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MEMORANDUM

To:	Linda Berry-Maraist, Pope Resources/Olympic Property Group	**Date:**	October 7, 2016
From:	Kathy Ketteridge, Ph.D., P.E., and John Laplante, P.E., Anchor QEA, LLC		
Cc:	Clay Patmont, Anchor QEA, LLC		
Re:	Port Gamble Bay Cleanup Project Coastal Engineering Evaluation of Shoreline Erosion		

The Port Gamble Bay Cleanup Project (Project) includes structure removal, excavation, and armored capping of shorelines at the former Mill Site (Site) located in Port Gamble, Washington. The 2 season construction project is currently underway, with the first season of in-water work being completed in January 2016. In March 2016, several significant wind events caused movement of relatively small areas of the shoreline armor rock. In addition to the observed armor movement, areas of the unarmored shorelines where structures were removed during Season 1 have eroded.

This purpose of this memorandum is to summarize observations and evaluations of the movement of armor rock along the shoreline and erosion of unarmored shoreline areas at the Site that were the result of a series of significant storm events that occurred in March 2016. This memorandum also presents design solutions to address erosion issues where necessary. As part of this discussion, wind statistics at the site were revised using updated wind data, which includes wind information through July 2016. This memorandum is divided into two sections: 1) Review of Storm Wind Conditions; and 2) Observed Armor Movement, Shoreline Erosion, and Mitigation Recommendations.

REVIEW OF STORM WIND CONDITIONS

In March 2016, two high wind storm events occurred throughout the Puget Sound area a few days apart, one on March 10 and one on March 13. Sustained wind speeds during these storm events are available from a buoy owned and maintained by the University of Washington (NOAA Station #46125) located in Hood Canal, 4 miles northwest of the Site. The height of the anemometer for that buoy is 2.1 meters above sea level. In order to

compare the wind speeds measured at the buoy with wind statistics developed in the Port Gamble Bay Cleanup Project Engineering Design Report (Appendix D; Anchor QEA 2015), the buoy wind data were transposed to the equivalent wind speeds at 10 meters above sea level[1]. Wind and tide data for both storms are summarized in Table 1.

Table 1
Summary of Winds during March Storm Events

Date	High Tide Elevations at Port Townsend[1] (MLLW)	Sustained Winds[2]			Maximum Winds[2]		
		Wind Speed (mph)	Wind Duration (hours)	Average Wind Direction	Wind Speed (mph)	Wind Direction	Time and Tide Elevation During Maximum Wind[1] (MLLW)
March 10, 2016	11.1 feet 9.7 feet	≥ 20	17	~140 degrees	46	~130	3:30 pm 7 feet
March 13 to 14, 2016	10.2 feet 9.1 feet	≥ 20	9	~140 degrees	48	~130	11:00 pm 6 feet

Notes:
MLLW = mean lower low water
mph = miles per hour
1. Measured tide data from Port Townsend Station #9444900. Multiple high tides occurred over the duration of the storm event.
2. Wind speeds from NOAA Station #46125, transposed to 10 meters above sea level

To support the Engineering Design Report for the Project (Anchor QEA 2015), a coastal engineering evaluation was completed to evaluate extreme wind speeds and associated wave heights at the Site for use in cap armor design. Long-term wind data used for this evaluation was taken from NOAA station WPOW1 in West Point, Washington, and included hourly wind speeds (2 minute averages) for the years from 1984 to 2009. The West Point station was used for Port Gamble because it is the closest gage location that has a long-term hourly sustained wind speed record (32 years at 10 meters above sea level).

Based on the wind statistics shown in Table 2 (from Anchor QEA 2015), the March 10 and March 13 storms were 50-year and 100-year return period events, respectively. In addition to being significant events, each storm event had an unusually long duration. The average

[1] 10 meters is the standard accepted height above the water surface where wind speeds are measured (or estimated) for use in wind-wave prediction. Data from the buoy (measured at 2.1 meters above sea level) was transposed to the equivalent wind speed at 10 meters above mean sea level using a logarithmic wind profile.

duration of high wind events (wind speeds greater than approximately 20 miles per hour) from southerly directions is about 4 hours (Finlayson 2006). The March 10 and 13 storms had durations of 17 hours and 9 hours, respectively. Such a prolonged high wind event would have likely caused a local wind-setup along the Port Gamble shoreline, increasing the water level above the predicted tide height for some portion of the storm events.

Table 2
Return Period Wind Speeds for South-East Storm Directions[1]

Direction (degrees)	2-year (mph)	10-year (mph)	20-year (mph)	50-year (mph)	100-year (mph)
121-150	33	41	44	47	49

Notes:
mph = miles per hour
1. Return period wind speeds are from Table D1-2 from Anchor QEA 2015.

OBSERVED ARMOR MOVEMENT, SHORELINE EROSION, AND MITIGATION RECOMMENDATIONS

On separate occasions in June, July, and August 2016, Anchor QEA, LLC, staff conducted site visits at Port Gamble to observe shoreline conditions and discuss armor movement and shoreline erosion with Pope Resources and Washington Department of Ecology (Ecology) staff. Four areas of interest were identified along the Port Gamble shoreline, as shown in Figure 1. Areas 1 through 3 are areas where structures were removed during Season 1 demolition, but no armored cap was required based on remedial design for the project. Shoreline erosion in these areas due to rare combination of prolonged storm events has resulted in damage to existing asphalt and/or erosion of bank material. Areas 4 and 5 were capped with Type 2 armor rock material (d_{50} of 9 inches) during Season 1 in accordance with the Ecology-approved design. Observations in this area noted movement of Type 2 armor rock in the upper inner tidal area. The cap material in this area was sized to balance requirements for protection of underlying isolation layer and habitat concerns. Therefore, material was sized to allow for some localized movement under the design storm event. For the majority of the area capped with Type 2 material, this movement was within acceptable and anticipated limits and no further action is required in most of those areas.

Area 1

Area 1 is located along the north-eastern corner of the Site (see Figure 1).

Observations

The shoreline erosion in this area occurred after creosote-treated piling were removed as part of Site remediation. The shoreline area above mean higher high water has eroded in this area, undermining asphalt paving at the top of the slope, as shown in Photograph 1. Figure 2e shows a pre- and post-storm survey transect that illustrates the erosion that has occurred at this location. In general, the slope of the beach in the upper intertidal area is adjusting to match the milder slope present in the lower intertidal area.

Photograph 1

Shoreline Erosion in Area 1

Recommendations

Design recommendations to address shoreline erosion in this area are shown in Figure 2e. Damaged asphalt at the top of the slope will be removed and the top of the bank at the landward landward extent of existing asphalt will be armored with Type 2 cap material with

Type 3 cap material placed underneath as a filter layer. Damaged asphalt shown in Photograph 1 has already been removed.

Area 2

Area 2 is located along the eastern shoreline that faces the inlet into Port Gamble Bay (see Figure 1), which is armored with large rip rap with asphalt paving along the top of the bank.

Observations

Similar to Area 1, asphalt at the top of the slope was damaged due to wave runup and overtopping, as shown in Photograph 2, which occurred after the structure in this area (the former Eastern Wharf) was removed. Figure 2d shows a pre- and post-storm survey transect that shows no movement of the armor rock on the slope occurred as a result of the storm events.

Photograph 2

Shoreline Erosion in Area 2

Recommendations (Work Completed)

The following recommendations to address shoreline erosion (shown in Figure 2d) were carried out prior to publication of this memorandum:

- Damaged asphalt at the top of the armored slope was removed
- Armor rock at the top of the slope was left in place
- The area where asphalt was removed was armored from the top of the remaining armor rock on the slope to the top of the bank
- Placed armor consisted of Type 3 material covered with large salvaged armor rock

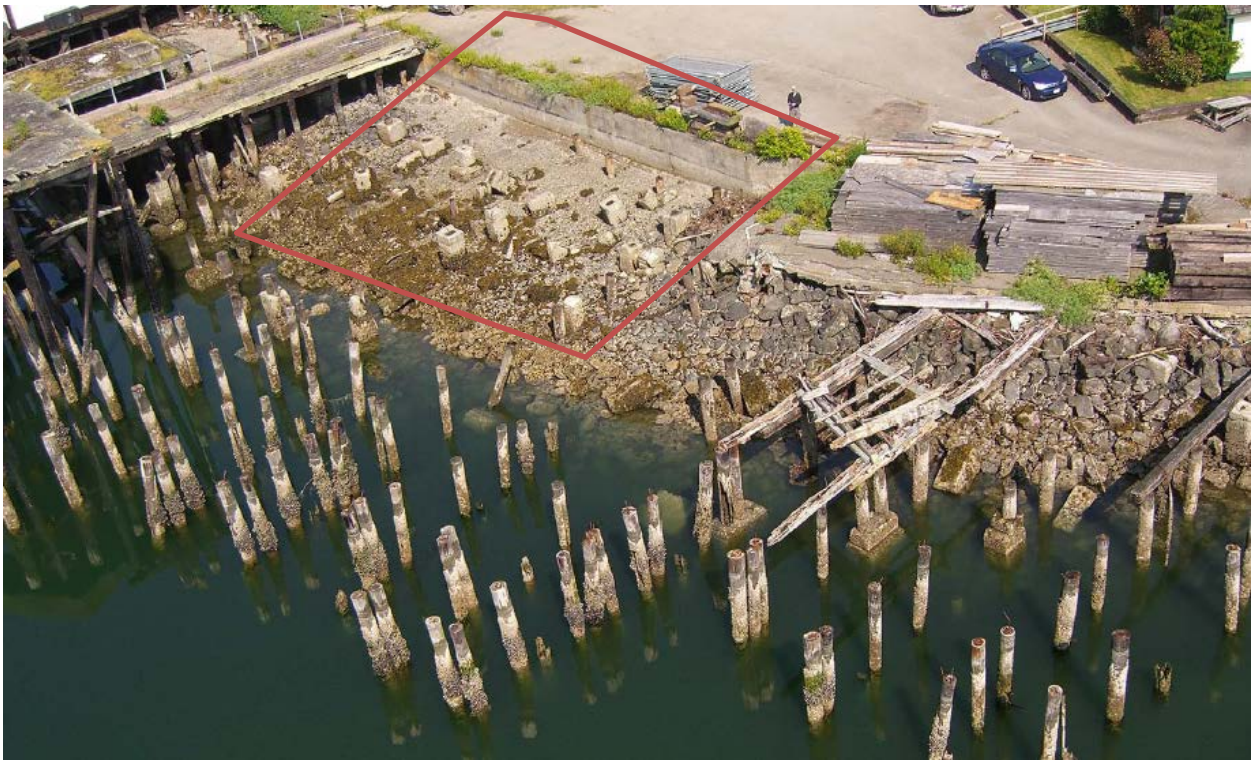
The work described above was completed on August 12, 2016. The completed stabilization work is shown in Photograph 3.

Photograph 3

Completed Shoreline Repair in Area 2

Area 3

Area 3 is located between the temporary transload facility and the eastern end of the Type 2 intertidal cap in SMA-2. Structures and piling were removed from this area as part of demolition for Site remediation. Photograph 4 shows the condition of the shoreline in Area 3 prior to structure removal; the approximate extent of Area 3 is outlined in red in Photograph 5. Following demolition work, the shoreline in Area 3 was not significantly armored.



Photograph 4

Shoreline Conditions in Area 3 Prior to Structure and Pile Removal

Observations

Erosion of the area during this storm event was intensified due to the two adjacent armored areas (the capped area to the west and the transload facility to the east), as seen in Photograph 5. Figure 2c shows a pre- and post-storm survey transect that shows the

shoreline erosion in this area. Similarly to Area 1, the upper shoreline has eroded back to a milder slope to match the existing slope in the lower intertidal area.

The shoreline area where the transload facility was constructed was armored prior to construction of the transload facility, as shown in Photograph 6. Following removal of the transload facility, that area will need be restored to similar pre-project conditions with shoreline armoring that blends into the proposed remedy for Area 3.

Photograph 5
Shoreline Erosion in Area 3

Photograph 6

Pre-Construction Shoreline Conditions at the Transload Facility

Recommendations

Design recommendations to address shoreline erosion in this area are shown in Figure 2c. The shoreline in this area will be armored between the end of the Type 2 cap area and the armored shoreline at the location of the temporary transload area. Armor will consist of a layer of Type 3 material covered with large salvaged armor rock. The armor will extend from the top of the bank down to elevation +5 feet mean lower low water. A launching toe section will be placed at the toe of the armor (an extra two layers of Type 2 cap material) to provide toe scour protection for the newly constructed armored slope. These design recommendations are focused on preventing erosion at the top of the bank and preventing loss of uplands due to future storm events. The armoring detail shown in Figure 2c will be blended into the Type 2 capped area to the east and the armored slope replaced at the transload facility once it is removed (as discussed above).

Area 4

Area 4 is located west of Pier 4, on the south-facing upper intertidal shoreline of SMA-2.

Observations

The upper intertidal shoreline in Area 4 was capped with Type 2 armor rock. Some of the armor rock was displaced in the upper inner tidal zone due to wave impact from the storm events. As stated previously, localized movement of armor rock can occur during a design storm event; this design decision allows for a balance of using a more habitat-friendly armor rock size while still ensuring the protectiveness of the remedy. The March 13 storm, as documented in Section 1, was up to a 100-year storm event based on wind velocity data, which was the design storm event for the slope. In addition, the high winds that occurred during that storm event lasted for approximately 32 hours, which is significantly longer than the typical design storm event in the Puget Sound area.

Figure 2b shows a survey transect within Area 4 that illustrates Type 2 rock movement where the majority of the design rock thickness was displaced. However, as seen in Photograph 7, the extent of this level of damage is small, affecting approximately 20 to 30 feet of shoreline. Area 5, shown in Figure 2a, illustrates more typical and expected movement of rock on the slope; this area still has acceptable coverage of armor rock over the filter material. Survey data from Section A show more typical and expected movement of rock on the slope. Area 5 is representative of the conditions of the majority of the Type 2 cap area.

Photograph 7

Shoreline Erosion in Area 4

Recommendations

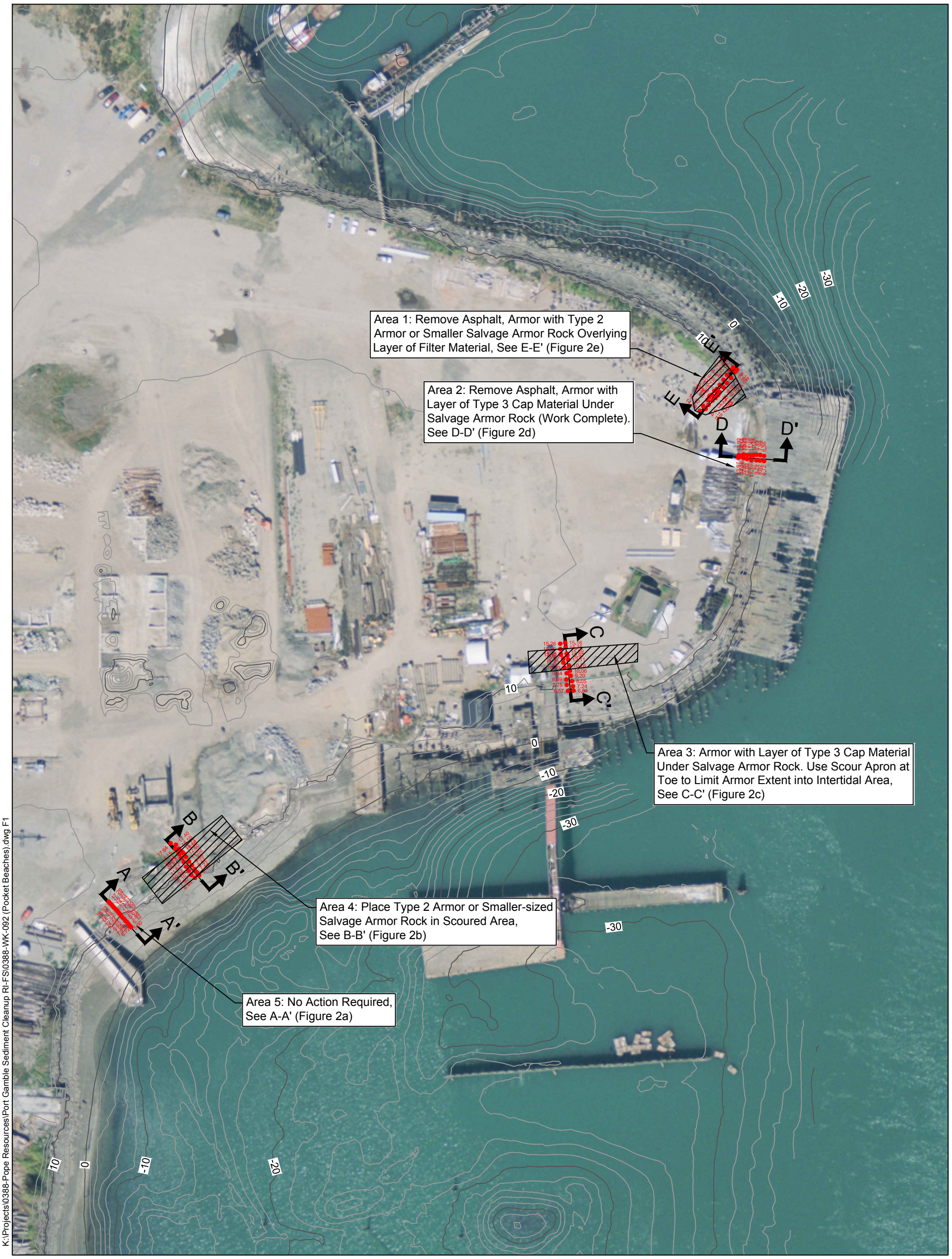
Design recommendations to address movement of the Type 2 cap material in Area 4 include adding additional Type 2 rock or smaller salvaged armor rock in the areas where significant movement has occurred (the approximate extent of this damage is shown in Figure 1).

REFERENCES

Anchor QEA, 2015. *Engineering Design Report, Port Gamble Bay Cleanup Project*.

Finlayson, D., 2006. *The Geomorphology of Puget Sound Beaches*. Technical Report 2006-02. Prepared in support of the Puget Sound Nearshore Partnership. Seattle, Washington: Washington Sea Grant Program, University of Washington. October 2006.

FIGURES



K:\Projects\0388-Pope Resources\Port Gamble Sediment Cleanup RI-FS\0388-WK-092 (Pocket Beaches).dwg F1

Oct 07, 2016 8:36am chewett

SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

Existing Contours (2' and 10' Interval)

Pocket Beach Sample Location and Elevation

0 100

Scale in Feet

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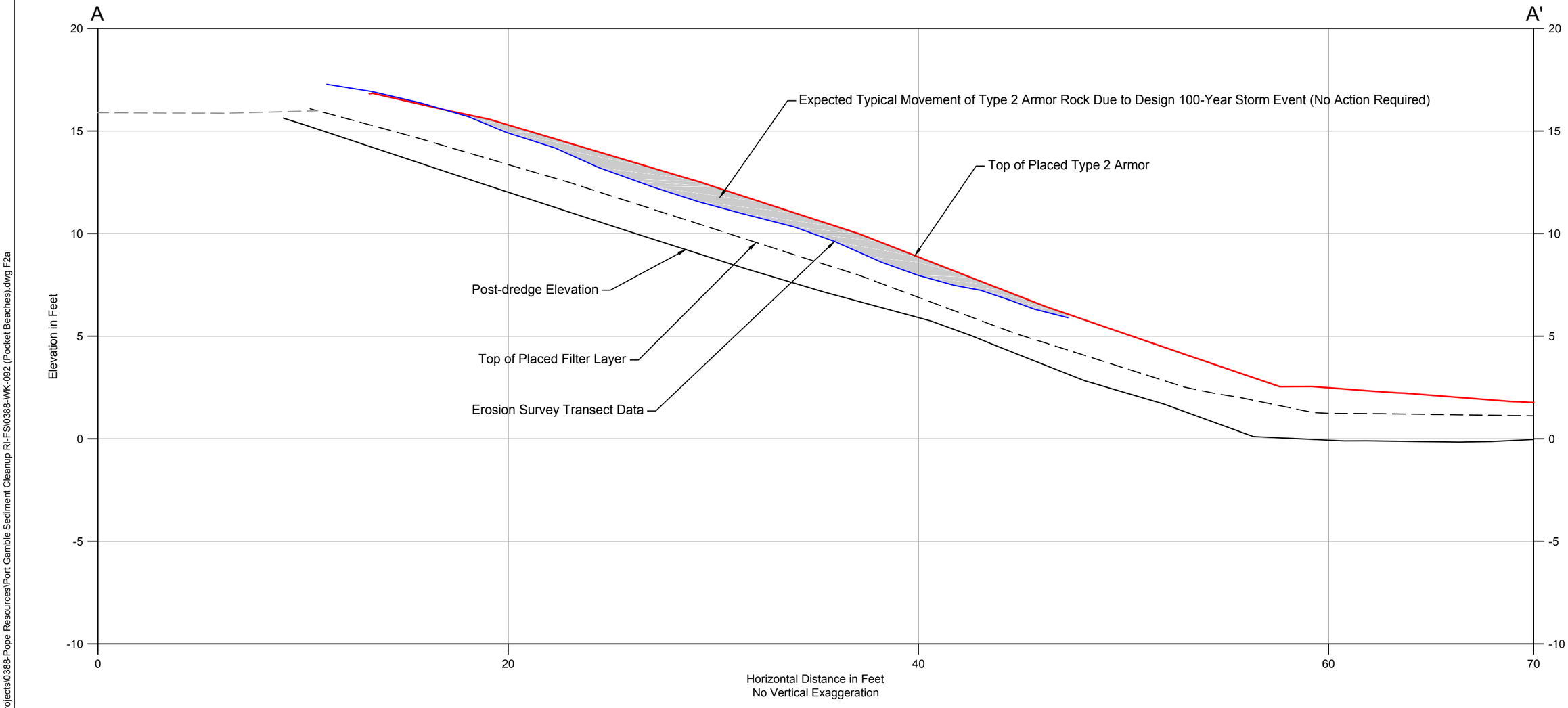
Figure 1
Pocket Beach Sample Locations (August 2016)
Port Gamble Bay Cleanup Project



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Oct 07, 2016 8:36am chewett

SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Existing Grade
- Season 1 Post-dredge Survey
- Season 1 Post-filter Placement Survey
- Season 1 Post-armor Placement Survey
- Erosion Survey Transect Data
- Typical Expected Movement of Type 2 Armor Rock (No Action Required)

0 5
Scale in Feet

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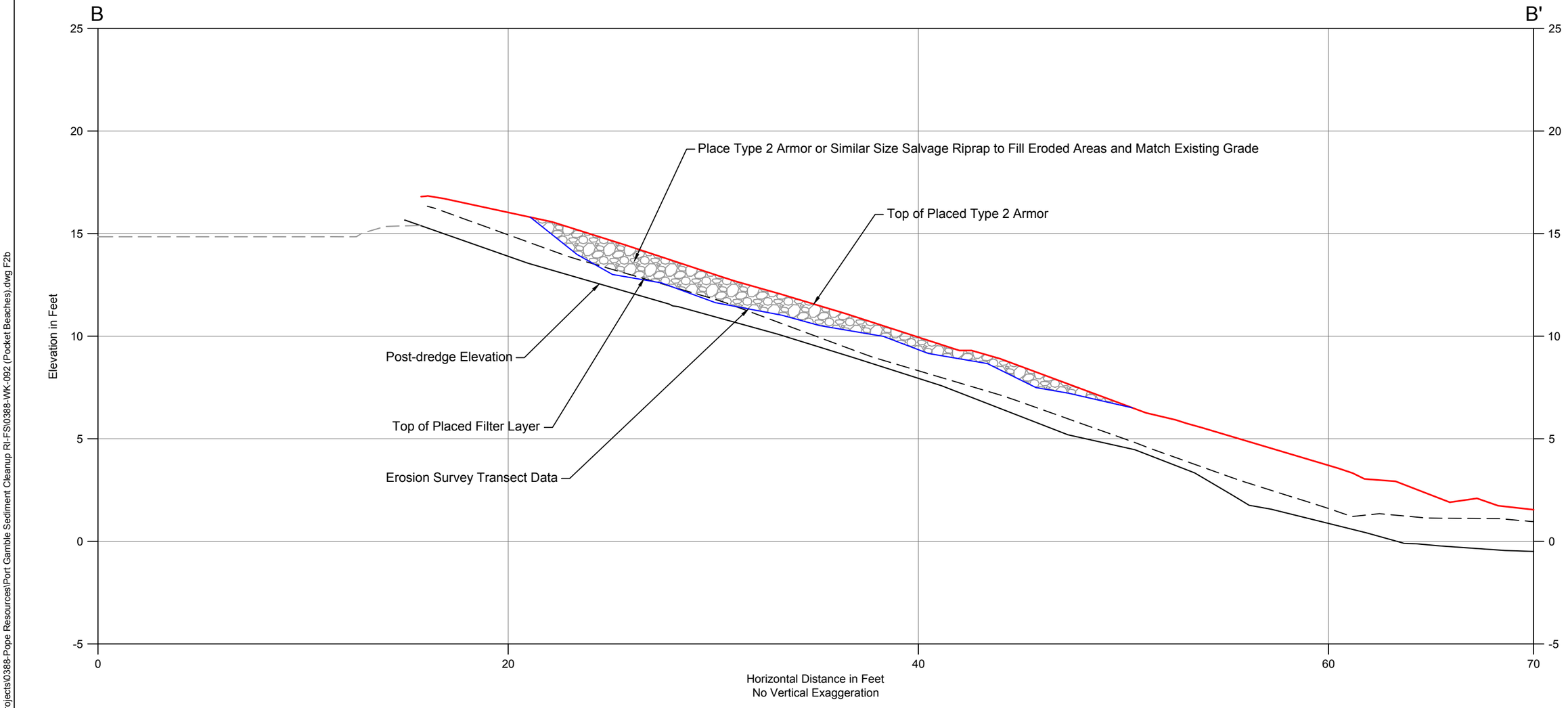
Figure 2a
Cross Section A-A'
Port Gamble Bay Cleanup Project



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Oct 07, 2016 8:36am chewett

SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Existing Grade
- Season 1 Post-dredge Survey
- Season 1 Post-filter Placement Survey
- Season 1 Post-armor Placement Survey
- Erosion Survey Transect Data
- Place Type 2 Armor or Similar Size Salvage Riprap

0 5
Scale in Feet

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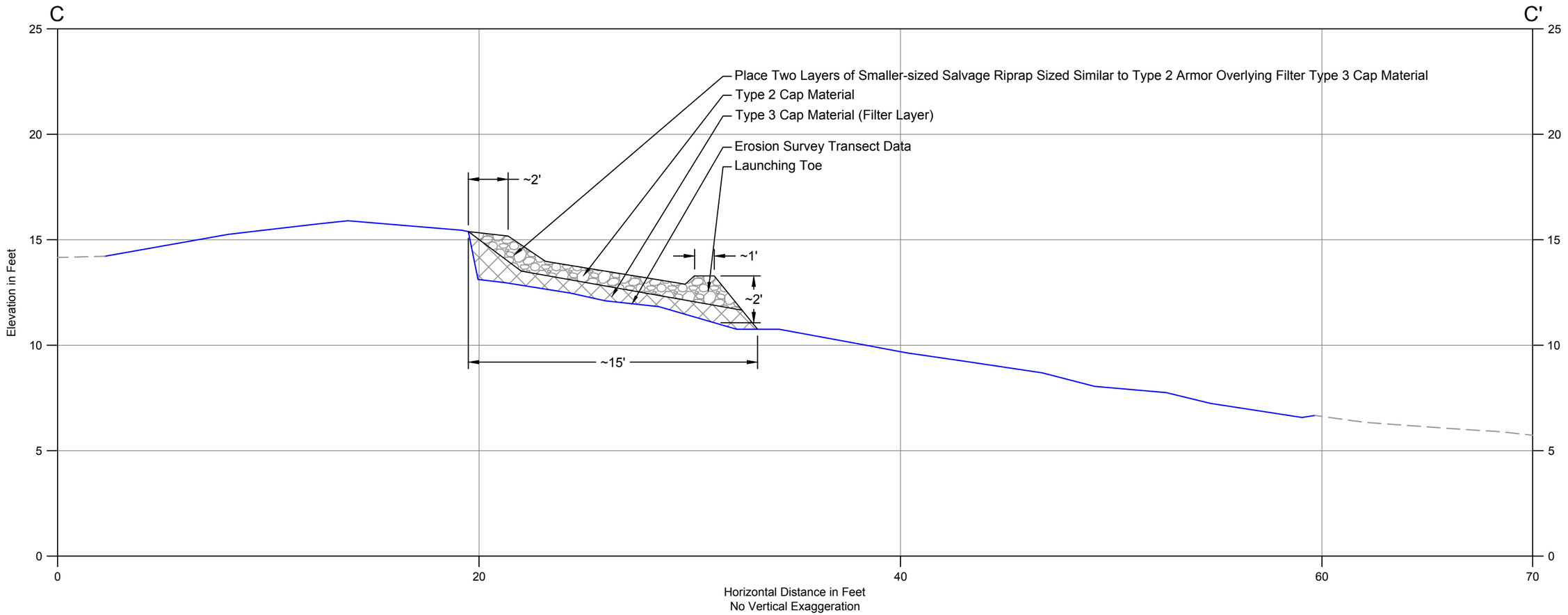
Figure 2b
Cross Section B-B'
Port Gamble Bay Cleanup Project



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Oct 07, 2016 8:36am chewett

SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Existing Grade
- Erosion Survey Transect Data
- Place Salvage Riprap over Filter Material

0 5
Scale in Feet

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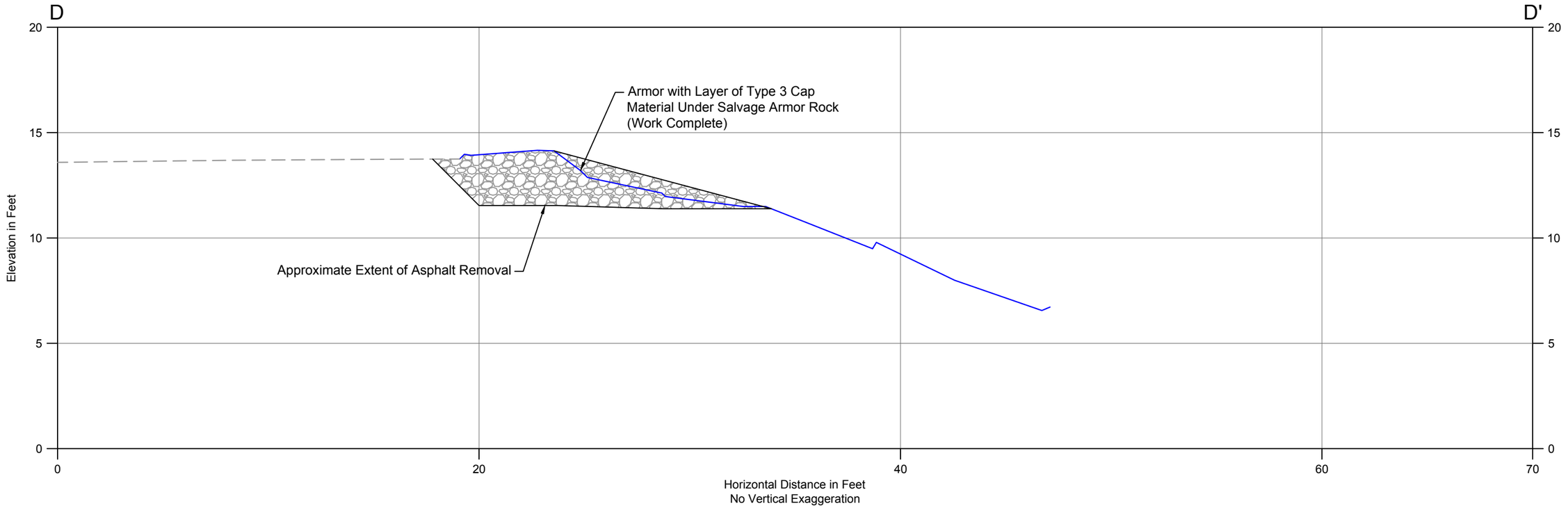
Figure 2c
Cross Section C-C'
Port Gamble Bay Cleanup Project



SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).
NOTE: Work shown has been completed.

LEGEND:

- Existing Grade
- Erosion Survey Transect Data
- Salvage Riprap over Type 3 Cap Material (Work Complete)

0 5
Scale in Feet

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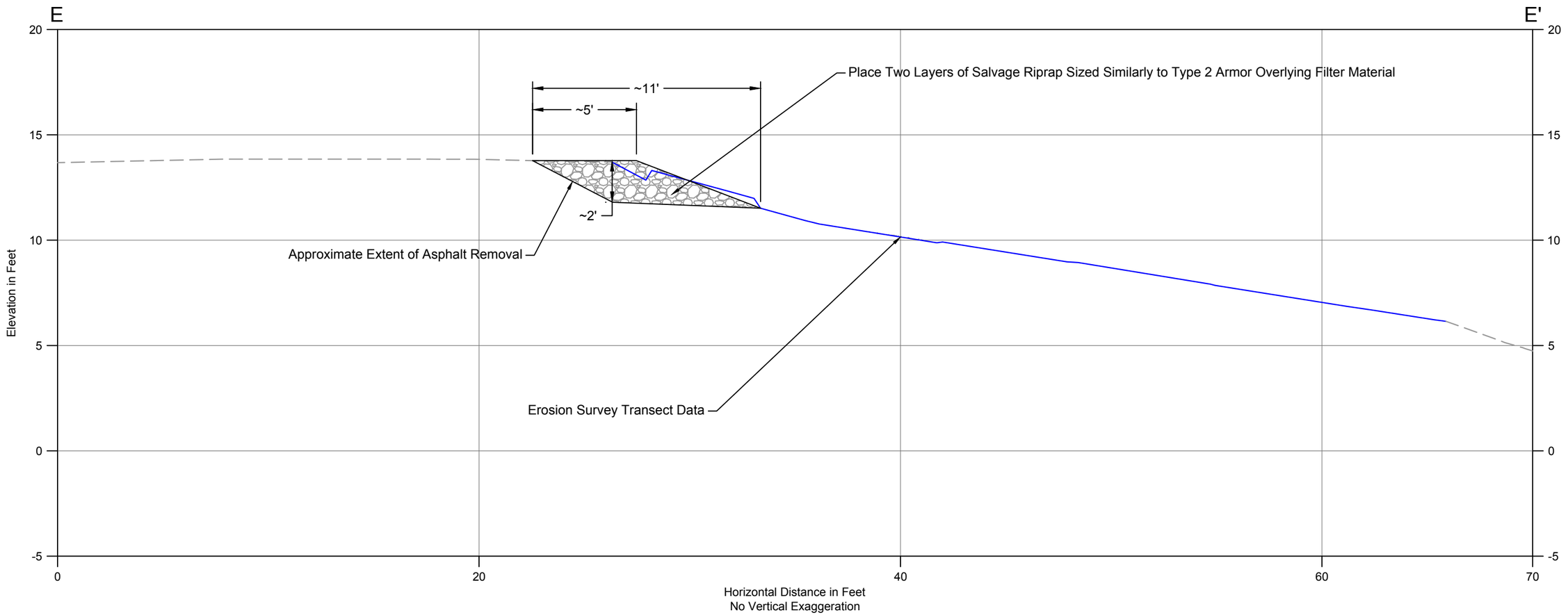
Figure 2d
Cross Section D-D'
Port Gamble Bay Cleanup Project



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Oct 07, 2016 8:36am chewett

SOURCE: Topography from Triad, dated 2012. Bathymetry from eTrac, dated August 17, 2016. Pocket beach sample locations from Orion, dated August 6, 2016.
HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.
VERTICAL DATUM: Mean Lower Low Water (MLLW).

LEGEND:

- Existing Grade
- Erosion Survey Transect Data
- Place Salvage Riprap over Filter Material

0 5
Scale in Feet

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Figure 2e
Cross Section E-E'
Port Gamble Bay Cleanup Project