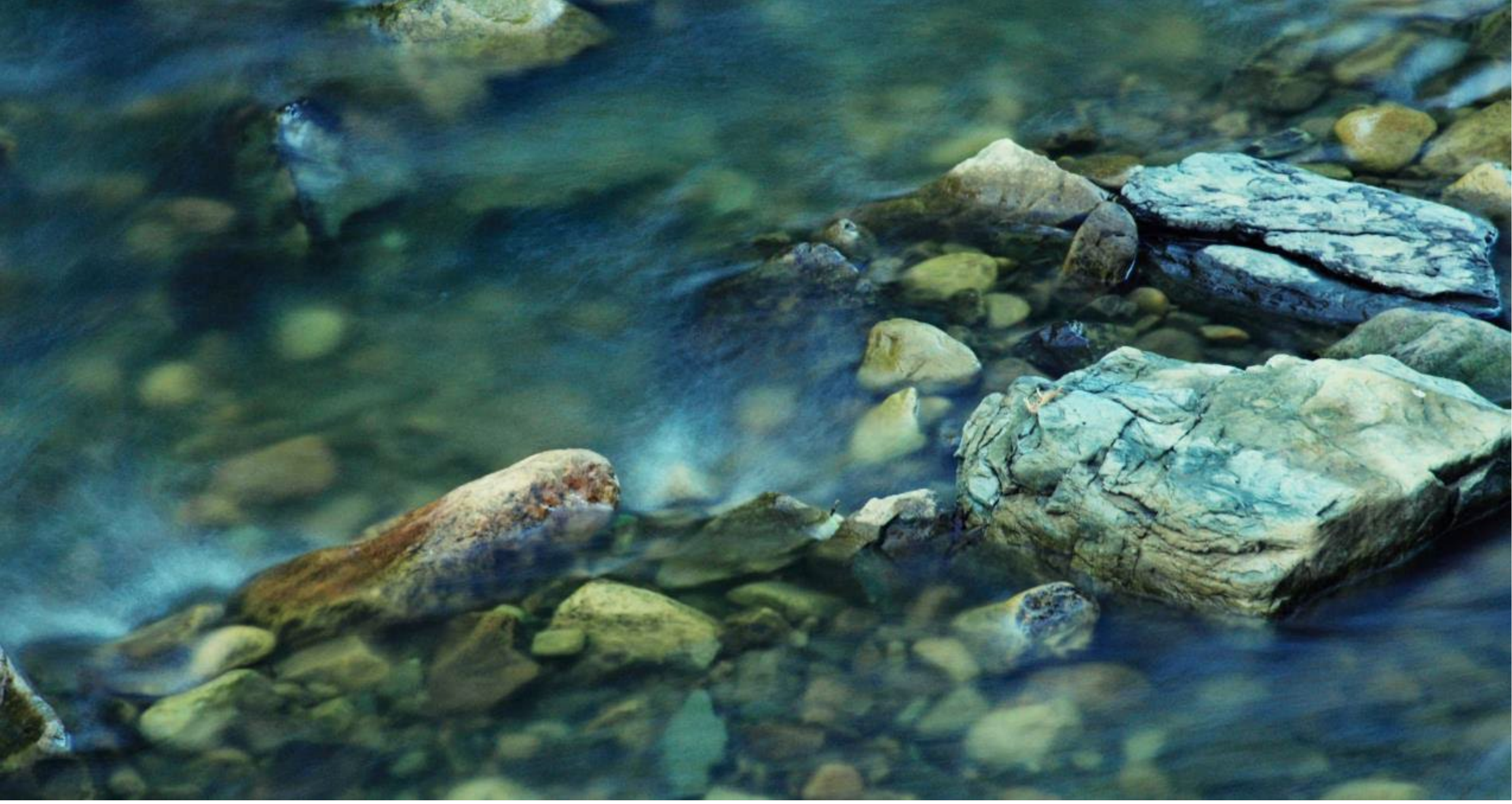

September 2022
Port Gamble Bay Cleanup

Five-Year Review

Washington State Department of Ecology

EXECUTIVE SUMMARY

This document presents the Washington State Department of Ecology's (Ecology's) *Five-Year Review* of post-cleanup site conditions at Port Gamble Bay (Bay). Cleanup actions in the Bay included removal of 8,592 decayed piling, nearly all of which were creosote treated, and removal of 110,000 cubic yards of wood debris and contaminated sediment. Clean engineered caps and sand layers were placed over 92 acres of the Bay to manage residuals and reduce sediment toxicity. Remedial construction was successfully performed by Pope Resources LP/OPG Port Gamble LLC under Ecology oversight.

Detailed post-construction monitoring has documented the integrity and protectiveness of engineered caps placed in the Bay. Newer sediments continue to accrete on the surface of the caps. Localized zones of erosion were proactively repaired shortly after completion of construction by placing larger armor stone materials. Recent monitoring reveals that all caps are stable and protective.

Post-construction chemical and biological monitoring data have verified that cleanup actions successfully reduced toxicity risks to benthic organisms throughout the Bay. While piling removal operations resulted in a small (0.2%) and unavoidable contaminant release to the Bay, shellfish tissue concentrations have nevertheless been reduced. Chemical and biological monitoring data reveal that post-construction Bay-wide human health risk reductions from ingestion of seafood are on track to achieve natural background conditions. Moreover, the Bay cleanup is providing a greater degree of protection compared to what would be required using new scientific information.

As described in this *Five-Year Review*, the Bay cleanup remedy appears on track to achieve objectives set forth in the CAP (Ecology 2013). A follow-on round of monitoring will be performed in 2026 to further document the integrity of engineered caps and verify attainment of cleanup objectives, informing the next Five-Year Review scheduled for 2027.

Ecology will publish a notice of this *Five-Year Review* in the site register and will provide an opportunity for review and comment by the public.

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ABBREVIATIONS

Bay	Port Gamble Bay
CAP	*Cleanup Action Plan*
cm	centimeter
cPAH	carcinogenic polycyclic aromatic hydrocarbon
cy	cubic yard
dioxins/furans	polychlorinated dibenzo-*p*-dioxins and dibenzofurans
DNR	Washington State Department of Natural Resources
Ecology	Washington State Department of Ecology
EMNR	enhanced monitored natural recovery
EPA	U.S. Environmental Protection Agency
H_2S	hydrogen sulfide
Mill	Former Port Gamble Sawmill Facility
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNR	monitored natural recovery
MTCA	Model Toxics Control Act
ng/kg	nanograms per kilogram
OMMP	*Operations, Maintenance and Monitoring Plan*
OPG-PG	OPG Port Gamble LLC
P&T	Pope & Talbot, Inc.
PGST	Port Gamble S'Klallam Tribe
PR	Pope Resources LP
Rayonier	Rayonier, Inc.
RI/FS	remedial investigation/feasibility study
SMA	sediment management area
SMS	Sediment Management Standards
SWAC	surface-weighted average concentration
TEQ	toxicity equivalent quotient
µg/kg	micrograms per kilogram
WAC	Washington Administrative Code

1 Introduction

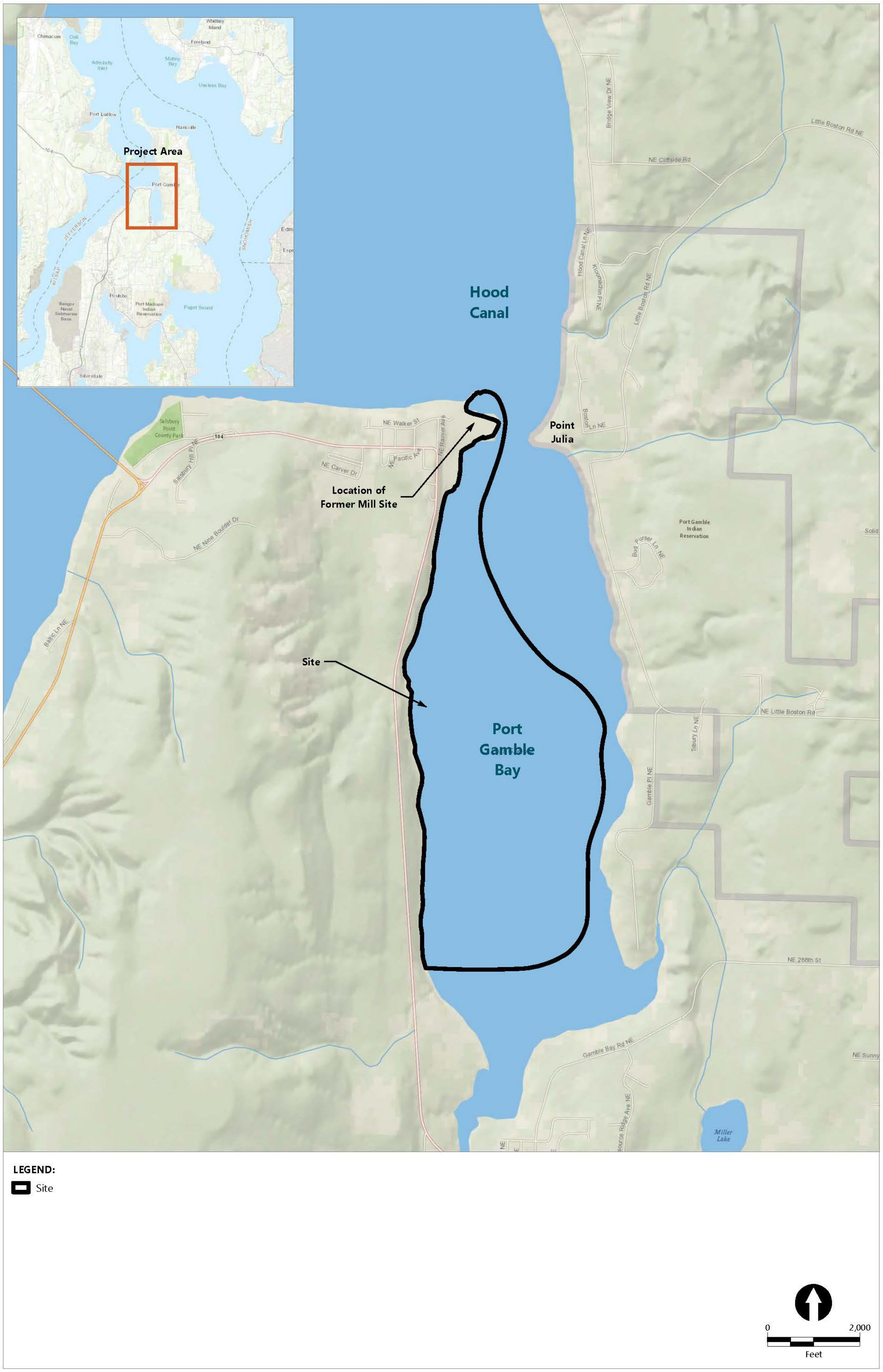
This document presents the Washington State Department of Ecology's (Ecology's) *Five-Year Review* of post-cleanup site conditions and monitoring data at Port Gamble Bay (Bay), a 730-acre portion of the Port Gamble Bay and Mill Site (Site) located in Port Gamble, Kitsap County, Washington (Figure 1). Pope Resources LP (PR)/OPG Port Gamble LLC (OPG-PG) completed cleanup construction in the Bay in 2017 under the Model Toxics Control Act (MTCA) regulations, Chapter 173-340 Washington Administrative Code (WAC), as well as the Sediment Management Standards (SMS) regulations, WAC 173-204. The purpose of this *Five-Year Review* is to determine whether the Bay cleanup remedy is protective of human health and the environment, based on the following:

- Post-construction monitoring of completed cleanup actions, including engineered caps, enhanced monitored natural recovery (EMNR) and monitored natural recovery (MNR)
- New scientific information for hazardous substances in the Bay
- Planned habitat restoration actions in shoreline cleanup areas of the Bay
- Other considerations, including current applicable state and federal laws, current and projected future uses in the Bay, the practicability of more permanent remedies, and improved analytical methods to evaluate compliance with cleanup levels

A follow-on round of monitoring will be performed in 2026 to further document the integrity of engineered caps and verify attainment of cleanup objectives, informing the next Five-Year Review scheduled for 2027.

Ecology will publish a notice of this *Five-Year Review* in the site register and will provide an opportunity for review and comment by the public.

Figure 1
Port Gamble Bay Vicinity Map



2 Site Background

Under Ecology's Toxics Cleanup Program Puget Sound Initiative, the Bay (Figure 1) is one of seven areas in Puget Sound identified for focused sediment cleanup. The Bay encompasses more than 2 square miles of subtidal and shallow intertidal habitat just south of the Strait of Juan de Fuca. The Bay and surrounding areas support diverse aquatic and upland habitats, as well as resources for fishing, shellfish harvesting, and other aquatic uses. The area surrounding the Bay remains largely rural, though more than 100 acres of the basin are currently in commercial land use, largely in the Gamble Creek watershed that drains into the southern portion of the Bay. The Port Gamble S'Klallam Tribe (PGST) Reservation is located east of the Bay; tribal members use the Bay for shellfish harvesting, fishing, and other resources.

Pope and Talbot, Inc. (P&T) continuously operated a sawmill facility (Mill) on the upland portion of the Site for a period of approximately 142 years (1853 to 1995; Figure 1). Over that period, the Mill underwent a variety of changes, including expansion by filling, as well as changes in the location and function of buildings and structures. Logs were stored throughout the Bay. A log rafting area along the western shore of the Bay was leased to P&T by the Washington State Department of Natural Resources (DNR) in several consecutive leases from 1974 to 1996. Most log rafting activities ceased in 1995 when the sawmill closed.

In 1985, P&T transferred ownership of the sawmill, uplands, and adjacent tidelands to PR. P&T continued wood products manufacturing at the Mill until 1995 under a lease with PR. OPG-PG, formerly known as Olympic Property Group LLC, was formed in 1998 to manage PR's real estate in Kitsap County. In 2007, P&T filed for bankruptcy (Delaware Case No. 07-11738). In 2020, PR/OPG-PG merged with Rayonier, Inc. (Rayonier).

Historical log and wood product transfer operations at the Mill released wood debris and hazardous substances to the Bay (Ecology 2012). Creosote treated pilings were placed throughout the Bay to support pier and wharf structures and to facilitate storage and transport of logs and wood products. Hazardous substances identified in the Bay include carcinogenic polynuclear aromatic hydrocarbons (cPAHs), polychlorinated dibenzo-*p*-dioxins and dibenzofurans (dioxins/furans), cadmium, and toxicity associated with wood debris and its breakdown products including dissolved hydrogen sulfide (H_2S). Ecology determined that releases of these hazardous substances presented a threat to human health and the environment in the Bay.

2.1 Completed Interim Actions and Site Characterization

Between 2002 and 2005, PR/OPG-PG excavated approximately 26,310 tons of contaminated soils from the former Mill and disposed the materials at an approved off-site landfill facility in Kitsap County. In 2003, PR/OPG-PG dredged approximately 13,500 cubic yards (cy) of sediment containing accumulations of wood debris and hazardous substances from a 1.8-acre area of the Bay and disposed the materials at an approved off-site landfill facility in Kitsap County. In 2007, Ecology and DNR dredged an additional 17,500 cy of wood debris from an adjacent one-acre area of the Bay and placed a six-inch layer of clean sand over a portion of the newly dredged area. Salt in the dredged wood waste was rinsed using a freshwater washing system to facilitate protective upland beneficial reuse of these materials at the Port Gamble Model Airplane Field in 2008 and 2009. While these earlier sediment cleanup actions reduced wood debris and hazardous substance risks, biological toxicity continued in portions of the Bay.

In 2012, Ecology completed a remedial investigation/feasibility study (RI/FS) of the Bay, including a detailed site characterization and evaluation of remedial alternatives (Ecology 2012). The RI/FS identified risks to sensitive benthic invertebrates in portions of the Bay adjacent to the former Mill as well as in certain offshore areas. Potential human health risks from cPAHs, dioxins/furans, and cadmium were also identified for those who may consume relatively large quantities of shellfish obtained from the Bay. Detailed RI/FS information is at http://www.ecy.wa.gov/programs/tcp/sites/.

2.2 Cleanup Action Plan

Based on the findings of the RI/FS, Ecology prepared the Cleanup Action Plan (CAP) for the Bay (Ecology 2013). The CAP provided the following:

- Identified cleanup objectives and standards
- Identified cleanup actions
- Established a schedule for the cleanup
- Required monitoring to demonstrate remedy effectiveness

The objectives of sediment cleanup actions at the Site, as detailed in the CAP (Ecology 2013), are summarized as follows:

- Eliminate, reduce, or otherwise control, to the extent practicable, Bay-wide human health risks from ingestion of seafood containing cPAHs, as measured by the toxicity equivalency quotient (TEQ), along with dioxin/furan TEQ and cadmium, exceeding natural background concentrations
- Eliminate, reduce, or otherwise control, to the extent practicable, risks to benthic organisms in localized areas of the Bay through exposure to sediments or porewater containing deleterious wood debris breakdown products or chemicals of concern exceeding SMS biological effects criteria

Cleanup standards consist of: (1) cleanup levels that are protective of human health and the environment; and (2) the point of compliance at which the cleanup levels must be met. The RI/FS

(Ecology 2012) provides detailed discussions of the derivation of site-specific standards to protect human health and the environment.

Human health risk-based standards were developed based on the highest of risk-based criteria, natural background concentrations, and practical quantitation limits. Human health-based cleanup levels were developed for cPAH TEQ, dioxin/furan TEQ, and cadmium.

Ecological risk-based cleanup standards for sediments were based on SMS biological criteria, using bioassay results presented in the RI/FS. The site-specific bioassay cleanup standard selected by Ecology (2013) was the biological effects criterion described in WAC 173-204-320(3) using amphipod, larval, and juvenile polychaete bioassay tests.

Table 1 summarizes site-specific sediment cleanup levels from the CAP (Ecology 2013).

Table 1
Sediment Cleanup Levels

Parameter	Site-Specific Cleanup Level
cPAH TEQ	16 µg/kg dry weight
Dioxin/furan TEQ	5.0 ng/kg dry weight
Cadmium	3.0 mg/kg dry weight
Toxicity due to wood debris breakdown products	SMS biological effects criteria (WAC 173-204-320[3])

Notes:
µg/kg – micrograms per kilogram
ng/kg – nanograms per kilogram
mg/kg – milligrams per kilogram

Under MTCA and SMS, the point of compliance is the location where cleanup levels must be attained. For marine sediments, the point of compliance for protection of the environment is surface sediments within the biologically active zone. The biologically active zone is the depth in surface sediments where benthic communities are located. For most of the Bay, the CAP (Ecology 2013) established a 10-centimeter (cm) point of compliance. However, in subtidal geoduck beds located south and east of the former Mill (South Mill), the point of compliance extends 3 feet below the sediment surface. In intertidal beaches surrounding the former Mill, the point of compliance extends 2 feet below the sediment surface.

The CAP (Ecology 2013) identified specific actions to achieve cleanup standards. These actions used different cleanup technologies for specific portions of the Bay, summarized as follows:

- Removal of creosote-treated piles and remnant creosote-treated structures
- Intertidal sediment excavation, primarily during low tide conditions to ensure protection
- Subtidal sediment dredging

- Intertidal and subtidal capping using a protective layer of clean silt, sand, gravel, cobble, and/or armor materials, as appropriate for specific areas of the Bay
- Placement of an EMNR layer of clean silt and/or sand, as appropriate for specific subtidal areas of the Bay
- Long-term monitoring and maintenance to ensure the protectiveness of the remedy

The CAP (Ecology 2013) called for construction activities to be sequenced to maximize overall protectiveness, beginning with source controls (i.e., demolition and removal of creosote-treated materials), followed closely in time by intertidal excavation and subtidal dredging. Capping and EMNR were sequenced to occur shortly after removal actions were completed to maximize control of residuals and accelerate natural recovery processes, reducing the overall restoration timeframe. Construction monitoring was implemented to ensure the protectiveness of the remedy (Section 2.6).

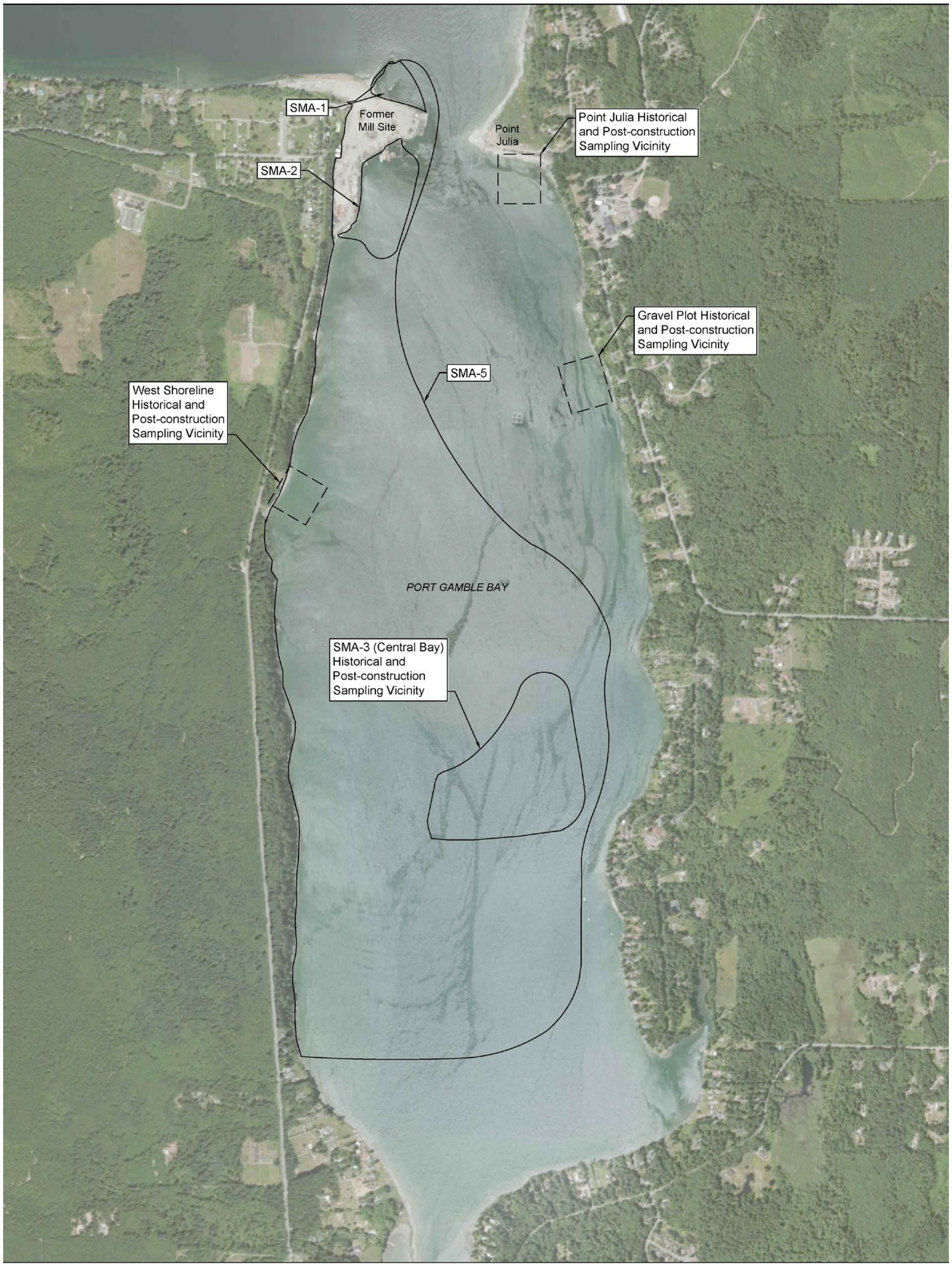
The CAP (Ecology 2013) anticipated that source controls, along with sediment removal, capping, and EMNR actions as summarized above would accelerate natural recovery processes throughout the Bay, achieving surface-weighted average concentration (SWAC)-based cleanup standards for cPAH TEQ, dioxin/furan TEQ, and cadmium within 10 years following completion of construction.

2.3 Sediment Management Areas

This section summarizes SMAs in the Bay, as refined during remedial design (Anchor QEA 2015). The SMAs collectively total 730 acres, summarized as follows (Figure 2):

- North Mill (SMA-1): A 6-acre area located in the embayment north of the former Mill, SMA-1 contained localized deposits of subtidal wood debris (primarily wood chips) located near a former chip loading area. SMA-1 was delineated during remedial design (Anchor QEA 2015) based on bioassay results that exceeded SMS biological effects criteria, as well as sediment surface cPAH TEQ and dioxin/furan TEQ concentrations that exceeded site-specific cleanup levels.
- South Mill (SMA-2): A 20-acre area located immediately south and east of the former Mill, SMA-2 also had localized deposits of subtidal wood debris (including sawdust, chips, and bark), particularly adjacent to another former chip loading area. SMA-2 was delineated during remedial design (Anchor QEA 2015) based on bioassay results that exceeded SMS biological effects criteria, as well as sediment surface cPAH TEQ and dioxin/furan TEQ concentrations that exceeded site-specific cleanup levels.
- Central Bay (SMA-3): During the RI/FS (Ecology 2012), an 80-acre area located in the south-central portion of the Bay exceeded SMS biological effects criteria, attributable to the presence of wood debris and associated breakdown products in sediments. The preliminary boundary of SMA-3 delineated during the RI/FS was refined during remedial design with additional bioassays (Anchor QEA 2015), reducing the size of SMA-3 to 61 acres.

Figure 2
Sediment Management Areas and Shellfish Sampling Locations



HORIZONTAL DATUM: Washington State Plane North, NAD83, U.S. Feet.

NOTES:
1. For in-situ shellfish sampling, historical sampling areas were reoccupied and target species to collected consisted of those previously sampled.

LEGEND:

SMA Area

Shellfish Sampling Area

0 1200
Scale in Feet

- Former Lease Area (SMA-4): During the RI/FS (Ecology 2012), a 20-acre area including portions of the former DNR log rafting lease area along the western shoreline of the Bay exceeded SMS biological effects criteria. The preliminary boundary of SMA-4 delineated during the RI/FS was refined during remedial design with additional bioassays (Anchor QEA 2015), revealing that SMA-4 no longer exceed SMS biological effects criteria. The former SMA-4 area is incorporated into SMA-5; see below.
- cPAH Background Area (SMA-5): A 620-acre area surrounding all the other SMAs, the boundary of SMA-5 was delineated during remedial design (Anchor QEA 2015) based on surface sediment cPAH TEQ concentrations exceeding the site-specific cleanup level. SMA-5 also included an area of elevated dioxin/furan TEQ near SMA-3, as well as one station with an elevated sediment cadmium concentration.

2.4 Permits and Approvals

In May 2015, Ecology issued a National Pollutant Discharge Elimination System Construction Stormwater General Permit for the cleanup action. In June 2015, the U.S. Army Corps of Engineers approved Nationwide Permit 38 (NWS-2013-1270) to perform cleanup actions. In August 2015, Ecology approved the remedial design, incorporating the outcome of the piling removal pilot demonstration (see below). Also in August 2015, DNR approved the Sediment Remediation Easement with PR/OPG-PG. In September 2015, PR/OPG-PG contracted with Orion Marine Contractors, Inc., to initiate in-water construction.

2.5 Piling Removal Pilot Demonstration

PR/OPG-PG conducted a piling removal pilot demonstration in July 2015, prior to the initiation of the full-scale cleanup project (Anchor QEA 2018b). The purpose of the piling removal pilot demonstration was to evaluate aggressive removal methods for effectiveness, reliability, ability to remove pilings intact, and practicability. The use of vibratory pile extraction methods was identified as the most effective removal method, and PR/OPG subsequently required the contractor use this method for the full-scale cleanup project. Requirements for cut-off depth and placement of an amended cap were also specified for piles that could not be practicably removed and needed to be cut.

2.6 Completed Cleanup Actions

In accordance with Consent Decree 3-2-02720-0 between Ecology and PR/OPG-PG, between September 2015 and January 2017, PR/OPG-PG and Orion Marine Contractors successfully completed the in-water construction phase of the Bay cleanup project with Ecology oversight (Anchor QEA 2018b). Construction activities were implemented in accordance with the Ecology-approved remedial design (Anchor QEA 2015), project technical specifications and drawings, and associated permitting requirements. Construction activities included the following:

- Removal and off-site landfill disposal[1] of 8,592[2] decayed piling, nearly all of which were creosote treated; 99.9% of the piles were successfully removed without breaking
- Removal and off-site landfill disposal[1] of 110,000[2] cy of wood debris and sediment
- Removal and off-site landfill disposal[1] of 1.3 acres of overwater and derelict structures
- Improvement of 3,485 linear feet of shoreline
- Placement of clean engineered caps over 13 acres of SMA-1 and SMA-2
- Placement of clean EMNR layers over 79 acres of SMA-1, SMA-2, and SMA-3 to manage residuals and reduce sediment toxicity

Construction oversight was performed by Anchor QEA to verify that construction activities were performed in accordance with project technical specifications and drawings and to implement the Ecology-approved Construction Quality Assurance Plan (Anchor QEA 2015). Construction activities were tracked to verify progress and the use of best management practices (Anchor QEA 2018b). Anchor QEA and Ecology coordinated on appropriate modifications to the design as necessitated by field conditions to meet Ecology's overall objectives for the Bay cleanup project.

2.7 Environmental Covenants

An environmental (restrictive) covenant is currently being finalized and executed between OPG-PG and Ecology pursuant to the Model Toxics Control Act Uniform Environmental Covenants Act, Chapter 64.70 Revised Code of Washington. The environmental covenant is for engineered caps located on tidelands owned by OPG-PG, restricting certain activities and uses in cap areas to ensure their continued integrity and protectiveness.

A similar environmental covenant for engineered caps located on state-owned aquatic lands is currently being developed by DNR and Ecology.

[1] All creosote piling, structures, debris, and sediments with higher chemical concentrations were disposed at specialized permitted landfill facilities outside of Kitsap County; sediments with lower chemical concentrations were disposed at the Limited Purpose Landfill at the Port Gamble Model Airplane Field in accordance with Kitsap Public Health District permit requirements.
[2] During construction, approximately 60% more creosote pilings and contaminated sediments were encountered and removed than anticipated during remedial design.

3 Post-Construction Monitoring

The Operations, Maintenance and Monitoring Plan (OMMP; Appendix F to the Ecology-approved remedial design, as amended [Anchor QEA 2018a]) describes long-term monitoring and adaptive management of engineered caps to ensure their long-term integrity and protectiveness. The OMMP also describes natural recovery monitoring in the Bay to document achievement of cleanup objectives, consistent with the CAP (Ecology 2013). Separate requirements for eelgrass monitoring and mitigation are being performed by Rayonier in accordance with the requirements of U.S. Army Corps of Engineers Nationwide Permit 38 (NWS-2013-1270), as amended.

3.1 Operations, Maintenance and Monitoring Plan

The OMMP (Anchor QEA 2018a) requires post-construction monitoring and maintenance of engineered caps constructed in SMA-1 and SMA-2 to ensure their long-term integrity and protectiveness. As discussed in Section 3.2, physical surveys of engineered cap areas were performed to monitor their integrity, surface elevation and thickness. During each monitoring event, focused follow-on chemical and biological monitoring was performed in targeted cap areas identified by the physical surveys to further evaluate the protectiveness of the caps. Localized proactive cap maintenance was performed based on the results of the monitoring (see below).

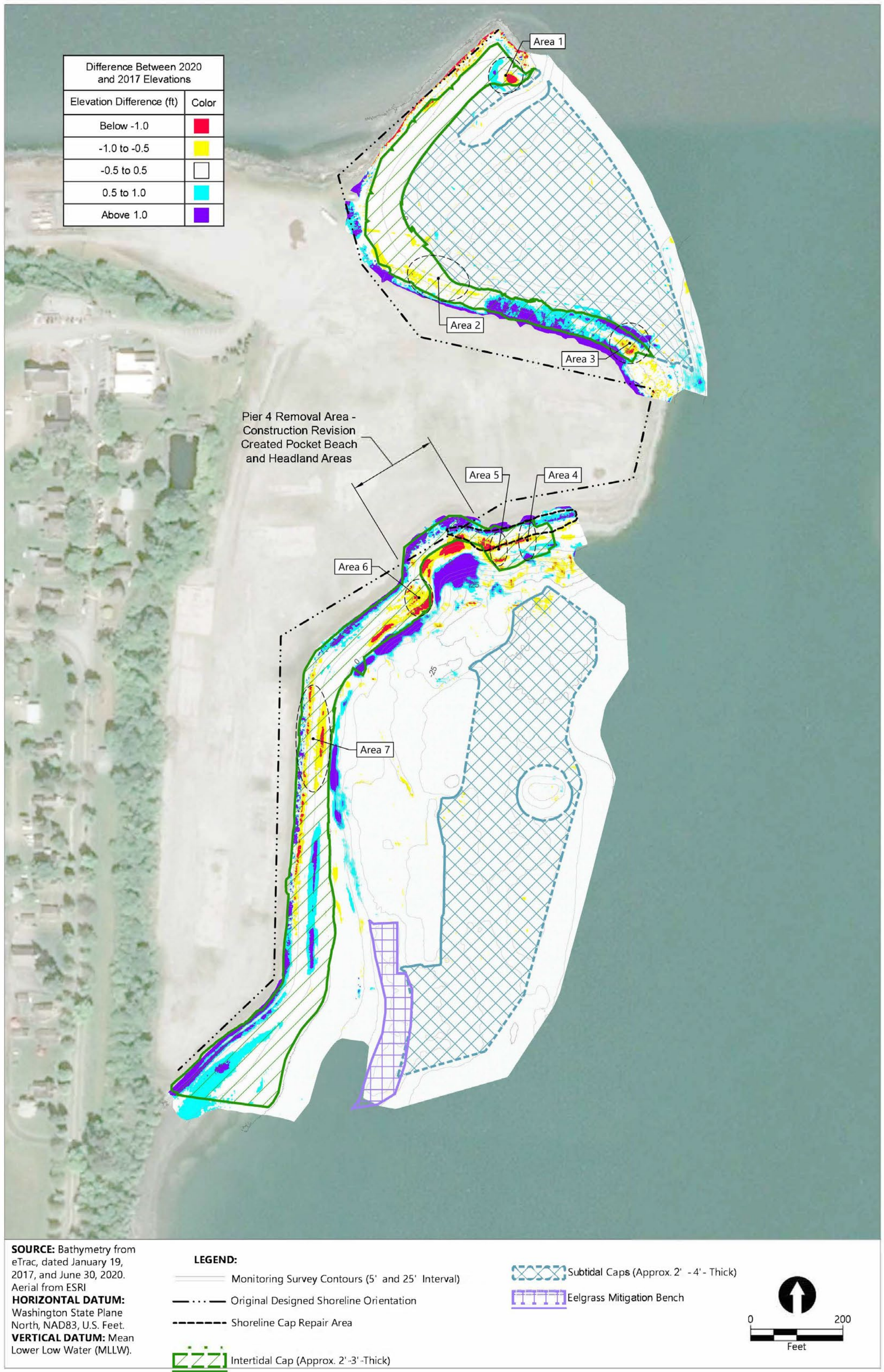
EMNR layers (placed either as the primary remedy or as a post-dredge residuals management technique) do not require long-term monitoring or maintenance (Ecology 2013).

MNR is the selected remedy throughout SMA-5 (Ecology 2015). The OMMP (Anchor QEA 2018a) projected that natural recovery processes in SMA-5 would be accelerated following source controls implemented during the remedial action (removal of decayed creosote treated piling, as well as dredging, capping, and EMNR). The OMMP used a mathematical model as a tool to evaluate progress based on past and future monitoring data. As discussed in Section 3.4, SMA-5 surface sediment monitoring to verify Bay-wide recovery trends began in 2020 (Anchor QEA 2021). Tissue monitoring of primary shellfish harvesting areas in SMA-5 was also performed in 2017 and 2021 to more directly evaluate whether human health-based cleanup objectives were achieved (Section 3.5).

3.2 Cap Physical Integrity Monitoring and Maintenance

Post-construction physical integrity monitoring of engineered caps in SMA-1 and SMA-2 was performed in 2018 and 2020 (Year 1 and 3 after completion of remedial construction, respectively; Anchor QEA 2019 and 2021). Based on comparisons of post-construction bathymetric surveys with the as-built survey (Figure 3), relatively minor changes in engineered cap surface elevations were identified in localized upper intertidal zones. While most of the cap areas have exhibited net accretion following construction, localized zones of apparent settlement and/or erosion were identified in upper intertidal areas of SMA-1 and SMA-2.

Figure 3
SMA-1 and SMA-2 Cap Isopach Comparison – 2020 vs. 2017



Follow-on low-tide visual inspections of the apparent settlement and/or erosion areas (denoted as Areas 1 to 7 in Figure 3) revealed that, except for Areas 4 and 5, surface elevation changes were the result of either anticipated deformation of the slope profile consistent with the Ecology-approved remedial design (Anchor QEA 2015), or anticipated movement of habitat substrate from the upper intertidal area to the lower intertidal area along the profile.

The 2018 monitoring (Anchor QEA 2018c) identified a small area (0.08 acre) of the SMA-2 upper intertidal cap near the former Pier 4 (Areas 4 and 5; Figure 3) where movement of the cap armor rock warranted proactive cap maintenance. Within this area, the remedial design was modified during construction to accommodate additional nearshore wood debris removal, which altered the geometry of this area and rendered the shoreline more susceptible to wave forces. Armor layers constructed at shoreline bends and corners are generally more exposed than straight shoreline sections due to refraction, which can focus wave energy on the corners. The armor rock size for the original remedial design in the Pier 4 area (based on an assumed straight shoreline) had a median diameter of 9 inches. Proactive maintenance of this 0.08-acre area was performed in 2018, resulting in the placement of a 0.5- to 1-foot-thick layer of 3-inch minus quarry spalls in areas where filter material was exposed, overlain with 12-to 18-inch armor rock.

Additional cap maintenance was performed in 2019 to address apparent shoreline erosion along several upper intertidal areas: 1) the exposed north-facing portion of SMA-1; 2) immediately west of the Pier 4; and 3) the southern-most portion of SMA-2 (Anchor QEA 2019). The 2019 maintenance included placement of a 0.5- to 1-foot-thick layer of 3-inch minus quarry spalls in areas where filter material was exposed, overlain with 18- to 24-inch armor rock. A portion of the area immediately west of Pier 4 (0.05 acre) was further maintained in 2020 by placing additional 18-inch armor rock (Anchor QEA 2021). All cap maintenance areas were graded to blend into the shoreline. Recent visual inspections (2022) indicate that intertidal caps throughout SMA-1 and SMA-2 are stable.

3.3 Cap and EMNR Chemical and Biological Monitoring

Surface sediment chemical and biological monitoring was conducted within the two areas of the Bay where nearshore wood debris deposits were capped along the shoreline: 1) within SMA-1 northwest of Area 2 (Figure 3); and 2) within the former Pier 4 area of SMA-2. Sampling of these two areas occurred in September 2018 and September 2020 (Year 1 and 3 after completion of remedial construction, respectively; Anchor QEA 2019 and 2021).

Sediment monitoring in nearshore wood debris cap locations consisted of an initial phase of passive in situ monitoring of porewater H_2S concentrations with concurrent temperature, pH, and salinity sampling. During the 2018 monitoring (Anchor QEA 2019), two samples collected within the north basin of SMA-1 and three samples collected within the former Pier 4 area of SMA-2 marginally exceeded the 0.07 milligram per liter (mg/L) risk-based benchmark discussed in the OMMP (Anchor

QEA 2018a). These sediment samples were submitted for confirmatory bioassay analyses. All amphipod, larval, and juvenile polychaete bioassay tests met the biological effects criterion described in WAC 173-204-320(3), confirming the protectiveness of the nearshore wood debris capping remedy.

During the 2020 monitoring (Anchor QEA 2021), none of the surface (6-inch depth) or subsurface (24-inch depth) porewater H_2S sample concentrations exceeded the 0.07 mg/L risk-based benchmark discussed in the OMMP (Anchor QEA 2018a). One representative sediment sample from SMA-1, along with three representative samples from the SMA-2 Pier 4 cap area, were submitted for confirmatory bioassay analyses. All amphipod, larval, and juvenile polychaete bioassay tests again met the biological effects criterion described in WAC 173-204-320(3), further confirming the protectiveness of the nearshore wood debris capping remedy.

In addition to the nearshore wood debris deposit cap monitoring described above, surface sediment chemical and biological monitoring of SMA-1 and SMA-2 caps was conducted in September 2018 and September 2020 (Year 1 and 3 after completion of remedial construction, respectively; Anchor QEA 2019 and 2021). During each monitoring event, surface sediment samples at six sentinel cap monitoring stations in SMA-1 and SMA-2 were collected as four- to five-point composites and submitted for chemical analyses and larval bioassay tests. In addition, during each monitoring event, a representative surface sediment sample from the SMA-3 EMNR area was collected and submitted for larval bioassay analysis.

Composite samples from each of the six sentinel cap monitoring locations were analyzed for cPAHs, dioxins/furans, and cadmium. As discussed in the OMMP (Anchor QEA 2018a), the point of compliance for cPAH TEQ, dioxin/furan TEQ, and cadmium cleanup levels (Table 1) is the SWAC across all subtidal areas of the Bay over the 0- to¬ 10-cm depth interval. Overall, post-construction surface sediment chemical concentrations in SMA-1 and SMA-2 cap areas were lower than concentrations measured in SMA-5 (MNR areas), confirming the protectiveness of the capping remedy. SWACs have been updated and evaluated as part of this *Five-Year Review*, as discussed in Section 3.4.

All six 2018 post-construction surface sediment larval bioassay tests performed on the SMA-1 and SMA-2 cap areas, as well as the SMA-3 EMNR area sample, met the biological effects criterion described in WAC 173-204-320(3), confirming the protectiveness of the capping and EMNR remedies (Anchor QEA 2019). In addition, five of the six 2020 post-construction surface sediment larval bioassay tests performed on the SMA-1 and SMA-2 cap areas, as well as the SMA-3 EMNR area sample, again met the biological effects criterion (Anchor QEA 2021). While one 2020 larval bioassay test performed on a SMA-1 subtidal cap sample marginally exceeded the biological effects criterion (by only 1%), this sample contained low chemical concentrations and no visible organic materials. The weight-of-evidence suggests that the 2020 SMA-1 subtidal bioassay result likely represents a natural condition unrelated to Site releases, consistent with similar confounding larval bioassay results observed at other Puget Sound areas (Floyd|Snider et al. 2020). All information considered, the 2018 and 2020 monitoring data confirm the protectiveness of the capping and EMNR remedies.

3.4 Sediment Recovery Monitoring

In accordance with the OMMP (Anchor QEA 2018a), surface sediment recovery monitoring began approximately 3 years after completion of remedial construction as part of the 2020 monitoring event (Anchor QEA 2021). Surface sediments were sampled at 12 sentinel sediment monitoring locations throughout the Bay: eleven located in SMA-5; and one in SMA-3 (Figure 2). Sediment samples were collected from the 0- to 2-cm and 2- to 10-cm intervals, homogenized, and submitted for cPAH, dioxin/furan, and cadmium analyses. Composite samples were also concurrently collected at SMA-1 and SMA-2 sediment cap sentinel cap monitoring stations and analyzed for the same chemical parameters (Section 3.3).

As discussed in Sections 2.2 and 3.3, the surface sediment point of compliance for cPAH TEQ, dioxin/furan TEQ, and cadmium cleanup levels (Table 2) is the 0- to 10-cm depth SWAC over all subtidal areas of the Bay (730 acres, including all SMAs; Figure 2). Using the subtidal sentinel monitoring data, 2020 SWACs and standard errors are summarized in Table 2. SWACs and standard errors from earlier 2008 to 2011 RI/FS sampling (Ecology 2012) and 2014 pre-design investigation sampling (Anchor QEA 2018a) are also summarized in Table 2.

Table 2
Surface Sediment 0- to 10-cm SWAC Summary

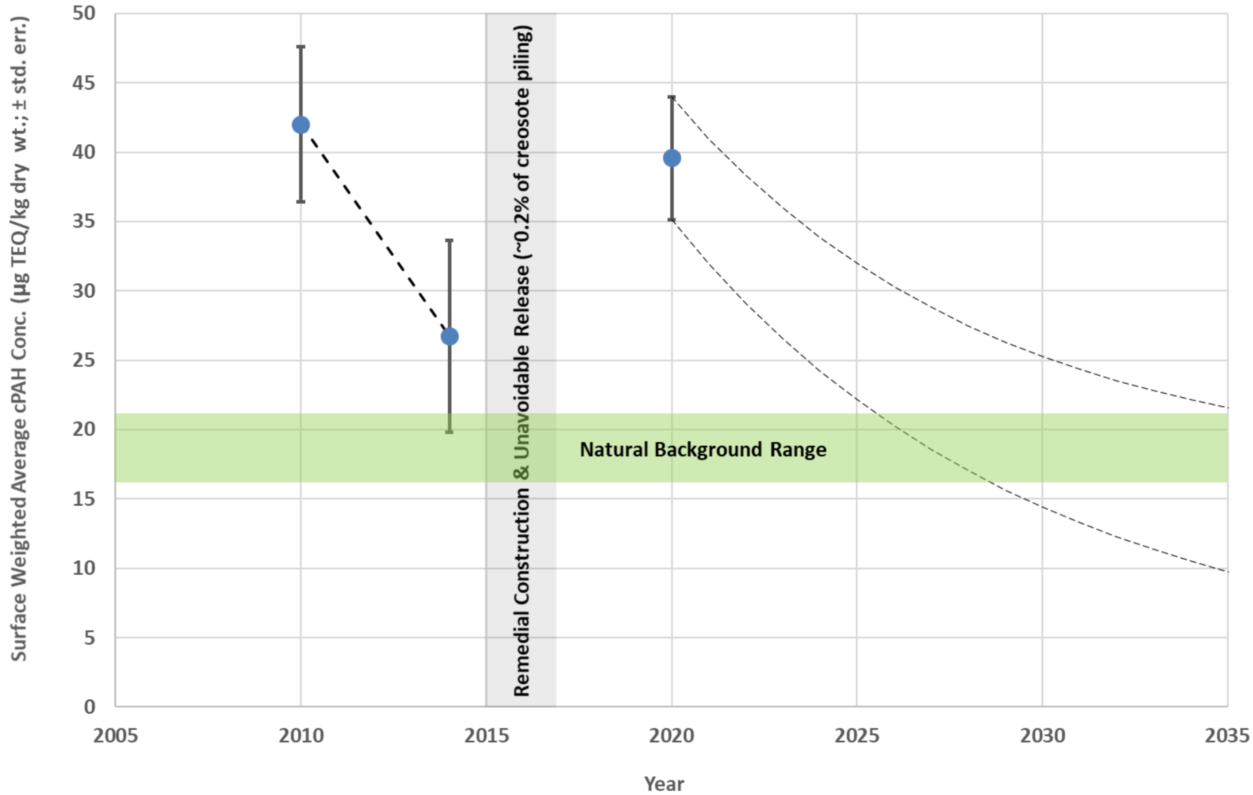
Parameter (units)	Cleanup Level	2008–2011 RI/FS SWAC[1]	2014 Pre-Design Investigation SWAC[1]	2020 Post-Construction SWAC[1]
cPAH TEQ (µg/kg)	16	42 ± 13	26 ± 7	40 ± 6
Dioxin/Furan TEQ (ng/kg)	5.0	3.0 ± 1.1	4.6 ± 0.6	4.3 ± 0.9
Cadmium (mg/kg)	3.0	1.4 ± 0.3	1.8 ± 0.4	1.2 ± 0.3

Notes:
1. SWAC ± standard error over all subtidal areas of the Site (730 acres).

The 2020 SWACs for dioxin/furan TEQ and cadmium have remained below cleanup levels, consistent with earlier RI/FS and pre-design investigation data, confirming the protectiveness of the remedy for these parameters (Table 2). However, the 2020 cPAH TEQ SWAC (40 ± 6 µg/kg) was significantly greater than the 2014 SWAC (26 ± 7 µg/kg TEQ), and approximately 2.5 times higher than the 16 µg/kg TEQ natural background cleanup standard set forth in the CAP (Ecology 2013). The measured

2020 cPAH TEQ SWAC was approximately 21 ± 7 µg/kg higher than pre-design modeling projections (Figure 4; Anchor QEA 2018a). As explained below, this increase is reasonably attributable to small and unavoidable cPAH releases from piling removal operations. Moreover, as detailed in Section 3.5, shellfish tissue cPAH concentrations have nevertheless been reduced to natural background levels.

Figure 4
Observed and Projected Surface Sediment cPAH TEQ SWAC Recovery



The lowest surface sediment cPAH TEQ levels measured in 2020 were in SMA-1 and SMA-2 cap areas, averaging 14 ± 3 µg/kg in 2020 (Anchor QEA 2021). These data further verify that the SMA-1 and SMA-2 remedy is protective, and that ongoing sources of cPAHs from the former Mill have been controlled. However, compared with 2014 concentrations, surface sediment cPAH TEQ levels were elevated throughout SMA-3 and SMA-5, particularly in the 0- to 2-cm surface interval. These monitoring data are consistent with a cPAH release during remedial construction.

The OMMP modeling projections accounted for anticipated sediment dredging residuals consistent with current industry understanding (e.g., an unavoidable release of 2% to 10% of the dredged cPAH TEQ mass; Anchor QEA 2018a). However, the OMMP projections did not address cPAH TEQ release from creosote piling removal, as release estimates from piling removal have not been previously reported in the scientific literature.

As discussed in Anchor QEA (2021), using literature data on creosote pile dimensions, density, and cPAH concentrations, pulling 8,592 decayed piling during the 2015 to 2017 cleanup, nearly all of which were creosote treated (99.9% of the piling were also successfully pulled without breaking; Section 2.6), removed approximately 1,600 kilograms of cPAH TEQ from the Bay. In comparison, the measured Bay-wide surface sediment cPAH TEQ increase of approximately 21 ± 7 µg/kg (compared to OMMP model projections; Anchor QEA 2018a) equates to a calculated cPAH TEQ mass increase of approximately 4 ± 1 kilograms. Thus, release of only 0.2% (4 ÷ 1,600) of the creosote pile cPAH TEQ mass removed would account for the observed increase in the 2020 SWAC (Table 2; Figure 4). Based on these calculations, the surface sediment cPAH TEQ increase measured in the Bay in 2020 is reasonably attributable to small and unavoidable cPAH releases from piling removal operations.

Using the same recovery modeling approach described in the OMMP (Anchor QEA 2018a), projected declines in the cPAH TEQ SWAC moving forward are summarized in Figure 4. Because observed recovery of cPAH TEQ between 2008/2011 and 2014 declined faster than model projections, it is likely that cPAH recovery moving forward may also occur more rapidly than the conservative OMMP model projections depicted in Figure 4. Based on the overall weight-of-evidence, the Bay-wide surface sediment cPAH TEQ SWAC appears on track to recover to natural background concentrations. Bay-wide natural recovery monitoring to verify the surface sediment cPAH TEQ SWAC recovery trend is scheduled for 2026 (Section 7.1).

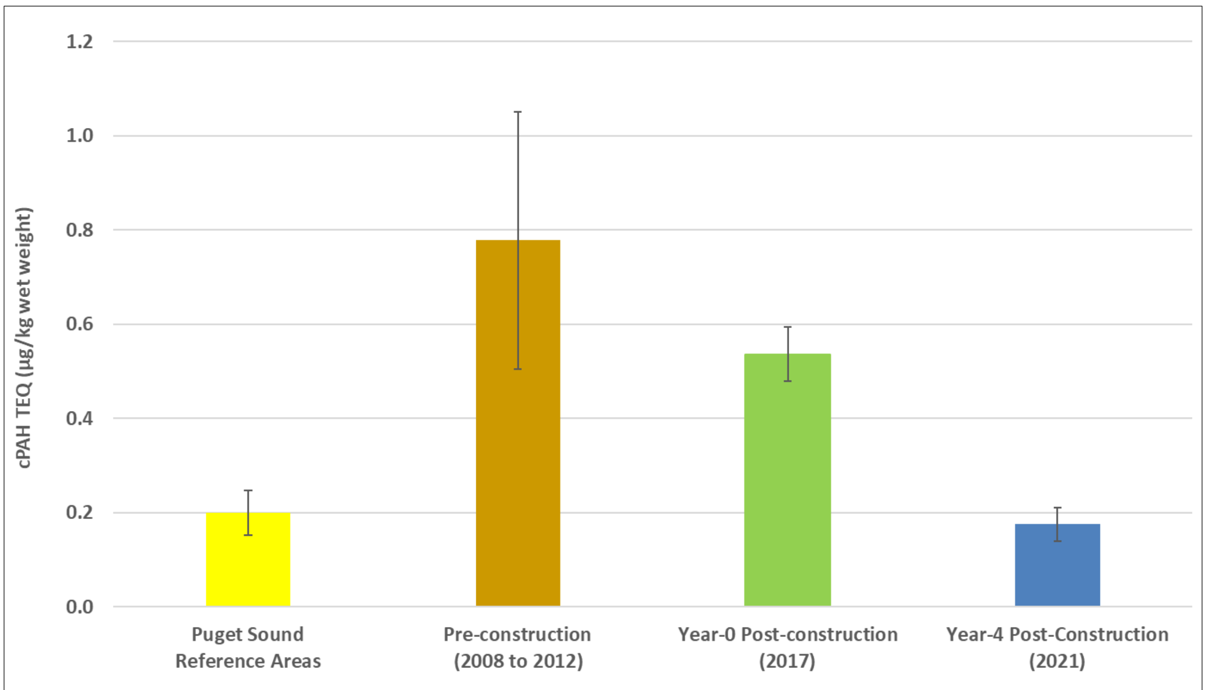
3.5 Shellfish Tissue Recovery Monitoring

As summarized in Section 2.2, the objective of cPAH cleanup (source control and sediment remediation) actions set forth in the CAP (Ecology 2013) was to "*eliminate, reduce, or otherwise control, to the extent practicable, Bay-wide human health risks from ingestion of seafood containing cPAH TEQ, along with dioxin/furan TEQ and cadmium, exceeding natural background concentrations.*" The RI/FS (Ecology 2012) and CAP hypothesized that reducing the subtidal surface sediment SWACs of these parameters to natural background levels would likely reduce site-wide tissue ingestion exposures to background levels, though no quantitative site-specific evaluation was performed for the RI/FS or CAP (no site-specific biota-sediment accumulation factor was developed; Ecology 2021).

Baseline (pre-construction) in situ shellfish tissue monitoring of target species was performed by PGST between 2008 and 2012 (Ecology 2012) at the four primary SMA-5 tissue sampling locations depicted in Figure 2 (three intertidal and one subtidal [SMA-3]). PGST resampled these same locations and species in 2017 to provide an updated characterization of in situ shellfish tissue concentrations in the Bay shortly after completion of construction (Anchor QEA and PGST 2017). Shellfish tissue samples were analyzed for cPAHs, dioxins/furans, cadmium, and polychlorinated biphenyls. Tissue concentrations of all these parameters were equivalent to or lower than baseline concentrations.

Given the surface sediment recovery monitoring data summarized in Section 3.4, and to help further determine whether human health cPAH risk reduction objectives set forth in CAP (Ecology 2013) have been achieved, PGST again resampled the same in situ shellfish tissue monitoring locations and species in 2021, four years after completion of construction (Anchor QEA and PGST 2022). Tissue samples were analyzed for cPAHs and lipids. Tissue cPAH TEQ levels measured in 2021 were consistent across the four sampling areas and were correlated with lipid content consistent with equilibrium partitioning, indicating similar cPAH exposure across the shellfish tissue sampling locations. As summarized in Figure 5, shellfish tissue cPAH TEQ levels measured in 2021 were significantly lower than 2017 post-construction concentrations, continuing the decline from earlier baseline (2008 to 2012) levels.

Figure 5
Pre- and Post-Construction Port Gamble Bay Shellfish Tissue cPAH TEQ Levels



Note: Charts depict average concentrations with standard errors

µg/kg: microgram per kilogram
cPAH: carcinogenic polycyclic aromatic hydrocarbon
TEQ: toxicity equivalence

The monitoring data summarized above reveal that shellfish tissue cPAH TEQ levels in the Bay (Figure 5) recovered more rapidly than subtidal surface sediments (Figure 4). This observation is consistent with shellfish tissue cPAH uptake occurring predominantly from water column exposure, which was successfully curtailed by source control and remedial actions.

In addition to assessing temporal trends, shellfish tissue monitoring data were also compared to Puget Sound reference levels to provide further context for data comparisons. As discussed in Anchor QEA and PGST (2017 and 2022), data sources compiled for the reference comparison included the following (Table 3):

- Natural background shellfish tissue concentrations compiled and evaluated in the Bay RI/FS (Ecology 2012)
- More recent data collected from the Penn Cove shellfish protection and harvest district (WDFW 2015; Anchor QEA 2018b)[3]

Table 3
cPAH TEQ Levels in Bivalve Tissues Collected from Puget Sound Reference Areas

Species	Tissue Type	Location	Year	Individuals Per Composite	Sample Detection Frequency	cPAH TEQ (µg/kg wet weight)			Source
						Mean	Minimum	Maximum	
Butter clam	soft parts	Padilla/Fidalgo Bay	1999	50	0/1	*0.85 U*	*0.85 U*	*0.85 U*	Ecology (2000)
Littleneck clam	soft parts	Padilla/Fidalgo Bay	1999	50	0/1	*0.88 U*	*0.88 U*	*0.88 U*	Ecology (2000)
Bay mussel	soft parts	Padilla/Fidalgo Bay	1999	50	0/1	*0.86 U*	*0.86 U*	*0.86 U*	Ecology (2000)
Geoduck	soft parts	Dungeness Bay	2002	1	1/3	0.13	0.11 U	0.17	Malcolm Pirnie (2007)
Geoduck	soft parts	Freshwater Bay	2002	1	1/3	0.12	0.11 U	0.14	Malcolm Pirnie (2007)
Littleneck clam	soft parts	Salsbury Point	2003	10-20	0/2	0.11 U	0.11 U	0.11 U	Parametrix (2003)
Geoduck	soft parts	Dungeness Bay	2008	2	1/1	0.07	0.07	0.07	E & E (2012)
Bay mussel	soft parts	Penn Cove	2014	96	1/1	0.41	0.41	0.41	WDFW (2015)
Blue mussel	soft parts	Penn Cove	2015	32	1/1	0.47	0.47	0.47	Anchor QEA (2018b)
Blue mussel	soft parts	Penn Cove	2016	32	2/2	0.44	0.37	0.50	Anchor QEA (2018b)

Notes:
U denotes that cPAHs were not detected above the indicated method detection limit.
Italicized values denote elevated detection limits; these values were not used for Puget Sound reference area levels (Figure 5).

Current (2021) shellfish tissue cPAH TEQ concentrations in the Bay have been protectively reduced to Puget Sound reference levels (Figure 5) and are now consistent with natural background tissue concentrations presented in the Bay RI/FS (Ecology 2012).

As discussed in Ecology (2021), tissue chemistry may potentially be used to evaluate compliance with SMS human health-based sediment cleanup standards (WAC 173-204-560[7]). As summarized above, the overall weight-of-evidence of the monitoring data suggests that human health risk reductions are on track to achieve objectives set forth in CAP (Ecology 2013) . Confirmatory in situ shellfish cPAH recovery monitoring is scheduled for 2026, using the same procedures as the 2021 sampling (Anchor QEA and PGST 2021; Section 7.1).

[3] Mussels harvested from relatively pristine Penn Cove commercial shellfish tracts were used in pre- and during-construction caged mussel deployments in the Bay; tissue chemical analyses defined baseline (time zero) conditions for the deployments and are also suitable for characterization of natural background tissue concentrations.

4 New Scientific Information

Since the CAP (Ecology 2013) was issued, two new scientific developments have occurred that influence the Bay cleanup remedy protectiveness evaluation:

- Updated cPAH toxicological reviews
- Updated cPAH sediment natural background concentration

Each of these developments are summarized below.

4.1 Updated cPAH Toxicological Reviews

In 2017, the U.S. Environmental Protection Agency (EPA) released an updated *Toxicological Review of Benzo(a)pyrene* (EPA 2017). The toxicological review was prepared under the auspices of EPA's Integrated Risk Information System program recognized under MTCA and SMS. EPA developed a revised oral cancer slope factor for benzo(a)pyrene based on a review of publicly available studies, superseding previous sources of toxicity information for conducting human health risk assessments. The EPA toxicological review modified the oral cancer slope factor for benzo(a)pyrene and other cPAHs from 7.3 to 1.0 milligram per kilogram per day. This change means that exposure to cPAHs is approximately seven times less toxic than assumed in the CAP (Ecology 2013).

EPA has also recently determined that benzo(a)pyrene is mutagenic—or causes cancer through induction of increased mutations—and that exposure during early life stages has a greater potential to cause cancers. To address this concern, EPA and Ecology currently recommend using age-dependent adjustment factors for calculating the risk of excess cancers for benzo(a)pyrene, which are applied to the TEQ derived for the group of cPAHs. The equations for this adjustment under SMS are provided in Ecology (2021). Overall, the combination of the revised oral cancer slope factor and early life stage exposure adjustment results in calculated cPAH cancer risks at natural background concentrations (the human health cleanup objective; Section 2.2) that are roughly 3-fold lower than assumed in the CAP (Ecology 2013).

4.2 Updated cPAH Sediment Natural Background Concentration

Ecology (2021) has also updated the Puget Sound natural background sediment cPAH TEQ concentration to 21 μg/kg, slightly higher than the 16 μg/kg cleanup level set forth in the CAP (Table 1; Ecology 2013; both values are depicted as the natural background range in Figure 4).

Taken together, the revised oral cancer slope factor, early life stage exposure adjustment, and updated natural background levels for cPAHs indicate that the Bay cleanup is providing a significantly greater degree of human health protection compared to what would be required using new scientific information.

5 Shoreline Habitat Restoration

Building on the success of the Bay cleanup, habitat restoration projects are currently being designed by Rayonier and PGST for portions of the Bay to restore shoreline processes and enhance habitat for benthos, forage fish, shellfish, and juvenile salmonids. Restoration construction is currently scheduled to begin in 2023. Within the southern Mill shoreline area, planned restoration actions include laying back intertidal slopes over approximately 1,450 lineal feet as depicted in Figure 6. Slopes would achieve smooth tie-ins with adjacent grades to optimize both habitat functions and protection, including additional dioxin/furan removal along the shoreline (see Figure 7). The intertidal cap and habitat layers would be constructed in three layers totaling approximately 3 feet thick, as follows:

- Lower angular cobble-sized armor (1 foot thick)
- Middle rounded cobble/gravel beach substrate (1 foot thick)
- Upper sand/gravel habitat substrate (1 foot thick)

The basis for cap and habitat substrate designs in the southern Mill shoreline area is described in the following paragraphs.

The Ecology-approved remedial design (Anchor QEA 2015) describes how habitat restoration at the former Mill modifies cleanup requirements. For example, laying back the upper intertidal zone of the former Mill reduces the size of required cap armor materials, but the restored slope will still need capping to ensure long-term protectiveness. Consistent with Bay cleanup requirements, the lower portion of the 2-foot-thick intertidal cap required by the 2013 Consent Decree would consist of a 1-foot-thick layer of salvaged armor rock and imported angular cobble-sized materials with a maximum size of approximately 12 inches (Figure 7).

Although angular cap materials provide greater resistance to wave forces and are preferred for protectiveness, rounded materials are preferred for habitat substrate functions and are more suitable for restoration. The remedial design (Anchor QEA 2015) projected that natural beach profile changes of rounded substrate will occur within the surf zone during peak storm events. For example, during 20-year event wave conditions, rounded gravel-sized materials placed on a restored slope were projected to locally move up and down the slope, developing profiles with troughs extending above and below the post-construction surface grade. Balancing cap protection and habitat objectives, the upper portion of the 2-foot cap layer required by the 2013 Consent Decree (and the middle layer of the combined cap/habitat substrate) would consist of a 1-foot-thick layer of rounded cobble/gravel beach substrate with a median diameter of approximately 2 to 3 inches (Figure 7).

Though cap designs must remain protective under peak wave conditions, restored beach habitat functions are determined by median wave conditions and associated sediment transport patterns.

Figure 6
Southern Mill Site Shoreline Restoration Plan

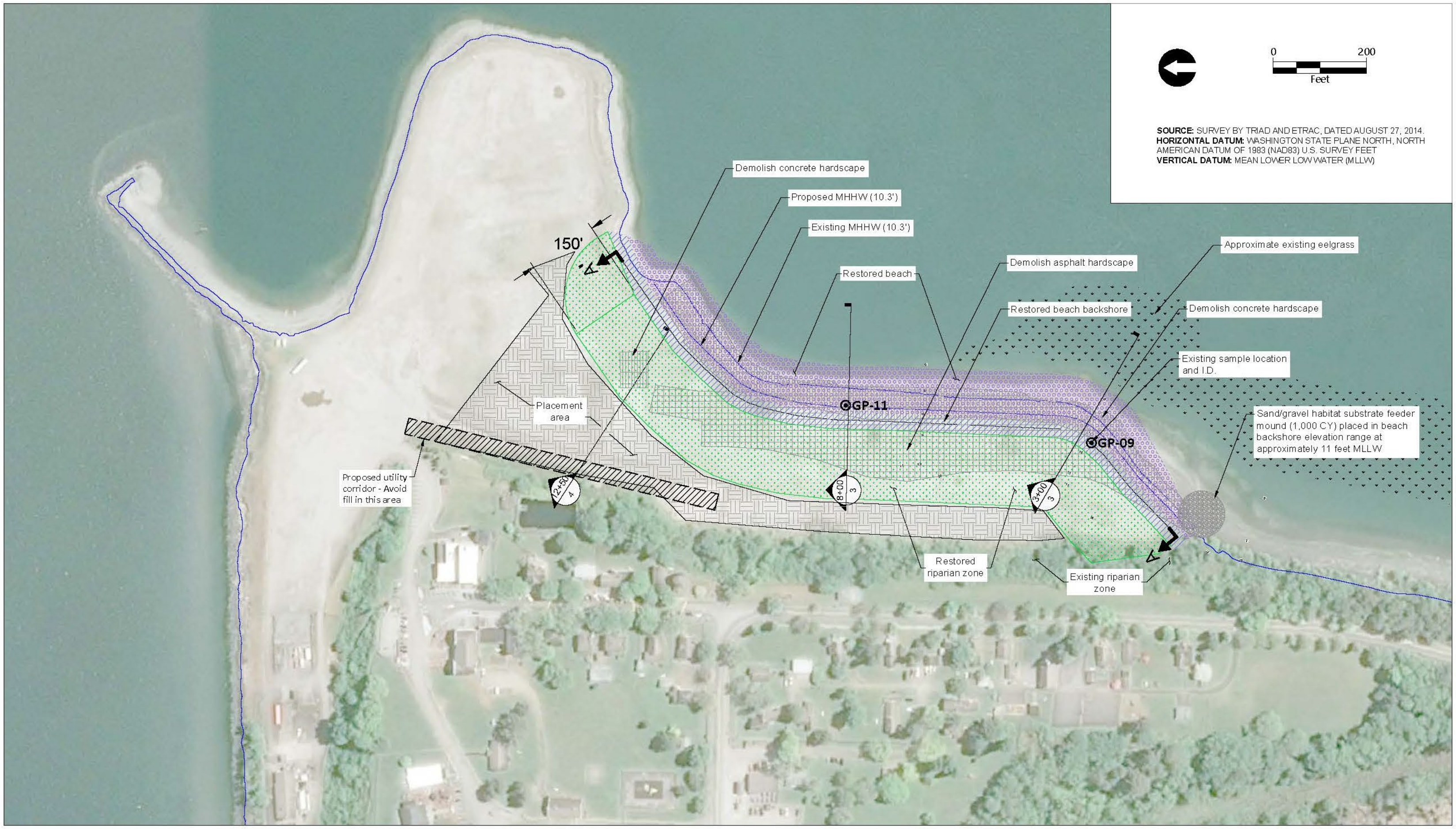
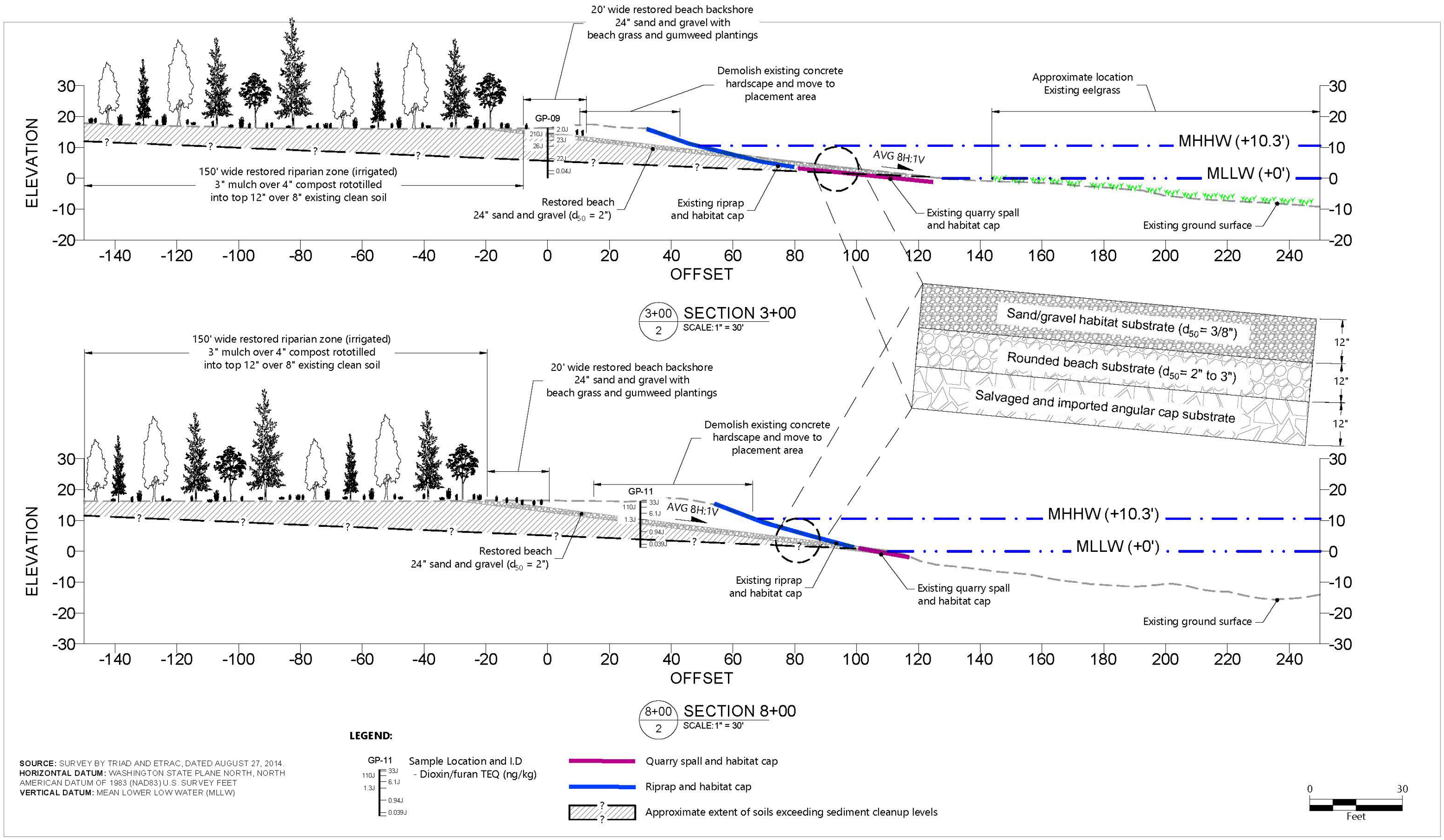


Figure 7
Southern Mill Site Shoreline Restoration Cross Sections



The remedial design (Anchor QEA 2015) includes an evaluation of net littoral drift rates into the southern Mill shoreline areas, defined as the annual net volume of sediment that moves along the beach. Littoral drift (also called longshore transport) occurs in the surf and swash zones for gravel or mixed sand/gravel beaches and is caused by breaking waves. The amount of littoral drift is dependent on wave height, wave period, beach slope, sediment size and gradation, and the angle of approach of the waves in relation to shoreline orientation. It is also related to sediment supply and downdrift characteristics. The southern Mill shoreline area receives sediment input from approximately 0.6 mile of shorelines to the south with relatively steep slopes or weak bank material, along with three streams that empty into the western shoreline of the Bay. These natural inputs nourish the southern Mill shoreline. The remedial design estimated that approximately 300 cy per year of sediment is transported through littoral drift into the southern Mill shoreline area.

Post-construction cap monitoring (see Section 3.2) included characterization of materials that have accreted on the surface of the SMA-2 cap. These data reveal that local littoral drift materials entering the southern Mill shoreline area are a mixture of sand, gravel, and silt with a median diameter of approximately 0.05 inch (medium sand). Under typical wave conditions, these littoral drift materials settle onto and mix into the rounded cobble/gravel beach substrate layer, improving and sustaining shoreline processes and habitat functions. Since completion of cleanup construction in early 2017, littoral drift materials have steadily deposited on top of angular caps placed in lower intertidal areas of the southern Mill shoreline, restoring beach habitat and functions (Anchor QEA 2021). Moreover, oyster populations have been concurrently expanding into these cap areas, providing further evidence of improving habitat functions that also help to stabilize the enhanced and restored beach and improve overall water quality conditions.

To further restore shoreline processes and enhance habitat for forage fish, shellfish, and juvenile salmonids along the southern Mill shoreline, the rounded cobble/gravel beach substrate described in the previous paragraphs would be overlaid with a 1-foot-thick surface layer of sand/gravel habitat substrate (median diameter of approximately 0.3 inch; Figure 7). The 1-foot-thick habitat substrate layer would support resident shellfish species including cockles, littleneck clams, manila clams, mussels, and oysters. A 1,000-cy habitat feeder berm (approximately 3 years of littoral drift supply, conservatively assuming no new incoming sources) with a similar grain-size distribution would also be placed at the southern end of the former Mill shoreline in the beach backshore to further ensure that shoreline processes and habitat functions are sustained (Figure 6).

Habitat restoration actions in the southern Mill shoreline area (Figure 6), as well as benthic and eelgrass restoration along the western shoreline, would be permitted by the U.S. Army Corps of Engineers through a Nationwide Permit 27 – Aquatic Habitat Restoration, Enhancement, and Establishment Activities. Ecology coordination would occur throughout the design and permitting process.

6 Other Considerations

As discussed in the CAP (Ecology 2013), other considerations that influence the Bay cleanup remedy protectiveness evaluation include the following:

- Current applicable state and federal laws
- Current and projected future uses in the Bay
- Practicability of more permanent remedies
- Improved analytical methods

Each of these considerations are summarized below.

6.1 Current Applicable State and Federal Laws

Cleanup levels for the Bay (Table 1) were developed by Ecology considering applicable state and federal laws that were current at the time of the CAP (Ecology 2013). Since the remedial action was completed, the SMS regulation and implementation guidance have been updated (Ecology 2021). As discussed in Section 4, these regulatory changes reveal that the Bay cleanup is providing a significantly greater degree of protection compared with what would be required using current regulations.

6.2 Current and Projected Future Uses in the Bay

Besides the habitat restoration projects summarized and addressed in Section 5, there are no other changes to current or projected future uses in the Bay.

6.3 Practicability of More Permanent Remedies

The Bay cleanup remedy included containment of hazardous substances in portions of the Bay, which continues to be protective of human health and the environment. While higher preference cleanup technologies such as further removal are available, they are not practicable at the Bay due to cost considerations, along with the potential for hazardous substances to be released into the Bay during removal actions, as described in the CAP (Ecology 2013).

6.4 Improved Analytical Methods

The analytical methods used at the time of remedial design and remedial action were capable of detection below cleanup levels for hazardous substances in the Bay. The presence of improved analytical techniques does not affect decisions or recommendations for the Bay cleanup.

7 Conclusions

Based on this *Five-Year Review*, Ecology has determined that the Bay cleanup remedy appears on track to achieve cleanup objectives set forth in the CAP (Ecology 2013). Ecology will publish a notice of this *Five-Year Review* in the site register and will provide an opportunity for review and comment by the public.

7.1 Future Monitoring and Maintenance

In 2026, Rayonier will perform additional physical integrity monitoring of the SMA-1 and SMA-2 caps consistent with the OMMP (Section 3.2; Anchor QEA 2018a). Additional physical monitoring of the caps may be triggered by specific storm or seismic events (e.g., a wind event with a recurrence interval of 20 years or more, or a seismic event greater than a magnitude of 5.5), as described in the OMMP. The need for and scope of additional long-term cap monitoring and maintenance will continue to be developed as a collaborative effort between Ecology and Rayonier.

In 2026, Rayonier will perform additional Bay-wide (all SMAs) surface sediment natural recovery monitoring to verify the cPAH TEQ SWAC recovery trend following OMMP methods (Figure 4; Anchor QEA 2018a). In 2026, Rayonier will also perform additional confirmatory in situ shellfish cPAH recovery monitoring following the 2021 sampling plan (Figure 5; Anchor QEA and PGST 2021).

7.2 Next Review

The next review of the Bay cleanup is scheduled for 2027, corresponding to the year that Bay-wide cleanup objectives are targeted to be achieved (Section 2.2).

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