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ECSI No. 1138
May 18, 2023
Former Portland Gas Manufacturing Site

ANCHOR QEA

Year 2 Monitoring Report: PGM Long-Term Monitoring and Maintenance

Prepared for NW Natural

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ABBREVIATIONS

µg/L	micrograms per liter
µs/cm	microsiemens per centimeter
ASTM	ASTM International
BTEX	benzene, toluene, ethylbenzene, and xylene
$CaCO_3$	calcium carbonate
cm/year	centimeter per year
CMA	Coastal Monitoring Associates
COC	contaminant of concern
cPAH	carcinogenic polycyclic aromatic hydrocarbon
CUL	cleanup level
DEQ	Oregon Department of Environmental Quality
DOC	depth of contamination
EMNR	enhanced monitored natural recovery
EPA	U.S. Environmental Protection Agency
GAC	granular activated carbon
LCS/LCSD	laboratory control sample/laboratory control sample duplicate
LTMMP	*Long-Term Monitoring and Maintenance Plan*
mg/kg	milligrams per kilogram
mg/L	milligrams per liter
MNR	monitored natural recovery
MS/MSD	matrix spike/matrix spike duplicate
mV	millivolt
NWTPH-Dx	Northwest Total Petroleum Hydrocarbons diesel range
OAR	Oregon Administrative Rule
ORP	oxidation-reduction potential
PAH	polycyclic aromatic hydrocarbon
PGM	Portland Gas Manufacturing
PSEP	Puget Sound Estuarine Protocol
RA	remedial action
ROD	Record of Decision
SDU	Sediment Decision Unit
SM	Standard Method
SW	surface water
TOC	total organic carbon
TPH	total petroleum hydrocarbons
TSS	total suspended solids
TZW	transition zone water
Year 2 Addendum	*Long-Term Monitoring and Maintenance Plan, Year 2 Addendum*

1 Introduction

The former Portland Gas Manufacturing (PGM) site is located along the west bank of the Willamette River in downtown Portland near river mile 12.2 (Figure 1). The Oregon Department of Environmental Quality (DEQ) issued a Record of Decision (ROD) for the PGM site on July 3, 2017 (DEQ 2017). NW Natural and its contractors, Sevenson Environmental Services, Inc., and Anchor QEA, LLC, completed the sediment remedial action (RA) in July through October 2020 under DEQ oversight, as described in the *Project Completion Report* (Anchor QEA 2021a). There were two primary objectives of the RA: 1) to directly address in-water contamination and reduce risks to aquatic life and humans from exposure to contaminated sediments and porewater; and 2) to provide source control for contaminants in groundwater discharging to sediments and porewater. The contaminants of concern (COCs) in site sediments from historical manufactured gas plant operations and other potential sources are polycyclic aromatic hydrocarbons (PAHs); total petroleum hydrocarbons (TPH); benzene, toluene, ethylbenzene, and xylene (BTEX); free cyanide; and three metals (lead, mercury, and zinc).

Remedial construction was performed pursuant to the PGM Consent Judgment in Multnomah County Circuit Court Case No. 20CV15456 between the State of Oregon and NW Natural, and associated Statement of Work, dated April 15, 2020, and entered in court on May 6, 2020. Long-term monitoring and maintenance of the remedy, including the collection and analysis of Year 2 monitoring results described in this report, are also being performed under the Consent Judgment.

The *Long-Term Monitoring and Maintenance Plan* (LTMMP; Anchor QEA 2020, Appendix F) was prepared as part of the remedial design documents to define the requirements and evaluation criteria for the post-construction long-term monitoring program. The baseline condition following RA completion is described in the *Year 0 Monitoring Report* (Anchor QEA 2021b). The *Long-Term Monitoring and Maintenance Plan, Year 2 Addendum* (Year 2 Addendum; Anchor QEA 2022) describes recommended modifications to the Year 2 monitoring activities, including additional sampling and analysis of sediment, surface water (SW), transition zone water (TZW), and porewater, and was approved by DEQ on June 22, 2022. The sampling and analysis modifications are based on observed physical changes in bathymetric conditions relative to the post-construction baseline condition in some localized cover areas. Although a majority of the PGM site is stable and depositional, there has been some redistribution and downstream transport of material resulting in a loss of elevation in a few particular cover areas. Areas where the cover thickness is less than the minimum 12-inch placement specification were targeted for more detailed Year 2 sampling and analysis, as described in this *Year 2 Monitoring Report*.

1.1 PGM Cleanup Levels

PGM cleanup levels (CULs) for sediment, TZW, and SW are listed in Table 1. CULs serve as long-term numeric performance criteria for remedy effectiveness and are briefly described in this section.

Sediment Cleanup Levels: CULs for benthic organisms are evaluated on a point-by-point basis, whereas CULs for bioaccumulation-based criteria are evaluated on a site-wide basis using site-wide average concentrations, which is consistent with the spatially averaged nature of bioaccumulation-based exposures.

TZW and SW Cleanup Levels: CULs for aquatic life are evaluated on a point-by-point basis in TZW and SW. Aquatic life criteria for lead and zinc are based on the dissolved fraction and an assumed hardness of 25 milligrams per liter (mg/L). CULs for bioaccumulation-based criteria (the most conservative being human health fish consumption criteria) are evaluated on a site-wide basis using site-wide average concentrations in SW, which is consistent with the spatially averaged nature of bioaccumulation-based exposures.

1.2 Summary of Remedial Construction Activities

The PGM cleanup area is divided into 11 Sediment Decision Units (SDUs), designated SDUs A through H, as shown in Figure 2. The selected remedy included a combination of dredging, reactive capping (in situ treatment with granular activated carbon [GAC]), cap armoring where needed for erosion protection, enhanced monitored natural recovery (EMNR), monitored natural recovery (MNR), residuals cover placement, institutional controls, and long-term monitoring and maintenance of the remedy (DEQ 2017).

The remedial technologies applied to each SDU were as follows:

Remedial Technology	SDU	Dredging	Cap and Cover Placement
MNR	B1, F2	No active construction	No active construction
EMNR	B2	None	Minimum 12 inches gravelly sand cover
EMNR	C3, F1	None	Minimum 12 inches sand cover
GAC-Amended Treatment	A, D	Stabilize dredging side slope (SDU A only)	Minimum 12 inches GAC-amended, gravelly sand (SDU A), or sand (SDU D) cover
Partial Dredge/ Armored Treatment Cap	C1	Maintenance of berthing depth	Minimum 12 inches GAC-amended, gravelly sand cap plus minimum 12 inches protective armor stone
Hot Spot Dredge/ Armored Treatment Cap	E	Hot spot removal	Minimum 12 inches GAC-amended, gravelly sand cap plus minimum 12 inches protective armor stone
Full Dredge and Residual Cover	G	Full removal of contamination	Minimum 6 inches sand cover

Remedial Technology	SDU	Dredging	Cap and Cover Placement
Residual Cover	H	Stabilize dredging side slopes	Minimum 6 inches sand cover

RA activities, including detailed descriptions of dredging, debris removal, cap and cover placement operations, and construction monitoring activities are described in greater detail in the *Project Completion Report* (Anchor QEA 2021a).

2 Year 2 Hydrology and Bathymetry

This section describes the Year 2 hydrologic conditions in the Willamette River and riverbed elevations and morphologies as determined by two sequential multibeam bathymetry surveys in April and June 2022.

2.1 Hydrologic Conditions in the Willamette River

Hydrologic time series of gage height, discharge, and water velocity in the Willamette River from January through July 2022 are presented in Figure 3, as measured at the U.S. Geological Survey river gage at the Morrison Bridge (Gage #14211720) at river mile 12.8, approximately 0.6 mile upstream from PGM. The datum for the Morrison Bridge gage is 2.93 feet higher than the City of Portland datum (PGM project datum). These time series are provided to characterize the hydrologic conditions during the Year 2 surveying and sampling activities.

The Willamette River is normally characterized by high water levels and currents in late spring and early summer in response to the seasonal snowmelt from the Cascade Mountains. This year, the water levels and currents in the river were exacerbated by unusually high rainfall during the spring months. The June 14, 2022, bathymetry survey was conducted near the peak seasonal water level and corresponding peaks in river discharge and velocity (Figure 3). SW and TZW sampling via Trident probes occurred slightly later in June, when water levels remained high and currents were declining but still moderately strong and unidirectional (i.e., without tidal reversals). During sediment grab sampling in early July, water levels and currents had declined significantly and the summer pattern of low water levels and more pronounced tidal fluctuations (i.e., periodic flow reversals) had begun to develop.

2.2 Year 2 Bathymetry Surveys

In October 2020 (Year 0; Anchor QEA 2020), July 2021 (Year 1; Anchor QEA 2021c) and April and June 2022 (Year 2; this report), the post-remediation physical condition of the PGM sediment cleanup site was assessed using high-resolution multibeam bathymetry. The Year 2 bathymetry surveys (April 12 and June 14, 2022) are presented in Figures 4a and 4b, respectively. To better characterize how riverbed elevations and morphologies have changed over time during the monitoring period, and in particular, the extent to which cap and cover areas may have accreted or eroded after the completion of the RA, the following graphics were prepared:

- **Figure 5a, 2020 vs. 2021 Bathymetry Comparison:** Isopach map showing changes in riverbed elevation between the Year 0 and Year 1 surveys (first year post-construction)
- **Figure 5b, 2021 vs. June 2022 Bathymetry Comparison:** Isopach map showing changes in riverbed elevation between the Year 1 and Year 2 surveys (second year post-construction)

- **Figure 5c, 2020 vs. June 2022 Bathymetry Comparison:** Isopach map showing changes in riverbed elevation between the Year 0 and Year 2 surveys (first 2 years post-construction)
- **Figure 6, 2020 vs. June 2022 Bathymetry Grid Comparison:** Isopach map showing changes in riverbed elevation between the Year 0 and Year 2 surveys, locally averaged using the pre-established PGM compliance grid (approximately 10-foot by 10-foot grids on flat areas and 3-foot by 3-foot grids on sloped areas)
- **Figures 7a and 7b, 2020 vs. June 2022 Bathymetry Comparison Cross Sections:** Longitudinal and transverse cross sections through the site showing the pre-construction riverbed elevation, extents and thicknesses of placed caps and covers, and areas of post-construction accretion or erosion; cross-section locations shown in Figure 5c
- **Figures 8a, 8b, 8c, and 8d, Detailed Cross Sections of Subsurface Contamination:** Detailed cross sections showing the distribution of subsurface contamination in areas where erosion of sediment or cover material has been observed (SDUs B1, C3, D, and F1), current and historical sediment samples and sampling depths, maximum exceedance ratios, and COCs associated with the maximum exceedance ratios
- **Figure 9, June 2022 Cap, Cover, and Infill Thickness:** Isopach map of cap and cover thickness, plus any infill sedimentation on top of the caps and covers; this surface was prepared by comparing the June 2022 bathymetry to the 2020 pre-cap surface, which includes post-dredge and post-debris removal surfaces in removal areas combined with the pre-construction surface in non-removal areas (i.e., areas of cap or cover on grade)

A preliminary bathymetric condition survey was performed on April 12, 2022, and a follow-up bathymetric survey was performed on June 14, 2022, immediately after Rose Festival Fleet Week and immediately prior to the Year 2 field sampling activities (Figure 4b). There were negligible changes in bathymetric elevations between the April and June surveys (i.e., elevation differences were less than 0.5 foot and within the accuracy of the surveys), except for a relatively small scour hole that developed in a downstream MNR area (SDU B1), which was apparently caused by propwash during Navy vessel docking or undocking during Fleet Week.

Average bathymetric elevation changes on an SDU-specific and site-wide basis are presented in Table 2. This table also provides the estimated thickness of cap and cover material remaining at the site as of the June 2022 bathymetry survey, plus any subsequent riverine deposition (i.e., infill sediment). The estimated accuracy of the bathymetric surveys is 0.5 foot, consistent with the assumption used in the Portland Harbor Feasibility Study (EPA 2016, pp. 3–14).

SDUs showing net deposition greater than the estimated survey accuracy are shaded in green (SDUs C1 and E), and SDUs showing net erosion greater than the estimated survey accuracy are shaded in orange (SDUs D, C3, and F1). (Note, although SDU G also shows measurable erosion, the full depth of contaminated sediment was dredged from SDU G during the remedial action, such that the “leave” surface was not impacted.) SDU F1 was the only area that showed measurable erosion in both Year 1 and Year 2 (i.e., year-over-year erosion). In all other SDUs, the measured bathymetric differences in Year 2 were less than the bathymetric survey accuracy, indicating relative site stability during Year 2.

Post-remediation bathymetric survey results are summarized as follows (refer to Figures 5a, 5b, 5c, 6, 7a, 7b, and 8, and Table 2, as appropriate):

- **Armored GAC-Amended Caps:** The armored, GAC-amended caps in SDU C1 and SDU E remained stable throughout the post-remediation survey period, with average combined cap plus infill thicknesses of 3.7 and 3.1 feet, respectively (Table 2). SDU C1 was a depression finished below grade in the inner half of the dredge cut and has since accumulated between 6 and 24 inches or more of new sediment over much of the area. This newly accumulated sediment on top of the armor rock allowed for sediment and direct TZW sampling in SDU C1 for the first time in the long-term monitoring program.
- **Sand Covers and GAC-Amended Sand Covers:** GAC-amended covers in SDU A and sand covers in SDU B2 have been stable throughout the survey period. Some loss of cover material was evident in SDUs C3, D, and F1 during Year 1 (2020 to 2021) as the river was equilibrating with the newly constructed surface (Figure 5a). After this initial post-construction period of hydrodynamic reworking, the site has been comparatively stable during Year 2 (2021 to 2022) (Figure 5b). As of June 2022, the average remaining thickness of sand or GAC-amended sand cover material in SDUs C3, D, and F1 was 0.88, 0.64, and 0.17 foot, respectively (Table 2). ~~Areas where the sand or GAC-amended sand~~ Because the cover thickness has decreased to less than the minimum ~~12-inch~~ placement specification of 1 foot, these areas were targeted for supplemental Year 2 sampling (Section 3.1). In contrast, SDUs A and B2 continue to retain an adequate thickness of cover material (1.75 and 1.21 feet, respectively).
- **MNR Areas:** MNR areas (SDUs B1 and F2) have been relatively stable throughout the survey period, with most areas showing little or no measurable change in elevation, with two localized exceptions. First, deposition of 6 to 18 inches of new sediment was observed in ~~the outer~~ some parts of SDU F2 as a result of sand cover material migrating downstream from SDU F1 (Figure 9). Second, a relatively small scour hole, approximately 20 feet by 50 feet, developed in SDU B1 between the April 2022 and June 2022 surveys, apparently the result of propwash disturbance associated with Navy vessel docking or undocking during Fleet Week (Figures 4b and 5b). However, the average depths of erosion and sedimentation in SDUs B1 and F2 (-0.04 and 0.18 foot, respectively) are within the range of bathymetric survey accuracy when averaged over the scale of an SDU (Table 2). This was an expected outcome: given the previously estimated PGM sedimentation rates (3.4 cm/year [mean] ±2.6 cm/year [standard deviation]; Anchor QEA, 2020, Appendix H), changes in bathymetric elevations would not be

measurable over much of the site (i.e., would not exceed the survey accuracy) until post-construction Year 5 (2025).

2.3 Depths of Contamination in Sediment

Table ~~2~~3 provides a summary of estimated present-day depths of contamination (DOCs) in existing PGM sediment samples from pre-remediation sediment investigations (collected between 2007 and 2017) relative to the Year 2 mudline elevation. Year 2 DOC estimates were calculated based on the mudline elevation and the DOC at the time of sampling adjusted to the Year 2 mudline elevation in consideration of any material that was removed in dredging areas and/or placed in cap and cover areas during the 2020 RA. The maximum exceedance ratio of PGM CULs at the DOC and the chemical associated with the maximum exceedance ratio are compiled for each sediment sample. In dredging areas where the upper portion of the contaminated sediment sequence was removed, the post-dredge exceedance ratios and chemicals were revised accordingly.

Detailed cross sections showing the distribution of subsurface contamination in areas where erosion of sediment or cover material has been observed are shown in Figure 8a (cross section location map), Figure 8b (cross sections SDU B1 and SDU C3), Figure 8c (SDU D), and Figure 8d (SDU F1). Current (Year 2) and historical sediment samples and sampling depths, maximum exceedance ratios, and the chemicals associated with the maximum exceedance ratios are projected onto the cross sections. The cross sections illustrate the DOC in historical sediment cores relative to the current Year 2 mudline elevations and surface sediment concentrations.

In most areas, the estimated DOC values during Year 1 and Year 2 were within a few tenths of a foot. This is within the accuracy of the bathymetric surveys, indicating overall bathymetric stability between Year 1 and Year 2, except for the recent propwash scour observed in SDU B2 and the ongoing, downstream sand cover migration in SDU F1.

The estimated DOC in armored cap areas (SDUs C1 and E), GAC-amended cover areas (SDUs A and D), and most of the sand cover (SDUs B2 and C3) and MNR areas (SDU F2) are well over 1 foot and typically multiple feet below the mudline as a result of cap and cover placement combined with ongoing deposition of new sediment. However, in two areas—SDU F1 (sand cover) and SDU B1 (MNR)—shallower DOC are estimated, with burial depths of less than 1 foot. Shallower burial depths in these areas are caused by a loss of overlying material by downstream sand cover migration (SDU F1) and propwash scour during Fleet Week (SDU B1). As a result, additional surface sediment samples were collected, specifically targeting the aforementioned areas with shallower DOC.

As described in Section 4.3, Year 2 sediment sampling results confirm that no significant contaminant exposure has occurred in any of these areas. Year 2 sediment sample elevations and exceedance ratios are included on the cross sections in Figures 8b, 8c, and 8d.

3 Field Sampling Activities

The field sampling activities associated with the Year 2 monitoring event consisted of sampling and analysis of surface sediment, SW, TZW, and porewater in June and July 2022.

3.1 Modifications to the Year 2 Monitoring Plan

Modifications to the Year 2 post-construction monitoring program included additional sampling and analysis of sediment, SW, TZW, and porewater based on observed physical changes in bathymetric conditions relative to the post-construction baseline condition, as measured in October 2020. Modifications to the Year 2 sampling and analysis program are described in the Year 2 Addendum (Anchor QEA 2022), which was approved by DEQ on June 22, 2022. Areas where the sand or GAC-amended sand cover thickness decreased to less than the minimum 12-inch placement specification, as supported by analysis of Figures 5a, 5b, 5c, 7a, 7b, and 8, were targeted for supplemental Year 2 sampling. Actual Year 2 sampling locations are shown in Figure 10.

An area-by-area summary of Year 2 sampling modifications is provided in this section.

3.1.1 Armored, GAC-Amended Caps

As per the LTMMP, armored, GAC-amended caps (Stations LTM-13 through LTM-16) are to be sampled for sediment quality, when sufficient new sediment has accumulated over the rock armor, and colocated porewater quality, via the manhole sampling ports, until sufficient new sediment has accumulated to allow direct TZW sampling in the overlying sediment using push probes (i.e., Trident probes). As per the LTMMP, a minimum of 12 inches of new sediment accumulation is recommended to attempt direct TZW sampling, and a minimum of 2 inches of new sediment is recommended to attempt diver-assisted surface sediment sampling over the rock armor layer. In practice, 4 inches of new sediment accumulation were required to provide a 2-inch depth of sediment recovery because the diver-assisted sediment corer has a 2-inch cutter head.

In SDUs with armored, GAC-amended caps, Year 2 monitoring activities and modifications included the following:

- **SDU C1:** This inner part of the armored cap was finished below grade and has since accumulated between 0.5 and 2.5 feet of new sediment. This was sufficient to allow both surface sediment grab sampling and direct TZW sampling at Stations LTM-13 and LTM-14 in lieu of the manhole sampling ports, as per the LTMMP. The 3-point composite surface sediment samples (SED-13 and SED-14) are colocated with their respective manholes. The TZW sample locations (TZW-13 and TZW-14) are situated adjacent to the manholes (i.e., within approximately 20 feet of the manholes) in areas with thicker sediment accumulations of at least 12 inches and are approximately colocated with the composited surface sediment samples, although slightly offset due to the presence of the manholes at the center location.

- **SDU E:** This deeper part of the armored cap has much less new sediment accumulation compared to SDU C1, generally less than 6 inches, especially in the outermost part of the cap. However, it was still possible to collect shallow, diver-assisted sediment grab samples from both LTM-15 and LTM-16 in the Year 2 monitoring event with sufficient volume to analyze the entire list of PGM COCs. Three successful diver-assisted sediment grabs were collected from Station LTM-15, whereas only two successful diver-assisted sediment grabs could be obtained from Station LTM-16. As a result, SED-16 was prepared as a 2-point composite sample rather than a 3-point composite sample. Direct TZW sampling was not feasible in SDU E during the Year 2 event; therefore, porewater samples were collected from the manhole sampling ports at Stations LTM-15 and LTM-16.

3.1.2 GAC-Amended Covers

As per the LTMMP, GAC-amended covers (Stations LTM-09 through LTM-12) are to be sampled for sediment quality and colocated TZW quality via push probes (i.e., Trident probes). In GAC-amended cover areas, Year 2 monitoring activities and modifications included the following:

- **SDU A:** SDU A retained at least 12 inches of GAC-amended cover material over more than 95% of the area, and approximately 50% of the area retained a cover thickness of 18 to 24 inches, which provides supplemental protection above the design requirement. Sediment and TZW samples were collected as specified in the LTMMP.
- **SDU D:** SDU D showed inconsistent retention of GAC-amended cover material, with alternating thick and thin spots. Specifically, two contiguous areas below the minimum 12-inch placement specification were elongated transverse to the river current (Figure 9). As a result, sample coverage in SDU D was increased from one monitoring station (LTM-12) to two stations (LTM-12.1 and LTM-12.2) (Figure 10). The three subsamples in each of the surface sediment composites were aligned with the thinner cover areas, and the TZW samples were collected at the centroid locations. GAC content determinations (Section 3.5.3.3 of the *Construction Quality Assurance and Control Plan* [Anchor QEA 2020, Appendix E]) were also added to the sediment testing list in SDU D to assess the amount of GAC present in the remaining surface sediments.

3.1.3 Sand Covers

As per the LTMMP, sand covers (Stations LTM-01, LTM-04, and LTM-08) are to be sampled for sediment quality. In sand cover areas, Year 2 monitoring activities and modifications included the following:

- **SDU B2:** SDU B2 retained at least 12 inches of sand cover material over approximately 85% of the area. There was a thinner cover area in the inner half of the SDU that was at the minimum 12-inch placement thickness, plus or minus, considering the accuracy of the bathymetric survey. Therefore, the original LTMMP station (LTM-01) was relocated to the thinner cover area (LTM-01.1; Figure 10).
- **SDU C3:** SDU C3 showed inconsistent retention of sand cover material, with variable thick and thin spots. There is a particular area of thinning at the top of the dredging side slope on the north side of SDU C1, which has been rounded off by river currents. As a result, the original LTMMP station (LTM-04) was relocated to the thinned cover area at the top of the side slope (LTM-04.1; Figure 10).
- **SDU F1:** SDU F1 has experienced downstream transport of sand cover material, and a majority of SDU F1 has dropped below the 12-inch placement specification. As a result, sample coverage in SDU F1 was increased from one LTMMP station (LTM-08) to three stations (LTM-08.1, LTM-08.2, and LTM-08.3; Figure 10) during the Year 2 event. These three stations are sited along the upstream portion of SDU F1 where the remaining sand cover material is thinnest.

3.1.4 Monitored Natural Recovery Areas

As per the LTMMP, MNR areas (Stations LTM-02 and LTM-03 in SDU B1 and Stations LTM-05, LTM-06, and LTM-07 in SDU F2) are to be sampled for sediment quality. In MNR areas, Year 2 monitoring activities and modifications included the following:

- **SDU B1:** Mudline elevations in SDU B1 were stable in the post-construction period through the April 2022 bathymetric survey; however, a localized scour hole developed in the outer part of the area by the time of the June 2022 survey. Due to the scour depth (2 to 2.5 feet at its deepest) and focused spatial extent of this feature (approximately 20 feet by 50 feet), it appears to have been caused by propwash from the docking or undocking of the visiting Navy ship during Fleet Week. As a result, the downstream LTMMP station (LTM-02) was relocated directly over the scour hole (LTM-02.1). The observed scour did not affect the upstream station in SDU B1 (LTM-03), which was sampled at its originally specified location.
- **SDU F2:** Mudline elevations in SDU F2 have been stable since the 2020 RA, with the exception of Station LTM-06, which is characterized by high sedimentation rates, evidently the result of in-migrating sand cover material from SDU F1. Sediment samples in SDU F2 were collected as specified in the LTMMP.

3.2 Surface Sediment Sampling

Nineteen composited surface sediment grab samples were collected from July 6 to July 8, 2022, at the locations shown in Figure 10. Stations LTM-02.1, LTM-03, LTM-05, LTM-06, and LTM-07 provide coverage of MNR areas that did not receive any caps or covers; Stations LTM-01, LTM-04.1, and LTM-08.1 through LTM-08.3 provide coverage of EMNR areas that received a minimum 1-foot-thick sand cover; Stations LTM-09 to LTM-12.2 provide coverage of in situ treatment areas that received GAC-amended sand covers; and Stations LTM-13 through LTM-16 represent newly deposited sediment that has accumulated on top of the engineered rock armor layer since remedial construction (Figure 2).

3.2.1 Sediment Sampling Procedures

Surface sediment samples were collected by Research Support Services out of Poulsbo, Washington, using a 12-inch by 24-inch pneumatic power grab sampler and a diver-assisted surface sediment corer. The diver-assisted corer was used at Stations LTM-15 and LTM-16 where accumulation of new sediment was insufficient to collect surface sediment samples with the pneumatic power grab sampler. The recovered sediment was sampled to a depth of 4 inches (10 centimeters) below the mudline for compositing and chemical analysis, as specified in the LTMMP. Each sample submitted for chemical analysis was a 3-point composite (LTM-##a, LTM-##b, and LTM-##c) of individual grabs spaced approximately 25 feet apart in a triangular pattern, with the exception of LTM-16, which was a 2-point composite sample because of a lack of new sediment over the rock armor layer at one of the three grab sample locations.

Surface sediment sample location coordinates are listed in Table ~~3~~4. The average coordinates for each composite sample are simply the averages of the northings and eastings of the three component grab samples.

3.2.2 Geologic Description of Surface Sediments

Surface sediment grab samples were logged in the field, and geologic descriptions of surface sediments are summarized in Table ~~4~~5. Detailed surface sediment grab sample logs and photographs are compiled in Appendices A and B, respectively.

MNR Areas: Surface sediment grab samples in the MNR areas (Stations LTM-2.1 and LTM-3 in SDU B1, and Stations LTM-05, LTM-06, and LTM-07 in SDU F2) were composed of sand and silty sand, with some gravel present near the downstream propwash scour hole (Station LTM-2.1). Most of the grab samples were covered with a thin surficial silt layer, approximately 1 centimeter thick (0.5 to 2 centimeters thick). Organic debris (twigs, leaves, and plant debris) was relatively common, occurring in trace to moderate amounts.

Isolated spots of sheen, approximately 1 centimeter in diameter, were observed in a few discrete surface sediment grabs from MNR areas (SED-02.1c, SED-03c, SED-05b, and SED-07a). The spots were too thin and small to be observed in field photographs (Appendix B) and were not reproducible between neighboring grabs. There is no analytical evidence of contamination in these samples because PAH and TPH concentrations were one or more orders of magnitude below CULs at the locations where isolated sheen spots were observed. Moreover, no petroleum odors were evident in these or any other site samples.

EMNR Areas (Sand Cover Areas): Surface sediment grab samples in the EMNR sand cover areas are largely derived from the material that was placed in these areas. For example, samples from SDU C3 (Station LTM-04.1) and SDU F1 (Stations LTM-08.1, LTM 08.2, and LTM 08.3), which received sand covers, were composed of relatively well-sorted sand with minimal fines content, and samples from SDU B2, which received gravelly sand covers, exhibited higher gravel contents consistent with the material type. Most samples also had traces of organic debris and shells.

GAC-Amended Sand Cover Areas: Surface sediment grab samples in SDU A (Stations LTM-09, LTM-10, and LTM-11), which received GAC-amended gravelly sand covers, were composed of sand with some gravel, consistent with the material type. In most samples, visible GAC was present. The surficial, soft silt layer overlying the cover material in SDU A was much thicker than other parts of the site, typically ranging from 5 to 10 centimeters in thickness. Thicker accumulations of recent sediment are evidence of higher sedimentation rates at the foot of the seawall along the inner part of the site, as has been previously documented (Anchor QEA 2020, Appendix H).

Surface sediment grab samples in SDU D (Stations LTM-12.1 and LTM-12.2), were composed of gravelly sand containing some of the highest gravel contents observed in the Year 2 monitoring event. In most samples, visible GAC was present. Although GAC-amended sand was initially placed in SDU D, GAC-amended gravelly sand was placed in the final lifts to make use of leftover material from adjacent areas. Because there has been some movement and redistribution of material in SDU D, the gravel content of the cover material may have been further concentrated in residual lag deposits, effectively forming an in situ armor layer.

Armored, GAC-Amended Caps: Surface sediment grab samples in the armored cap areas represent newly deposited sediment on top of the armor layer. These samples were composed of well-sorted sand with minimal fines content in SDU C1 (Stations LTM-13 and LTM-14) and well-sorted gravelly sand with minimal fines content in SDU E (Stations LTM-15 and LTM-16). The lower fines content is attributed to active current reworking in these deeper, outer areas, which precludes any significant accumulations of fine-grained sediments.

3.3 Transition Zone Water, Surface Water, and Porewater Sampling

Paired SW and TZW samples were collected at seven stations (LTM-09, LTM-10, LTM-11, LTM-12.1, LTM-12.2, LTM-13, and LTM-14), and paired SW and porewater samples were collected at two stations (LTM-15 and LTM-16), as shown in Figure 10. SW/TZW and SW/porewater field sampling procedures are described in this section.

3.3.1 Transition Zone Water/Surface Water Sampling Procedures

Trident probes were used to sample TZW in the top foot of the sediment in SDUs A, D, and C1, along with colocated, near-bottom SW samples from 1 foot above the mudline. Trident probes are direct, low-flow sampling ports inserted into the sediment on steel rods deployed remotely from the boat deck and were developed and operated by Coastal Monitoring Associates (CMA) of San Diego, California. Trident probes are described in more detail in the *Year 0 Monitoring Report* (Anchor QEA 2021b).

From June 20 to June 22, 2022, paired TZW and SW samples were collected at seven stations, including three stations in SDU A (LTM-09, LTM-10, and LTM-11), two stations in SDU D (LTM-12.1 and LTM-12.2), and two stations in SDU C1 (LTM-13 and LTM-14). Actual sample locations are shown in Figure 10 and sampling coordinates are listed in Table ~~5~~6. Field sampling data sheets are compiled in Appendix C, and the CMA Field Report is presented in Appendix D.

During line purging and sampling, field parameters (temperature, conductivity, pH, and oxidation-reduction potential [ORP]) were monitored, as described in Section 3.3.3. After purging, porewater and near-bottom SW samples were collected, processed and preserved as appropriate, and dispatched to the analytical laboratory under chain of custody. TZW and SW analytical results are presented and discussed in Section 4.

3.3.2 Porewater/Surface Water Sampling Procedures

On July 11 and 12, 2022, paired porewater and near-bottom SW samples were collected from two manhole sampling ports in SDU E (Stations LTM-15 and LTM-16). Actual sample locations are shown in Figure 10 and sampling coordinates are listed in Table ~~5~~6. Field sampling data sheets are compiled in Appendix C.

Porewater piezometer design and sampling procedures are described in the LTMMP and the *Year 0 Monitoring Report* (Anchor QEA 2020, 2021b). Diver assistance was used to establish a valved connection to the porewater piezometer at each location. Once the connection was established, purging and sampling were conducted remotely from the boat deck.

During line purging and sampling, field parameters (temperature, conductivity, pH, and ORP) were monitored, as described in Section 3.3.3. After purging, porewater and near-bottom SW samples were collected, processed and preserved as appropriate, and dispatched to the analytical laboratory under chain of custody. Porewater and SW analytical results are presented and discussed in Section 4.

3.3.3 Water Quality Field Parameters

During TZW and porewater sampling, field parameters (ORP, electrical conductivity, temperature, and pH) were monitored to characterize in situ water quality conditions and to ensure that SW was not short-circuiting to the TZW/porewater intake screen and diluting the TZW/porewater concentration. Water quality field parameters, compiled in Table ~~6~~7, indicate TZW/porewater had distinct water quality characteristics compared to SW, confirming the integrity of the TZW/porewater samples and the lack of any significant short-circuiting.

ORP: ORP appears to be the most sensitive parameter for differentiating between TZW/porewater and SW and provides the strongest evidence supporting the integrity of TZW/porewater samples and lack of short-circuiting with SW. TZW and porewater had significantly lower ORP (-34 to 84 millivolt [mV], averaging 22 mV) compared to SW (134 to 381 mV, averaging 270 mV), indicating more reducing conditions in TZW and porewater and more oxygenated conditions in SW. This trend was consistently observed across all sampling stations. Some of the greatest differences in ORP values were observed in SDU D (Stations LTM-12.1 and LTM-12.2) and SDU C1 (Station LTM-14).

Electrical Conductivity: In general, TZW and porewater had significantly higher specific conductivity (64 to 298 microsiemens per centimeter [µS/cm], averaging 193 µS/cm) compared to SW (67 to 80 µS/cm, averaging 74 µS/cm), indicating higher concentrations of dissolved species in TZW and porewater. The contrast in electrical conductivity was less distinct at two deep-water locations—Station LTM-12.1 (64 versus 68 µS/cm) and Station LTM-16 (97 versus 86 µS/cm)—possibly because of coarser grained sediment, stronger currents, and enhanced porewater flushing. At all other locations, however, the electrical conductivity of TZW and porewater was approximately two to four times higher than SW, providing good differentiation of these media.

Temperature: TZW temperatures collected in mid-June were consistently lower (12.9°C to 13.8°C) than colocated SW temperatures (13.3°C to 14.3°C), and the temperature difference ranged from -0.1°C (Station LTM-12.2) to -1.0°C (Station LTM-10). Porewater and SW samples collected 3 weeks later in July were approximately 7°C warmer, due to seasonal warming of the Willamette River, and temperature differences were even less pronounced, ranging from 0 to -0.4°C. In general, temperature differences were subtle, and temperature was not a very sensitive parameter for differentiating TZW and porewater from SW.

pH: pH measurements in TZW and porewater (pH = 6.5 to 7.3) did not show a distinctive trend compared to SW (pH = 6.7 to 7.5), and the average site-wide pH value in TZW and porewater (pH = 6.9) was nearly indistinguishable from SW (pH = 7.0). Therefore, pH is not a sensitive parameter for differentiating TZW and porewater from SW.

3.4 Deviations from the LTMMP and Year 2 Addendum

The following deviations from the LTMMP and Year 2 Addendum occurred during the Year 2 monitoring event:

- There was a 1-week delay in schedule due to the vessel operator testing positive for COVID-19 and having to quarantine. As a result, no field work occurred from June 23 through July 5, 2022. Aside from the scheduling delay, this deviation had no impact on data quality.
- At LTM-16, a 2-point composite surface sediment sample was collected with diver assistance instead of a 3-point composite sample. The deeper part of the armored cap in SDU E had much less new sediment accumulation compared to the armored cap in SDU C1, and negligible accumulation in the outermost part of SDU E (Figure 5c), in particular. As a result, subsample LTM-16c could not be collected because there was less than 2 inches of accumulated sediment, likely due to higher currents. Although surface sediment sample SED-16 was composed of two grabs instead of three, it is nevertheless considered representative of the thin and intermittent new sediment in the area sampled, with minimal impact on data quality.
- Boat-based TZW sampling from the river surface using Trident probes attached to metal rods was challenged by high and fast flow conditions in the river following an unusually wet spring (Section 2.1; Figure 3). These challenges were most severe at Stations TZW-12.1 and TZW-12.2. These are the deepest, outermost stations, subjected to the strongest river currents, with water depths (56 feet at time of sampling) significantly greater than the other stations (35 to 43 feet at time of sampling). At TZW-12.1 and TZW-12.2, it was difficult to hold the vessel position, and the Trident probes were agitated during sample collection. This resulted in very high total suspended solids (TSS) concentrations (253 and 780 mg/L, respectively), such that the unfiltered sampling results, and possibly even the filtered sampling results, were impacted by field conditions and entrained sediments (see Section 4.5 for further discussion).

Otherwise, there were no sample positioning deviations such that every sample was collected within 10 feet of its target location. No sample custody or quality control deviations were noted during sample processing, handling, or transporting of sediment or water samples to the analytical laboratory. Target sample volumes were obtained for all locations and analytes, including total and dissolved phases, where specified, such that laboratory detection limits were not volume-limited.

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4 Laboratory Analytical Results

PGM Year 2 analytical testing was performed in accordance with the requirements of the LTMMP and the Year 2 Addendum. Year 2 sediment and water samples were analyzed by Apex Laboratories from Tigard, Oregon.

4.1 Analytical Data

This section describes the analytical testing parameters and test methods used to characterize surface sediment, SW, TZW, and porewater.

4.1.1 Surface Sediment

Surface sediment analytical results are presented in Table ~~7~~8. Laboratory analytical reports and data validation reports are provided in Appendices E and F, respectively.

Surface sediment was analyzed for the following parameters:

- PAHs (U.S. Environmental Protection Agency [EPA] 8270E)
- Target metals (lead, mercury, and zinc) (EPA 6020A)
- TPH (diesel and residual fractions) (Northwest Total Petroleum Hydrocarbons diesel range [NWTPH-Dx])
- Total organic carbon (TOC) (Puget Sound Estuarine Protocol [PSEP] 5310B-Mod)
- Grain size (ASTM International [ASTM] 422D-Mod)
- Total solids (Standard Method [SM] 2540G)

Additionally, at Stations LTM-12.1 and LTM-12.2 (located in SDU D, a GAC-amended cover area), GAC content determinations were performed using a density separation method in the Anchor QEA Environmental Geochemistry Laboratory to determine the in situ GAC content of the residual cover material.

4.1.2 Surface Water, Transition Zone Water, and Porewater

SW data are presented in Table ~~8~~9, and TZW and porewater data are presented in Table ~~9~~10. Laboratory analytical reports and data validation reports are provided in Appendices E and F, respectively. SW, TZW, and porewater were analyzed for the following parameters:

- PAHs (total and laboratory-filtered dissolved fractions) (EPA 8270E)
- BTEX (EPA 8260D)
- Free cyanide (ASTM D7237-10)
- Target metals—lead, mercury, and zinc (total and dissolved [field-filtered] fractions) (EPA 6020A)

- Hardness (SM 2340B)
- TSS (SM 2540D)

4.2 Data Validation

Data quality objectives and quality assurance procedures are provided in the LTMMP (Anchor QEA 2020, Appendix F) and the Year 2 Addendum (Anchor QEA 2022). Data quality of each laboratory package was reviewed and evaluated by Anchor QEA and documented in the data validation reports provided in Appendix F. All data qualifiers applied to the data during final validation have been incorporated into the project database and the Year 2 report tables (Tables ~~7,~~ 8, ~~and~~ 9, and 10).

All data were considered useable as reported or as qualified, based on the criteria specified in the National Functional Guidelines (EPA 2020a, 2020b) and described in Appendix F. Data qualifiers assigned during data validation include the following:

- "J" indicates the associated numerical value is an estimated concentration.
- "U" indicates a reporting limit below which the analyte was not detected.
- "UJ" indicates an approximate reporting limit below which the analyte was not detected.

The laboratory followed the specified analytical methods and all requested sample analyses were completed. Accuracy was acceptable as demonstrated by the surrogate, laboratory control sample/laboratory control sample duplicate (LCS/LCSD), and matrix spike/matrix spike duplicate (MS/MSD) recovery values, with the exceptions noted in Appendix F and summarized in Sections 4.2.1 through 4.2.3. Precision was acceptable as demonstrated by the LCS/LCSD, MS/MSD, laboratory duplicate, and field duplicate results. Completeness goals were met.

Reporting limits were deemed acceptable to meet project objectives. Reporting limits for undiluted water samples were consistent with the reporting limit goals specified in the LTMMP. If sample dilution was necessary due to matrix interference, the reporting limits reflect the dilution factor. Reporting limits for sediment and water were below the CULs specified in the ROD (DEQ 2017), with the following exceptions:

- **Mercury in Water:** The method detection limit for mercury in water (0.04 micrograms per liter [µg/L]) is above the chronic water quality criterion (0.012 µg/L) but is nevertheless consistent with the LTMMP analytical requirements as well as ambient background concentrations in the Pacific Northwest (DEQ 2002).
- **cPAHs in Water:** The reporting limits for carcinogenic polycyclic aromatic hydrocarbons (cPAHs) in SW (0.015 to 0.017 µg/L) are higher than the human health fish consumption criteria (0.0018 µg/L) but are nevertheless consistent with LTMMP analytical requirements and the practical quantitation limits of the analysis.

4.2.1 Surface Sediment Data Validation Summary

Sediment data validation resulted in the qualification of zinc results in eight samples, due to an MSD percent recovery value below the project control limit. PAH results in 15 samples were qualified due to a low surrogate recovery, as well as low recoveries in the MS and/or the MSD. Individual results were qualified with a "J" or a "UJ" to indicate a potentially low bias. In addition, PAH results in five samples were qualified with a "J" due to laboratory or field duplicate relative percent difference values above the project control limit. These results should be considered estimated.

All surface sediment results are acceptable as reported or as qualified.

4.2.2 Surface Water Data Validation Summary

The validation of SW resulted in the qualification of one result for TSS because the sample was analyzed past the holding time due to an error on the chain of custody form.

All SW results are acceptable as reported or as qualified.

4.2.3 Transition Zone Water/Porewater Data Validation Summary

The validation of TZW and porewater resulted in the qualification of one TZW sample for lead and zinc (2022-TZW-09), as well as the field duplicate sample for zinc (2022-TZW-109), due to a relative percent difference value above the project control limit in the field duplicate. These results should be considered estimated. Total and dissolved benzo(g,h,i)perylene results in one sample (2022-TZW-12.2) recovered below the control limit in the MS and MSD and were qualified with a "J" to indicate a potentially low bias. One TSS result (2022-PW-16) was rejected due to the holding time issue mentioned previously.

With the exception of the one rejected TSS result, TZW and porewater results are acceptable as reported or as qualified.

4.3 Surface Sediment Analytical Results

This section summarizes the sediment characteristics (TOC, grain size, and weight percent GAC) and chemical concentrations (lead, mercury, zinc, PAHs, and TPH) of PGM sediments, and a comparison of Year 2 sediment concentrations to PGM CULs. Year 2 sediment testing results are summarized in Table ~~7~~8.

4.3.1 Sediment Characteristics

Grain Size: Sediments with higher fines content (silt plus clay), ranging from 15% to 40% fines, were typically reported in MNR areas (SED-02.1, SED-03, SED-05, and SED-07) and in areas along the seawall, including SDU A (SED-09, SED-10, and SED-11) and SDU B2 (SED-01.1), where higher sedimentation rates have been observed. Sediments with lower fines content (i.e., less than 10% fines), were reported in sand cover areas with lesser thicknesses of new infill sediment, such as SDU C3 (SED-04.1) and SDU F1 (SED-08.1, SED-08.2, and SED-08.3), as well as sediments in the deeper, outer parts of the site, including new sediments on the armored cap, which are subjected to higher currents and winnowing processes (e.g., SDU D [SED-12.1 and SED-12.2], SDU C1 [SED-13 and SED-14], and SDU E [SED-15 and SED-16]). Sediments with the highest gravel contents, ranging from 43% to 45% gravel, were reported in SDU D (SED-12.1 and SED-12.2) and SDU E (SED-15); gravels were included in the placed cap and cover materials in these areas and may have been further concentrated by current winnowing.

TOC: TOC content tended to correlate with percent fines, such that sediments with higher fines content also had higher TOC content. TOC contents ranging from 0.9% to 2.2% were reported in MNR areas, including SDU B1 (SED-02.1 and SED-03) and SDU F2 (SED-05 and SED-07), and in areas along the seawall with higher sedimentation rates and thicker accumulations of new sediment, including SDU A (SED-09, SED-10, and SED-11) and SDU B2 (SED-01.1). In other parts of the site with lower sedimentation rates, TOC contents were usually less than 0.5%.

GAC Content: In situ GAC measurements were targeted toward areas of thinned cover material in SDU D, at Stations SED-12.1 and SED-12.2, with resulting GAC contents of 1.8% and 2.0%, respectively. The GAC contents in SDU D are less than the GAC contents placed during construction (approximately 10% GAC during placement). However, the sediments in SDU D nevertheless retain significant treatment capacity in spite of some loss of cover material. Cap modeling results for sediments in SDU D showed that 0.7% GAC would be protective of TZW and surface sediment quality for a minimum of 100 years and likely much longer in consideration of PAH biodegradation and other ongoing natural recovery processes (Anchor QEA 2020, Appendix C). Other GAC-amended cover areas (SDU A) and armored, GAC-amended caps (SDUs C1 and E) have retained substantially all of their treatment layer thickness; therefore, GAC contents in these areas are expected to be at or close to their original in situ GAC content of 10%, well in excess of the design requirement.

It is expected that these are worst-case measurements of GAC content as the GAC samples were collected from worst-case erosional areas in SDU D and from surficial material in the top 10 centimeters (4 inches) of the sediment. In comparison, there is an average of 8 inches and as much as 18 inches of residual cover material in SDU D. The GAC content measured in these surface sediments is more likely to be affected by current winnowing or mixing with incoming sandy sediment compared to deeper cover material.

4.3.2 Sediment Chemical Concentrations

Surface sediment analytical results were screened against the PGM sediment CULs, as shown in Table ~~7~~8. At all stations, regardless of remedial technology, metals, PAHs, and TPH were typically 1 to

2 orders of magnitude below PGM CULs, indicating excellent overall remedy performance, with a single nominal exception (SED-02.1).

As discussed in Section 3.1.4, sediment sample SED-02.1 was relocated over a propwash scour hole in SDU B1 that was observed following Fleet Week 2022. SDU B1 is a designated MNR area and was not part of the 2020 RA. SED-02.1 had a nominal exceedance of mercury (1.11 milligrams per kilogram [mg/kg] compared to CUL = 1.06 mg/kg) but no exceedances of any other COCs. The mercury exceedance factor is only 1.05x, which is well within the accuracy of the analytical method. A similar low-level exceedance of mercury (1.28 mg/kg) was detected in a historical surface sediment sample (UG-07) in SDU B1, approximately 30 feet away. Mercury was detected at even higher concentrations (1.85 mg/kg) in shallow subsurface sediments (1 to 3 feet below mudline) at the PGM upstream background station (core PGM-01), indicating relatively recent upstream sources may have contributed mercury to site sediments.

This lone, isolated, low-level mercury exceedance at SED-02.1 does not pose a concern for long-term remedy performance. Natural recovery remains the most effective remedial technology for this area. As detailed in Appendix H of the *Revised Final Design Report, Version 4*, the estimated 10-year recovery factors on this downstream part of the site range from 2.7 to 9.2, which should quickly alleviate the slight mercury exceedance of 1.05 in a very short period of time. In addition, the small and localized 1-foot- to 2-foot-deep scour hole is likely a transient feature that should quickly infill with sediment. Nevertheless, Anchor QEA alerted the Portland Harbor Master of the location and size of the erosional feature and requested consideration of vessel docking and undocking practices that could help to minimize propwash erosion in the future.

4.4 Surface Water Analytical Results

Analytical results from near-bottom SW samples collected from 1 foot above the mudline were compared to PGM CULs for protection of aquatic life (chronic water quality criteria) and human health via fish consumption (Table 1; Oregon Administrative Rules [OAR] 340-041-0033, Tables 30 and 40, respectively; DEQ 2014). Analytical results are summarized in Table ~~8~~9 and discussed in this section.

4.4.1 Surface Water Conventionals

SW samples exhibited good clarity, with TSS concentrations ranging from 6 to 13 mg/L. SW hardness ranged from 23 to 30 mg/L as calcium carbonate ($CaCO_3$). This is consistent with the hardness that was assumed to derive PGM CULs for dissolved lead and zinc (assumed 25 mg/L $CaCO_3$).

4.4.2 Surface Water Chemical Concentrations

All SW concentrations were below PGM CULs based on aquatic life (i.e., chronic water quality criteria). Free cyanide, total and dissolved mercury, dissolved lead, and BTEX compounds were not detected in any SW samples. Low-level concentrations of dissolved zinc, below the laboratory reporting limit, were consistent with ambient concentrations of zinc in the Willamette River (Anchor QEA 2021a) and are typical of site background conditions.

There were a few sporadic detections of cPAHs near or below the laboratory reporting limit, and the limit of resolution of the analytical method, in the following samples: SW-10, SW-12.2, and SW-14 (Table ~~8~~9). The fish consumption criteria for cPAHs are evaluated using site-wide average concentrations to account for the spatial scale of this type of exposure. In a site-wide context, these few cPAH detections do not pose a concern for long-term remedy performance for the following reasons:

- All of the cPAH detections are isolated, and none are confirmed by a second result. Sporadic detections of one or two cPAHs in the total (unfiltered) fraction at SW-12.2 and SW-14 are not present in the dissolved fraction. Conversely, sporadic detections of two cPAHs in the dissolved fraction at SW-10 are not present in the total fraction.
- The single, isolated detections of a few cPAHs are not significant on an average site-wide basis. Site-wide average concentrations for cPAHs are calculated in Table ~~8~~9, assuming half the value of the method detection limit for nondetects (i.e., half of 0.008 µg/L). Because there are so few cPAH detections (between 75% and 100% of the cPAH data are undetected), and the majority of detections are J-flagged concentrations below the laboratory reporting limit (0.016 µg/L), the average site-wide concentration for any cPAH, in either total or dissolved fractions, is below the method detection limit (less than 0.008 µg/L). Therefore, cPAHs are effectively unmeasurable in SW on a site-wide scale.
- Similar levels of cPAHs (approximately 0.01 to 0.02 µg/L) were detected in a Willamette River background sample during the PGM pre-construction monitoring event in June 2020 (see PGM *Project Completion Report*, Table 13 [Anchor QEA 2021a]).
- Although DEQ has updated its risk-based concentrations to account for the new cancer slope factor for benzo(a)pyrene (EPA 2017), it has not updated its water quality criteria for fish consumption, which are the basis for the PGM bioaccumulation-based SW CULs. Once that adjustment is made, the cPAH criteria are expected to be approximately seven times higher (i.e., seven times less stringent) than the current SW CULs.

4.5 Transition Zone Water/Porewater Analytical Results

This section summarizes the TZW/porewater analytical results for conventional parameters (TSS and hardness) and chemical concentrations (free cyanide, total and dissolved metals [lead, mercury, and zinc], BTEX compounds, and total and dissolved PAHs), and a comparison of Year 2 TZW/porewater concentrations to PGM CULs. Year 2 analytical results for TZW and porewater are summarized in Table ~~9~~10.

4.5.1 Transition Zone Water/Porewater Conventionals

Total Suspended Solids: Porewater samples from the manhole ports exhibited good clarity, with TSS concentrations ranging from less than 5 to 6 mg/L. In contrast, most of the TZW samples collected 3 weeks earlier using Trident probes were significantly more turbid, including six samples above 50 mg/L and three samples above 100 mg/L TSS. The highest TSS concentrations were reported in SDU D (253 mg/L and 780 mg/L at LTM-12.1 and LTM-12.2, respectively). The high concentrations of suspended sediments in these and other TZW samples are attributed to challenging field conditions.

Boat-based TZW sampling from the river surface using Trident probes attached to metal rods was challenged by high and fast flow conditions in the river following an unusually wet spring. These challenges were most severe at Stations TZW-12.1 and TZW-12.2. These are the deepest, outermost stations, subjected to the strongest river currents, in water depths (56 feet at time of sampling) significantly greater than other stations (35 to 43 feet at time of sampling). At these two stations, it was difficult to hold the vessel position, and the Trident probes were agitated during sample collection, causing entrainment of suspended sediments in the samples. The resultant high TSS concentrations impacted the unfiltered sampling results, and possibly even the filtered sampling results.

Hardness: TZW/porewater hardness values ranged from 26 to 140 mg/L, averaging 89 mg/L as $CaCO_3$. Most TZW/porewater values are significantly higher than the hardness that was assumed to derive hardness-based CULs for dissolved lead and zinc (assumed 25 mg/L). As porewater hardness increases, certain metals such as lead and zinc become more complexed, less bioavailable, and less toxic. The relationships between hardness and water quality criteria for lead and zinc are shown in Table ~~10~~11. As the hardness increases from 25 mg/L to 150 mg/L, which is commensurate with the range of TZW/porewater hardness values observed at PGM, the water quality criteria increase by multiples of 7.2 and 4.6 for lead and zinc, respectively. As a result, sample-specific hardness adjustments to TZW/porewater criteria are appropriate for these metals.

4.5.2 Transition Zone Water/Porewater Chemical Concentrations

Free Cyanide: Free cyanide was not detected in any Year 2 TZW or porewater samples.

Metals: Mercury was not detected in any total or dissolved TZW or porewater samples from Year 2. After adjusting water quality criteria for in situ hardness, total (unfiltered) lead concentrations were above the PGM CUL at Stations TZW-12.1 and TZW-12.2 and total zinc was above the PGM CUL at Station TZW-12.2. However, these unfiltered results were impacted by unusually high TSS concentrations due to agitation during sample collection in unusually deep water and high flow conditions (see Section 4.5.1). In contrast, there were no exceedances of PGM CULs for lead or zinc in the dissolved (filtered) fraction, which is the basis for the water quality criteria.

BTEX: No BTEX compounds were detected in any Year 2 TZW or porewater samples.

PAHs: In the total, unfiltered fraction at Station TZW-12.2, concentrations of two PAHs were slightly above PGM CULs (acenaphthene at 1.1x, phenanthrene at 1.3x), due to high TSS. In the dissolved fraction, there was a slight exceedance of one PAH (phenanthrene at 1.1x), which is within the accuracy of the analytical method. During the filtering of such a turbid sample, some fine clays or colloids may have passed through the filter and contaminated the dissolved fraction as well, especially if those fine clays included some pulverized GAC.

The apparent exceedance of dissolved phenanthrene is not consistent with groundwater transport of buried contaminants. Based on the results of the PGM cap model for SDU D (Anchor QEA 2020, Appendix C), the critical breakthrough COC for groundwater is naphthalene, the lightest and most mobile of the PAHs. Further, the model predicted that naphthalene breakthrough, if it were to occur, would exceed the CUL in sediment before it exceeded the CUL in porewater. However, the naphthalene concentration in TZW (TZW-12.2) is 500 times less than the CUL, and the naphthalene concentration in colocated sediment (SED-12.2) is 80 times less than the CUL and below the laboratory reporting limit. The PAH fingerprints indicate the low-level phenanthrene contamination in TZW is therefore an artifact of entrained sediments during sampling.

5 Conclusions

The results and conclusions of the Year 2 monitoring event are summarized in this section. Although some loss and redistribution of unarmored cover material and recent sediment was observed in a few areas, primarily right after construction during Year 1 (2020 to 2021 period), Year 2 chemical analytical results showed no substantive exceedances of PGM CULs in surface sediment, SW, TZW or porewater, including samples that were specifically located to target areas of cover loss and erosion. As a result, DEQ and NW Natural determined that no corrective construction actions (e.g., replenishment of cover material) were warranted during Year 2. The Year 2 chemical analytical results confirm that the PGM remedy is protective. Remedy performance and compliance with PGM CULs will continue to be monitored as part of the long-term monitoring program.

The results and conclusions of the Year 2 monitoring event are summarized as follows:

Year 2 Bathymetry

- Year 2 multibeam bathymetry surveys were performed on April 12 and June 14, 2022, as shown in Figures 4a and 4b, respectively.
- Bathymetric comparison maps and cross sections were prepared to assess the physical stability of the PGM remedy, as shown in Figures 5a, 5c, 5c, 6, 7a, ~~and~~ 7b, and Table 2, and the distribution and thickness of remaining cap and cover material, as shown in Figure 9 and Table 2.
- In post-construction Year 1 (2020 through 2021), some loss and redistribution of placed material was observed in some unarmored cover areas as the river sought to reestablish a smooth hydraulic gradient after remedial construction. The main areas affected by material redistribution included SDU F1 (sand cover), SDU C3 (sand cover), and SDU D (GAC-amended sand cover).
- In post-construction Year 2 (2021 to 2022), the site had largely stabilized with minimal changes in bathymetric conditions, except for the following: 1) a relatively small scour hole that developed in a downstream MNR area (SDU B1), apparently caused by propwash during Navy vessel docking or undocking during Fleet Week; and 2) continued downstream movement of sand cover material from SDU F1 to SDU F2.
- Areas of thinner cover material were targeted for additional sediment and/or TZW/porewater analysis during the Year 2 monitoring event, as detailed in the Year 2 Addendum (Anchor QEA 2022).

Surface Sediment

- Based on the bathymetric surveys, several surface sediment sample locations were modified in SDUs B1, B2, and C3, and three new surface sediment samples were added in SDUs F1 and D to target areas of thinning cover material, where the cover thickness had decreased to less than the minimum 12-inch placement specification (Anchor QEA 2022).

- This was the first time that the depth of newly deposited sediment was sufficiently thick that surface sediment samples could be collected on the armored cap in SDUs C1 and E.
- Surface sediment composite samples were collected in MNR areas (SED-02.1, SED-03, SED-05, SED-06, and SED-07), EMNR areas (SED-01.1, SED-04.1, SED-08.1, SED-08.2, and SED-08.3), GAC-amended cover areas (SED-09, SED-11, SED-12.1 and SED-12.2), and armored cap areas with newly deposited sediment (SED-13, SED-14, SED-15, and SED-16) for analysis of grain size, TOC, target metals (lead, mercury, and zinc), PAHs, and TPH, as summarized in Table ~~7~~8.
- There were no exceedances of surface sediment CULs in any of the 18 surface sediment samples from the Year 2 event, with a single exception: there was one nominal exceedance of mercury (1.05 times the CUL) at Station SED-02.1 in the B1 MNR area. This does not pose a concern for long-term remedy performance for the following reasons:
  - The mercury exceedance factor is only 1.05, which is well within the accuracy of the analytical method.
  - The estimated 10-year recovery factors on this downstream part of the site already designated for MNR range from 2.7 to 9.2, which should quickly alleviate the slight mercury exceedance of 1.05 in a very short period of time.
  - The small and localized 1-foot- to 2-foot-deep scour hole is likely a transient feature that should quickly infill with sediment.
  - Relatively recent, upstream background sources (e.g., 1.85 mg/kg in shallow subsurface sediment at upstream background Station PGM-01) could have contributed to this nominal mercury exceedance.

Surface Water

- Near-bottom SW samples were collected in GAC-amended cover areas (SW-09, SW-10, SW-11, SW-12.1, and SW-12.2) and armored, GAC-amended cap areas (SW-13, SW-14, SW-15, and SW-16) for analysis of TSS, free cyanide, target metals (total and dissolved lead, mercury, and zinc), BTEX, and PAHs (total and dissolved), as summarized in Table ~~8~~9.
- There were few detections of any contaminants in PGM SW. No detected concentrations exceeded SW CULs for protection of aquatic life (chronic water quality criteria).
- SW analytical results were generally consistent with ambient background conditions in the Willamette River based on upstream river samples collected during the PGM RA (Anchor QEA 2021a).

- There were a few sporadic detections of cPAHs at individual sampling stations, near or below the laboratory reporting limit and at the limit of resolution of the analytical method (Table ~~8~~9). However, the fish consumption criteria for cPAHs are evaluated using site-wide average concentrations. In a site-wide context, the few cPAH detections do not pose a concern for long-term remedy performance for the following reasons:
  - All of the cPAH detections are isolated and none are confirmed to occur in both total and dissolved fractions, nor were any corroborated by adjacent samples.
  - The site-wide cPAH concentrations average to a concentration below the detection limit and are therefore unmeasurable on a site-wide scale.
  - The sporadic SW detections do not correlate with any sediment or TZW concerns.
  - Similar levels of cPAHs (approximately 0.01 to 0.02 µg/L) were detected in a Willamette River background sample during the PGM pre-construction monitoring event in June 2020 (see *Project Completion Report*, Table 13).
  - The cPAH fish consumption criteria have not yet been updated to account for the revised (i.e., less stringent) benzo(a)pyrene slope factor (EPA 2017).

TZW and Porewater

- Water quality field parameters, compiled in Table ~~6~~7, indicate TZW/porewater had distinct water quality characteristics compared to SW, confirming the integrity of the TZW/porewater samples and the lack of any significant short-circuiting.
- TZW or porewater samples were collected in GAC-amended cap areas (TZW-09, TZW-10, TZW-11, TZW-12.1, and TZW-12.2) and armored GAC-amended cap areas (TZW-13, TZW-14, PW-15, and PW-16) for analysis of TSS, hardness, free cyanide, target metals (total and dissolved lead, mercury, and zinc), BTEX, and PAHs (total and dissolved), as summarized in Table ~~9~~10.
- Most of the TZW/porewater hardness values were significantly higher (26 to 140 mg/L, averaging 89 mg/L $CaCO_3$) than the hardness that was assumed to derive hardness-based CULs for dissolved lead and zinc (assumed 25 mg/L $CaCO_3$). As a result, sample-specific hardness adjustments to TZW/porewater criteria are appropriate for lead and zinc.
- In spite of the high TSS concentrations observed in some TZW samples, due to challenging field conditions, there were no detections of total or dissolved mercury, free cyanide, or BTEX compounds in any TZW or porewater samples, and no exceedances of PGM CULs for lead or zinc in the dissolved (filtered) fraction, which is the basis for chronic water quality criteria.
- At Station TZW-12.2, two PAHs were slightly above PGM CULs in the total fraction (acenaphthene at 1.1x, phenanthrene at 1.3x), due to high TSS, and one PAH was slightly above the CUL in the dissolved fraction as well (phenanthrene at 1.1x). All of these low-level exceedances are within the accuracy of the analytical method. The PAH concentrations in

TZW-12.2 do not pose a concern for long-term remedy performance for the following reasons:

- The unfiltered sample at TZW-12.2 is clearly impacted by high TSS (780 mg/L), due to challenging field conditions (i.e., high water levels and currents) and probe agitation during sampling. Fine clays and colloids may have contaminated the dissolved (filtered) sample as well.
- The occurrence of phenanthrene in TZW, a middle-weight PAH, is not consistent with groundwater transport. The PGM cap model (Anchor QEA 2020, Appendix C) shows that the critical breakthrough COC for groundwater is naphthalene, the lightest and most mobile of the PAHs. However, naphthalene concentrations were two to three orders of magnitude below PGM CULs in both surface sediments and TZW. In contrast, phenanthrene is a common PAH in sediment, including background sediment in the Willamette River. The PAH fingerprints in TZW and sediment therefore indicate the contamination is an artifact of entrained sediments during sampling.

6 Recommendations

Recommendations for future monitoring events in the PGM long-term monitoring program are provided in this section.

- **Year 3 Bathymetric Survey:** According to the LTMMP, the next monitoring event (combined surveying and sampling event) is scheduled to occur in Year 5 (2025). However, DEQ and NW Natural have agreed to add a contingency bathymetric survey in Year 3 (2023), in consideration of the movement and erosion of cover material and river sediment that have been observed in some areas. Consistent with previous surveys, the Year 3 bathymetric survey will be performed after Fleet Week ships have departed in mid- to late June. If areas of significant new erosion are observed, DEQ and NW Natural will discuss the need for follow-up chemical monitoring of sediment or TZW or the use of other diagnostic tools such as GAC content determinations or current meters. Consistent with the LTMMP, a~~A~~reas of significant new erosion (~~will be defined as areas covering at least 1,000 square feet (consistent with the area represented by a 3-point composite surface sediment sample) that have experienced new erosion~~ i.e., erosion beyond what has already been documented and chemically verified in the Year 2 event) will be identified by DEQ and NW Natural on a case-by-case basis in consideration of the depth, extent, and volume of new erosion and the potential risk of exposing underlying contamination. ~~Such areas would include the following:~~
  - ~~A new cover area of at least 1,000 square feet that has dropped below the minimum 12-inch placement specification~~
  - ~~A new MNR area of at least 1,000 square feet that has been scoured at least 12 inches below the surrounding riverbed~~
  - ~~An existing erosional area, as documented in the Year 2 event, that is continuing to lose elevation over an area of at least 1,000 square feet, with at least 6 inches of continued elevation loss below the Year 2 surface, which would indicate measurable elevation loss beyond the accuracy of the multibeam bathymetric survey~~

  DEQ and NW Natural will discuss the need for a Year 4 (2024) bathymetric survey after reviewing the results of the Year 3 survey and whether, or to what extent, additional erosion continues to be observed in different parts of the site.
- **Scheduling of Trident Probe Work:** Boat-based TZW sampling from the river surface using Trident probes attached to metal rods was challenged by high and fast flow conditions in the river, which caused agitation of the probes during sampling and entrainment of unusually high TSS concentrations, especially at the deepest sample stations (TZW-12.1 and TZW-12.2 in SDU D). In the future, these sampling artifacts could be minimized by delaying Trident probe work by several weeks, until approximately mid-July, after the seasonally high, early summer flows in the Willamette River subside. Alternatively, if high flow conditions cannot be avoided,

the Trident probes could be deployed by divers rather than remotely using metal rods, to minimize sample agitation during collection.

- **Monitoring of Propwash Scour during Fleet Week:** During Year 2, a small scour hole was observed in a downstream MNR area (SDU B1), which was evidently caused by propwash during Navy vessel docking or undocking during Fleet Week. As a result, Anchor QEA contacted the Portland Harbor Master (Sean Whalen) and notified him of the location and extent of the observed scour feature. Anchor QEA further requested that Mr. Whalen consider any operational practices that could minimize propwash scour within the project area. Using the scheduled multibeam bathymetry surveys in the PGM long-term monitoring program, the NW Natural team will continue to monitor for the presence of scour holes and other evidence of propwash during Fleet Week and coordinate with Mr. Whalen if such features continue to be observed.

7 References

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New Table

Table 2
Average SDU and Site-Wide Bathymetric Differences and Cap/Cover/Infill Thicknesses

SDU	Average Bathymetric Difference Measurement (feet)			Estimated Cap/Cover/Infill Thickness (feet)
Start:	October 2020	July 2021	October 2020	June/August 2020[1]
End:	July 2021	June 2022	June 2022	June 2022
Armored Cap				
C1	0.90	-0.01	0.90	3.70
E	0.52	-0.28	0.24	3.14
GAC/Sand Cover				
A	0.38	-0.28	0.09	1.75
D	-0.89	-0.25	-1.14	0.64
Sand Cover (EMNR)				
B2	0.26	-0.30	-0.04	1.21
C3	-0.26	-0.36	-0.62	0.88
F1	-0.63	-0.58	-1.21	0.17
MNR				
B1	0.32	-0.38	-0.05	-0.04
F2	0.43	-0.35	0.08	0.18
Residuals Cover				
G	-0.44	-0.34	-0.78	0.47
H	-0.23	-0.27	-0.49	0.60
No Action				
Other[2]	0.08	-0.20	-0.12	0.03
Work Site Total	0.19	-0.26	-0.07	0.93

Legend for Average Bathymetric Difference Measurements:
- (green) Measurable deposition occurred during the specified time interval.
- (yellow) Measurable erosion occurred during the specified time interval.
- (white) Bathymetric difference is within the range of survey measurement accuracy (± 0.5 feet), indicating deposition and/or erosion are uncertain.

Green cells: C1 (October 2020–July 2021, October 2020–June 2022); E (October 2020–July 2021). Yellow cells: D (October 2020–July 2021, October 2020–June 2022); C3 (October 2020–June 2022); F1 (all three intervals); G (October 2020–June 2022).

Notes:
1. Post-dredge/post-debris removal surface (pre-cap/pre-cover) merged with pre-construction surface in undredged areas.
2. Includes outer peripheral areas within the PGM Work Site not assigned to an SDU.
EMNR: enhanced monitored natural recovery
GAC: granular activated carbon
MNR: monitored natural recovery
PGM: Portland Gas Manufacturing
SDU: Sediment Decision Unit