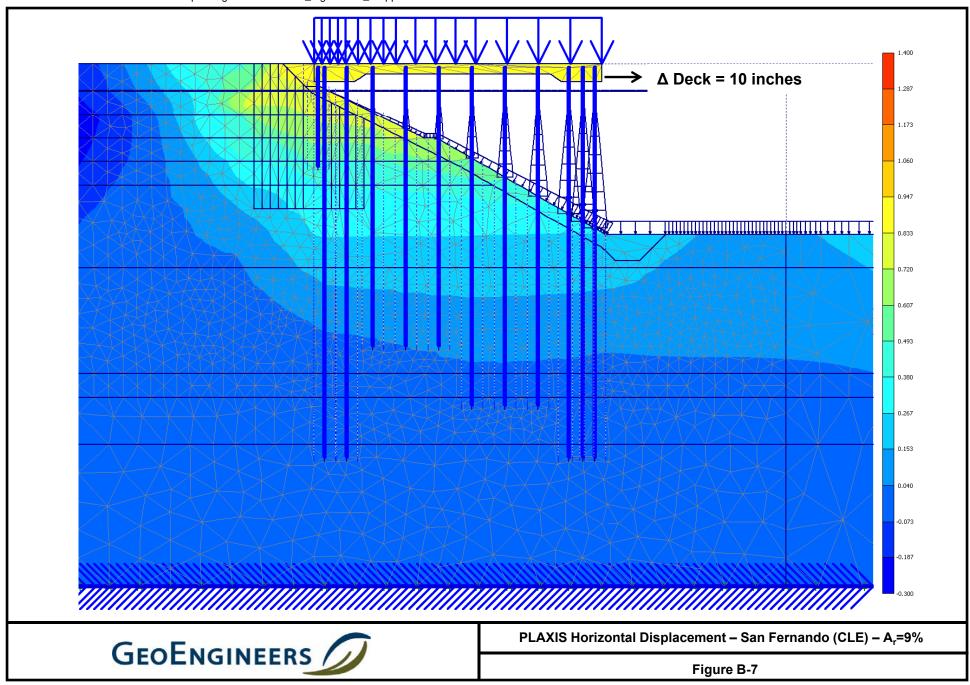


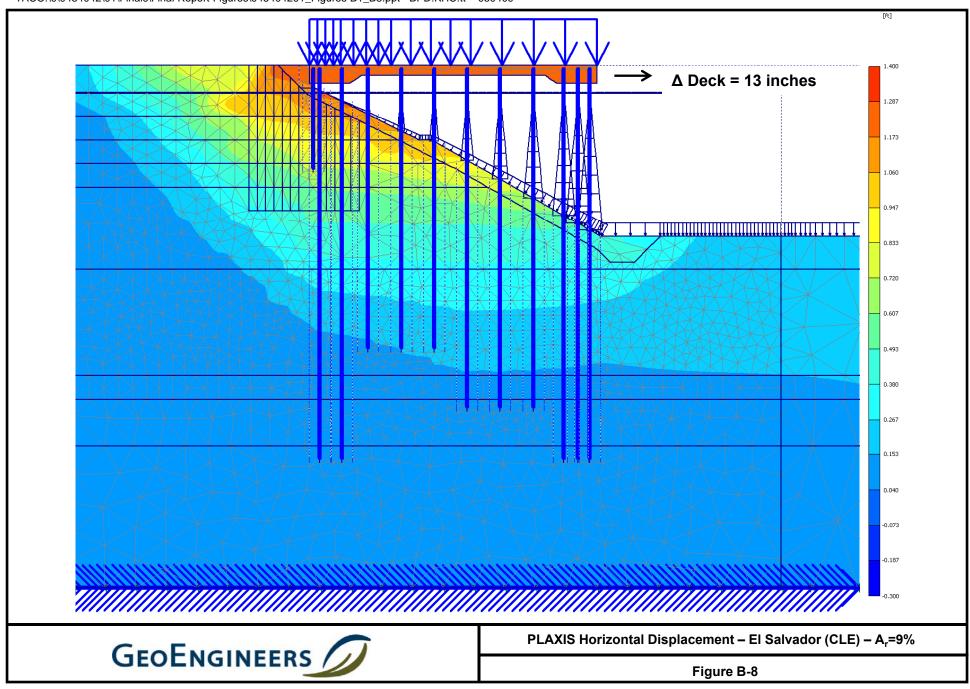








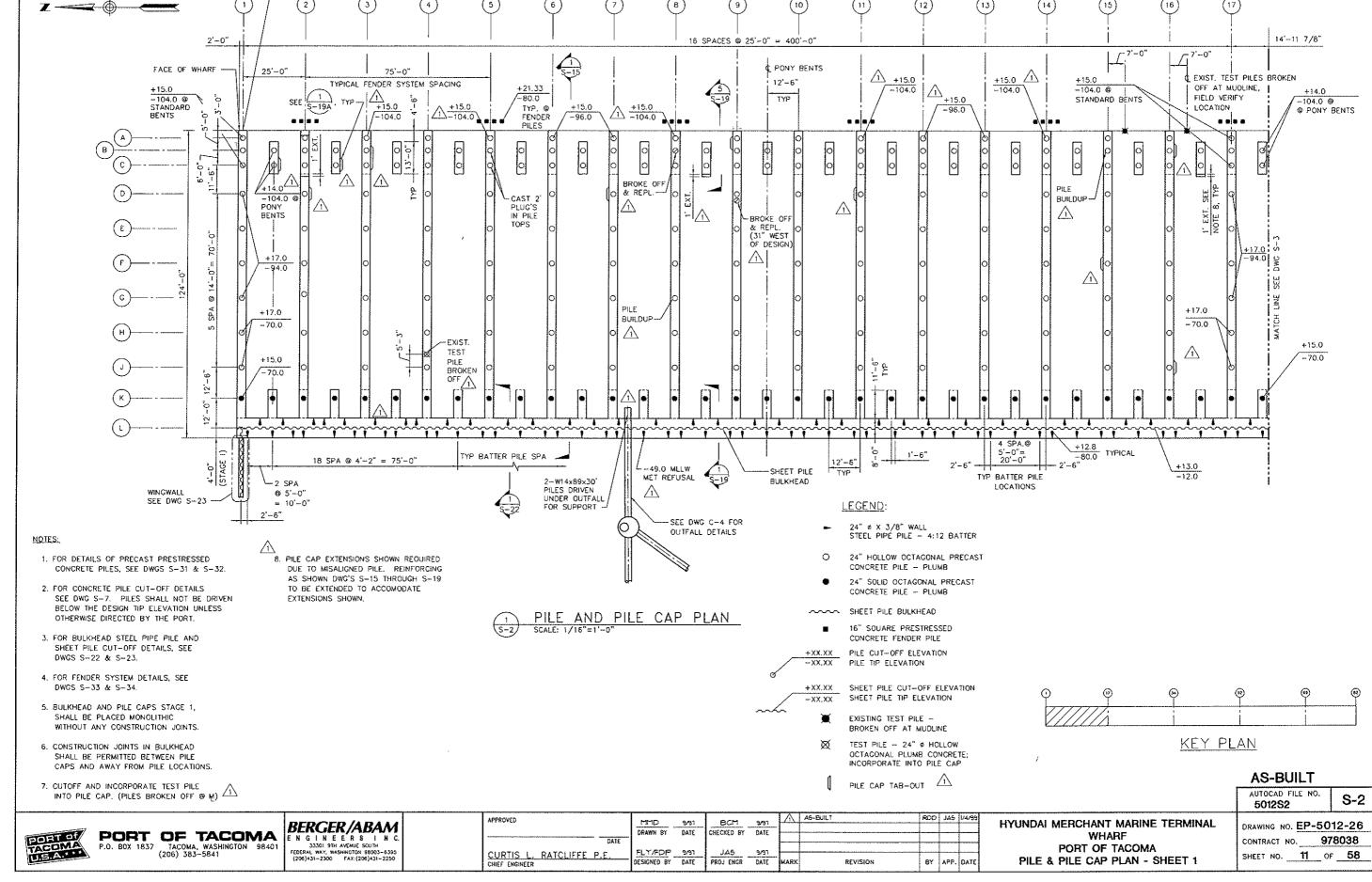






APPENDIX C EXISTING WUT TERMINAL – SELECT PLANS AND PILE DRIVING RECORDS

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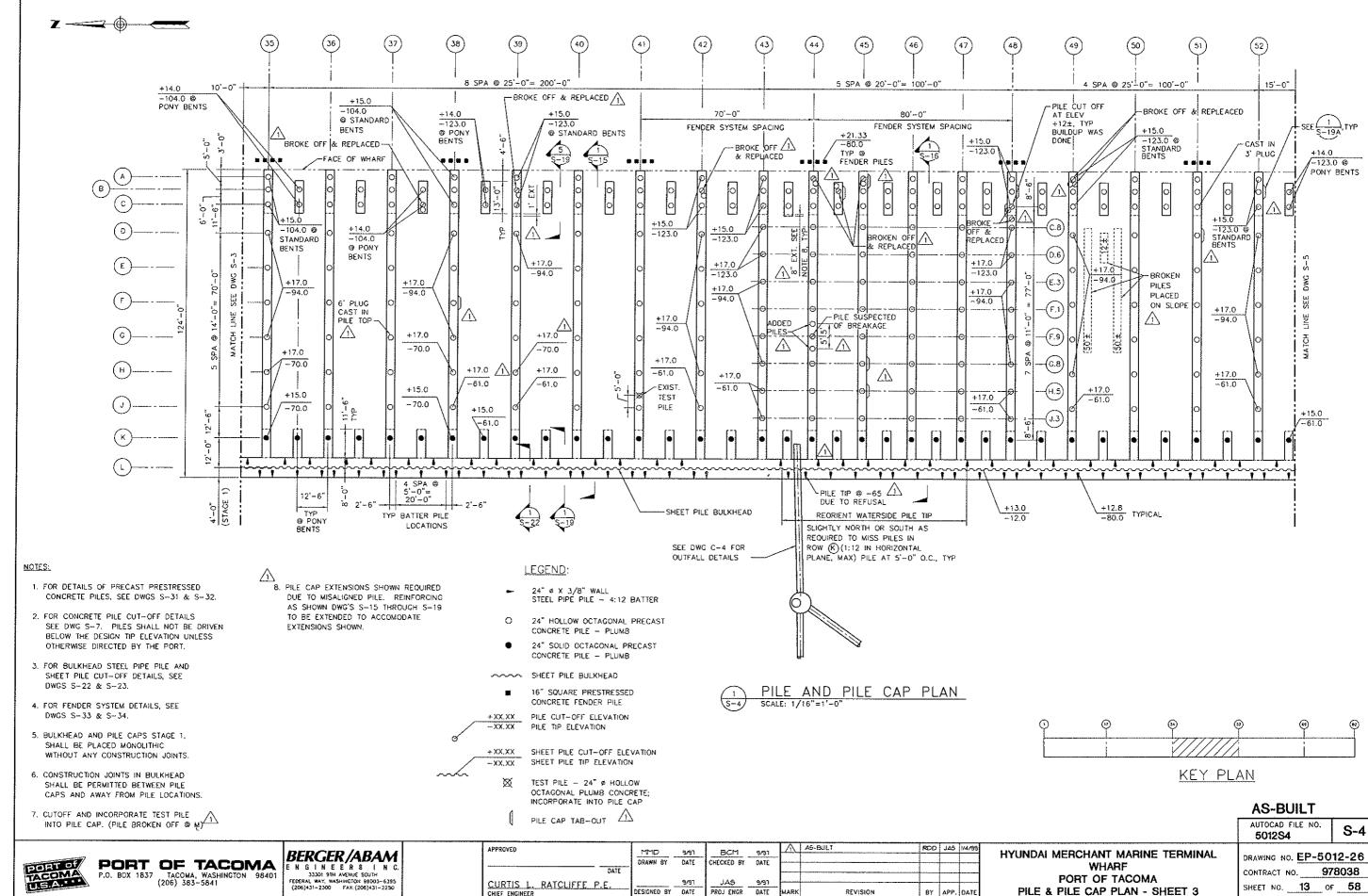
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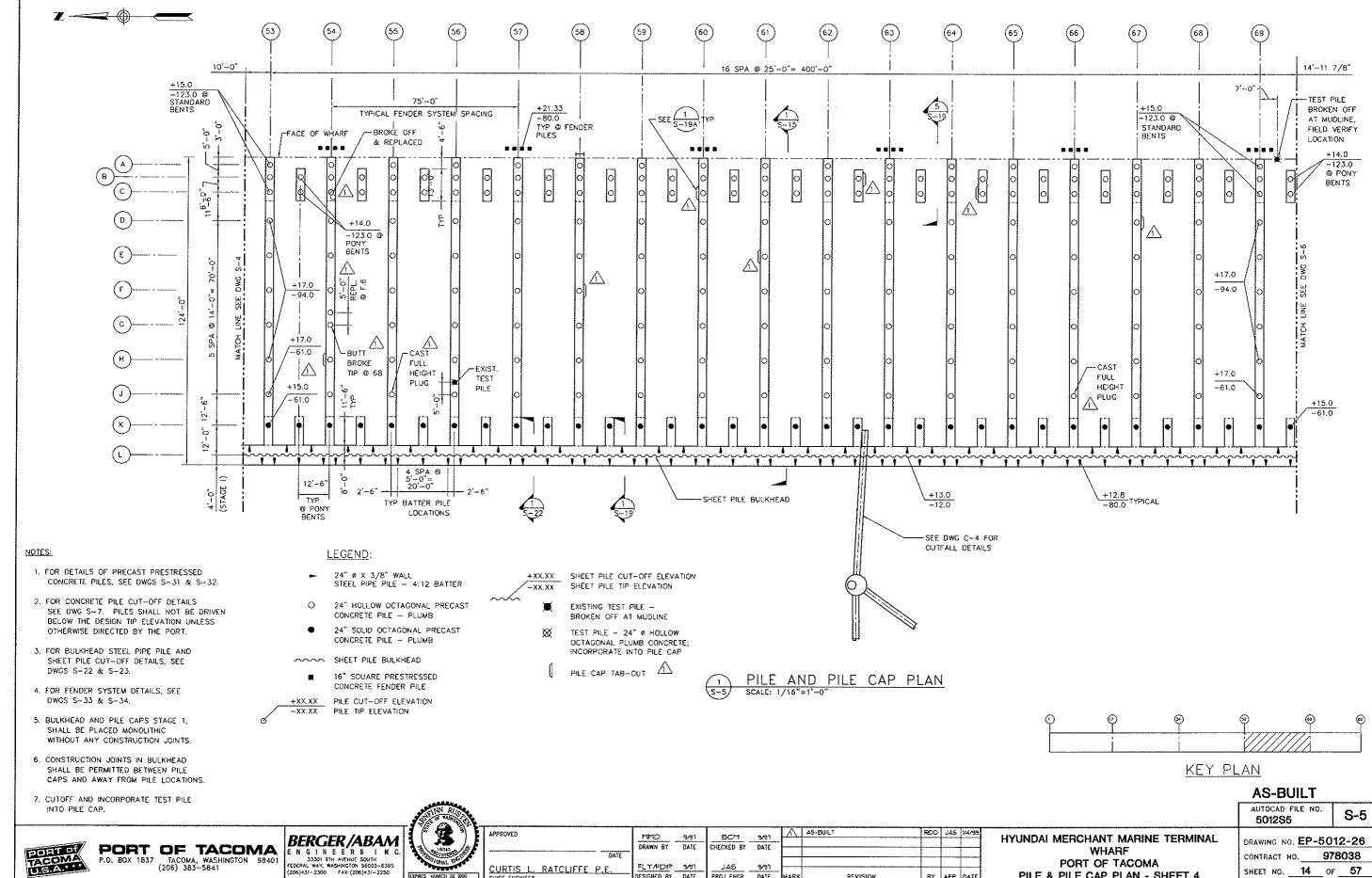
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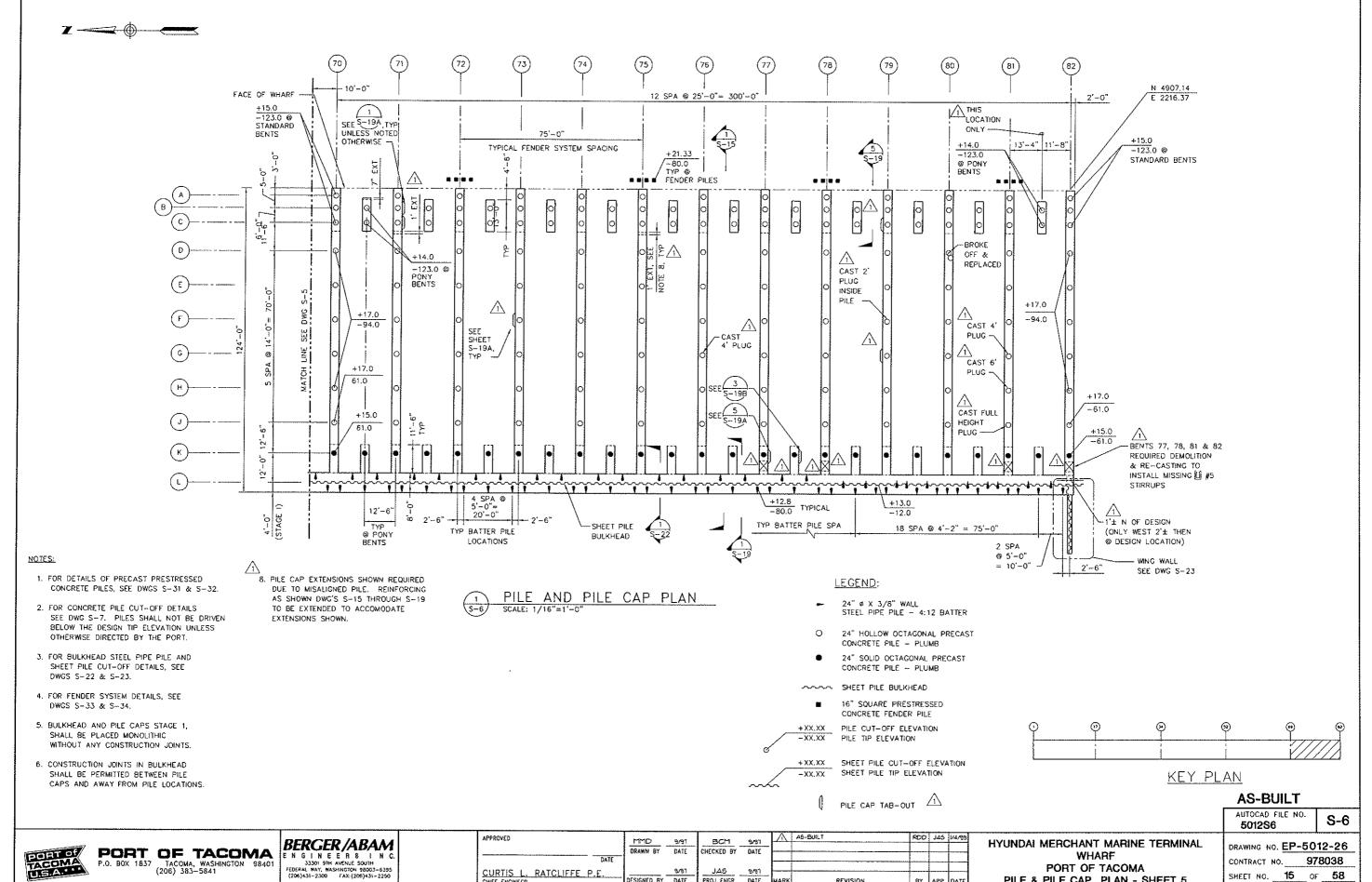
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PILE & PILE CAP PLAN - SHEET 4

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PILE & PILE CAP PLAN - SHEET 5

CURTIS L. RATCLIFFE P.E.

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| I JOB LOCATION DIBIT WATERWAY, TROOMS, WA. | Ratcliff |
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| DRIVING CONTRACTOR PARE DE CALL CONSTRUCTION SUPT. | |
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| | 11100 |
| Penetration: Weight of Ram 20,000 tb. | 00 15 7 |
| Ground Elev. Before Driving Strokes Per Minute Ground Elev. After Driving Steam Pressure at Boiler | |
| Ground Elev. After Driving Tip Elev. After Driving Butt Elev. After Driving Group To Steam Pressure at Boiler Driving Cap, Anvil, Helmet, Etc.: Weight 0596, Description | |
| Butt Elev. After Driving Group 7-20 Weight 089b. Description 66 CO | 5460n |
| (Make sketch on back) | |
| 20' Time: Start Driving 11:12 4 Finish Driving 11:55 Driving Time 43 | |
| 2" NORTH Driving Time Min. | |
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| DRIVING RESISTANCE LAST FOOT | |
| 1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12" | |
| Remarks*** 2"NORTH OF PROPER . If wood, state kind, seasoning and treatment. If con | Crete, state |
| NOT TELL RICHT TOOT COUNTY Note any falling off in rated speed and stroke during | |
| Jetting, cause and duration of rislans in delicas | ء ما |
| USE BACK OF SHEET condition of cushions, types and thickness of cushio twisting, bending, damage, driving shoe, wetting of p | |

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|--|---------------------------|-----------------------|-----------------|--|--|--------------------------|---|---------|--------------------------|-------------------------------------|--------------------------|---|-----------------|-------------------------|-----------------|
| P. O. BOX TACOMA, PILE DRIVING RECORD PAGE NO. L JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA. PILE LOCATION BENT 82 YOUR TO DATE OUT BRIVE COUNTY DRIVING CONTRACTOR AMERICAN PILE: Type 14 HOLOW PILE: Type 24 HOLOW PROBLEM IN Weight Ib. Stroke: Pased Meac. Weight of Rem Ib. Stroke: Pased Meac. Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta Stream Pressure at Boiler Driving Cep, Anvil, Helmet, Etc.: Weight of Rem Ib. Strokes Per Minuta St | | | | | | | | | | | | A. OF. Rateli | iffe DW | | |
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CLOCKTION & DESIGN

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| PORT OF TACOMA PILE DRIVING RECORD PILE NO. 87 PAGE NO. 1 OF JOH JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA. PILE LOCATION BENT 87 RAW DATUM MLLW SUPT. LEWARD KNUT DRIVING CONTRACTOR A MERICAN Pile: Type 74 HOLLOW Hammer: Make and Model ICS 20:5 S Length 11 4 Weight Ib. Stroke: Rated Mess Penetration: Ground Elev. After Driving Stroke: Parked Mess Weight of Ram Ib. Strokes Per Minute Strokes Per M | | | | | | | | | | | | | |) ffe | | |
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| PIL JOB JOB PILI DRI Pile: | P. O. Box 1837 TACOMA, WA. PILE DRIVING RECORD Z PILE NO. 82 B JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA. PILE LOCATION Blair Waterway, Tacoma, WA. DRIVING CONTRACTOR AND BLAIR BACLLIFFE Length Y Weight Ib. Penetration: WATER Ground Elev. After Driving 123 132 Y Butt Elev. After Driving Group 124 Y Butt Elev. After Driving Group 125 B Butt Ele | | | | | | | | | | | | | | |
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| Remy | DRIVING RESISTANCE LAST FOOT 1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12" Remerks: 5 STRAC MAIL 70' MeN If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Note any falling off in rated speed and stroke during driving. Setting, cause and duration of delays in driving, boulders, bark, condition of cushions, types and thickness of cushions, plumbness, twisting, bending, darnage, driving shoe, wetting of pile surface, etc. The first of the stroke during of pile surface, etc. The first of the stroke during of pile surface, etc. The first of the stroke during of pile surface, etc. | | | | | | | | | | | | | | |

P. O. Box PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 13 PILE NO. 85 PAGE NO. ____ OF __ JOB NO. 978038 NAME Hyundai Merchant Marine Terminal Blair Waterway, Tacoma, WA JOB ENGINEER JOB LOCATION_ DATUM_MLLW PILE LOCATION... SUPT. LEONAND DRIVING CONTRACTOR. Hammer: Make and Model_ Stroke: Rated Weight of Rem Penetration: WATER Strokes Per Minute Ground Elev: Before Driving Ground Elev. After Driving Steam Pressure at Boiler, Tip Elev. After Driving Driving Cap, Anvil, Helmet, Etc.: . · Butt Elev. After Driving Group, Weight_____Ib. Description XIXCXX = INSTURMENT Time: Start Driving 15132 Finish Driving 11:16 _. Driving Time 82B Bumped By 82A UNDER WATCH TOP matta NORTHI No. of No. 4 Blows Blows Blows Blows Blows Blows Ft. Bioms 90 80 120 100 3 110 **9** 6 DRIVING RESISTANCE LAST FOOT 1"4 2"8 3"2 4"2 5"3 6"6 7" If wood, state kind, seasoning and treatment. If concrete, state

INSTUREMENT RECORDED 748 Blows TOTAL

mix and age. If steel, state weight per foot," >

Note any falling off in rated speed and stroke during driving.

Jetting, cause and duration of delays in driving, boulders, bark, condition of cushions, types and thickness of cushions, plumbness twisting, bending, damage, driving shoe, wetting of pile surface, at

P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD_ JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA. PILE LOCATION BONT DRIVING CONTRACTOR AM CRUCKEY SUPT. Hammer: Make and Model 108 100/20 205 5 Stroke: Rated_____ Penetration: Strokes Per Minute_ Ground Elev. Before Driving_ Steam Pressure at Boiler Driving Cap, Anvil, Helmet, Etc.: 16 "CUSATON" Weight 1080 lb. Description 16 "CUSATON" Butt Elev. After Driving Group + 15.01 (Make sketch on back) _____ Driving Time. Time: Start Driving..... _ Finish Driving.... -----No. of No. of F٤ Blows Blows Ft. , Ft. Blows Blows Fŧ، Blows Ft. Blows Blows Ft. Blows Ft. 0 ٥ 2 2 3 5 .5 6 Б 8 8 8 В Я 9 DRIVING RESISTANCE LAST FOOT _8<u>"___9"___10"___11"___12"</u>_ If wood, state kind, seasoning and treatment. If concrete, state

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mix and age. If steel, state weight per foot,

Note any falling off in rated speed and stroke during driving.

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condition of cushions, types and thickness of cushions, plumbness, twisting, bending, damage, driving shoe, wetting of pile surface, etc.

| | PORT OF TACOMA | | | | | | | | | | | | . Bo | x 1 | .837 | 7 | | | |
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P. O. Box 1837

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P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 17 PILE NO. 80 E PAGE NO. OF _ JOB NO. 978038 NAME Hyundai Merchant Marine Terminal Blair Waterway, Tacoma, WA. JOB ENGINEER Curtis Ratcliffe JOB LOCATION DATUM MLLW PILE LOCATION-DRIVING CONTRACTOR Hammer: Make and Model ... Pile: Type 1 Stroke: Rated_____ Meas. Length. Weight of Ram_ Penetration: Ground Elev. Before Driving. Strokes Per Minute Ground Elev. After Driving. Steam Pressure at Boiler... Tip Elev. After Driving ... Driving Cap, Anvil, Helmet, Etc.: _ Butt Elev. After Driving Group Weight _____ Ib. Description_ (Make sketch on back) Time: Start Driving 08:30 Finish Driving 08: Driving Time ķλ No. of Ft. Biows Ft. Blows Blows FL Biows Ft. Blows Ft. Blows Ft FL Blows Blows Ty. 50 100 60 80 110 · 8 DRIVING RESISTANCE LAST FOOT _ 9''_ _10__ if wood, state kind, seasoning and treatment. If concrete, state BILEVE -18:33 mix and age, if steel, state weight per foot, PILE HALD AGAINST. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back, SPRUNG condition of cushions, types and thickness of cushions, plumbness, twisting, banding, damage, driving shoe, wetting of pile surface, atc.

PORT OF L.COMA TACOMA, WA. PILE DRIVING RECORD 18 PILE NO. 80-8 PAGE NO. B OF JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA JOB ENGINEER Curtis Ratcliffe DATUM MLLW DRIVING CONTRACTOR & MERICANI. COMSTAUCTION SUPT. _____ Hammer: Make and Model # CE 1800/21 205 Stroke: Rated # Meas. * 170,000 US. Weight of Ram 20,000 lb. CONTINIOUS Length. Penetration: Ground Elev. Before Driving Way En Strokes Par Minute Ground Elev. After Driving WH Steam Pressure at Boiler_ Driving Cap, Anvil, Helmet, Etc.; _ Tip Elev. After Driving Weight 1080 lb. Description 16" CUShilow · Butt Elev. After Driving Group... (Make sketch on back) No. of Ft. Ft Ft. Blows Blows Ft. Blows Blows Blows Blows Blows Blows 60 80 30 80 3 :3 5 5 5 Ø, 6 6 8 8 В DRIVING RESISTANCE LAST FOOT I'MORTA 411 WELT if wood, state kind, seasoning and treatment. If concrete, state PLUANK mix and age. If steel, state weight per foot. Now any falling off in rated speed and stroke during driving. Jetting, cause and duration of dalays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, twisting, banding, damage, driving shoe, wetting of pile surface, etc.

P. O. Box 1837

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| | e chan i | ¥ HA | MMBYL Fom I | | | 100. | -14:04 | _ ` ' | 9 <u>"</u> f wood, st | _10 <u>"</u> to kind, | 11 | 12 <u>"_</u> and treat | ment. If co | oncrete, | stete |
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P. O. Box 1837

TACOMA, WA.

Note any falling off in rated speed and stroke during driving.

Jetting, cause and duration of delays in driving, boulders, bark, condition of cushions, types and thickness of cushions, plumbness, twisting, bending, demage, driving shoe, wetting of pile surface, etc.

| | PIL | E DRIV | ING F | RECORI | بـــــــــــــــــــــــــــــــــــــ | 0_ | PILE | NO | 30.2 | <u> </u> | | | PAG | E NO | OF _ | |
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| | DRI | VING CON | | | | | | | | | | UPT. <u>) 6</u> | | • | _ | |
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| | Pens | Length stration: | 170 | | W | right | | lb. | , | | | | | | | |
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| • | ٦ | Ground Elev Fip Elev. Af | ter Drivi | ing | | 123 | | | Dr | | Anvil, H | elmet, Etc. | : | | | |
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P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 28 PILE NO. 80-10 PAGE NO. 6 OF_ 12-28-84 JOB NO. 978038 NAME! Hyundai Merchant Marine Terminal JOB ENGINEER Curtis Ratcliffe DATUM MILW Blair Waterway, Tacoma, WA JOB LOCATION... PILE LOCATION DON'T BE SUPT. LEONARU DRIVING CONTRACTOR A 14 ERICAV. Hammer: Make and Model 108 Noodst 201 Pile: Type: CONCARTE 24" & HOLLOW Stroke: Rated_____ Weight of Rem Penatration: Strokes Per Minute_ Ground Elev. Before Driving_ Steam Pressure at Boiler_ Ground Elev. After Driving.... Oriving Cop, Anvil, Helmet, Etc.: 1611. CUS 410 4 Tip Elev. After Driving -Butt Elev. After Driving Group. (Make sketch on back) No. of Blows FŁ Blows Fŧ. Blows Blows Blows Ft. Blows Blows Blows Ft. 90 100 60 30 40 5 6 8 9 DRIVING RESISTANCE LAST FOOT 8<u>" 9" 10" 11" 12"</u> If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, twisting, banding, darnage, driving shoe, wetting of pile surface, etc.

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| | 1 111 | MACK OF BH | KET | | | | | | | | | | | | | |

P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 33 PILE NO. 80.5 C PONY PAGE NO. ____ OF__ JOB NO. 978038 NAME Hyundai Merchant Marine Terminal Curtis Ratcliffe Blair Waterway, Tacoma, WA. JOB LOCATION____ JOB ENGINEER PILE LOCATION BETWEEN DATUM_MLLW DRIVING CONTRACTOR AND WILLIAM CONSTRUCTION SUPT. ___ Hammer: Make and Model CC Stroke: Rated. Length Weight of Ram 20,000 Penetration: Ground Elev. Before Driving LINER + 9 Strokes Par Minute. Ground Elev. After Driving WETTER, +10 Steam Pressure at Boiler. -123.01 Driving Cap, Anvil, Halmet, Etc.:

Weight 180 lb. Description 161 CES 11. Tip Elev. After Driving ----Butt Elev. After Driving Group +14-01 (Make sketch on back) Finish Driving 2:08 0-60 Min. BLOWS OUN Stopel No. of Ft. Blows Ft. Blows Ft Blows Blows Blows Ft. Ft. TO CONCO Fr. Blows Ft. Blows Blows 570004 To seem // o 430 12 o 90 LO 0 ヶ。 80 on 42 MAR ٨ 5 ٨ Et STURES 3 5 0 8 8 8 DRIVING RESISTANCE LAST FOOT 9"___10". _11__ .12" Remarks*** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. * Jetting, cause and diuration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness. twisting, bending, demage, driving shoe, wetting of pile surface, etc.

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USE MACK OF SHEET

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| | - | • | | | | , , | | · ; | | _, | | TAC | OM | A, M | ĮΑ. | • |
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| - | | and Defini | : | 1.6.5. | .0. | | | Dr. | iving Cap. | Anvil, F | leimet, Etc. Description, | : - 16 | 161154 | 1100 | |
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P. O. Box 1837

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| | • | | | RECORD | | , | | | | | | | | ie no. <u>/</u> | | |
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| , | 1 7 | To Elev Afr | er Drivi | nn | | | | | Dr | iving Cap, | Anvil, H | leimet, Etc. Description | · | £ 17.5 /s | <u> </u> | |
| ٠ | E | lutt Elev. A | f te r Dri | ving Group | <u> </u> | 18-01 | | | | Weight 2 | <u>080</u> їь. 1 | Description | 10" | CUSAI | <u> </u> | • |
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| | UOK | | M.Y | | | | | | | | | | | | | |

PORT OF TACOMA P. O. Box 1837 TACOMA, WA. _ PILE NO. 2.5 C PAGE NO. ____ OF_ PILE DRIVING RECORD_____ JOB NO. 978088 NAME: Hyundai Merchant Marine Terminal JOB ENGINEER Curtis Retcliffe Blair Waterway, Tacoma, WA. JOB LOCATION.... DATUM MLLW PILE LOCATION surr. Leonard Knutson DRIVING CONTRACTOR American Construction Hammer: Make and Model Delmag D80 Hollow/Solid Pile: Type ... Stroke: Rated_____ Length. Weight of Ram..... Penetration: Ground Elev. Before Driving + 6.0 Stroker Per Minute_ Ground Elev. After Driving 49.5 Steam Pressure at Boiler... Driving Cap, Anvil, Helmet, Etc.: __ Tip Elev. After Driving 103,5 __ Ib. Description_ Butt Elev. After Driving Group +18.5 Weight ... 16" Plywood Cushion (Make sketch on back) Time: Start Driving 9:56 Finish Driving 10:29 Driving Time No. of F٤. Blows Blows Blows Blows Ft. Blows Blows Ft. Ft. Blows Ft. Blows 80 100 110 70 50 (,0 4 29 (3) 29 33 5 0 2 4 0 29 \% 24 \bigcirc 10 5 16 19 6 6 (3) 15 6 7 30 14 17 10 DRIVING RESISTANCE LAST FOOT 1" 2" 3" 4" 5" 6" 7" 8" 9" 10" 11" 12" If wood, state kind, seasoning and treatment. If concrete, state Remerks ... (1) STOP 9:55 62' REMOVE BOTH CHOKERS mix and age. If steel, state weight per foot. @ BUCKING 10:03 Note any falling off in rated speed and stroke during driving. 3 STOP 10:06 60' / REMOVED HAMMER - NEALY WITHER Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, twisting, bending, damage, driving shoe, wetting of pile surface, etc. USE BACK OF SHEET VIDEO LOCATION CASTING 1025 x 2 w

7/22/98

01:00:00

1127 110

PORT OF TACOMA

| JOB JOB PILI PRI | Ground Elev. Before Driving 12.0 Ground Elev. After Driving 12.0 Tip Elev. After Driving 104.5 Butt Elev. After Driving Group 17.5 Finish Driving 17.4 Butt Elev. After Driving Group 17.5 Butt Elev. After Driving Group 17.5 Butt Elev. After Driving Group 17.5 Weight b. Description (Make sketch on back) Alia No. of Blows Ft. No. of Blows Ft. No. of Blows Ft. B | | | | | | | | | | | | | | |
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| Ft. | Butt Elev. After Driving Group Till Time: Start Driving Finish Drivin | | | | | | | | | | | | | | |
| 4. 5 6 7 8 8 0 | Penetration: Ground Elev. Balone Driving +2.0 Stocket Per Minute Steam Pressure at Boiler Driving Ground Elev. After Driving 104.5 Steam Pressure at Boiler Driving Ground Elev. After Driving G | | | | | | | | | | | | | | |
| | | 1′′ | . 2'' 3 | 3 <u>"</u> ' | 4 <u>′′</u> 5′. | | | | If wood, at | ate kind | . sasoning | and tres | unent. If a | oncrete | , state |
| ®' | STOP II: | 22 | io' / Rev | move 17 | fmmen. | - REAL | lan u/pi | LE | mix and ag Note any fi Jetting, cau condition o | e. If ste siling of see and of of cushic | hel, state well if in rated ap duration of a ons, types as damage, driv II. | ight per eed and delays in id thick ring show | foot. Istroke duri Indriving, bo Mass of cush | ing drivi suld ers , sions, pl | ng. berk, umbness, |

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P. O. Box

1837

PORT OF TACOMA

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P. O. Box 1837

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6/9/98 PI

PORT OF TACOMA

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P. O. Box 1837

6/9/98

PORT OF TACOMA

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P. O. Box

STOP 1:07:24

1837

P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 171 PILE NO. 70.5-C PAGE NO. 5 OF 7 JOS NO. 978038 NAME Hyundai Merchant Marine Terminal Blair Waterway, Tacoma, WA. Bent Row Curtis Ratcliffe JOB ENGINÉER_ JOB LOCATION. DATUM_MLLW PILE LOCATION_ SUPT. Leonard Knutson American Construction DRIVING CONTRACTOR Hammer: Make and Model Ice 205S Hollow/Komm Mess. 170,000 Ft. 16 Stroke: Rated 8 Length. Weight of Ram 20,000 16. CONTINUOUS Penetration: Ground Elev. Before Driving. WATER + 10 Ground Elev. After Driving_ Steam Pressure at Boiler. -1231 Tip Elev. After Driving Driving Cap, Anvil, Halmet, Etc.: +181 Butt Elev. After Driving Group___ Weight 7080th, Description, 16" Plywood Cushion (Make sketch on back) Time: Start Driving 154 Finish Driving 2:12 Driving Time. 345×645 40.57 PUSHED No. of -60 Blows Ft. Blows Blows Blows Ft. Blows Ft. Ft. Blows Blown Ft. Blows 17 lows 70 80 90 10 0 21 0 L3 a 120 8 (o (C) ٠, 5 2 2 10 lo 3 SPRED O PETERSE (o ZAPS 5 100 12 o 6 ESTART U w 1104 lı18 DRIVING RESISTANCE LAST FOOT _9" .8" _10__ _11"_ Remarks*** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, bank,

condition of cushions, types and thickness of cushions, plumbness, twisting, banding, carnage, driving shoe, wetting of pile surface, etc.

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TACOMA, WA. PAGE NO. 7 OF 7 PILE DRIVING RECORD 173 PILE NO. 70 C 1/25/98 JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB ENGINEER Curtis Ratcliffe Blair Waterway, Tacoma, WA. JOB LOCATION_ DATUM MLLW Bent Row PILE LOCATION_ supt. Leonard Knutson American Construction DRIVING CONTRACTOR. 24[#] Hammer: Make and Model Ice 205S Hollow/www. Pile: Type" 8 Mens . 170,000 F4. 16 Stroke: Flated___ Weight Length_ Weight of Ram 20,000 16. CONTINUOUS. Penetration: WATER Strokes Per Minute ... Ground Elev. Before Driving... Ground Elev. After Driving WATER Steam Pressure at Boiler_ Driving Cap, Anvil, Helmet, Etc.: . Tip Elev. After Driving -4-18 Weight 2080 lb. Description Butt Elev. After Driving Group, 16" Plywood Cushion (Make sketch on back) Time: Start Driving 3: 49 Finish Driving, 561 70 4 1 USHED No. of Ft. Biows Ft. Biows Ft. Blows Blows Blows Ft. Blows Blows Blows 90 100 #1 0 130 70 多o 12.0 (leo 14 0 0 12 Coltun · Remove ZARS **3:53** ESTART 3:58 R 40 10 8 4.00 DRIVING RESISTANCE LAST FOOT 8.... Remarks*** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, twisting, banding, damage, driving shoe, wetting of plie surface, etc., USE BACK OF BHEST

PORT OF TACOMA

P. O. Box

1837

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| i | | nerics*** | 1" | 2′′; | 3 <u>''</u> | 4"_5" 0 enti 5"N | <u>"</u> 6 | 7"7"_ | 8 <u>"</u> • | If wood, a mix and a | pe. If m | d, seasoning | right pe | aument, if | | |

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P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 301 PILE NO. 60.5B PAGE NO. 7 OF 12 JOB NO. 978088 NAME Hyundai Merchant Marine Terminal Curtis Ratcliffe Blair Waterway, Tacoma, WA. Bent 60.5 Row B JOB ENGINEER _ JOB LOCATION_ DATUM_MLLW Bent Leo.5 Row PILE LOCATION_ DRIVING CONTRACTOR American Construction surt. Leonard Knutson Hammer: Make and Model_Delmag D80 Hollow/EliteM Pile: Type". Stroke: Rated 10' Mess. .. 225,000 Ft Iles 1400 Weight_ Length. Weight of Ram 19,500 lb. CONTINUOUS Penetration: 34-45 WATER + Strokes Per Minute___ Ground Elev. Before Driving. Steam Pressure at Boiler. Ground Elev. After Driving. -1231 Driving Cap, Anvil, Helmet, Etc.: ___ Tip Elev. After Driving -+181 Weight 7580 lb. Description_ Butt Elev. After Driving Group... 16" Plywood Cushion (Make sketch on back) Time: Start Driving 12:45 Finish Driving 1:01 Driving Time PUSHED No. of No. of No. of No. o No. of No. of No. of No. of Blows Ft. Blows Blows Ft. Blow Ft. 2200 FŁ Blows Blows Ft. Blows Blows 40 كالكناد 10 **(3**0 *10* o 110 120 80 70 Loo 10 1 X, 2 0 12 3 ľO 4 PREO 12:49 5 2 12 TART 6 6 1:51 10 8 8 0 9 9 9 9 DRIVING RESISTANCE LAST FOOT 8" 9" __10′′_ __11''_ __12"_

X = Point AT Which CABLES

If wood, state kind, seasoning and treatment. If concrete, state

Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbon twisting, bending, damage, driving shoe, wetting of pile surface,

mix and age, if steel, state weight per foot.

LOCATION

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P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 302 PILE NO. 60 C PAGE NO. B OF 12 JOB NO. 978088 NAME: Hyundai Merchant Marine Terminal JOB LOCATION Blair Waterway, Tacoma, WA. DATE. Curtis Ratcliffe JOB ENGINEÉR . DATUM MLLW PILE LOCATION. supt. Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/Add/W Mess .. 225,000 Ft 165 Pile: Type Stroke: Rated___ Weight. Weight of Ram 19,500 16. CONTINUOUS Longth. Penetration: Strokes Per Minute_ Ground Elev. Before Driving. Steam Pressure at Boiler_ Ground Elev. After Driving. Driving Cap, Anvil, Helmet, Etc.: -123 Tip Elev. After Driving -Weight 700 lb. Description. 418 Butt Elev. After Driving Group. 16" Plywood Cushion (Make sketch on back) 158 Driving Time_ Time: Start Driving 1138 Finish Driving PUSHED No. of No. of No. t No. of No. of No. of No. of No. of FŁ Blow Ft. Blows Ft. Blows Ft. Blows Biogra 7- (00¹ FL Biows Blows Blows 40 $\iota \triangleright_0$ 130 عصر 120 80 70 8 10 1 > q 9 10 \supset 3 7 3 2 OPPED 0 1147 3 TART j :46 q 7 a 8 8 10 8 9 9 9 DRIVING RESISTANCE LAST FOOT 7"__8"__9"__10"___11"___12" If wood, state kind, sessoning and treatment. If concrete, state Remarks*** mix and age. If steel, state weight per foot.

X = Point AT Which CABLES

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Note any falling off in rated speed and stroke during driving.
*** Jetting cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbor twisting, banding, damage, driving shoe, wetting of pile surface.

F. O. Rox 1834 PORT OF TACOMA TACOMA, WA. PILE DRIVING RECORD 303 PILE NO. 608 PAGE NO. 9 OF 12 JOB NO. 978088 NAME: Hyundai Merchant Marine Terminal Curtis Ratcliffe Blair Waterway, Tacoma, WA. JOB ENGINEER JOB LOCATION_ DATUM_MLLW Bent Co Row PILE LOCATION.... surt, Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/Month Pile: Type: Stroke: Rated 10' Mess ... 225,000 Ft 165 Weight_ Weight of Ram 19,500 Ib. CONTINUOUS Lanoth. Penetration: Strokes Per Minute_ Ground Elev. Before Driving Steam Pressure at Boiler. Ground Elev. After Driving. Driving Cap, Anvil, Helmet, Etc.: Tip Elev. After Driving -Weight 7082 tb. Description_ Butt Elev. After Driving Group_ 16" Plywood Cushion (Make sketch on back) Time: Start Driving 2:48 3:03 Driving Time. Finish Driving... PUSHED No. of No. of No. of No. o No. of No. of No. of No. of Ft. Blow FŁ Biows Blows Blows Ft. Blows Blows Ft. Ft. Blows Blows 10 o 1LO 120 ß 90 70 80 Q 131.25 O 5 O W Q W)3 10 lø SPIED \mathbb{B} 10 10 ŀo B 5 250 4 0 10 TART 0 :53 10 (o 7 S 0 8 8 8 DRIVING RESISTANCE LAST FOOT __9''' __10<u>′′</u>___11<u>′′</u>___12<u>′′</u> 8"

X = Point AT Which CABLES

If wood, state kind, seasoning and treatment. If concrete, state

Note any falling off in rated speed and stroke during driving.

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mix and age. If steel, state weight per foot.

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PORT OF TACOMA

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| | PILE DR | IVING F | RECORD | | PAGE NO. 10 OF 12 | | | | | | | | | | | | | |
| | JOB NO. 9 | 78038 | VING RECORD 304 PILE NO. 60A 18088 NAME Hyundai Merchant Marine Terminal ON Blair Waterway, Tacoma, WA. HON Bent 60 Row A NTRACTOR American Construction | | | | | | | | | DATE 2/13/98 JOB ENGINEER Curtis Ratcliffe DATUM MLLW SUPT. Leonard Knutson | | | | | | |
| | Pile: Type* | 24 ¹¹ | Ho11 | OW/E | Ueud | | Hammer: Make and Model Delmag D80 Stroke: Rated 10 / Mess. 225,000 F4 /L | | | | | | | | | | | |
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P. O. Box 1837

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P. O. Box 1837

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| | | Off Elev. W | | Antib Groop | | | | | • | 16 | u Ply | wood Cu (Make ske | <u>shion</u> | | | |
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P. O. Box 1837

1837 P. O. Box PORT OF TACOMA TACOMA, WA. PAGE NO. 7 OF 7 PILE DRIVING RECORD 458 PILE NO. 40.58 JOB NO. 978088 NAME! Hyundai Merchant Marine Terminal 6-20-98 JOB ENGINEER Curtis Ratcliffe Blair Waterway, Tacoma, WA. Bent 40.5 Row B JOB LOCATION__ DATUM_MLLW PILE LOCATION. supt. Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/Goodwall Pile: Type" Mess .. 225,000 Ft.lbs Stroke: Rated 10 / Length. Weight Weight of Ram 19,500 lb. Cardinuous Penetration: 36 - US Strokes Per Minute_ Ground Elev. Before Driving. Steam Pressure at Boiler... Ground Elev. After Driving... Driving Cap, Anvil, Helmet, Etc.: . Tip Elev. After Driving ... 4171 . Ib. Description_ Butt Elev. After Driving Group. 16" Plywood Cushion (Make sketch on back) Time: Start Driving 405 Finish Driving Pushel 54 No. of No. of No. o No. of No. of No. of No. of No. of FŁ Blows Ft. Blows Ft. Blows Blow Ft. Blows Ft. Blows Blows Ft. Blows 40 Blows *L*3 0 /0₀ கூ 90 // o 120 60 70 32 10 1 * Q 20 a, 0 .2 2 26 l e 12 3 12 0 W PS 16 18 29 412 2 34 15 0 a 28 12 12 8 0 14 K) 9 DRIVING RESISTANCE LAST FOOT 8''_ __9''_ __10''_ Remarks*** If wood, state kind, seasoning and treatment. If concrete, state

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mix and age. If steel, state weight per foot.

Note any falling off in rated speed and stroke during driving.

Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness twisting, banding, damage, driving shoe, wetting of pile surface, ex-

P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PAGE NO. 2 OF. PILE DRIVING RECORD 681 PILE NO. 40C 6-24-98 JOB NO. 978088 NAME: Hyundai Merchant Marine Terminal JOB ENGINEER Curtis Ratcliffe Blair Waterway, Tacoma, WA. JOB LOCATION__ DATUM MLLW Bent 40 ROW PILE LOCATION supt. Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/6600000 Pile: Type* Mem. .. 225,000 Ft. 165 Stroke: Rated__ 10 / Length. Weight of Rem 19,500 1b. Continuous Penetration: 36-45 Strokes Per Minute, Ground Elev. Before Driving Water Steam Pressure at Boiler___ Ground Elev. After Driving. ~ 1231 Driving Cap, Anvil. Helmet, Etc.: . Tip Elev. After Driving Weight Ib. Description. Butt Elev. After Driving Group_ 16" Plywood Cushion (Make sketch on back) 810 Driving Time. Finish Driving. Pushed No. of Ft. Blown Blows Blows Ft. Blows Ft. Blows Ft. Ft. Blows Ft. Blows Ft. Blows Blows 70 23 30 100 120 13n පිර 90 Le o 10 24 ප ļ, 1 1 42B18 1805 9 19 25 2 /D 10 23 20 22 19 21 Stop なのなけ 20 741 14 5 23 12 13 Start 18 6 6 746 26 **6** 15 26 10 228 Stop 128.5 0 \mathcal{L} 9 3> JO. cleck line DRIVING RESISTANCE LAST FOOT __12"_ __11′′_ 9" 10" If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, twitting, banding, damage, driving shoe, wetting of pile surface, etc USE BACK OF SHEET

cables were removed.

P. O. Box 1837 PORT OF TACOMA TACOMA, WA. PAGE NO. 3 OF ___ PILE DRIVING RECORD 482 PILE NO. 408 6-24-98 JOB NO. 978038 NAME: Hyundai Merchant Marine Terminal Blair Waterway, Tacoma, WA. Bent 40 Row R JOB ENGINEER Curtis Rateliffe JOB LOCATION_ DATUM MLLW PILE LOCATION... surt. Leonard Knutson American Construction DRIVING CONTRACTOR. Hammer: Make and Model Delmag D80 Hollow/CANDON Pile: Type? Stroke: Rated___10 / Men ... 225,000 Ff. lbs Length_ Weight of Rem 19,500 lb. Continuous Penetration: Water + 3.5 36-45 Strokes Per Minute_ Ground Elev. Before Driving Water Steam Pressure at Boller.... Ground Elev. After Driving... -1231 Driving Cap, Anvil, Helmet, Etc.: . Tip Elev. After Driving _ lb. Description_ Butt Elev. After Driving Group_ 16" Plywood Cushion (Make sketch on back) Time: Start Driving 848 924 __ Finish Driving_ . Driving Time 49' Pushed No. of No. o No. of No. of No. of No. of No. of No. of FŁ Blow Ft. Blows Biows Blows Ft. Blows Ft. Blows Ft. Blows Ft. **Biows** Blows 16 120 150 90 *1*0 n 11 0 70 kο 20 (p 18 14 15 28 14 1 0 14 28 18 20 13 14 4 a 20 13 م)[18 3 3 a 18 20Stop 28 22 -10 27 14 849 5 5 5 **)** Stort 24 24854 2222 21 21 Shp 7 7 120 19 20 20 യ 10 R В В ₿ 919 0 20 ን 8 9 422 9 0 DRIVING RESISTANCE LAST FOOT 8" 9" 10" __11<u>''____12''</u> Remarks*** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, back,

X Q 5B' t = When cables were removed.

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P. O. Box 1837 PORT OF TACOMA TACOMA, WA. __ PILE NO. 30-5C PAGE NO. 2 OF. JOB NO. 978088 NAME Hyundai Merchant Marine Terminal DATE. Curtis Ratcliffe JOB ENGINEER _ Blair Waterway, Tacoma, WA. Bent 30.5 Row DATUM MLLW PILE LOCATION_ surt. Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/648/MA Mess. - 225,000 Ft. 165 Stroke: Rated___10 / Weight Weight of Rem 19,500 1b. Continuous Length. Penetration: 36 - 45 Strokes Per Minute_ Ground Elev. Before Driving. Steam Pressure at Boiler Ground Elay, After Driving, Driving Cap, Anvil, Heimet, Etc.: _ Tip Elev. After Driving -_ lb. Description, Butt Elev. After Driving Group 16" Plywood Cushion (Make sketch on back) Time: Start Driving 647 Finish Driving Driving Time No. o No. of Ft. Blow Blows Ft. Ft. Biows Blooms Blows Blows Ft. Blows Blows 39 Blows 120 110 100 90 80 Ļο 70 Ber 12 1 10 BPM ما 2 2 K 10 9 B 10 30 Q1 ฉา 10 10 25 10 10 21 8 9 ø DRIVING RESISTANCE LAST FOOT If wood, state kind, sessoning and treatment. If concrete, state

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mix and age. If steel, state weight per foot.

Note any falling off in rated speed and stroke during driving.
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PORT OF TACOMA TACOMA, WA. PAGE NO. 3 OF_ PILE DRIVING RECORD 772 PILE NO. 30.5 B JOB NO. 978038 NAME Hyundai Merchant Marine Terminal JOB ENGINEER Curtis Ratcliffe Blair Waterway, Tacoma, WA. Bent 305 Row B JOB LOCATION... DATUM_MLLW PILE LOCATION. supr. Leonard Knutson American Construction DRIVING CONTRACTOR___ Hammer: Make and Model_Delmag_D80 Hollow/swypau Mess . 225,000 Ft. lbs Stroke: Rated_ 10 / Length. Weight of Rem 19,500 lb. Cartinuous Penetration: 34-45 Strokes Per Minute_ Ground Elev. Before Driving. Steam Pressure at Boller Ground Elev. After Driving... -105 Driving Cap, Anvil, Helmet, Etc.: _ Tip Elev. After Driving --lb. Description_ Weight Butt Elev. After Driving Group_ Plywood Cushion (Make sketch on back) Finish Driving 807 Min. Driving Time Pushel No. o No. of Ft. Blows Blows FL Blow 0-60 Ft. Blows Ft. Blows Blows Ft. Blows Ft. Blows 38 Blows 90 120 100 70 60 80 5 10 1 8 ø 6 2 al 10 400 24 24 745 5 438h Start 20 Э (o 7 BPM 10 В スプ ピ 10 9 DRIVING RESISTANCE LAST FOOT __8<u>"__9"___10"___11"___12"</u> 3" Remarks** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of delays in driving, boulders, bank, condition of cushions, types and thickness of cushions, plumbness twisting, bending, damage, driving shoe, wetting of pile surface, at DRE BYCK D& BAKKL cables were removed.

P. O. Box 1837

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P. O. Box 1837

$\overline{P. 0}$. Box 1837 PORT OF TACOMA TACOMA, WA. PAGE NO. 5 OF 9 PILE NO. 30 B PILE DRIVING RECORD_774 NAME: Hyundai Merchant Marine Terminal JOB NO. 978088 JOB ENGINEER Curtis Ratcliffe Blair Waterway, Tacoma, WA. JOB LOCATION_ DATUM MLLW 30 ROW B Bent PILE LOCATION supt. Leonard Knutson American Construction DRIVING CONTRACTOR_ Hammer: Make and Model Delmag D80 Hollow/Work Pile: Type Stroke: Rated 10 / Mess. - 225, 000 Ff. !! Weight Length. Weight of Rem 19,500 lb. Continuous Penetration: Strokes Per Minute ... Ground Elev. Before Driving Steam Prassure at Boiler Wate Ground Elay, After Driving_ Driving Cap, Anvil, Heimet, Etc.: . Tip Elev. After Driving Ib. Description_ Butt Elev. After Driving Group. 16" Plywood Cushion (Make sketch on back) Finish Driving 1028 Driving Time Time: Start Driving 95 6 _ Min. No. o No. of No. of No. of No. of No. of No. of Ft. Blow 0-50 FŁ Blows Ft. Blows Ft. Blows Blows Ft. Blows Ft. Blows Ft. Blows スス Blows 27 100 110 90 80 70 50 4486 ೩೩ 1 .12 2 なななな B 10 18 5 3 3 53 16 Stop 10 10 1000 4 Stairt 40 **'**>-D P 1005 15 œ 18 30 20 51.0 623 8 Ω 1024 DRIVING RESISTANCE LAST FOOT 8" 9" 10" 11" 1" 2" 3" 4" 6".....7" If wood, state kind, seasoning and treatment. If concrete, state Remarks*** mix and age. If steel, state weight per foot.

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Note any falling off in rated speed and stroke during driving.

Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness twisting, bending, damage, driving shoe, wetting of pile surface, at

PORT OF TACOMA TACOMA, WA. PAGE NO. LP OF PILE DRIVING RECORD 77.5 JOB NO. 978038 NAME Hyundai Merchant Marine Terminal DATE. Curtis Ratcliffe Blair Waterway, Tacoma, WA JOB ENGINEER JOB LOCATION. DATUM MLLW Bent 30 ROW PILE LOCATION. surt. Leonard Knutson American Construction DRIVING CONTRACTOR... Hammer: Make and Model Delmag D80 Hollow/ ENDOW Pile: Type* Stroke: Rated 107 Mex. .. 225,000 Ft. 165 Weight Length. Weight of Rem 19,500 16. Continuous Penetration: 36-45 Strokes Per Minute ... Ground Elev. Before Driving Steam Pressure at Boiler_ Ground Elev. After Driving... -1041 Driving Cap, Anvil, Helmet, Etc.: Tip Elev. After Driving ... 4181 . lb. Description. Weight_ Butt Elev. After Driving Group... 16" Plywood Cushion (Make sketch on back) Time: Start Driving //41 Finish Driving /21 Driving Time Min. 44 No. No. of No. of No. of No. of No. of No. of 0-50 Blows Blows Ft. Blows ۴ŧ, Blows Ft. Blo Blows ۴ŧ, Blows ۴ŧ. Biows 39 Blows (OD iD o 90 40 50 フロ 8º 0 BPM u 18 Q 1 9 9 9 6 12 O 2 7 2 9 G 10 10 10 Stop 1.2 16 ÌО 147 10 Start ೩೦ 10 32 7.0 1149 26 27 10 M7 cί 38 23 13 1212 В 8 8 Ю q 1214 9 DRIVING RESISTANCE LAST FOOT ...8" __11''___12''_ ...9′′ __10___ Remarks*** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot, Note any falling off in rated speed and stroke during driving. Jetting, cause and duration of dalays in driving, boulders, bank, condition of cushions, types and thickness of cushions, plumbnes twisting, banding, damage, driving shoe, wetting of pile surface, a X@ 49' were removed. cables

P. O. Box

1837

PORT OF TACOMA

P.O. Box 1837 TACOMA, WA.

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PORT OF TACOMA PILE DRIVING RECORD 888 PILE NO. 20.5 B

P. O. Box 1837 TACOMA, WA.

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| | | | | | y. | = Whe | n ca | bles u | ع مرد د | Memou | id. | | | | | |

TACOMA, WA. PILE DRIVING RECORD 889 PILE NO. 20 C PAGE NO. 4 OF 7 JOB NO. 978088 NAME: Hyundai Merchant Marine Terminal Blair Waterway, Tacoma, WA. Curtis Ratcliffe JOB LOCATION_ JOB ENGINEER Bent 20 ROW C DATUM_MLLW PILE LOCATION_ surr. Leonard Knutsor American Construction DRIVING CONTRACTOR___ Hollow/600000 Hammer: Make and Model_Delmag_D80 Pile: Type 1 Stroke: Rated___10 / Mess. .. 225,000 Ft. lbs Length. lb. Weight of Rem 19,500 1b. Continuous Penetration: 36-45 Ground Elev. Before Driving Strokes Per Minute... water Ground Elev. After Driving. Steam Pressure et Boiler. -10U Tip Elev. After Driving _ Driving Cap, Anvil, Heimet, Etc.: +181 Butt Elev. After Driving Group_ th, Description, 16" Plywood Cushion Broken Pile. (Make sketch on back) Finish Driving 1007 Driving Time Min. 54 Broken at Pushe about No. of 0-40' ۴ŧ۰ Blows Blows Ft. Blows Ft. Blows Blows Ft. Blows Ft. Biows Ft. Blows 34 عصط 15 37 51 30 (¢0 70 90 20 100 110 0 G 42 30 44 862 2 m 10 20 Stop 20 937 40 Start 13 43887 22 BP3 23 32 43 17 / B 30 49 8 9 DRIVING RESISTANCE LAST FOOT Remarks** If wood, state kind, seasoning and treatment. If concrete, state mix and age. If steel, state weight per foot. Note any falling off in rated speed and stroke during driving. *** Jetting, cause and duration of delays in driving, boulders, back, condition of cushions, types and thickness of cushions, plumbness, 4-15-98 Marks twisting, banding, damage, driving shoe, wetting of pile surface, etc. x Q,591 cables were removed.

PORT OF TACOMA

P. O. Box

1837

| | 1 |) () D | m , | $\Omega \overline{r}$ | ПΛ | $\alpha\alpha$ | A / T / A | | | | | P. 0 | . Bo | x 1 | .837 | 7 |
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| · Ł | UNKE | CK OF SKKK | Ψ. | | | | | | - E | · · · · · · · · · · · · · · · · · · · | | - (- A-2 - (7) (A); | 'A MILE, | -werning Di | PIPE PUR | e, etc. |

PORT OF TACOMA

| | POI | . F. T. | Or | TA | ÇO) | AT 7-3 | | | | | TAC | OM | A, W | /A. | |
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| • | JOB NO JOB LOCAT PILE LOCA DRIVING C | 78088 110N | NAME Blair V Bent | Hyun Water 20 | idai Me way, Ta Row B | rchar | nt Mari | ine Te | rmina | • | DATE IOB ENGIN DATUM_E SUPT. LEC | LLW | Curtis . | | iffe |
| | Pile: Type Length. Penetration: Ground E Ground E Tip Elev. Butt Elev. Time: Start I | 24 ¹¹ Elev. Before liev. After Driv. After Driving | Holl /22' Driving ing iving Groun 33/ | OW/60 | export . | ÷ 2 | | Ď: | Stroke: Weight or Strokes P Steam Pn iving Cap, Weight 16 | Rated FRam er Minu essure at Anvil, F | Model_De 10' 19,500 te3(Boller_ delmet, Etc. Description rwood Cu [Make ake | | - 225 c | 100 F, | 1.lbc |
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P. O. Box 1837

condition of cushions, types and thickness of cushions, plumbness, twisting, banding, damage, driving shoe, wetting of pile surface, etc.

PORT OF TACOMA

P.O. Box 1837 TACOMA, WA.

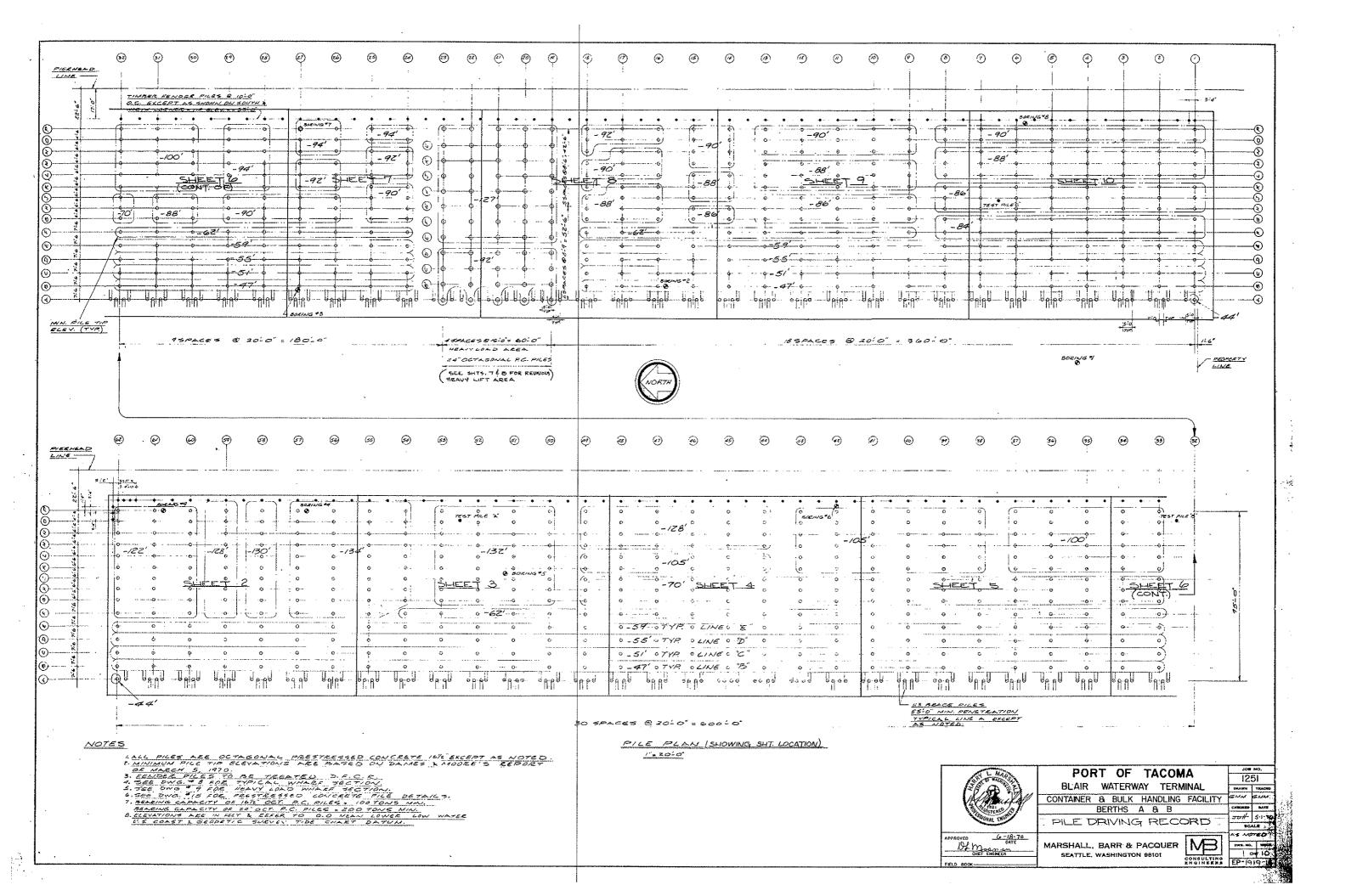
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| | | B LOCATI | DN | Blair V | Vater | way, T | acoma | . WA. | | | | JOB ENGIN | LEER | Curtis | Ratcl | iffe |
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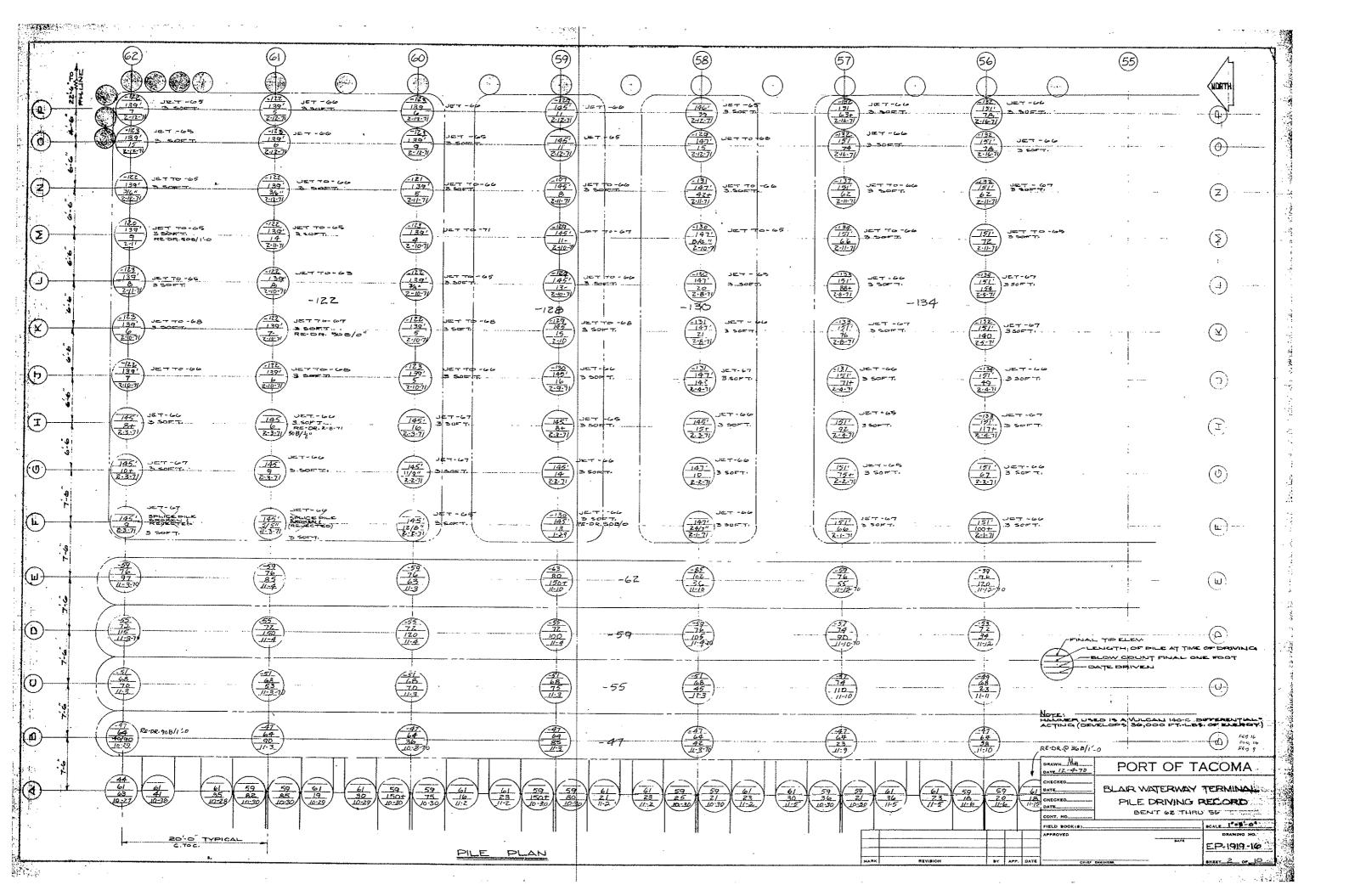
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| | G | retion: (round Elev. round Elev. | . After I | Driving | | | | | Strokes Per Minute Steam Pressure at Boiler Driving Cap, Anvil, Halmet, Etc.: 10 4 10 10 10 10 10 10 10 10 10 10 10 10 10 | | | | | | | | |
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| gree ^{te} | 7 | 1/7 | | 14 | 7 | 1.17 | 7 | $\frac{1}{a}$ | 7 | 24 | 7 | | 7 | | 7 | | |
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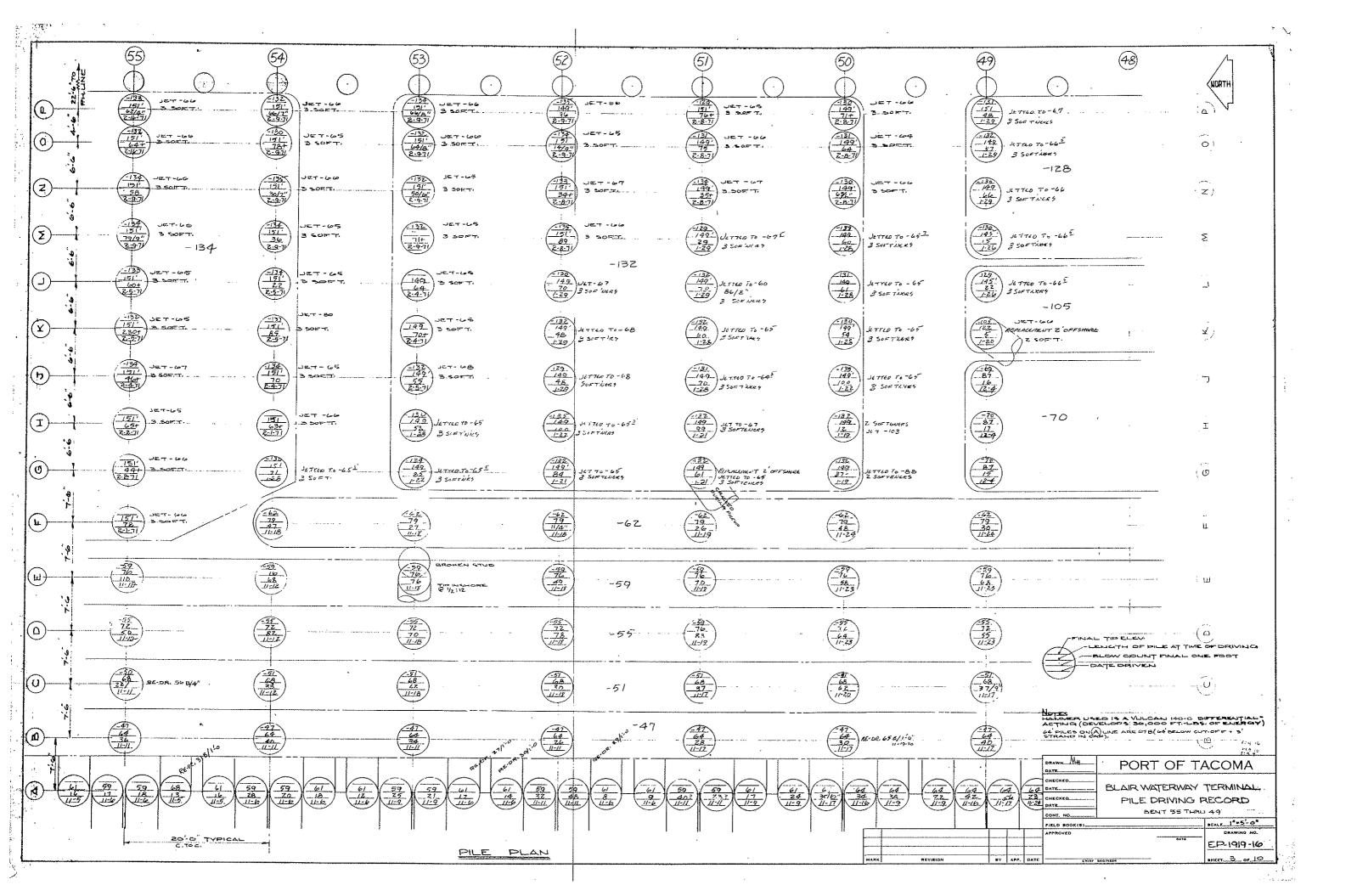
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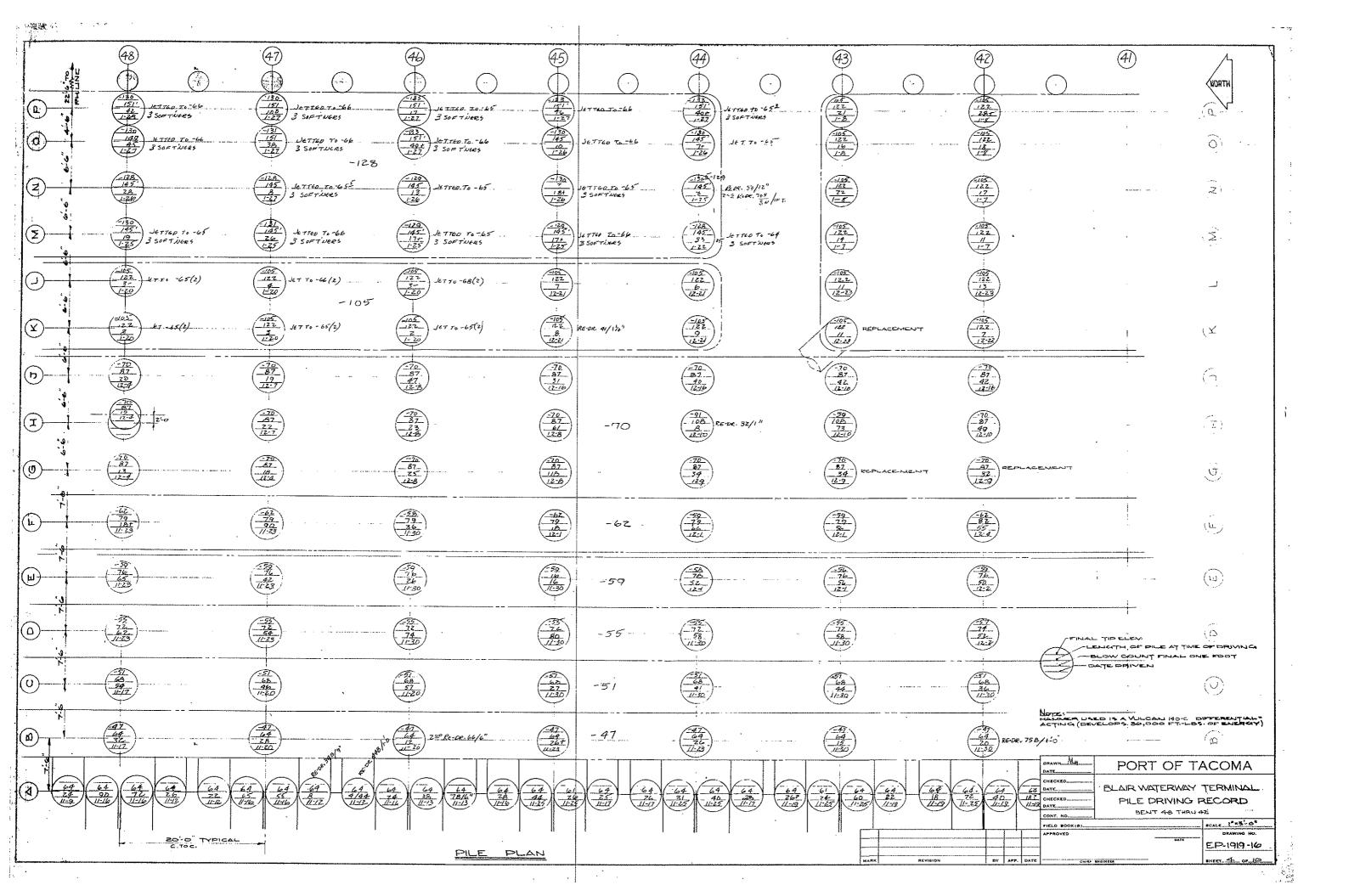


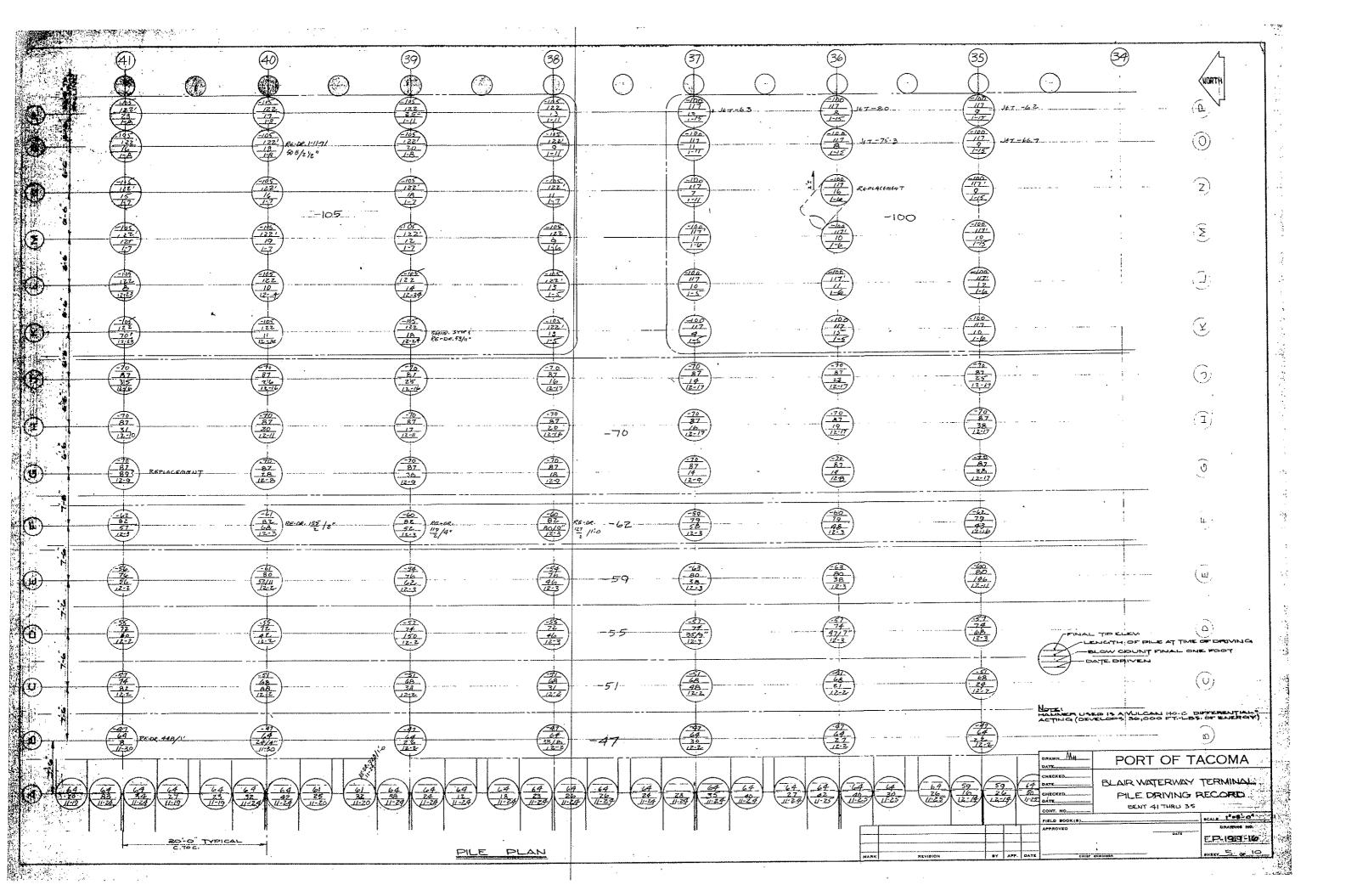
APPENDIX D BLAIR WATERWAY TERMINAL – PILE DRIVING RECORD

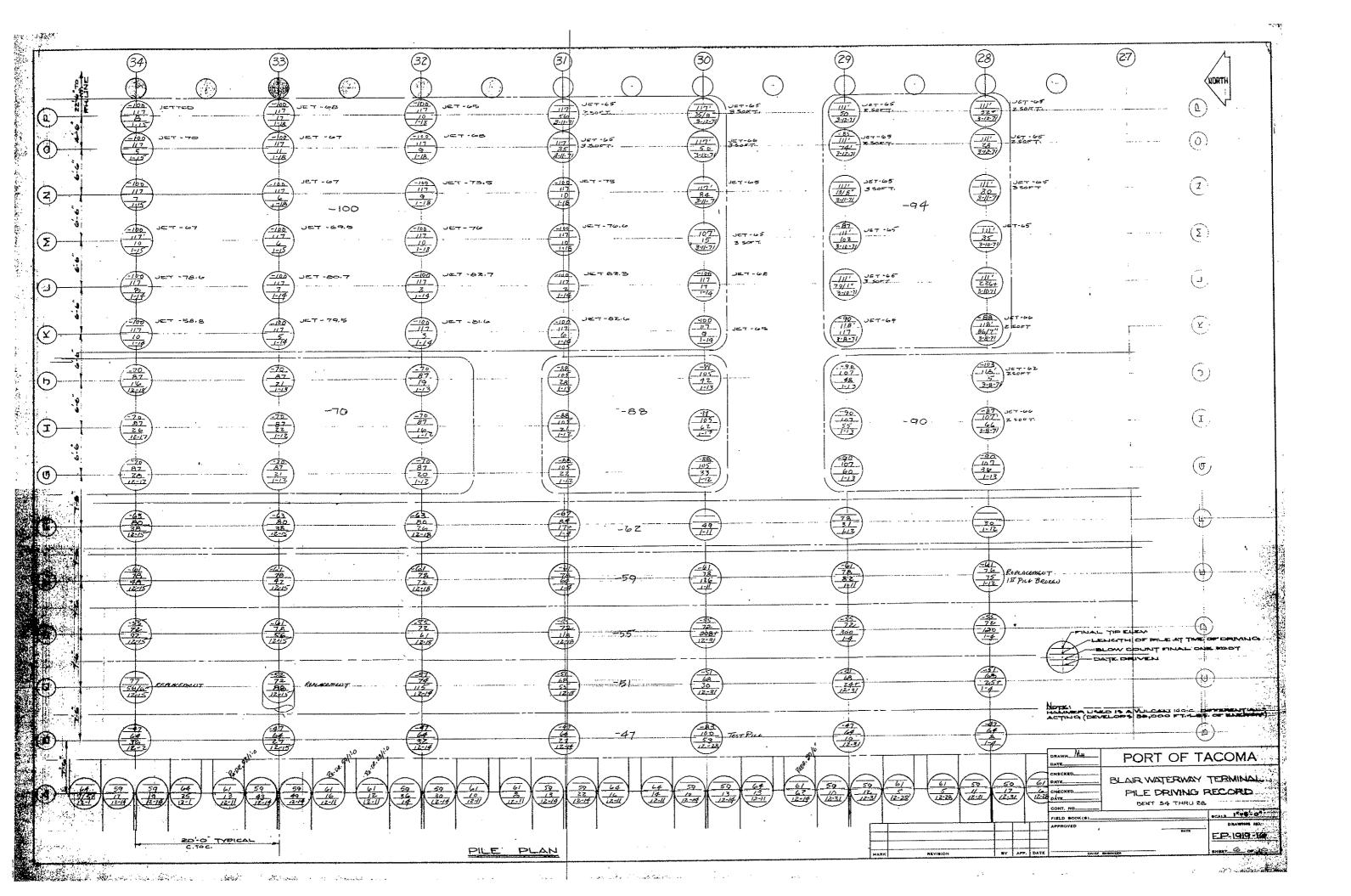


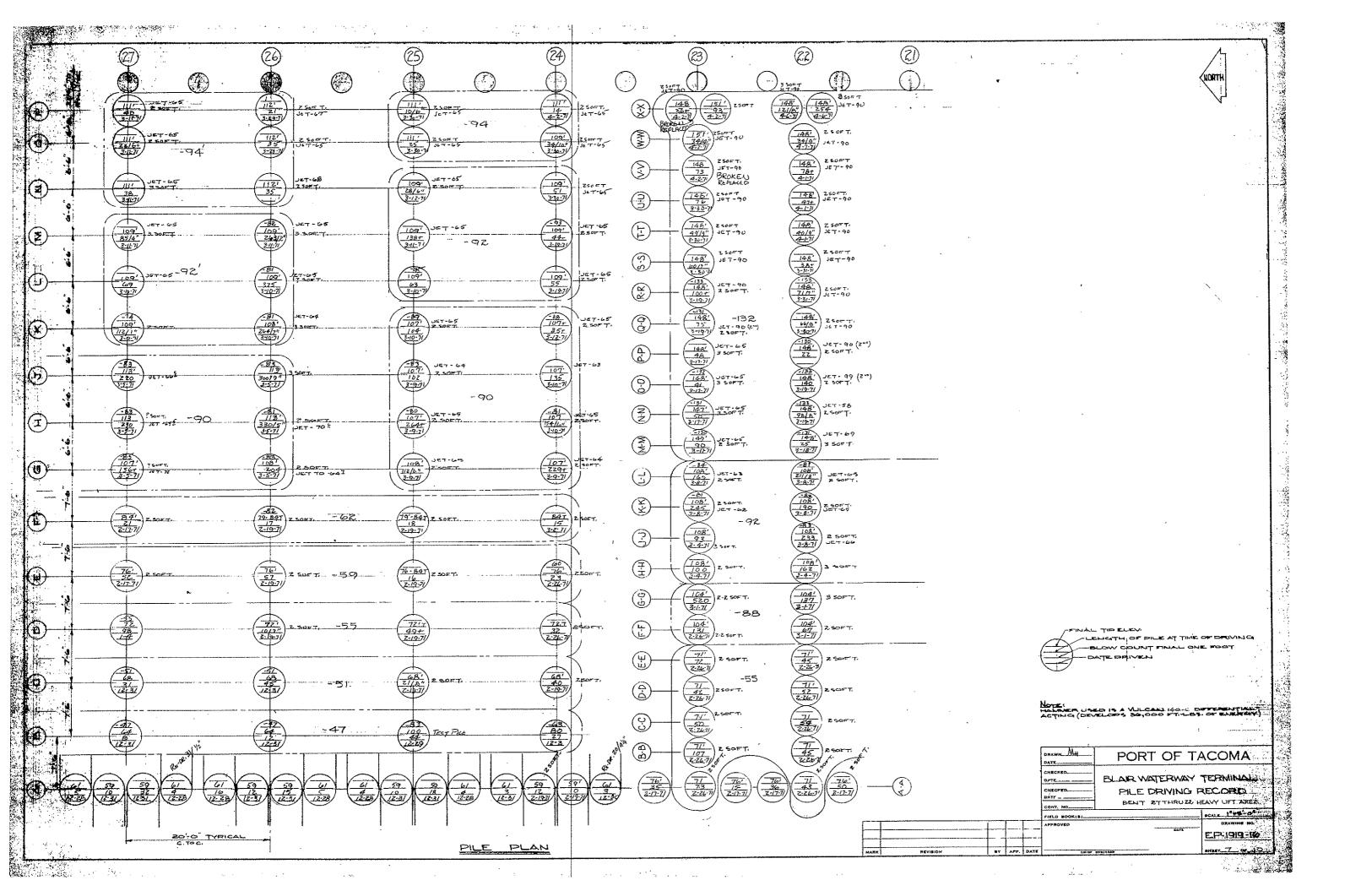


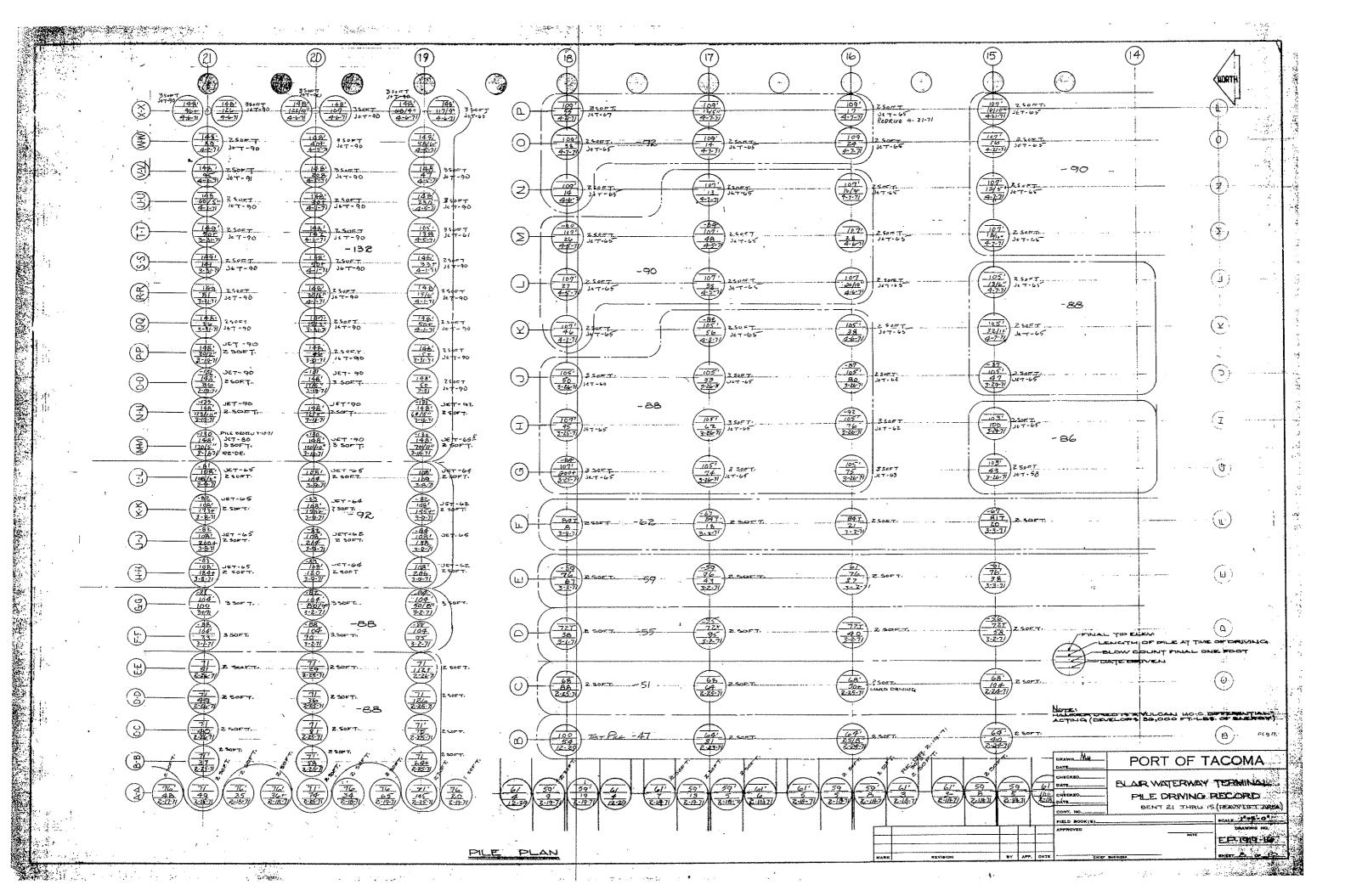


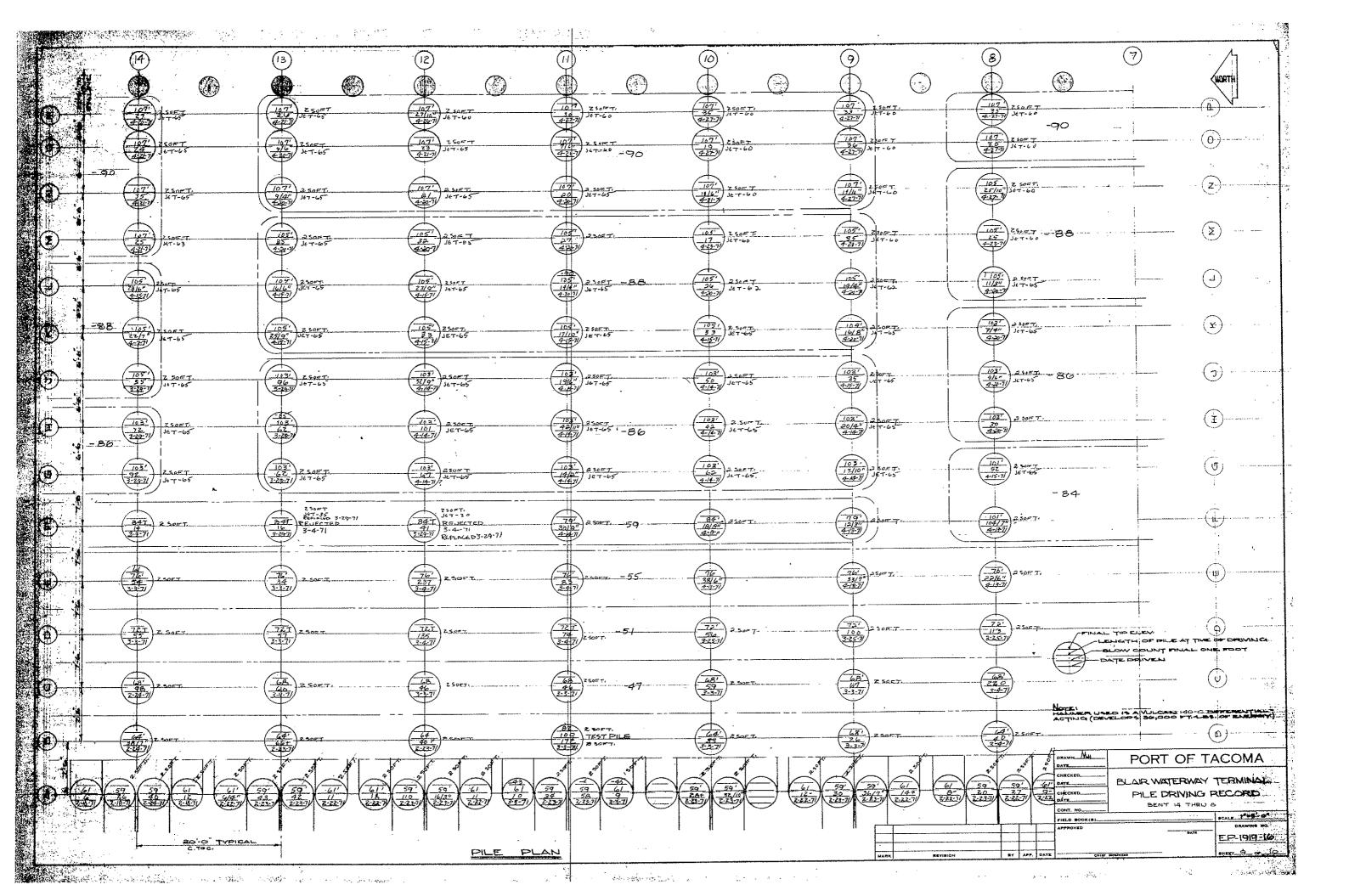


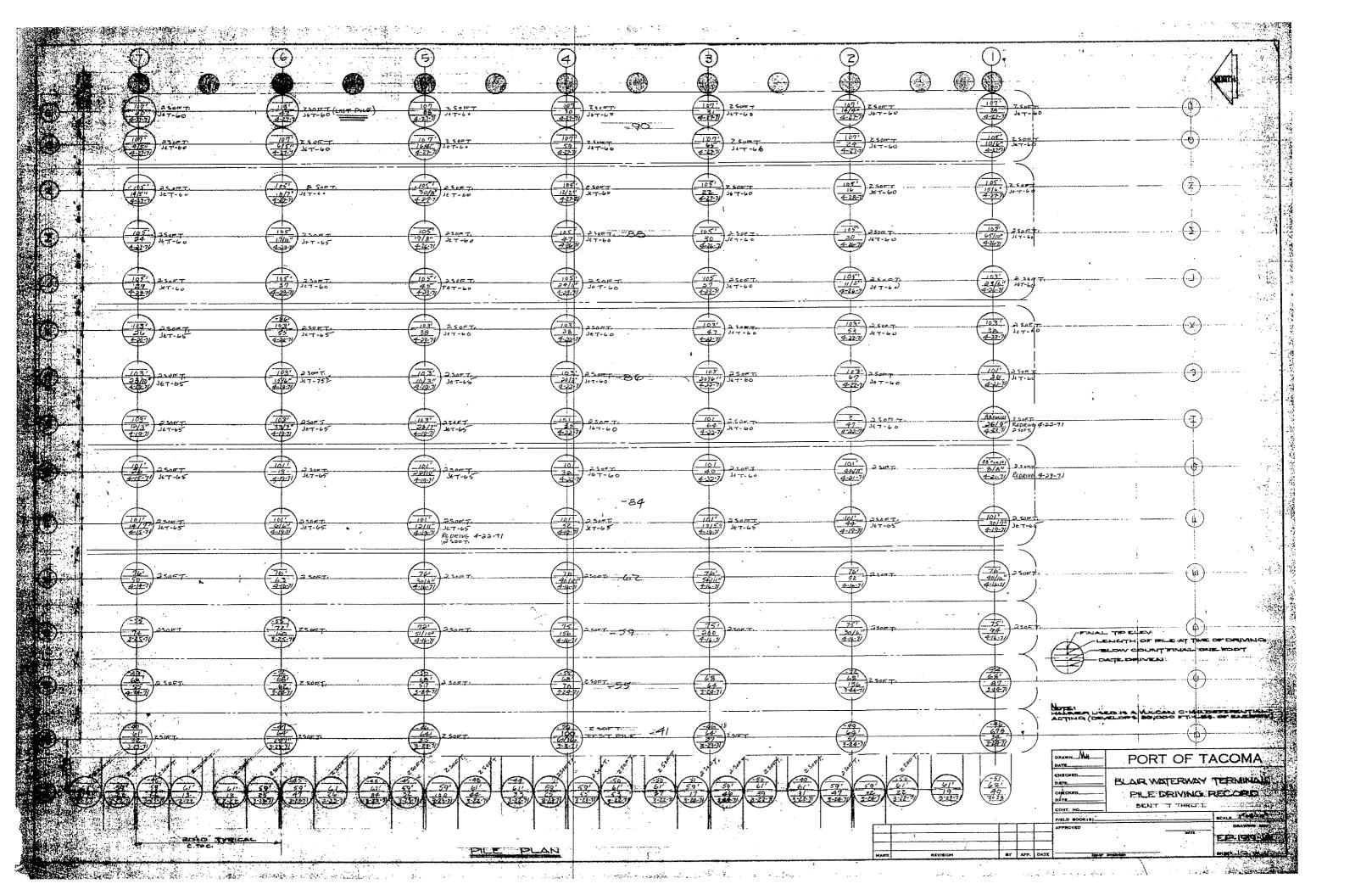














APPENDIX E REPORT LIMITATIONS AND GUIDELINES FOR USE

APPENDIX E REPORT LIMITATIONS AND GUIDELINES FOR USE¹

This appendix provides information to help you manage your risks with respect to the use of this report.

GEOTECHNICAL SERVICES ARE PERFORMED FOR SPECIFIC PURPOSES, PERSONS AND PROJECTS

This report has been prepared for use by BergerABAM and the Port of Tacoma. This report is not intended for use by others, and the information contained herein is not applicable to other sites.

GeoEngineers structures our services to meet the specific needs of our clients. For example, a geotechnical or geologic study conducted for a civil engineer or architect may not fulfill the needs of a construction contractor or even another civil engineer or architect that are involved in the same project. Because each geotechnical or geologic study is unique, each geotechnical engineering or geologic report is unique, prepared solely for the specific client and project site. No one except BergerABAM, Port of Tacoma and other members of the design team should rely on this report without first conferring with GeoEngineers. This report should not be applied for any purpose or project except the one originally contemplated.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT IS BASED ON A UNIQUE SET OF PROJECT-SPECIFIC FACTORS

This report has been prepared for the WUT Wharf Extension project in Tacoma, Washington. GeoEngineers considered a number of unique, project-specific factors when establishing the scope of services for this project and report. Unless GeoEngineers specifically indicates otherwise, do not rely on this report if it was:

- not prepared for you,
- not prepared for your project,
- not prepared for the specific site explored, or
- completed before important project changes were made.

For example, changes that can affect the applicability of this report include those that affect:

- the function of the proposed structure,
- elevation, configuration, location, orientation or weight of the proposed structure,
- composition of the design team, or
- project ownership.

If important changes are made after the date of this report, GeoEngineers should be given the opportunity to review our interpretations and recommendations and provide written modifications or confirmation, as appropriate.

² Developed based on material provided by ASFE, Professional Firms Practicing in the Geosciences; www.asfe.org.

SUBSURFACE CONDITIONS CAN CHANGE

This geotechnical or geologic report is based on conditions that existed at the time the study was performed. The findings and conclusions of this report may be affected by the passage of time, by manmade events such as construction on or adjacent to the site, or by natural events such as floods, earthquakes, slope instability or groundwater fluctuations. Always contact GeoEngineers before applying a report to determine if it remains applicable.

MOST GEOTECHNICAL AND GEOLOGIC FINDINGS ARE PROFESSIONAL OPINIONS

Our interpretations of subsurface conditions are based on field observations from widely spaced sampling locations at the site. Site exploration identifies subsurface conditions only at those points where subsurface tests are conducted or samples are taken. GeoEngineers reviewed field and laboratory data and then applied our professional judgment to render an opinion about subsurface conditions throughout the site. Actual subsurface conditions may differ, sometimes significantly, from those indicated in this report. Our report, conclusions and interpretations should not be construed as a warranty of the subsurface conditions.

GEOTECHNICAL ENGINEERING REPORT RECOMMENDATIONS ARE NOT FINAL

Do not over-rely on the preliminary construction recommendations included in this report. These recommendations are not final, because they were developed principally from GeoEngineers' professional judgment and opinion. GeoEngineers' recommendations can be finalized only by observing actual subsurface conditions revealed during construction. GeoEngineers cannot assume responsibility or liability for this report's recommendations if we do not perform construction observation.

Sufficient monitoring, testing and consultation by GeoEngineers should be provided during construction to confirm that the conditions encountered are consistent with those indicated by the explorations, to provide recommendations for design changes should the conditions revealed during the work differ from those anticipated, and to evaluate whether or not earthwork activities are completed in accordance with our recommendations. Retaining GeoEngineers for construction observation for this project is the most effective method of managing the risks associated with unanticipated conditions.

A GEOTECHNICAL ENGINEERING OR GEOLOGIC REPORT COULD BE SUBJECT TO MISINTERPRETATION

Misinterpretation of this report by other design team members can result in costly problems. You can lower that risk by having GeoEngineers confer with appropriate members of the design team after submitting the report. Also retain GeoEngineers to review pertinent elements of the design team's plans and specifications. Contractors can also misinterpret a geotechnical engineering or geologic report. Reduce that risk by having GeoEngineers participate in pre-bid and preconstruction conferences, and by providing construction observation.

DO NOT REDRAW THE EXPLORATION LOGS

Geotechnical engineers and geologists prepare final boring and testing logs based upon their interpretation of field logs and laboratory data. To prevent errors or omissions, the logs included in a geotechnical engineering or geologic report should never be redrawn for inclusion in architectural or other design drawings. Only photographic or electronic reproduction is acceptable, but recognize that separating logs from the report can elevate risk.

GIVE CONTRACTORS A COMPLETE REPORT AND GUIDANCE

Some owners and design professionals believe they can make contractors liable for unanticipated subsurface conditions by limiting what they provide for bid preparation. To help prevent costly problems, give contractors the complete geotechnical engineering or geologic report, but preface it with a clearly written letter of transmittal. In that letter, advise contractors that the report was not prepared for purposes of bid development and that the report's accuracy is limited; encourage them to confer with GeoEngineers and/or to conduct additional study to obtain the specific types of information they need or prefer. A prebid conference can also be valuable. Be sure contractors have sufficient time to perform additional study. Only then may an owner be in a position to give contractors the best information available, while requiring them to at least share the financial responsibilities stemming from unanticipated conditions. Further, a contingency for unanticipated conditions should be included in your project budget and schedule.

CONTRACTORS ARE RESPONSIBLE FOR SITE SAFETY ON THEIR OWN CONSTRUCTION PROJECTS

Our geotechnical recommendations are not intended to direct the contractor's procedures, methods, schedule or management of the work site. The contractor is solely responsible for job site safety and for managing construction operations to minimize risks to on-site personnel and to adjacent properties.

READ THESE PROVISIONS CLOSELY

Some clients, design professionals and contractors may not recognize that the geoscience practices (geotechnical engineering or geology) are far less exact than other engineering and natural science disciplines. This lack of understanding can create unrealistic expectations that could lead to disappointments, claims and disputes. GeoEngineers includes these explanatory "limitations" provisions in our reports to help reduce such risks. Please confer with GeoEngineers if you are unclear how these "Report Limitations and Guidelines for Use" apply to your project or site.

GEOTECHNICAL, GEOLOGIC AND ENVIRONMENTAL REPORTS SHOULD NOT BE INTERCHANGED

The equipment, techniques and personnel used to perform an environmental study differ significantly from those used to perform a geotechnical or geologic study and vice versa. For that reason, a geotechnical engineering or geologic report does not usually relate any environmental findings, conclusions or recommendations; e.g., about the likelihood of encountering underground storage tanks or regulated contaminants. Similarly, environmental reports are not used to address geotechnical or geologic concerns regarding a specific project.

BIOLOGICAL POLLUTANTS

GeoEngineers' Scope of Work specifically excludes the investigation, detection, prevention, or assessment of the presence of Biological Pollutants in or around any structure. Accordingly, this report includes no interpretations, recommendations, findings, or conclusions for the purpose of detecting, preventing, assessing, or abating Biological Pollutants. The term "Biological Pollutants" includes, but is not limited to, molds, fungi, spores, bacteria, and viruses, and/or any of their byproducts.