CONCENTRATIONS AND CHARACTER OF PAH IN SEDIMENTS IN THE PROPOSED REMEDIAL ALTERNATIVES AREA OF THE PORTLAND HARBOR SUPERFUND SITE, RIVER MILES 5 – 6

2015 INVESTIGATION

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Acronyms and Abbreviations

BaP Eq	Benzo(a)pyrene equivalents
BP	British Petroleum
COC	Contaminants of concern
CRD	Columbia River Datum
cPAHs	Carcinogenic Polycyclic Aromatic Hydrocarbons
DDT	Dichlorodiphenyltrichloroethane
DDx	Degradation products of dichlorodiphenyltrichloroethane
DQOs	Data quality objectives
ETRs	Environmental Testing Reports
FS	Feasibility Study
GC	Gas chromatography
HFO	Heavy fuel oil
LCS	Laboratory control sample
LIMS	Laboratory information management system
LWG	Lower Willamette Group
MGP	Manufactured gas plant
MS	Mass spectrometry
MS	matrix spikes
PAH	Polycyclic aromatic hydrocarbons
PCB	Polychlorinated biphenyls
PTW	Principal Threat Wastes
QC	Quality control
RAA	Remedial Alternatives Area
RALs	Remedial action levels
RI	Remedial Investigation
RM	River Mile
SDU	Sediment Decision Units
SFS	Portland Harbor Superfund Site
SIM	Select ion monitoring
TPAH17	Sum of 16 EPA priority pollutant PAH plus 2-methylnaphthalene
TPH	Total petroleum hydrocarbon
UCL	Upper confidence levels
UCM	Unresolved complex mixture

Executive Summary

The LWG Remedial Investigation identified an area between River Mile (RM) 5.0 and the St. Johns Bridge (located at approximately RM 6.0) that is contaminated with polycyclic aromatic hydrocarbons (PAH). The PAH levels were sufficiently high to deem part of this area a candidate for remediation**.** The 2015 EPA Draft Feasibility Study describes Remedial Action Level (RAL) concentrations and various remedial concentration contours for PAH in numerous segments of the river. The contoured areas of incremental PAH RALs between approximately RM 5 and the NW St. Johns Bridge are operationally defined in this report as the Remedial Alternatives Area.

NewFields conducted two sampling events in 2014 and 2015 to investigate the concentrations and chemical nature of PAH in the proposed Remedial Alternatives Area. This investigations had two main objectives:

1. Evaluate the nature (e.g. pyrogenic vs petrogenic) and source of PAH compounds in the sediments.
2. Determine concentrations of PAH at the current sediment surface, and three depths representing potential dredge horizon intervals (-48 to -49’ CRD, -51’ to -52’ CRD, and -53’ to -54’ CRD).

Additionally, the potential for Principal Threat Waste (PTW) occurring in various depth intervals was examined. Eight COCs, previously identified in the 2015 EPA Draft Feasibility Study, were evaluated versus the corresponding PTW concentration thresholds for polychlorinated biphenyls (PCB); five chlorinated dioxin/furan congeners; DDT (dichlorodiphenyltrichloroethane) and its degradation products (collectively, DDx); and carcinogenic PAH (expressed as benzo(a)pyrene equivalents—BaP Eq).

Key findings from the NewFields investigation are:

- The highest PAH concentrations were found proximal to the former Gasco Property, and decreased systematically downstream from the property to at least RM 5. In the Remedial Alternatives Area, TPAH17 sediment concentrations averaged 67,677 µg/kg, and with a maximum of 2,389,590 µg/kg.
- The chemical characteristics of PAH found proximal to the former Gasco Property are consistent with pyrogenic MGP derived tar wastes. These high concentration PAH are highly pyrogenic in character, derived from combustion/pyrolysis processes, and distinct in chemical character and readily differentiated from petroleum-derived (petrogenic) PAH.
- The highest concentrations of TPAH17 occur along a downstream axis just west of center of the river channel. The concentration of TPAH17 varied with depth. The highest TPAH17 concentrations are found in current surface sediments, with lower concentrations noted with depth, and the east and west margins of the high concentration axis.
- The characteristics of PAH across the entirety of the proposed Remedial Alternative Area are highly pyrogenic in nature. “Tar balls” of pyrogenic MGP waste were found at numerous locations in the study area. With few exceptions (noted below), there is no evidence for petrogenic PAH in the study area sediments, regardless of depth interval. The data indicate that pyrogenic PAH are consistent with wastes from the former Gasco Property. MGP wastes are also the source of elevated concentrations of PAH in sediments proximal to the Former ExxonMobil Terminal.

- A small number (14) of sediment samples contained varying amounts of petroleum-derived PAH were found. Only two of these samples contained PAH above any RAL.
- RAL exceedances in the Remedial Alternatives Area are driven by pyrogenic PAH. 98% of all samples in the study area at concentrations above the lowest RAL G contained PAH of pyrogenic origin.
- The samples with any petrogenic content near the Former ExxonMobil Terminal all had concentrations below all RALs. Based on these data, the Former ExxonMobil Terminal accounted for none of PAH contamination in RM 5-6 that would require remediation.
- There was no evidence for chemicals of concern (PCBs, DDx, selected chlorinated dioxin/furan isomers, BaP Eq), in the proposed Remedial Alternatives Area at mean concentrations that would classify them as Potential Threat Wastes.

In summary, the overwhelming PAH signature in the proposed Remedial Alternatives Area is pyrogenic in nature, and likely arises from MGP wastes originating from the former Gasco Property. All of the samples in the proposed Remedial Alternatives Area, except two, at concentrations greater than Alternative G (5,400 µg/kg TPAH17—the lowest RAL concentration) are pyrogenic in nature. Finally the Former ExxonMobil Terminal does not appear to be the source of any PAH requiring remediation in RM 5-6.

1.0 INTRODUCTION

Polycyclic aromatic hydrocarbons (PAH) are chemicals of potential concern found in sediments of the Portland Harbor Superfund Site (SFS). Based on several rounds of remedial investigation data developed by the Lower Willamette Group (LWG) and from available private party studies, it is evident that PAH in the Portland Harbor SFS are ubiquitous, and found both in the surface sediment layer (< 30 cm or approximately 0.98 feet), as well as deeper horizons of the sediment column (Lower Willamette Group, 2011).

The 2015 EPA Draft Portland Harbor Feasibility Study (FS: EPA 2015) identified Sediment Decision Units (SDU), where different key contaminants are identified as drivers for potential remedial action. The study described herein focuses on an area of the SFS between approximately River Mile 5 and River Mile 6, where PAH are principal contaminants of concern (COC). The 2015 EPA Draft FS developed remedial action levels (RALs) for PAH, expressed as TPAH17[1] (LWG, 2015). A range of TPAH17 RALs were established as part of the FS process to identify areas of surface sediments where capping and/or dredging could be used as remediation methods to meet cleanup objectives. Six RALs were developed for PAH, based on TPAH17 concentrations:

Alternative B:	170,000 µg/kg
Alternative C:	130,000 µg/kg
Alternative D:	69,000 µg/kg
Alternative E:	35,000 µg/kg
Alternative F:	13,000 µg/kg
Alternative G:	5,400 µg/kg

All six of the PAH remedial alternatives consist of substantial capping and/or dredging options as identified in the 2015 EPA Draft FS.

Section 3.3.1.2 of the 2015 EPA Draft FS describes Remedial Action Level concentrations and concentration contours for PAH in various segments of the river. These contours were depicted as concentration isopleth maps, with the concentration intervals broken out according to the six RAL concentrations. The isopleth maps were computed from the existing RI data using a natural neighbor algorithm, based on Theissen polygons. Polygons were drawn around contiguous regions where the interpolated data exceeded a given RAL concentration.

The LWG RI investigations documented particularly high PAH concentrations along the western nearshore zone of the Willamette River, downstream of River Mile 6.8. The 2015 EPA Draft FS identified an area between River Mile (RM) 5.0 and the St. Johns Bridge (located at approximately RM 5.8) that is significantly contaminated with PAH. PAH levels were sufficiently high to deem part of this area as a candidate for remediation (**Figure 1).** In this report, we refer to that contoured areas of incremental PAH RALs between approximately River Mile 5 and the NW St. Johns Bridge as the Remedial Alternatives Area.

The former Gasco MGP property (Gasco Property, aka Northwest Natural Gas Company) is located on the western shoreline of the Willamette River between River Mile 6.1 and 6.4 of the SFS, upstream of

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[1] TPAH17: the sum of the 16 EPA Priority Pollutant PAH (Table 2), plus 2-methylnaphthalene.

the main portion of the Remedial Alternatives Area. A former manufactured gas plant (MGP) operated at the Gasco Property between 1913 and 1956; the property was also the site of a coal tar pitch distribution facility. Coal tar pitch is a distillation residual of crude coal tar,[2] composed primarily of high molecular weight PAH compounds (McNeil, 1966). High concentration, PAH-rich MGP tar wastes were released to the river from the Gasco Property (Hahn and Associates, 2007). The Gasco Property was an EPA Early Action Site. In 2005, some 15,300 cubic yards of tar-like material and tar-like contaminated sediments were removed by dredging from the riverbank and nearshore sediments adjacent to the facility.

It is reasonable to hypothesize that elevated PAH concentrations downstream of the Gasco Property found in the Remedial Alternatives Area are due in whole or in part to MGP waste materials that migrated with current flow from the immediate shoreline area of the Gasco Property. However, other properties in the vicinity of the Remedial Alternatives Area are also potential sources of PAH to the local sediments. In 2014, NewFields conducted an investigation of the nature of PAH downstream of the Gasco Property, along the western portion of the channel (NewFields, 2015). In this report, that study is referred to as the NewFields 2014 Investigation. That work documented that the overwhelming source of high concentration PAH downstream of the Gasco Property (at least to approximately River Mile 4.8, proximal to the Linnton Plywood property) were pyrogenic (i.e., combustion-derived) in nature, and consistent in character with PAH arising from MGP tar wastes.

NewFields Study Objective

The objective of NewFields current study was to investigate the concentration distributions and chemical nature of PAH in the proposed Remedial Alternatives Area in an effort to

- Determine concentrations of PAH in hypothetical surface sediments that would result from potential dredging at specified depth horizons,
- Characterize the chemical nature of PAH, in order to understand the likely source(s) of the PAH found in the sediments, and
- Determine the extent, if any, of potential contributions of PAH to the proposed Remedial Alternatives Area from the Former ExxonMobil Terminal. The Former ExxonMobil Terminal is located on the west shore of the Willamette River between approximately River Miles 4.9 to 5.4, and is immediately proximal to a segment of the Remedial Alternatives Area discussed above.

In this regard, NewFields' work focused on determining if the PAH found in the proposed Remedial Alternatives Area were of pyrogenic (combustion), petrogenic (petroleum), or a mixed petrogenic-pyrogenic character. The chemical characteristics (nature) of the PAH points to the likely type of source(s) responsible for the PAH found in the sediments.

In addition to characterizing PAH chemistry in the Remedial Alternative Area, the potential presence of Principal Threat Wastes (PTW) within the sediments in the Remedial Alternatives Area was also investigated. The concept of principal threat was developed by EPA in the NCP to be applied on a site-specific basis when characterizing source material (EPA, 1991). Source material is defined as material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for

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[2] In this report, the term "coal tar" is used broadly to describe the tarry, PAH-rich waste that is an end product of an MGP process, regardless if the source of carbon in the process is coal, coke, or petroleum.

migration of contamination to groundwater, to surface water, to air or acts as a source for direct exposure. The 2015 EPA Draft FS identified eight chemicals of concern in the Superfund Site that occurred at concentrations exceeding a 10^{-3} risk level: total polychlorinated biphenyls (PCB); five chlorinated dioxin/furan congeners; DDT (dichlorodiphenyltrichloroethane) and its degradation products (collectively, DDx); and carcinogenic PAH (expressed as benzo(a)pyrene equivalents—BaP Eq). In the 2015 NewFields Investigation, a statistically-selected subset of sediment samples was analyzed for these eight COCs to evaluate if concentrations of these COCs occurred in the study area at levels that would categorize them as PTW wastes.

2.0 SEDIMENT SAMPLING STRATEGY

In the current NewFields 2015 investigation, sediment samples were collected across a network of stations in the proposed Remedial Alternatives Area (**Figure 2**). Both the number of samples and specific sampling locations were developed using Visual Sampling Plan software (Matzke et al., 2014), using previous RI investigation data and the NewFields 2014 Investigation data from the area as input variables. This tool supports the development of a defensible sampling plan based on statistical sampling theory and the statistical analysis of sample results to support confident decision making. A non-parametric systematic sampling approach with a random start was employed such that the resulting data could be used to construct a confidence interval on the true population median value within the Remedial alternative Area. Note that dredging had been carried out offshore of the Shore Terminal Property in 2014. No samples from either the NewFields 2014 Investigation or the current (2015) investigation were taken within the area dredged during this event.

The data collected in this 2015 study was supplemented by directly comparable surface chemistry data collected during the 2014 NewFields Investigation in the same study area (**Figure 3**). The NewFields 2014 Investigation data were particularly useful, because sediment samples containing PAH-rich, MGP-related wastes were collected from immediately proximal to the Gasco Property. Forensic chemical analysis of these samples provided a depiction of the concentrations and chemical makeup of the PAH associated with former operations at the Gasco site.

The sampling approach employed in this study focused on characterizing the sediment condition of the current river bed surface, and that for hypothetical surface sediment conditions for different potential navigational depths that the U.S. Army Corps of Engineers might consider for dredging of the Willamette River channel. The sediment bed depth intervals sampled in this investigation were:

- **Interval A (Surface)**
  Surface sediment samples collected from 0 to 1 foot below the current mudline at all locations.
- **Interval B (Future Channel)**
  Subsurface samples were collected from a depth of -48 to -49 feet Columbia River Datum (CRD). This interval was not collected from locations where the current mudline was below -47 feet CRD.
- **Interval C (Future Overdredge)**
  Subsurface samples collected from a depth of -51 to -52 feet CRD. This interval was not collected from locations where the current mudline was below -50 feet CRD.

- **Interval D. Future (Overdredge Plus Cap Buffer)**
  Subsurface samples collected from a depth of -53 to -54 feet CRD. This interval was not collected from locations where the current mudline was below -52 feet CRD.

Figure 4 is a schematic that illustrates the sampling strategy. Three cases were considered in designing the sampling:

(1) Case 1. Obtain contaminant chemistry data for the current sediment surface.
    a. Top 30 cm of each core will be collected, i.e., the red colored segments in **Figure 4** (Note: for some of the deeper sampling locations, this may be the entire core).

(2) Case 2. Navigational depth set at -43' CRD (Currently Authorized).
    a. Normal over-dredge would be 3 feet, bringing the bottom of the dredge prism to -46' CRD.
        i. The top of the core for all sampling locations were already below -46' CRD (or within less than one foot of -46 CRD), so the data collected in Case 1 (red-colored segments) suffice. Thus, no additional sampling need be conducted to describe sediment quality at -46' CRD.
    b. If the -43' CRD sediment horizon is deemed to be sufficiently impacted, a 5 foot over-dredge (3 feet buffer + 2 foot cap zones) might be required, bringing the bottom of the dredge prism to -48' CRD.
        i. Thus, data on sediment quality between -48' and -49' CRD would be necessary to define the new surface at -48' CRD.
        ii. For those sampling locations where the top of the core is currently below -48' CRD, the data from Case 1 (red-colored segments, 0-1' interval) suffice.
        iii. For those locations where the top of the core extends slightly above -48' CRD, the data from Case 1 (red-colored segment, 0-1' interval) are representative of the sediment quality at -48' CRD.
        iv. For those locations where the top of the core extends higher than -48' CRD, additional samples between -48' and -49' CRD were collected, i.e., the yellow-colored segments in **Figure 4**.

(3) Case 3. Navigation depth set at -48' CRD (Future Channel Depth).
    a. Sediment quality at -48' CRD determine in Case 2.
    b. If sediment quality at -48' CRD is not impacted, 3 feet over-dredge to -51' CRD would be performed.
        i. Thus, data on sediment quality between -51' and -52' CRD would be necessary to define the new surface at -51' CRD.
        ii. For those few locations where the top of the core extends only slightly above -51' CRD, the data from Case 1 (red-colored segment, 0-1' interval) suffice.
        iii. Thus, for those locations where the top of the core extends significantly higher than -51' CRD, additional samples between -51' and -52' CRD were collected, i.e., green-colored segments in **Figure 4**.

c. If sediment quality at the new surface at -48' CRD is deemed to be impacted, 5 feet over-dredge to -53' CRD (Future Overdredge +Cap Buffer) would be performed. Additional samples between -53' and -54' were collected (blue-colored segment in **Figure 4**).

Collectively, this data was used to describe the chemical nature of the current sediment surface, and that of several potential post-dredging surfaces.

3.0 SEDIMENT SAMPLE COLLECTION AND ANALYSES

The following sections provide a brief summary of the sample collection and laboratory analyses used pertaining to this 2015 investigation. The field and laboratory work, including technical procedures, are described in more detail in the Field Sampling Plan (**Appendix A**) and the Field Sampling Report (**Appendix B**).

3.1 Sample Collection

Field sampling operations were conducted between October 19 and October 23, 2015 by NewFields staff. Marine Sampling Systems (Port Orchard, WA) provided the vessel and sediment sampling equipment. Sample collection and handling were consistent with methods used in the LWG RI investigation. Surface (0-1') samples were collected using a hydraulic grab sampler. Subsurface samples were collected using a vibracore, consisting of an 18 foot tower with an 8 foot by 8 foot base, and 15 foot aluminum core tubes. Sediment cores were transferred from the sampling vessel to a cargo truck for transport to an-off site processing laboratory. At the processing facility the aluminum core tubes were cut along the vertical axis using a circular saw. The cores were carefully split using a spatula and opened to expose the sediment. Sediment cores were photographed and logged (e.g., with penetration depths, lengths recovered, calculated recoveries, and other observations). Individual sediment samples representative of intervals A, B, C, and D, adjusted for core compaction, were homogenized and placed into sample jars for shipment to the laboratory for chemical analysis.

An inventory of the samples collected for analysis is set forth in **Table 1**.

Table 1. Number of Samples, and Analyses Performed in the 2015 Investigation.

Sampling Interval	Horizon Description	Depth Interval	Forensic Chemical Analysis		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-Alkanes	DDx	PCB Congeners	PCDD/F Congeners
A	Surface	0 to -1 ft	53	53	14	14	14
B	Future Channel	-48 to -49 ft CRD	15	15	3	3	3
C	Future Overdredge	-51 to -52 ft CRD	34	34	5	5	5
D	Future Overdredge Plus Cap Buffer	-53 to -54 ft CRD	40	40	7	7	7

After processing, the samples were shipped to NewFields' alliance laboratory, Alpha Analytical Laboratory (Alpha; Mansfield, Massachusetts) for chemical analysis. The samples arrived intact and in good condition between October 23 and October 29, 2015. Upon receipt of samples, the samples were logged into Alpha's laboratory information management system (LIMS) and given unique laboratory identifications. The samples were stored in a limited access refrigerator at 4°C until processed by the laboratory staff for chemical fingerprinting analysis.

3.2 Laboratory Analyses

The sediment samples collected in this investigation were analyzed using methods designed specifically for the forensic analysis of petroleum described in detail by Douglas et.al. (2007). These are the same methods conducted by the same laboratory as used by the Federal Government and British Petroleum (BP) in the *Deepwater Horizon* oil spill investigation (NOAA, 2011). Samples were analyzed using complimentary methods that allow for qualitative identification of the type(s) of hydrocarbons comprising the samples by gas chromatography, and the quantitative measurement of an extended list of alkylated PAH compounds by gas chromatography/ mass spectrometry. Together, the resulting data can be used to reconcile PAH patterns and concentrations with likely sources within the SFS. The analytical methods of analysis are presented below.

3.2.1 Polycyclic Aromatic Hydrocarbons

A modified EPA Method 8270C gas chromatography/mass spectrometry (GC/MS-SIM) method was used to determine the concentrations of semi-volatile compounds or compound groups, including a broad range of 2- to 6- ring PAH, selected alkylated PAH homologues, sulfur-containing aromatics (dibenzothiophenes) and other compounds useful for the identification of hydrocarbon sources in the environment. Distribution patterns of PAH compounds provide a useful tool for petroleum product identification and differentiation. These tools are particularly valuable for identifying petroleum (petrogenic material) in the presence of combusted or partially combusted matter (pyrogenic material). **Table 2** lists the PAH target analytes measured in the study, and provide compound abbreviations used in graphical presentation of the data. The 16 Priority Pollutant PAH, along with 2-methylnaphthalene, that make up TPAH17, are shown in bold.

3.2.2 TPH and Gas Chromatographic "Fingerprints"

A modified EPA Method 8015B gas chromatography method was used to determine the total petroleum hydrocarbon (TPH) concentration (C_8-C_{44}), as well as concentrations of *n*-alkanes (C_9-C_{40}) and selected (C_{15}-C_{20}) acyclic isoprenoids (e.g., pristane and phytane) in the samples. A high resolution gas chromatogram produced by this method provides a detailed "fingerprint" of the hydrocarbons that compose the study samples. This analysis allowed for the characterization of the general boiling range(s) and type(s) of petroleum or other hydrocarbons present in the sample, as well as the degree(s) of weathering.

3.3 Compilation of Analytical Data

The complete Alpha Environmental Testing Reports (ETRs) including all sample preparation data, instrument calibrations, QC data and chromatograms is maintained on file by NewFields. A data summary containing pertinent gas chromatograms and tabulated results of all chemical analyses and quality control results is presented in **Appendix C**.

All analyses were conducted following established laboratory data quality objectives (DQOs) as described by Douglas et al. (2007). Appropriate laboratory quality control (QC) samples were processed along with the samples, which included a laboratory method blank (B), a laboratory control samples (LCS/LCSD), a sample duplicate (D), matrix spikes (MS), sediment reference material (SRM), and a reference oil. Resulting data underwent several levels of review. NewFields performed an independent review of the data generated by Alpha in order to ensure that DQOs were satisfied, and that the results were traceable to the raw data. NewFields also reviewed the data for compliance with the laboratory's documented procedures and established laboratory quality objectives. The data were found to be accurate and traceable, and met laboratory established method DQOs.

4.0 PAH – A FORENSIC CHEMISTRY PERSPECTIVE

Polycyclic aromatic hydrocarbons are ubiquitous compounds in the environment (ATSDR 1995). They originate from a large number of sources which can be broadly classified as either biogenic, petroleum-derived (petrogenic), or combustion-derived (pyrogenic).

- Biogenic sources are natural sources of PAH. PAH from these naturally occurring processes arise from the geologic processes that accompany the degradation of natural organic matter.
- Petroleum-derived (petrogenic) sources, of both natural and anthropogenic origins. Natural sources of PAH include natural seeps and petroleum-containing rock outcroppings. Anthropogenic sources of PAH arise directly from crude oil or refined petroleum products. Often in environmental investigations, the PAH from these kinds of sources are observed in media contaminated with spilled oil or fuel. In urban environments, petroleum-derived PAH can arise from a wide array of materials including pavement asphalt, building materials, fuels, and oils.
- Combustion-derived (pyrogenic) sources are generally anthropogenic sources of PAH and include those derived from fires, combustion of petroleum products, combustion and conversion of coal, and metallurgical processing. Notably, urban air and urban soils are impacted by PAH that arise from tailpipe exhausts, controlled and uncontrolled combustion typical of urban areas, and tar-derived construction materials.

Petroleum and pyrogenic materials contain hundreds of PAH parent and alkylated isomers. The 16 EPA Priority Pollutant PAH (listed in bold in **Table 2**) are a small subset of a much larger number of parent and alkylated PAH assemblages. Forensic chemists measure groups of similar alkylated PAH, and report them as alkyl homologues with different levels of alkyl substitution, e.g. the sums of C1-, C2-, C3- and C4-substituted parent PAH (Douglas et al. 2007). See **Table 2** for a listing of the PAH and alkylated PAH analyzed in the 2015 NewFields Investigation.

Because of their varied natural and anthropogenic sources, PAH are commonly found in sediments from urban, rural, and remote environments. PAH preferentially adsorb to sediments because of their affinity for particulate surfaces. PAH are common in sediments. They migrate to sediments via atmospheric deposition, point and non-point discharges, land runoff, and landside point-source releases of PAH-containing wastes. Because of their ubiquity, PAH are present at some *background* concentration in water, soil and sediments. Background concentrations of PAH in environmental media are dependent upon many variables, but are consistently higher in urbanized areas than in rural areas due to the higher degree of anthropogenic activities in urbanized areas (EPRI 2003) and have generally increased over the past 100 years due to increased urbanization (Yan et al. 2005).

Stout et al. (2004) compiled concentrations and distribution of PAH in "urban background" sediments (i.e. unaffected directly by point source discharges) from various waterways. The vast majority (96%) of the urban background-impacted sediments studied contained less than 20,000 µg/Kg Total EPA Priority Pollutant PAH (TPAH16). Sediments containing significantly higher concentrations of PAH were suggested by Stout et al. to indicate the presence of, or additional contributions from, one or more point sources.

4.1 Source Characteristics of PAH

While there are a multiplicity of sources of PAH found in the environment, the origins of PAH are generally classified either as petroleum- derived (petrogenic) or combustion- derived (pyrogenic) (Douglas et al. 2007). Petroleum-derived PAH are dominated by lower molecular weight 2- through 3-ring PAH and their C1 to C4 alkyl homologues that occur in “bell shaped” distributions that favor the alkyl homologues; pyrogenic PAH are dominated by 4- through 6-ring parent PAH, with significantly lesser amounts of alkyl homologues. The pyrogenic PAH occur in patterns dominated by the parent (unsubstituted) PAH, with systematically decreasing amounts of higher alkyl homologues, i.e. a “sloped” distribution of the parent PAH and its related alkylated homologues.

GC chromatograms and the PAH histograms for several common petroleum products (crude oil, heavy fuel oil (HFO), diesel fuel) are contrasted with that of a pyrogenic manufactured gas plant tar in **Figure 5.** Petroleum products contain only modest concentrations of PAH—typically in the low tens of thousands of parts per million**.** The classic “bell shaped” distribution of alkylated PAH homologues are clearly evident among the petroleum products. Note that crude oil is composed of the broadest range of 2- through 4-ring alkylated PAH homologues, and contains only traces of higher molecular weight 5- and 6-ring PAH like benzo(a)pyrene. By virtue of distillation, diesel fuel contains only 2- and 3-ring alkylated PAH. By contrast, the pyrogenic MGP tar is comprised of a broad range of 2- through 6-ring PAH, with each class of PAH dominated by the parent, alkyl unsubstituted, PAH compound.

Often, investigations of the nature and sources of PAH are limited to the use of so-called EPA Priority Pollutant PAH data. The 16 Priority Pollutant PAH are 2- through 6 ring parent (alkyl unsubstituted) PAH that are measured for regulatory purposes (See **Table 1**, listed in bold). There are no alkylated PAH measured in Priority Pollutant data sets, which limits the ability to recognize mixtures of petroleum- and combustion-derived PAH (Stout et al., 2015). While some basic assessments of EPA Priority Pollutant data sets can offer some insight into the potential nature of PAH, they are inherently limited by the lack of alkylated PAH data. In order to develop the most useful metrics to determine the presence and relative amounts of petrogenic and pyrogenic PAH in sediments, it is necessary to utilize more robust, alkylated PAH data.

Datasets that contain alkylated PAH data allow the sediment investigator to more accurately identify contributions from both petrogenic and pyrogenic PAH. A convenient means to classify the type(s) of PAH in sediments (i.e., petrogenic-dominant or pyrogenic-dominant, or mixtures thereof) is to evaluate the proportion of alkylated PAH found in the samples. A simple but powerful metric—% Alkyl PAH—can be calculated from environmental data, and compared to literature reference materials in order to ascertain the PAH source characteristics and approximate percentages of petroleum and tar-derived PAH found in sediments (Douglas et al. 2016). The metric is defined as:

%Alkyl PAH = (∑C1, -C2-, C3-, and C4-alklyated homologues of 2-, 3- and 4-ring PAH)/(∑Parent+alkylated PAH)

This ratio simply compares the relative amount of the sum of alkyl-substituted PAH (abundant in petroleum hydrocarbons) to the sum of total PAH in samples. Review of data for various kinds of petroleum (e.g., crude oils, heavy fuel oils, distillate fuels), pyrogenic materials (e.g. MGP tars, creosote), and urban dust, and urban background sediment offer a framework to classify the %Alkyl PAH values for the “pure” source materials, and mixtures thereof:

Material[a]	**Typical %Alkyl PAH**[b]
Diesel Fuel (Fresh)	89%
Diesel Fuel (Weathered)	98%
Heavy Fuel Oil #6 (Fresh)	86%
Heavy Fuel Oil (Weathered)	96%
Coal Oil Tar (Fresh)	18%
Coal Oil Tar (Weathered)	25%
Urban Dust (NIST 1649a)	36%
Urban Background Sediment[c]	28%

[a] Data from NewFields petroleum and hydrocarbon products chemical analysis library. Data available upon request.

[b] Based on 53 parent and C_1-C_4 alkylated PAH.

[c] Data from Stout et al. 2004. Data available upon request.

For classification purposes, it is reasonable to identify that PAH from petroleum origin contain >~85% Alkyl PAH, and PAH from pyrogenic materials like MGP tars contain less than ~30% %Alkyl PAH. Mixtures of petrogenic materials and pyrogenic materials have %Alkyl PAH values between these endmember values. Thus, the degree of "petrogenicity" or "pyrogenicity" measured in sediment samples, and the relative contribution of petroleum versus pyrogenic mater, samples can be evaluated using these benchmarks.

4.2 Features of PAH in Urban Sediments

Stout et al. (2004) studied the PAH features of sediments from 9 waterways in the United States. They report that "urban background" sediment contain PAH that are dominantly pyrogenic mixtures of PAH, with an median %Alkyl PAH of 28%. At the same time, the PAH data from Stout et al. (2004) show a range in the %Alkyl PAH content among the sample data (%Alkyl PAH from 14% to 65%). These observations derived from the Stout et al. (2004) dataset demonstrated that, in urban sediments, a range of PAH character exists, and likely is a result of varying inputs of petrogenic and pyrogenic materials to the sediments.

In summary, the %Alkyl PAH metric provides a means to identify the general nature, and potential localized petrogenic or pyrogenic features of PAH within a sediment system. We use this metric as an important means to identify the nature of PAH, and the contributions of pyrogenic and petrogenic PAH in sediments evaluated in NewFields 2015 Investigation.

5.0 RESULTS OF THE 2015 SEDIMENT INVESTIGATION

The schedule of analyses performed on the individual sediment samples collected as part of NewFields' current (2015) sediment investigation are presented in **Table 3**. Data for individual sample analyses are summarized in **Table 4**. The concentration results for PAH are expressed herein in two fashions: as Total PAH (the sum of the 2- through 6-ring parent and alkylated PAH) and as TPAH17 (the sum of the 16 Priority Pollutant PAH highlighted in **Table 2**, plus 2-methylnaphthalene). When examining concentration trends in the investigation data set, we focus on TPAH17, since this is the metric used for remedial decision-making in the 2015 EPA Draft FS. Summary statistics for the findings of Total PAH and TPAH17 in sediments by depth horizon are presented in **Table 5** and **Table 6**, respectively. Note that the data compiled for each depth horizon includes samples at the specified depth, plus any surface samples that exist at a deeper depth interval. This accounting approach defines the conditions of a hypothetical sediment surface after dredging to any one of the specified depths. Note that the highest PAH concentration sample (T05-S, 2,389,580 µg/kg) was a surface sample taken at the deepest -53 to -54 CRD interval. Thus, it appears as the maximum TPAH17 concentration for the current surface and each of the potential depth horizons.

A summary for the number of samples that comprise each of the four depth horizons studied and which exceeded the six Remedial Alternative Levels is presented in **Table 7a and b**. The locations of these exceedances are discussed in the text. Note that the data compiled for each depth horizon includes samples at the specified depth, plus any surface samples that exist at a deeper depth interval.

A description of the general hydrocarbon features and depiction of the PAH characteristics of sediment samples is presented, with particular focus on those samples that exceed the minimum RAL concentration of 5,400 µg/kg TPAH17, since these samples arguably contain PAH that may drive future remediation decisions.

Results from the analyses of PTW chemicals of concern are listed in **Table 8**, and discussed below in the text of this report.

5.1 PAH Concentration Trends Found at Depth Horizons

Data from the LWG RI investigations clearly document an abrupt and dramatic increase in PAH sediment concentration on the western margin of the river beginning at approximately River Mile 6.4, in the vicinity of the Gasco Property (**Figure 6**). The NewFields 2014 Investigation provided the same, albeit higher resolution perspective, viz., very high concentrations of PAH were noted in the sediments immediately proximal to the Gasco Property, followed by generally diminishing (but still high) concentrations in downstream sediments to at least River Mile 4.8, proximal to the Linnton Plywood property (**Figure 7).** This synoptic perspective on PAH data in the vicinity of River Mile 5 to River Mile 6 forms a backdrop against which the current data can be evaluated.

TPAH17 concentration trends were evaluated for the four sediment horizons studied in this investigation**:** the current surface (0 to 1'), and potential surface sediments after dredging at -48 to -49' CRD, -51' to -52' CRD, and -53' to -54' CRD. Note that data from NewFields 2014 Investigation were combined with the current 2015 data to supplement the analysis of PAH spatial and depth trends. Each depth horizon discussed in this section are comprised of samples at the specified depth, plus any surface samples that exist at a deeper depth interval. This approach defines the conditions of a hypothetical sediment surface after dredging to the specified depth.

The distribution of PAH concentrations in sediments at each of the specified dredging horizons between approximately River Mile 5 and River Mile 6 is shown in **Figures 8 (a) – Figure 8 (d)**. Here, the PAH concentrations at specified depth horizons are shown projected onto the PAH RAL contour map taken from the 2015 EPA Draft FS. The sediment TPAH17 concentrations were classified by RAL category.

The concentrations of TPAH17 measured in the sediments in the proposed Remedial Alternative Area are generally elevated in all four depth horizons, but the highest concentrations were found in the current surface interval (**Table 5**). The average and 95th percentile TPAH17 concentrations, respectively, indicate that the concentration trends with propose dredge horizon in the study area decline gradually with increasing depth of potential dredging.

Depth Horizon	TPAH17 Average (µg/kg)	TPAH17 95th Percentile (µg/kg)
0 to -1’	188,870	1,230,448
-48 to -49’ CRD	147,450	572,691
-51 to -52 CRD	108,400	546,808
-53 to -54 CRD	110,529	450,141

The general spatial distribution of TPAH17 concentrations is similar among the different depth horizons, where the highest concentrations occur along a downstream axis just west of the center of the river channel. Lower TPAH17 concentrations are noted on both the eastern and western margins of the high concentration axis. This high concentration axis likely represents a zone of preferential deposition.

Generally, the highest TPAH17 concentrations measured in this investigation are in good geographic agreement with the highest TPAH17 concentrations shown in the Remedial Action Level contour map developed for the 2015 EPA Draft FS. However, the data collected in this investigation indicate that the boundaries between RAL contours could be adjusted and optimized, both horizontally and vertically. The current data suggest that the areas of the RAL contours would likely be reduced in both dimensions. For example, there are more samples at low TPAH17 concentration (< RAL-G) at depth than at the current surface (e.g., 66% of the samples at -53’ to -54’ CRD, compared to 36% at the surface). Notably, while TPAH17 concentrations generally decrease with depth, the concentrations are slightly elevated at the -53’ to -54’ CRD horizon. This increase is attributable to the influence of a small number of high TPAH17 concentration samples found at depth, and located offshore of Marine Finance.

Conversely, the frequency of higher concentration samples are noted in the current surface (0 to -1’) horizon, e.g., 34% of the samples had TPAH17 concentrations that exceeded RAL Alternative E (35,000 µg/kg), whereas 25% of the samples in the deepest potential horizon (-53 to -54’) had TPAH17 concentrations that exceeded RAL Alternative E. Collectively, the data suggests that an optimal three-dimensional dredge prism would be asymmetric, with lower volume at increasing depth.

5.2 Character of PAH in the Remedial Alternatives Area

In this section, data from both the NewFields 2014 Investigation and the current investigation are combined for interpretative purposes. As discussed above in Section 5.1, the NewFields 2014 Investigation showed that very high concentrations of PAH (as high as 13,400,000 µg/kg) were noted in the sediments immediately proximal to the Gasco Property, followed by generally diminishing (but still high) concentrations in downstream sediments to at least approximately River Mile 4.8, in the vicinity of the Linnton Plywood property. Furthermore, the NewFields 2014 Investigation concluded that the source of PAH in the sediments downstream of Gasco Property are, with just a few exceptions, of pyrogenic, tar-derived origin, and reconciled with the type of wastes and PAH discharged from the former MGP at the Gasco Property. These conclusions were reached through evaluation of the descriptive forensic hydrocarbon and PAH chemistry.

Characteristics of Hydrocarbons and PAH in Sediments Adjacent to the Gasco Property

Descriptive hydrocarbon chemistry of samples immediately proximal to the Gasco Property was found to be consistent with MGP tar wastes (NewFields 2014 Investigation). The gas chromatography fingerprints for the Gasco Property sediment samples (**Figure 9**), are emblematic of MGP tar residues (Douglas et al. 2007), namely a chromatogram dominated by individual peaks recognized as parent PAH compounds, with a minimal unresolved complex mixture (UCM, or chromatographic "hump"). These chromatograms are distinctly different than typical urban sediments (Stout et al. 2004) or petroleum-impacted sediments.

The PAH histograms for sediment samples collected in the vicinity of the Gasco Property are presented in **Figure 9**. The major PAH homologue series in the samples show the well-recognized pattern of pyrogenic PAH, i.e., highly skewed homologue patterns for the naphthalene, phenanthrene, and fluoranthene/pyrene series. Additionally, significant relative amounts of pyrogenic 5- and 6- ring PAH are present in the samples. These high PAH concentration samples found offshore of the Gasco site are representative of MGP tar wastes released during former operations at the site. The very high concentrations of PAH proximal to the Gasco Property make this site the most likely source of pyrogenic PAH to the downstream sediments.

Hydrocarbon Characteristics of Sediments Downstream of the Gasco Property

Many of the sediments collected in the proposed Remedial Alternatives Area, regardless of depth, shared the same unique chromatographic features as the upstream sediments proximal to the Gasco Property. In particular, the higher PAH concentration samples exhibited features of MGP tar derived wastes. These features include gas chromatograms that are dominated by individual peaks recognized as parent PAH compounds, with a limited unresolved complex mixture (**Figure 10**). Similarly, the PAH histograms of the sediments in the Remedial Alternatives Area (with the exception of a few, discussed below) were overwhelmingly pyrogenic in nature. Like the upstream samples offshore the Gasco property, the major PAH homologue series in the Remedial Alternatives Area samples show the well-recognized pattern of pyrogenic PAH, i.e., highly skewed homologue patterns for the naphthalene, phenanthrene, and fluoranthene/pyrene series. In addition, the samples contain significant amounts of pyrogenic 5- and 6- ring PAH. A few of the high concentration PAH samples contained pyrogenic PAH assemblages suggestive of either highly weathered MGP tar, or possibly tar pitch. The PAH assemblages of these samples were composed primarily of 4-ring and higher pyrogenic PAH (**Figure 11**). Discovery of potential pitch-like PAH is not necessarily surprising, since historic operations at the Gasco property included a pitch distribution facility.

It is noteworthy that the field team observed and recorded the presence of tar balls of various sizes in numerous sediment samples, at varying depths, in the Remedial Alternatives Area. Locations where tar balls were observed are noted on **Figure 8 (a) – 8 (d)**. The tar balls are indicators of high PAH concentration MGP-derived source material in the proposed Remedial Alternatives Area.

Analysis of one of these tar balls from location PH15-38 (River Mile 5.55) revealed the unmistakable chemical characteristics of MGP tar-derived waste. The concentrations of Total PAH for the tar ball was exceedingly high (194,923,000 µg/kg or 19.4%). The gas chromatogram for the tar ball sample (**Figure 12, top panel**) depicted the unmistakable features of weathered MGP tar. These features included a chromatogram composed exclusively of individual resolved peaks identified as parent PAH compounds, with little meaningful unresolved complex mixture.

The PAH histogram for the tar ball sample (**Figure 12, bottom panel**) was consistent with MGP-derived tar material. The PAH alkyl homologue patterns were highly skewed, and dominated by the parent PAH for the naphthalene, phenanthrene, and fluoranthene/pyrene series. Significant amounts of pyrogenic

5- and 6- ring PAH are present in the tar ball. The PAH assemblage, dominated by 4-ring and higher compounds, could represent highly weathered tar or tar pitch.

Source Characteristics of PAH in RM 5- 6 Sediments

Figure 13 depicts the % Alkyl PAH index versus the TPAH17 concentrations in the study area sediments. Samples collected immediately offshore of Gasco are plotted in red symbols on the same graph. The %Alkyl PAH values for the high PAH concentration Gasco sediments range from about 10% to 32% — values consistent with highly pyrogenic, MGP tar waste materials.

Figure 13 clearly shows that that the majority of the sediment data, regardless of concentration, are highly pyrogenic in nature, and fall within the range of %Alkyl PAH values found in sediments just offshore of the Gasco Property. In other words, PAH of similar pyrogenic character to those found proximal to the Gasco Property dominate the makeup of the PAH in the proposed Remedial Alternative Area.

Notable in the lower right quadrant of **Figure 13** are ten samples taken from five locations with variable, but relatively higher %Alkyl PAH indices than the majority of the samples collected in the Remedial Alternatives Area. These ten samples have low TPAH17 concentrations (< 10 µg/kg) and %Alkyl PAH indices from 40% up to approximately 70%. The elevated %Alkyl PAH values indicate contribution of variable amounts of petroleum-derived PAH to the overall PAH composition of the samples. Evidence for contribution of petroleum-derived PAH to these samples can be seen in their respective PAH distributions, i.e., “bell shaped” (or reversed skewed) homologue distributions for some PAH homologue groups that arise from petroleum (**Figure 14**).

The PAH concentrations in these ten petroleum-affected samples is low—less than 10 µg/kg TPAH17. As can be seen in **Figure 13**, these concentrations are lower than reference sediments taken well upstream of the Gasco Property, which were found to range from 100 to 200 µg/kg TPAH17 (NewFields 2014 Investigation). Interestingly, the upstream reference samples exhibited a range of %Alkyl PAH character, from highly pyrogenic to highly petrogenic. This feature demonstrates the PAH composition of upstream sediments is variable, and composed of mixtures of low concentration petrogenic and pyrogenic PAH. Such features are consistent with various inputs from different types of sources, e.g., land runoff, combined sewer overflow discharges, and various point-source discharges. The ten low-level TPAH17 samples, taken from 5 locations offshore of the Former ExxonMobil Terminal, are the only samples containing some petrogenic PAH that are found proximal to the facility. These (and two other samples, S03-Z and T03-Z, described below) are the only samples in RM 5-6 containing petrogenic PAH that could potentially be linked to operations at the Former ExxonMobil Terminal.

Also depicted in the center-right area of **Figure 13** are four samples that have relatively high TPAH17 (1,000 to ~80,000 µg/kg), and which have % Alkyl PAH indices that indicate the presence of some petrogenic PAH. These samples are identified as S19-S (surface), S19-Z (-2 to -3’ below surface), S03-Z (-2 to -3’ below surface) and T03-Z (-2 to -3’ below surface). These samples have anomalously high %Alkyl PAH indices compared to the other samples in the study area with similar concentrations of TPAH17. Note that samples S03-Z (2,485 µg/kg) and T03-Z (2,210 µg/kg) have TPAH17 concentrations below RAL-G; sample S19-S (38,621 µg/kg) contains TPAH17 just above RAL-E, while sample S19-Z (69,757 µg/kg) contains TPAH17 just above RAL-D.

The %Alkyl PAH metric can be used to map the locations of pyrogenic-dominant and petrogenic-dominant PAH, respectively, as a function of depth horizon (**Figures 15 (a) – Figure 15 (d))**. Clearly, the overwhelming PAH signature in the proposed Remedial Alternatives Area is pyrogenic in nature. The few locations where petrogenic-dominant samples are encountered are, as described above, generally of low concentration (TPAH17 < 10 µg/kg). Several sampling locations contained petroleum PAH at multiple depths (i.e., PH15-01, PH15-02 and S19).

Note that the only samples containing petrogenic PAH at concentration above any RAL (i.e., S19-S and S19-Z) were found offshore of U.S. Moorings—upstream of the Former ExxonMobil Terminal. Twelve samples from 7 locations offshore of the Former ExxonMobil Terminal contained some petrogenic PAH. However, all twelve of these samples had TPAH17 concentrations below any RAL.

5.3 Principal Threat Wastes

The concept of principal threat was developed by EPA in the NCP to be applied on a site-specific basis when characterizing source material (EPA, 1991). Source material is defined as material that includes or contains hazardous substances, pollutants or contaminants that act as a reservoir for migration of contamination to groundwater, to surface water, to air or acts as a source for direct exposure.

The 2015 EPA Draft FS identified eight chemicals of concern (COC) that occurred in certain areas of the SFS at threshold concentrations exceeding a 10^{-3} risk level, thus defining those materials as PTW:

Chemicals of Concern	**Highly Toxic PTW Threshold (µg/kg) (10^{-3} risk)**
PCBs	200
Dioxin/Furan Congeners	
2,3,7,8-TCDD	0.01
2,3,7,8-TCDF	0.6
1,2,3,7,8-PeCDD	0.01
2,3,4,7,8-PeCDF	0.2
1,2,3,4,7,8-HxCDF	0.04
DDx	7,050
cPAHs (BaP Eq)	106,000

In this investigation, a geostatistically-selected subset of 29 investigation samples was analyzed for these COCs (except BAP Eq) to evaluate, with 95% confidence, if the population mean concentrations of the COCs occurred in the Remedial Alternatives Area at levels that would exceed PTW threshold risk concentrations. In the case of BAP Eq, this analysis was completed using data from the 142 samples collected in the defined Remedial Alternatives Area.

The results of the analysis of PTW compounds is summarized in **Table 8** [Note: concentrations reported as pg/g for several of these COCs]. Compounds exceeding the threshold waste limit are highlighted in grey. The results of the statistical analysis of the COC data is presented in **Appendix D**. **Tables 1 through 5** in **Appendix D** provide a summary of the statistical analysis.

With the exception of BaP Eq, there is no significant difference in PTW chemical concentration with respect to depth horizon. The concentration of BaP Eq is significantly higher at the surface horizon compared to deeper horizons. The finding of the highest concentrations of PAH (i.e., as BaP Eq) in the current surface sediment horizon suggests that there have been recent, and perhaps on-going releases of PAH-rich MGP tar wastes from sediments proximal to the Gasco Property.

There were two individual samples that marginally exceeded PTW threshold limits for dioxin congeners, and two that exceeded BaP Eq:

- PH15-11 A, a surface sample offshore of the Transloader International Property, exceeded the PTW threshold limit for 1,2,3,4,7,8-HxCDF (0.069 µg/kg).
- PH15-12-A, a surface sample offshore of the Marine Finance Property, slightly exceeded the PTW threshold limit for 1,2,3,4,7,8-HxCDF (0.103 µg/g) and 1,2,3,7,8-PeCDD (0.0114 µg/g).
- TO5-S (181,156 µg/kg), a surface samples located offshore of the Transloader International Property exceeded the PTW limit for BAP Eq. The PAH assemblage of this sample was pyrogenic.
- PH15-07-A (134,486 µg/kg), a surface sample offshore the Shore Terminal Property, exceeded the PTW limit for BaP Eq. The PAH assemblage of this sample was pyrogenic.

Statistical analysis shows that the mean concentrations for all eight of the COCs in the proposed Remedial Alternatives Area are below PTW thresholds. At the 95% confidence level, none of the COCs are classified as PTW wastes.

6.0 CONCLUSIONS

The LWG RI identified an area between River Mile (RM) 5.0 and the St. Johns Bridge (located at approximately RM 5.8) that is contaminated with PAH. PAH levels were sufficiently high to deem part of this area as a candidate for remediation**.** The 2015 EPA Draft FS describes Remedial Action Level concentrations and concentration contours for PAH in various segments of the river. In this report, we refer to that contoured areas of incremental PAH RALs between approximately River Mile 5 and the NW St. Johns Bridge as the Remedial Alternatives Area.

NewFields conducted a field survey in 2015 to investigate the concentration distributions and chemical nature of PAH in the proposed Remedial Alternatives Area in an effort to:

- Determine concentrations of PAH at the current sediment surface, and for several potential surface sediment horizons that would result from dredging at certain specified depths.
    - Samples were collected at several depth horizons to define these surfaces: the current surface (0 to 1'), and at -48 to -49' CRD, -51' to -52' CRD, and -53' to -54' CRD. Data from the NewFields 2014 Investigation in the same area were combined with the current 2015 data to supplement this analysis.
- Characterize the nature of PAH, in order to understand the likely source(s) of the PAH found in the sediments.
- Evaluate the potential for Principal Threat Wastes (PTW) occurring in the Remedial Alternatives Area. The 2015 EPA Draft FS identified eight COC, and corresponding risk-based concentration thresholds for PTW: polychlorinated biphenyls (PCB); five chlorinated dioxin/furan congeners; DDT (dichlorodiphenyltrichloroethane) and its degradation products (collectively, DDx); and carcinogenic PAH (expressed as benzo(a)pyrene equivalents—BaP Eq). NewFields screened a subset of investigation samples for these COC to determine if there was evidence for PTW in the study area.

Key findings from the NewFields investigation are:

- Elevated concentrations of PAH are encountered in the proposed Remedial Alternatives Area. The highest PAH concentrations were found proximal to the former Gasco Property, and decreased systematically downstream from the property to at least River Mile 4.8, proximal to the Linnton Plywood property.
    - In the Remedial Alternatives Area, TPAH17 sediment concentrations averaged 67,677 µg/kg, and with a maximum concentration of 2,389,590 µg/kg.
- TPAH17 concentrations varied with the depth of the potential surface sediment horizon. The highest concentrations occur along a downstream axis just west of center of the river channel. The highest TPAH17 concentrations are found in current surface sediments, with lower concentrations noted with depth, and on both the eastern and western margins of the high concentration axis.
- Generally, the highest TPAH17 concentrations measured in this investigation align in the areas predicted to have the highest TPAH17 concentrations by the Remedial Action Level Contour map developed for the 2015 EPA Draft FS.
- The frequency of samples in the study area that exceeded RAL limits decreased with increasing depth of the potential surface sediment horizons. For example, 36% of the current surface samples had TPAH17 concentrations below the lowest RAL level (Level G: 5,400 µg/kg), whereas 66% of the samples at a potential surface at -53' to -54' CRD had TPAH17 concentrations below RAL Level G.
    - The TPAH17 data indicate that the boundaries between RAL contours could be adjusted and optimized, both horizontally and vertically. The data suggest that the areas of the RAL contours would likely be reduced in both dimensions.
- The chemical characteristics of PAH found proximal to the former Gasco Property are consistent with MGP derived tar wastes. These high concentration PAH are highly pyrogenic in character, i.e., derived from combustion/pyrolysis processes. These pryogenic PAH are distinct in chemical character and readily differentiated from petroleum-derived (petrogenic) PAH.
- The characteristics of PAH across the entirety of the proposed Remedial Alternative Area are highly pyrogenic in nature. With few exceptions (noted below), there is no evidence for purely petrogenic PAH in the segments, regardless of depth horizon. The data support a conclusion that pyrogenic PAH of character consistent with wastes from the former Gasco Property MGP are the major source of elevated concentrations of PAH in sediments of the proposed Remedial Alternatives Area.
    - Tar balls, with very high PAH concentration (e.g., sample from PH15-38, TPAH17 of 194,923,000 µg/kg) and with chemistry fully consistent with MGP tar waste, are found in numerous locations across the proposed Remedial Alternative Area, further supporting a conclusions that MGP wastes are a dominant source of PAH to the sediments between River Mile 5 and River Mile 6.
- Overall very few sediment samples contained petroleum-derived PAH.
    - Ten sediments from five near-shore locations (PH15-01, PH15-02, PH15-03, PH15-04, and PH15-05) contain variable amounts of petroleum-derived PAH. Approximately 50-75% of the total PAH in these samples were of petrogenic origin. The PAH

    concentrations found in these petroleum-impacted samples is low—less than 10 µg/kg TPAH17.
  - Four samples (S19-S, S19-Z, S03-Z and T03-Z) contained petroleum-impacted PAH at TPAH17 greater than 1,000 µg/kg. Only two of these samples, from the same location were found to contain TPAH17 above the lowest RAL (Level G)—S19-S contains TPAH17 just above RAL-E, and S19-Z contains TPAH17 just above RAL-D. Samples S03-Z and T03-Z contained TPAH17 below the lowest RAL concentration benchmark (Alternative G).
  - The two samples containing petrogenic PAH at concentration above any RAL (i.e., S19-S and S19-Z) were found offshore of U.S. Moorings—upstream of the Former ExxonMobil Terminal.
  - Twelve samples from 7 locations offshore of the Former ExxonMobil Terminal contained some petrogenic PAH. However, all twelve of these samples had TPAH17 concentrations below any RAL.
  - Based on these data, the Former ExxonMobil Terminal account for none of the PAH contamination in the RM 5-6 area that would require remediation.

- RAL exceedances in the Remedial Alternatives Area are driven by pyrogenic PAH.
  - 98% of samples >RAL G contained PAH of pyrogenic origin.
  - 97% of samples >RAL F contained PAH of pyrogenic origin.
  - 96% of samples >RAL E contained PAH of pyrogenic origin.

- In summary, the overwhelming PAH signature in the proposed Remedial Alternatives Area is pyrogenic in nature, and likely arises in whole or in part from waste emissions from the MGP that was sited at the former Gasco Property. All of the samples in the proposed Remedial Alternatives Area, save two, at concentrations greater than Alternative G (5,400 µg/kg TPAH17—the lowest RAL concentration) are pyrogenic in nature. These pyrogenic PAH are the driving factors in any remedial action that may be taken in sediments between River Mile 5 and River Mile 6.
- Other sources of PAH arising from various activities (i.e., maintenance dredging, roadway runoff, and stormwater discharge, upstream sites) in the vicinity of River Mile 5 to River Mile 6 may contribute some PAH to the sediments in River Mile 5 to River Mile 6.
- There was no evidence for chemicals of concern (PCBs, DDx, selected chlorinated dioxin/furan isomers, BaP Eq), in the proposed Remedial Alternatives Area at mean concentrations that would classify them as Potential Threat Wastes.

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Tables

Table 2. Polycyclic Aromatic and Related Heterocyclic Target Analytes.[a]

Abbr.	Compound	Abbr.	Compound
D0	cis/trans-Decalin	**FL0**	**Fluoranthene**
D1	C1-Decalins	**PY0**	**Pyrene**
D2	C2-Decalins	FP1	C1-Fluoranthenes/Pyrenes
D3	C3-Decalins	FP2	C2-Fluoranthenes/Pyrenes
D4	C4-Decalins	FP3	C3-Fluoranthenes/Pyrenes
BT0	Benzothiophene	FP4	C4-Fluoranthenes/Pyrenes
BT1	C1-Benzo(b)thiophenes	NBT0	Naphthobenzothiophenes
BT2	C2-Benzo(b)thiophenes	NBT1	C1-Naphthobenzothiophenes
BT3	C3-Benzo(b)thiophenes	NBT2	C2-Naphthobenzothiophenes
BT4	C4-Benzo(b)thiophenes	NBT3	C3-Naphthobenzothiophenes
N0	**Naphthalene**	NBT4	C4-Naphthobenzothiophenes
N1	C1-Naphthalenes	**BA0**	**Benz[a]anthracene**
N2	C2-Naphthalenes	**C0**	**Chrysene**/Triphenylene
N3	C3-Naphthalenes	BC1	C1-Chrysenes
N4	C4-Naphthalenes	BC2	C2-Chrysenes
B	Biphenyl	BC3	C3-Chrysenes
DF	Dibenzofuran	BC4	C4-Chrysenes
AY	**Acenaphthylene**	**BBF**	**Benzo[b]fluoranthene**
AE	**Acenaphthene**	**BJKF**	**Benzo**[j]**+[k]fluoranthene**
F0	**Fluorene**	BAF	Benzo[a]fluoranthene
F1	C1-Fluorenes	**BEP**	Benzo[e]pyrene
F2	C2-Fluorenes	**BAP**	**Benzo[a]pyrene**
F3	C3-Fluorenes	PER	Perylene
A0	**Anthracene**	**IND**	**Indeno[1,2,3-cd]pyrene**
P0	**Phenanthrene**	**DA**	**Dibenz[a,h]anthracene**
PA1	C1-Phenanthrenes/Anthracenes	**GHI**	**Benzo[g,h,i]perylene**
PA2	C2-Phenanthrenes/Anthracenes	CAR	Carbazole
PA3	C3-Phenanthrenes/Anthracenes		
PA4	C4-Phenanthrenes/Anthracenes	2MN	2-Methylnaphthalene
RET	Retene	1MN	1-Methylnaphthalene
DBT0	Dibenzothiophene	26DMN	2,6-Dimethylnaphthalene
DBT1	C1-Dibenzothiophenes	167TMN	1,6,7-Trimethylnaphthalene
DBT2	C2-Dibenzothiophenes	4MDT	4-Methyldibenzothiophene
DBT3	C3-Dibenzothiophenes	2MDT	2/3-Methyldibenzothiophene
DBT4	C4-Dibenzothiophenes	1MDT	1-Methyldibenzothiophene
BF	Benzo(b)fluorene	3MP	3-Methylphenanthrene
		2MP	2/4-Methylphenanthrene
		2MA	2-Methylanthracene
		9MP	9-Methylphenanthrene
		1MP	1-Methylphenanthrene

[a]The 16 EPA Priority Pollutant PAH are shown in bold.

Table 3. Samples and Analyses.

Station ID	Sample ID	Depth Interval	Forensic Chemical Analysis		Ancillary Measurements		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-alkanes	Grain Size	TOC	DDx	PCB Congeners	Dioxin/Furan Congeners
PH15-01	PH15-01-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-01-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-01-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-01-D	-53 to -54 ft CRD	X	X	X	X			
PH15-02	PH15-02-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-02-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-02-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-02-D	-53 to -54 ft CRD	X	X	X	X			
PH15-03	PH15-03-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-03-B	-48 to -49 ft CRD	X	X	X	X	X	X	X
	PH15-03-C	-51 to -52 ft CRD	X	X	X	X	X	X	X
	PH15-03-D	-53 to -54 ft CRD	X	X	X	X	X	X	X
PH15-04	PH15-04-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-04-A-FD	0 to 1 ft below mudline	X	X	X	X			
	PH15-04-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-04-C	-51 to -52 ft CRD	X	X	X	X			
PH15-05	PH15-05-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-05-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-05-C	-51 to -52 ft CRD	X	X	X	X			
PH15-06	PH15-06-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-06-B	-48 to -49 ft CRD	X	X	X	X	X	X	X
	PH15-06-C	-51 to -52 ft CRD	X	X	X	X	X	X	X
PH15-07	PH15-07-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-07-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-07-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-07-D	-53 to -54 ft CRD	X	X	X	X	X	X	X
	PH15-07-D-FD	-53 to -54 ft CRD	X	X	X	X			

Station ID	Sample ID	Depth Interval	Forensic Chemical Analysis		Ancillary Measurements		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-alkanes	Grain Size	TOC	DDx	PCB Congeners	Dioxin/Furan Congeners
PH15-08	PH15-08-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-08-B	-48 to -49 ft CRD	X	X	X	X			
PH15-09	PH15-09-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-09-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-09-D	-53 to -54 ft CRD	X	X	X	X			
PH15-10	PH15-10-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
PH15-11	PH15-11-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-11-D	-53 to -54 ft CRD	X	X	X	X	X	X	X
	PH15-11-D-FD	-53 to -54 ft CRD	X	X	X	X	X	X	X
PH15-12	PH15-12-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-12-D	-53 to -54 ft CRD	X	X	X	X			
PH15-13	PH15-13-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-13-D	-53 to -54 ft CRD	X	X	X	X			
PH15-14	PH15-14-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-14-A-D	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-14-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-14-D	-53 to -54 ft CRD	X	X	X	X			
PH15-15	PH15-15-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-15-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-15-D	-53 to -54 ft CRD	X	X	X	X			
PH15-16	PH15-16-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-16-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-16-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-16-D	-53 to -54 ft CRD	X	X	X	X			
PH15-17	PH15-17-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-17-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-17-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-17-D	-53 to -54 ft CRD	X	X	X	X			
PH15-18	PH15-18-A	0 to 1 ft below mudline	X	X	X	X			

Station ID	Sample ID	Depth Interval	Forensic Chemical Analysis		Ancillary Measurements		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-alkanes	Grain Size	TOC	DDx	PCB Congeners	Dioxin/Furan Congeners
	PH15-18-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-18-D	-53 to -54 ft CRD	X	X	X	X			
PH15-19	PH15-19-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-19-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-19-C-FD	-51 to -52 ft CRD	X	X	X	X			
	PH15-19-D	-53 to -54 ft CRD	X	X	X	X			
PH15-20	PH15-20-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-020-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-20-D	-53 to -54 ft CRD	X	X	X	X			
PH15-21	PH15-21-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-21-C	-51 to -52 ft CRD	X	X	X	X	X	X	X
	PH15-21-D	-53 to -54 ft CRD	X	X	X	X	X	X	X
PH15-22	PH15-22-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-22-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-22-D	-53 to -54 ft CRD	X	X	X	X			
PH15-23	PH15-23-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-23-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-23-D	-53 to -54 ft CRD	X	X	X	X			
PH15-24	PH15-24-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-24-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-24-D	-53 to -54 ft CRD	X	X	X	X			
PH15-25	PH15-25-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-25-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-25-C-FD	-51 to -52 ft CRD	X	X	X	X			
	PH15-25-D	-53 to -54 ft CRD	X	X	X	X			
PH15-26	PH15-26-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-26-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-26-D	-53 to -54 ft CRD	X	X	X	X			
PH15-27	PH15-27-A	0 to 1 ft below mudline	X	X	X	X			

Station ID	Sample ID	Depth Interval	Forensic Chemical Analysis		Ancillary Measurements		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-alkanes	Grain Size	TOC	DDx	PCB Congeners	Dioxin/Furan Congeners
	PH15-27-D	-53 to -54 ft CRD	X	X	X	X			
PH15-28	PH15-28-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-28-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-28-D	-53 to -54 ft CRD	X	X	X	X			
PH15-29	PH15-29-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-29-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-29-D	-53 to -54 ft CRD	X	X	X	X			
PH15-30	PH15-30-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-30-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-30-D	-53 to -54 ft CRD	X	X	X	X			
PH15-31	PH15-31-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-31-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-31-D	-53 to -54 ft CRD	X	X	X	X			
PH15-32	PH15-32-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-32-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-32-D	-53 to -54 ft CRD	X	X	X	X			
PH15-33	PH15-33-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-33-D	-53 to -54 ft CRD	X	X	X	X			
PH15-34	PH15-34-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
PH15-35	PH15-35-A	0 to 1 ft below mudline	X	X	X	X			
PH15-36	PH15-36-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-36-D	-53 to -54 ft CRD	X	X	X	X			
PH15-37	PH15-37-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-37-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-37-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-37-D	-53 to -54 ft CRD	X	X	X	X			
PH15-38	PH15-38-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-38-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-38-B-FD	-48 to -49 ft CRD	X	X	X	X			

Station ID	Sample ID	Depth Interval	Forensic Chemical Analysis		Ancillary Measurements		PTW Characterization		
			Parent and Alkyl PAH	TPH and n-alkanes	Grain Size	TOC	DDx	PCB Congeners	Dioxin/Furan Congeners
	PH15-38-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-38-D	-53 to -54 ft CRD	X	X	X	X			
PH15-39	PH15-39-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-39-B	-48 to -49 ft CRD	X	X	X	X			
	PH15-39-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-39-D	-53 to -54 ft CRD	X	X	X	X			
PH15-40	PH15-40-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-40-B	-48 to -49 ft CRD	X	X	X	X	X	X	X
	PH15-40-C	-51 to -52 ft CRD	X	X	X	X	X	X	X
	PH15-40-D	-53 to -54 ft CRD	X	X	X	X	X	X	X
PH15-41	PH15-41-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-41-C	-51 to -52 ft CRD	X	X	X	X			
	PH15-41-D	-53 to -54 ft CRD	X	X	X	X			
PH15-42	PH15-42-A	0 to 1 ft below mudline	X	X	X	X			
PH15-43	PH15-43-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-43-D	-53 to -54 ft CRD	X	X	X	X			
PH15-44	PH15-44-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-44-A-FD	0 to 1 ft below mudline	X	X	X	X			
	PH15-44-D	-53 to -54 ft CRD	X	X	X	X			
PH15-45	PH15-45-A	0 to 1 ft below mudline	X	X	X	X			
	PH15-45-D	-53 to -54 ft CRD	X	X	X	X			
PH15-46	PH15-46-A	0 to 1 ft below mudline	X	X	X	X			
PH15-47	PH15-47-A	0 to 1 ft below mudline	X	X	X	X			
PH15-48	PH15-48-A	0 to 1 ft below mudline	X	X	X	X			
PH15-49	PH15-49-A	0 to 1 ft below mudline	X	X	X	X			
PH15-50	PH15-50-A	0 to 1 ft below mudline	X	X	X	X	X	X	X
	PH15-50-C	-51 to -52 ft CRD	X	X	X	X	X	X	X
	PH15-50-D	-53 to -54 ft CRD	X	X	X	X	X	X	X

Table 4. Summary of Key Hydrocarbon Parameters in Sediments and Tar Ball Samples.[1]

Station ID	Horizon	Depth	Matrix	River Mile	TPH (mg/kg)	TPAH17 (µg/kg)	Total PAH (µg/kg)	% Alkyl PAH	% TPAH	BaP Eq (µg/kg)
PH15-01	A	0 - 1 ft	Sediment	5.11	57	10,565	14,661	21	26	986
PH15-01	B	-48 to -49 ft	Sediment	5.11	14	5	21	69	0.1	0.3
PH15-01	C	-51 to -52 ft	Sediment	5.11	5	3	8	53	0.2	0.2
PH15-01	D	-53 to -54 ft	Sediment	5.11	34	4	21	72	0.1	0.3
PH15-02	A	0 - 1 ft	Sediment	5.16	22	4	21	73	0.1	0.3
PH15-02	B	-48 to -49 ft	Sediment	5.16	14	8	21	54	0.1	0.8
PH15-02	C	-51 to -52 ft	Sediment	5.16	10	4	14	63	0.1	0.4
PH15-02	D	-53 to -54 ft	Sediment	5.16	19	5	17	64	0.1	0.4
PH15-03	A	0 - 1 ft	Sediment	5.20	143	28,000	39,418	22	28	2,066
PH15-03	B	-48 to -49 ft	Sediment	5.20	25	110	170	29	1	7
PH15-03	C	-51 to -52 ft	Sediment	5.20	11	59	85	23	1	6
PH15-03	D	-53 to -54 ft	Sediment	5.20	41	7	33	72	0.1	0
PH15-04	A	0 - 1 ft	Sediment	5.25	72	13,689	16,468	9	23	1,796
PH15-04	A-FD	0 - 1 ft	Sediment	5.25	30	352	588	34	2	32
PH15-04	B	-48 to -49 ft	Sediment	5.25	3	2	5	45	0.2	0
PH15-04	C	-51 to -52 ft	Sediment	5.25	2	2	3	14	0.2	0
PH15-05	A	0 - 1 ft	Sediment	5.30	38	2,222	3,197	23	8	266
PH15-05	B	-48 to -49 ft	Sediment	5.30	0.5	7	10	19	2	1
PH15-05	C	-51 to -52 ft	Sediment	5.30	ND	1	4	64	NA	0
PH15-06	A	0 - 1 ft	Sediment	5.35	3,500	869,107	1,283,204	26	37	71,232
PH15-06	B	-48 to -49 ft	Sediment	5.35	1,180	324,175	483,901	27	41	22,403
PH15-06	C	-51 to -52 ft	Sediment	5.35	22	5,871	8,483	24	39	415
PH15-07	A	0 - 1 ft	Sediment	5.39	4,980	1,376,831	1,952,133	22	39	134,486
PH15-07	B	-48 to -49 ft	Sediment	5.39	45	10,775	16,089	27	36	715
PH15-07	C	-51 to -52 ft	Sediment	5.39	18	2,499	3,607	24	20	218
PH15-07	D	-53 to -54 ft	Sediment	5.39	1	382	535	22	53	30
PH15-07	D-FD	-53 to -54 ft	Sediment	5.39	2	333	450	19	29	27
PH15-08	A	0 - 1 ft	Sediment	4.45	1,560	464,074	615,313	18	39	32,906
PH15-08	B	-48 to -49 ft	Sediment	4.45	149	45,360	60,917	19	41	2,955
PH15-09	A	0 - 1 ft	Sediment	5.48	196	22,748	33,235	24	17	2,432
PH15-09	C	-51 to -52 ft	Sediment	5.48	81	6,770	9,536	21	12	840

Station ID	Horizon	Depth	Matrix	River Mile	TPH (mg/kg)	TPAH17 (µg/kg)	Total PAH (µg/kg)	% Alkyl PAH	% TPAH	BaP Eq (µg/kg)
PH15-09	D	-53 to -54 ft	Sediment	5.48	8	400	590	25	7	36
PH15-10	A	0 - 1 ft	Sediment	5.59	1,410	365,627	526,135	24	37	23,849
PH15-11	A	0 - 1 ft	Sediment	5.66	3,550	825,340	1,204,673	25	34	62,383
PH15-11	D	-53 to -54 ft	Sediment	5.66	995	223,644	319,896	22	32	24,299
PH15-11	D-FD	-53 to -54 ft	Sediment	5.66	918	196,240	276,260	20	30	23,586
PH15-12	A	0 - 1 ft	Sediment	5.72	386	9,503	14,550	29	4	961
PH15-12	D	-53 to -54 ft	Sediment	5.72	17	181	269	27	2	13
PH15-13	A	0 - 1 ft	Sediment	5.78	678	186,009	276,096	27	41	12,335
PH15-13	D	-53 to -54 ft	Sediment	5.78	275	85,793	119,701	22	44	5,854
PH15-14	A	0 - 1 ft	Sediment	5.15	71	6,902	9,721	22	14	579
PH15-14	A-FD	0 - 1 ft	Sediment	5.15	77	7,671	10,658	21	14	656
PH15-14	C	-51 to -52 ft	Sediment	5.15	3	333	445	18	14	32
PH15-14	D	-53 to -54 ft	Sediment	5.15	ND	29	34	13	NA	1
PH15-15	A	0 - 1 ft	Sediment	5.18	620	146,951	213,117	24	34	16,278
PH15-15	C	-51 to -52 ft	Sediment	5.18	7	230	330	24	5	24
PH15-15	D	-53 to -54 ft	Sediment	5.18	1	60	88	24	7	8
PH15-16	A	0 - 1 ft	Sediment	5.22	125	20,479	31,729	28	25	2,552
PH15-16	B	-48 to -49 ft	Sediment	5.22	7	808	1,208	27	16	71
PH15-16	C	-51 to -52 ft	Sediment	5.22	3	174	263	27	10	14
PH15-16	D	-53 to -54 ft	Sediment	5.22	2	47	62	17	4	1
PH15-17	A	0 - 1 ft	Sediment	5.27	1,120	345,017	457,925	17	41	39,670
PH15-17	B	-48 to -49 ft	Sediment	5.27	3	474	747	30	24	35
PH15-17	C	-51 to -52 ft	Sediment	5.27	0	45	63	21	187	2
PH15-17	D	-53 to -54 ft	Sediment	5.27	0	238	337	23	1,261	19
PH15-18	A	0 - 1 ft	Sediment	5.32	2,440	569,620	805,177	23	33	55,971
PH15-18	C	-51 to -52 ft	Sediment	5.32	3	337	497	26	19	27
PH15-18	D	-53 to -54 ft	Sediment	5.32	ND	49	67	22	NA	1
PH15-19	A	0 - 1 ft	Sediment	5.36	28	3,120	4,716	27	17	349
PH15-19	C	-51 to -52 ft	Sediment	5.36	2	30	44	26	3	2
PH15-19	C-FD	-51 to -52 ft	Sediment	5.36	2	106	169	31	8	11
PH15-19	D	-53 to -54 ft	Sediment	5.36	2	12	15	19	1	0
PH15-20	A	0 - 1 ft	Sediment	5.41	260	47,423	71,954	26	28	6,211
PH15-20	C	-51 to -52 ft	Sediment	5.41	ND	108	161	26	NA	12

Station ID	Horizon	Depth	Matrix	River Mile	TPH (mg/kg)	TPAH17 (µg/kg)	Total PAH (µg/kg)	% Alkyl PAH	% TPAH	BaP Eq (µg/kg)
PH15-20	D	-53 to -54 ft	Sediment	5.41	0	74	95	18	25	5
PH15-21	A	0 - 1 ft	Sediment	5.46	832	166,139	247,100	25	30	24,763
PH15-21	C	-51 to -52 ft	Sediment	5.46	31	6,964	9,735	20	32	1,009
PH15-21	D	-53 to -54 ft	Sediment	5.46	2	687	971	23	39	62
PH15-22	A	0 - 1 ft	Sediment	5.50	1,100	168,361	252,491	26	23	24,962
PH15-22	C	-51 to -52 ft	Sediment	5.50	20	2,441	3,493	22	18	381
PH15-22	D	-53 to -54 ft	Sediment	5.50	112	19,662	29,150	24	26	2,964
PH15-23	A	0 - 1 ft	Sediment	5.54	862	217,573	299,129	20	35	21,327
PH15-23	C	-51 to -52 ft	Sediment	5.54	16	2,459	3,500	23	22	284
PH15-23	D	-53 to -54 ft	Sediment	5.54	11	2,322	3,158	19	28	241
PH15-24	A	0 - 1 ft	Sediment	5.58	51	9,511	13,924	23	28	1,684
PH15-24	C	-51 to -52 ft	Sediment	5.58	5	144	207	22	4	25
PH15-24	D	-53 to -54 ft	Sediment	5.58	3	140	208	24	7	26
PH15-25	A	0 - 1 ft	Sediment	5.63	199	55,263	74,538	17	37	7,307
PH15-25	C	-51 to -52 ft	Sediment	5.63	26	4,493	6,487	22	25	705
PH15-25	C-FD	-51 to -52 ft	Sediment	5.63	30	4,882	7,156	23	24	777
PH15-25	D	-53 to -54 ft	Sediment	5.63	11	1,696	2,543	26	23	216
PH15-26	A	0 - 1 ft	Sediment	5.69	11	2,449	3,136	13	29	308
PH15-26	C	-51 to -52 ft	Sediment	5.69	6	1,010	1,398	18	22	175
PH15-26	D	-53 to -54 ft	Sediment	5.69	1	38	50	14	7	5
PH15-27	A	0 - 1 ft	Sediment	5.74	ND	352	512	24	NA	53
PH15-27	D	-53 to -54 ft	Sediment	5.74	4	408	641	28	18	68
PH15-28	A	0 - 1 ft	Sediment	5.79	31	1,492	2,110	20	7	240
PH15-28	C	-51 to -52 ft	Sediment	5.79	ND	312	448	22	NA	50
PH15-28	D	-53 to -54 ft	Sediment	5.79	ND	28	33	12	NA	0
PH15-29	A	0 - 1 ft	Sediment	5.15	710	103,687	173,405	33	24	13,196
PH15-29	C	-51 to -52 ft	Sediment	5.15	1,940	349,561	556,707	29	29	48,893
PH15-29	D	-53 to -54 ft	Sediment	5.15	0	560	791	21	573	96
PH15-30	A	0 - 1 ft	Sediment	5.19	141	26,091	34,565	18	25	3,550
PH15-30	C	-51 to -52 ft	Sediment	5.19	ND	78	123	30	NA	10
PH15-30	D	-53 to -54 ft	Sediment	5.19	ND	30	44	28	NA	2
PH15-31	A	0 - 1 ft	Sediment	5.24	149	23,391	33,343	22	22	3,307
PH15-31	C	-51 to -52 ft	Sediment	5.24	ND	755	1,102	23	NA	125

Station ID	Horizon	Depth	Matrix	River Mile	TPH (mg/kg)	TPAH17 (µg/kg)	Total PAH (µg/kg)	% Alkyl PAH	% TPAH	BaP Eq (µg/kg)
PH15-31	D	-53 to -54 ft	Sediment	5.24	ND	120	186	28	NA	18
PH15-32	A	0 - 1 ft	Sediment	5.29	47	4,228	6,277	23	13	796
PH15-32	C	-51 to -52 ft	Sediment	5.29	0	313	465	23	291	61
PH15-32	D	-53 to -54 ft	Sediment	5.29	ND	11	16	22	NA	2
PH15-33	A	0 - 1 ft	Sediment	5.34	326	41,096	62,752	27	19	6,800
PH15-33	D	-53 to -54 ft	Sediment	5.34	5	1,535	2,350	26	49	262
PH15-34	A	0 - 1 ft	Sediment	5.38	160	15,104	23,102	26	14	2,762
PH15-35	A	0 - 1 ft	Sediment	5.43	141	14,117	19,783	19	14	2,631
PH15-36	A	0 - 1 ft	Sediment	5.48	281	44,083	64,089	22	23	7,799
PH15-36	D	-53 to -54 ft	Sediment	5.48	274	42,822	63,471	25	23	6,307
PH15-37	A	0 - 1 ft	Sediment	5.51	80	10,562	15,461	22	19	1,807
PH15-37	B	-48 to -49 ft	Sediment	5.51	58	4,466	6,827	25	12	810
PH15-37	C	-51 to -52 ft	Sediment	5.51	166	26,902	41,216	26	25	4,291
PH15-37	D	-53 to -54 ft	Sediment	5.51	58	10,586	14,845	19	26	1,790
PH15-38	A	0 - 1 ft	Sediment	5.55	376	62,534	96,431	26	26	9,120
PH15-38	A	0 - 1 ft	Tar Ball	5.55	492,000	158,550,500	194,922,640	12	40	NA
PH15-38	B	-48 to -49 ft	Sediment	5.55	118	17,006	27,602	29	23	3,167
PH15-38	B-FD	-48 to -49 ft	Sediment	5.55	32	673	1,042	26	3	126
PH15-38	C	-51 to -52 ft	Sediment	5.55	34	4,167	6,264	24	18	754
PH15-38	D	-53 to -54 ft	Sediment	5.55	69	9,048	14,549	29	21	1,679
PH15-39	A	0 - 1 ft	Sediment	5.60	43	2,838	4,453	27	10	552
PH15-39	B	-48 to -49 ft	Sediment	5.60	31	1,487	2,230	24	7	283
PH15-39	C	-51 to -52 ft	Sediment	5.60	ND	64	108	33	NA	11
PH15-39	D	-53 to -54 ft	Sediment	5.60	ND	2	3	28	NA	0
PH15-40	A	0 - 1 ft	Sediment	5.65	30	3,033	4,808	27	16	596
PH15-40	B	-48 to -49 ft	Sediment	5.65	ND	91	149	31	NA	16
PH15-40	C	-51 to -52 ft	Sediment	5.65	ND	2	3	15	NA	0
PH15-40	D	-53 to -54 ft	Sediment	5.65	ND	3	3	14	NA	0
PH15-41	A	0 - 1 ft	Sediment	5.70	0	43	62	21	14	8
PH15-41	C	-51 to -52 ft	Sediment	5.70	ND	4	8	51	NA	0
PH15-41	D	-53 to -54 ft	Sediment	5.70	ND	2	5	54	NA	0
PH15-42	A	0 - 1 ft	Sediment	5.76	110	7,744	11,432	23	10	1,397
PH15-43	A	0 - 1 ft	Sediment	5.16	8	648	935	23	12	87

Station ID	Horizon	Depth	Matrix	River Mile	TPH (mg/kg)	TPAH17 (µg/kg)	Total PAH (µg/kg)	% Alkyl PAH	% TPAH	BaP Eq (µg/kg)
PH15-43	D	-53 to -54 ft	Sediment	5.16	ND	14	22	32	NA	2
PH15-44	A	0 - 1 ft	Sediment	5.21	59	2,592	3,724	24	6	267
PH15-44	A-FD	0 - 1 ft	Sediment	5.21	22	3,266	4,791	25	22	281
PH15-44	D	-53 to -54 ft	Sediment	5.21	ND	36	57	31	NA	4
PH15-45	A	0 - 1 ft	Sediment	5.26	116	11,093	16,731	26	14	1,633
PH15-45	D	-53 to -54 ft	Sediment	5.26	ND	23	36	30	NA	2
PH15-46	A	0 - 1 ft	Sediment	5.31	112	1,199	2,016	32	2	239
PH15-47	A	0 - 1 ft	Sediment	5.35	116	889	1,446	31	1	143
PH15-48	A	0 - 1 ft	Sediment	5.40	136	705	1,179	33	1	109
PH15-49	A	0 - 1 ft	Sediment	5.45	142	7,870	10,755	20	8	766
PH15-50	A	0 - 1 ft	Sediment	5.52	133	14,839	23,507	29	18	2,614
PH15-50	C	-51 to -52 ft	Sediment	5.52	18	1,234	1,958	28	11	206
PH15-50	D	-53 to -54 ft	Sediment	5.52	54	1,761	2,857	30	5	286

[1] Shaded cells represent PTW concentrations that exceed threshold limits.

Table 5. Total PAH (Parent PAH and Alkyl PAH) – Summary Statistics by Depth Horizon.

Horizon Interval	Depth Interval	n	Total PAH (µg/kg)				
			Minimum	Maximum	Average	Median	95th Percentile
All	All	176	2.7	3,342,740	97,276	4,851	532,098
Surface	0 to 1 ft	76	64	3,342,740	188,870	16,358	1,230,448
Future Channel	-48 to -49 ft CRD	58	4.9	3,342,740	147,450	11,318	572,691
Future Overdredge	-51 to -52 ft CRD	53	2.7	3,342,740	108,400	3,558	546,808
Future Overdredge Plus Cap Buffer	-53 to -54 ft CRD	53	4.4	3,342,740	110,529	812	450,141

The data compiled for each depth horizon includes samples at the specified depth, plus any surface samples that exist at a deeper depth interval. Note that the highest PAH concentration sample was a surface sample taken at the deepest -53 to -54 CRD interval. Thus, it appears as the maximum Total PAH concentration for the current surface and each of the potential depth horizons.

Table 6. TPAH17 (16 EPA Priority Pollutant PAH and 2-Methylnaphthalene) – Summary Statistics by Depth Horizon Interval.

Horizon Interval	Depth Interval	n	TPAH17 (µg/kg)				
			Minimum	Maximum	Average	Median	95th Percentile
All	All	176	1.3	2,389,580	67,677	2,881	364,511
Surface	0 to 1 ft	76	4.1	2,389,580	132,069	10,829	831,905
Future Channel	-48 to -49 ft CRD	58	2.3	2,389,580	103,167	7,807	416,824
Future Overdredge	-51 to -52 ft CRD	53	1.3	2,389,580	76,741	2,441	363,290
Future Overdredge Plus Cap Buffer	-53 to -54 ft CRD	53	1.6	2,389,580	79,100	560	347,768

The data compiled for each depth horizon includes samples at the specified depth, plus any surface samples that exist at a deeper depth interval. Note that the highest TPAH17 concentration sample was a surface sample taken at the deepest -53 to -54 CRD interval. Thus, it appears as the maximum TPAH17 concentration for the current surface and each of the potential depth horizons.

Table 7a. Percentage of RAL Exceedances – Cumulative Summary Statistics by Depth Horizon Interval.

Horizon Interval	Surface	Future Channel	Future Overdredge	Future Overdredge Plus Cap Buffer
Depth Interval	**0 to 1 ft**	**-48 to -49 ft CRD**	**-51 to -52 ft CRD**	**-53 to -54 ft CRD**
n	76	58	53	53
G	64%	59%	38%	42%
F	49%	43%	23%	30%
E	34%	31%	17%	25%
D	25%	19%	11%	17%
C	21%	16%	9%	13%
B	17%	14%	9%	13%

Table 7b. Percentage of Less than G Non-Exceedance – Summary Statistics by Depth Horizon Interval.

Horizon Interval	Surface	Future Channel	Future Overdredge	Future Overdredge Plus Cap Buffer
Depth Interval	**0 to 1 ft**	**-48 to -49 ft CRD**	**-51 to -52 ft CRD**	**-53 to -54 ft CRD**
n	76	58	53	53
< G	36%	41%	62%	66%

Table 8. Summary of Principal Threat Waste (PTW) Chemicals in Sediments Samples.[1,2]

Station ID	Matrix	Horizon	Depth	River Mile	Total PCBs (µg/Kg)	2,3,7,8-TCDD (pg/g)	2,3,7,8-TCDF (pg/g)	1,2,3,7,8-PeCDD (pg/g)	2,3,4,7,8-PeCDF (pg/g)	1,2,3,4,7,8-HxCDF (pg/g)	DDx (µg/Kg)	BAP Eq (µg/Kg)
PH15-03	Sediment	A	0 to 1 ft	5.20	2.8	ND	1.0	ND	0.6	2.0	9.7	2,066
PH15-03	Sediment	B	-48 to -49 ft	5.20	2.7	ND	ND	ND	ND	ND	ND	7.5
PH15-03	Sediment	C	-51 to -52 ft	5.20	ND	ND	ND	ND	ND	ND	ND	6.4
PH15-03	Sediment	D	-53 to -54 ft	5.20	0.03	ND	ND	ND	ND	ND	ND	0.9
PH15-06	Sediment	A	0 to 1 ft	5.35	3.7	ND	3.3	ND	2.2	2.6	33.2	71,232
PH15-06	Sediment	B	-48 to -49 ft	5.35	1.8	ND	0.7	ND	ND	0.6	20.5	22,403
PH15-06	Sediment	C	-51 to -52 ft	5.35	0.1	ND	0.0	ND	ND	ND	0.5	415
PH15-07	Sediment	D	-53 to -54 ft	5.39	0.02	ND	ND	ND	ND	ND	ND	30.1
PH15-10	Sediment	A	0 to 1 ft	5.59	2.5	ND	2.1	0.2	1.4	3.1	14.2	23,849
PH15-11	Sediment	A	0 to 1 ft	5.66	6.1	0.4	11.8	0.7	15.0	69.1	53.9	62,383
PH15-11	Sediment	D	-53 to -54 ft	5.66	1.3	ND	0.7	ND	0.6	1.1	5.4	24,299
PH15-11	Sediment	D-FD	-53 to -54 ft	5.66	4.6	ND	0.4	ND	0.4	0.8	7.6	23,586
PH15-12	Sediment	A	0 to 1 ft	5.72	27.8	8.5	66.3	11.4	45.4	103.0	58.3	961
PH15-14	Sediment	A-FD	0 to 1 ft	5.15	0.9	ND	1.1	ND	0.9	4.2	2.3	656
PH15-14	Sediment	A	0 to 1 ft	5.15	1.8	ND	0.9	ND	0.8	3.1	3.3	579
PH15-21	Sediment	A	0 to 1 ft	5.46	4.3	0.2	2.7	ND	1.1	7.8	9.0	24,763
PH15-21	Sediment	C	-51 to -52 ft	5.46	0.1	ND	ND	ND	ND	ND	0.8	1,009
PH15-21	Sediment	D	-53 to -54 ft	5.46	ND	ND	ND	ND	ND	0.3	ND	61.9
PH15-28	Sediment	A	0 to 1 ft	5.79	0.1	ND	ND	ND	ND	0.0	1.4	240
PH15-31	Sediment	A	0 to 1 ft	5.24	0.5	ND	0.9	ND	0.7	0.5	2.0	3,307
PH15-34	Sediment	A	0 to 1 ft	5.38	0.9	ND	0.6	ND	0.5	1.3	2.9	2,762
PH15-40	Sediment	A	0 to 1 ft	5.65	1.8	ND	ND	ND	ND	0.1	30.2	596
PH15-40	Sediment	B	-48 to -49 ft	5.65	ND	ND	ND	ND	ND	ND	ND	16.5
PH15-40	Sediment	C	-51 to -52 ft	5.65	ND	ND	ND	ND	ND	ND	ND	0.6
PH15-40	Sediment	D	-53 to -54 ft	5.65	ND	ND	ND	ND	ND	ND	ND	0.7
PH15-43	Sediment	A	0 to 1 ft	5.16	0.3	ND	ND	ND	ND	ND	0.8	86.9
PH15-50	Sediment	A	0 to 1 ft	5.52	0.7	ND	ND	ND	0.2	0.4	5.6	2,614
PH15-50	Sediment	C	-51 to -52 ft	5.52	0.2	ND	ND	ND	ND	0.2	1.1	206
PH15-50	Sediment	D	-53 to -54 ft	5.52	0.03	ND	ND	ND	ND	ND	13.0	286

[1] Shaded cells represent PTW concentrations that exceed threshold limits.

[2] Data from all 142 samples in Remedial Alternatives Area used for BaP Eq evaluation (see Table 4).

Figures

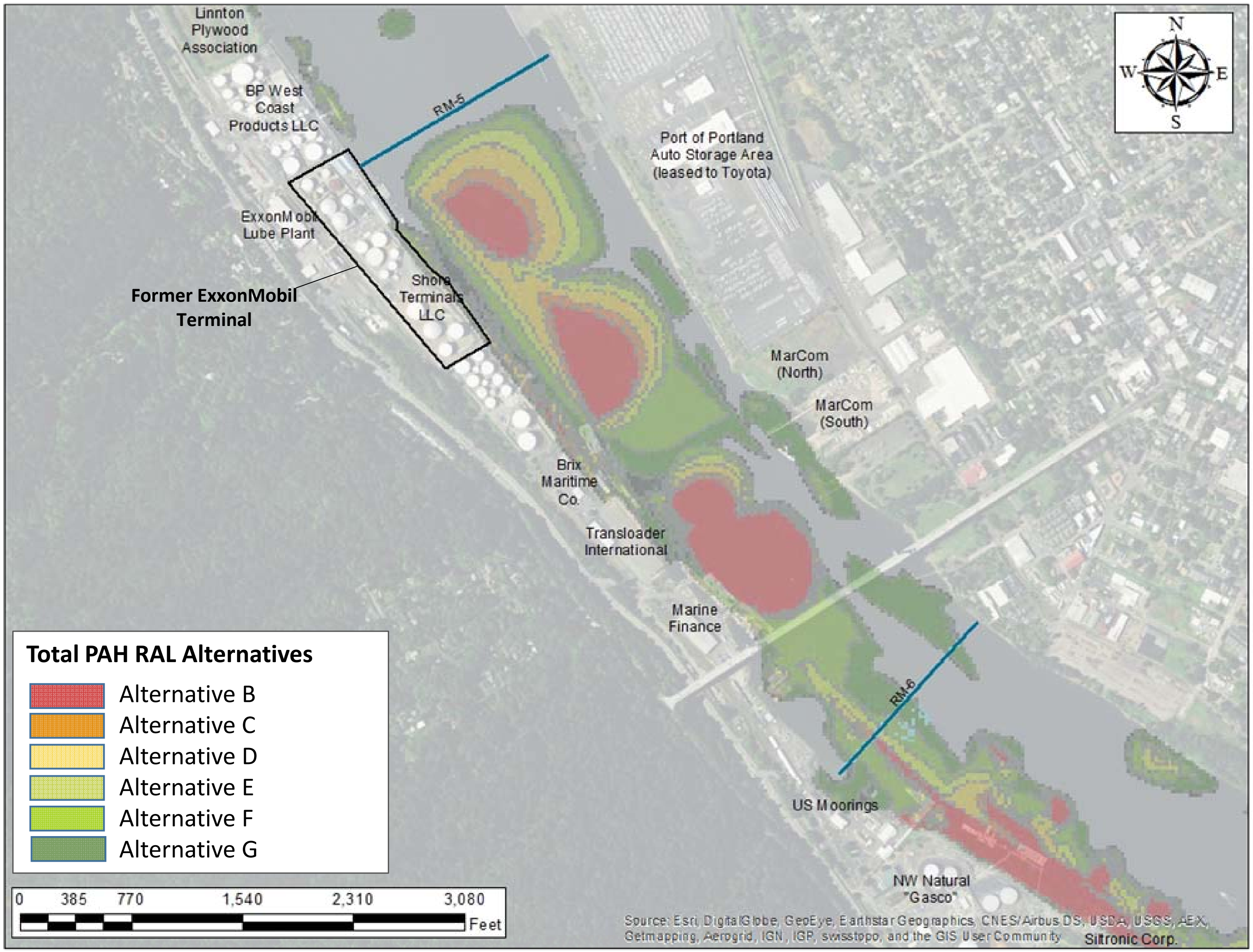


Figure 1. Remedial Action Level contours, in the vicinity of River Mile 5 to River Mile 6.

Source: 2015 EPA Draft Feasibility Study.

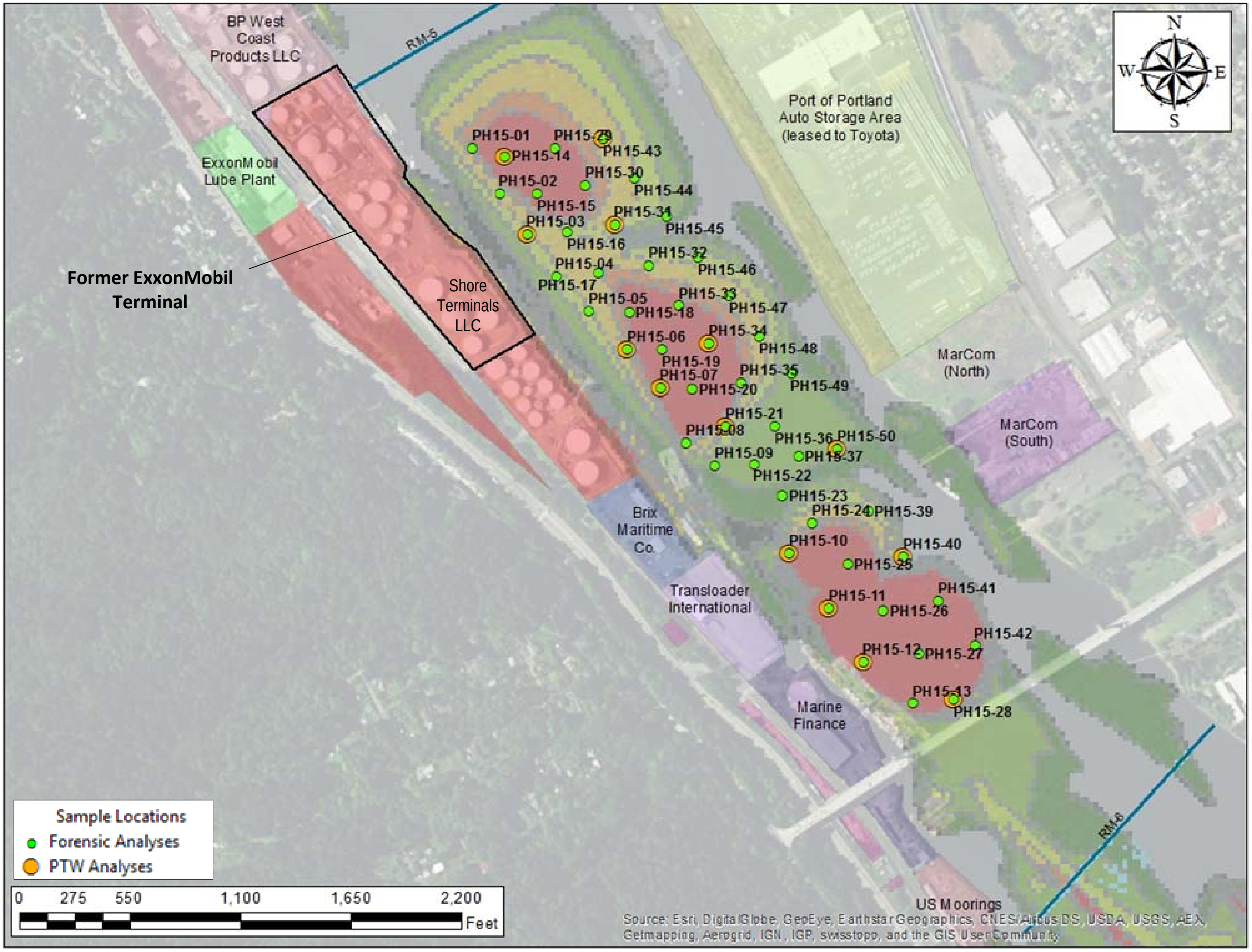
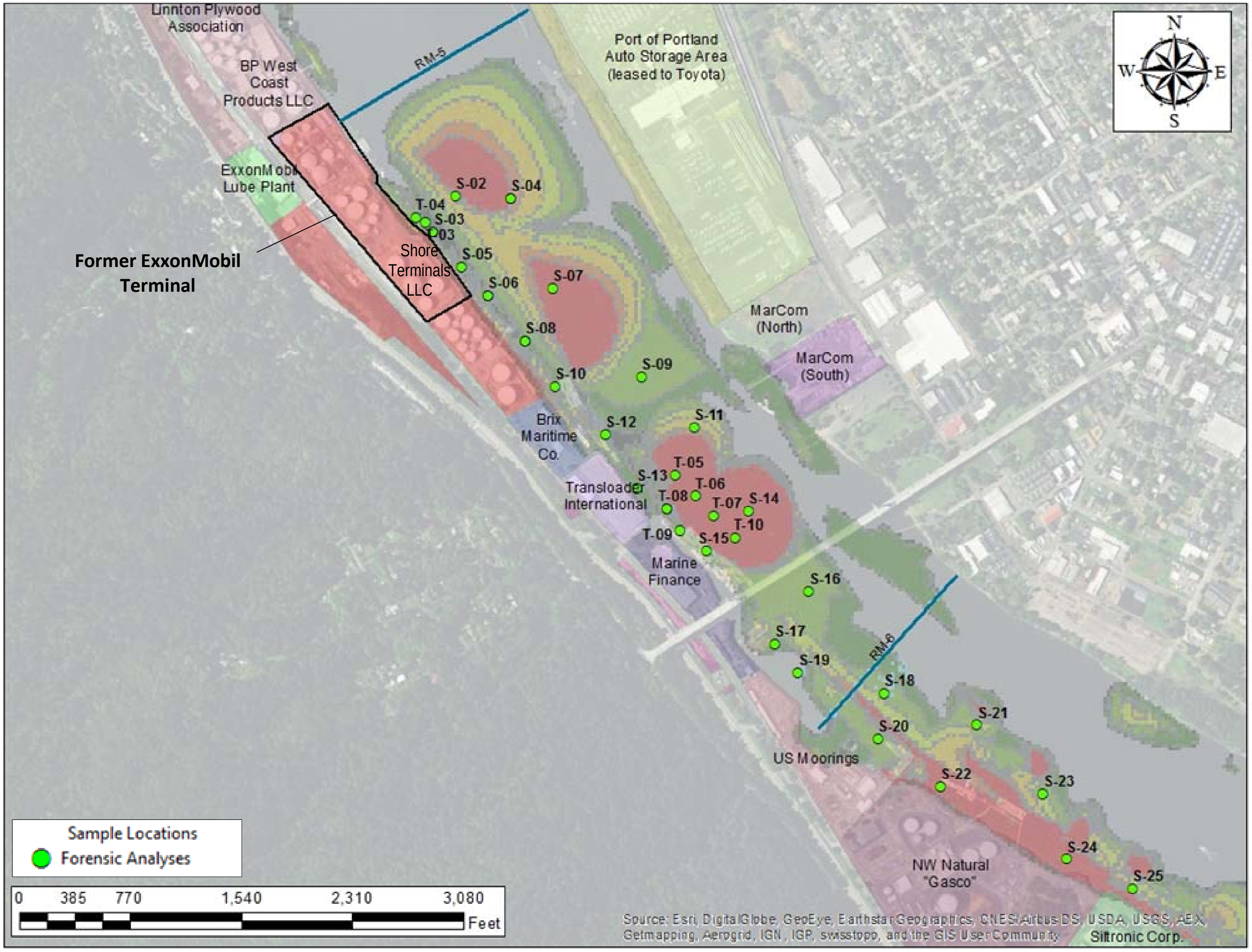


Figure 2. Sediment sampling locations for the NewFields 2015 investigation.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 3. Sediment sampling locations for the NewFields 2014 Investigation.

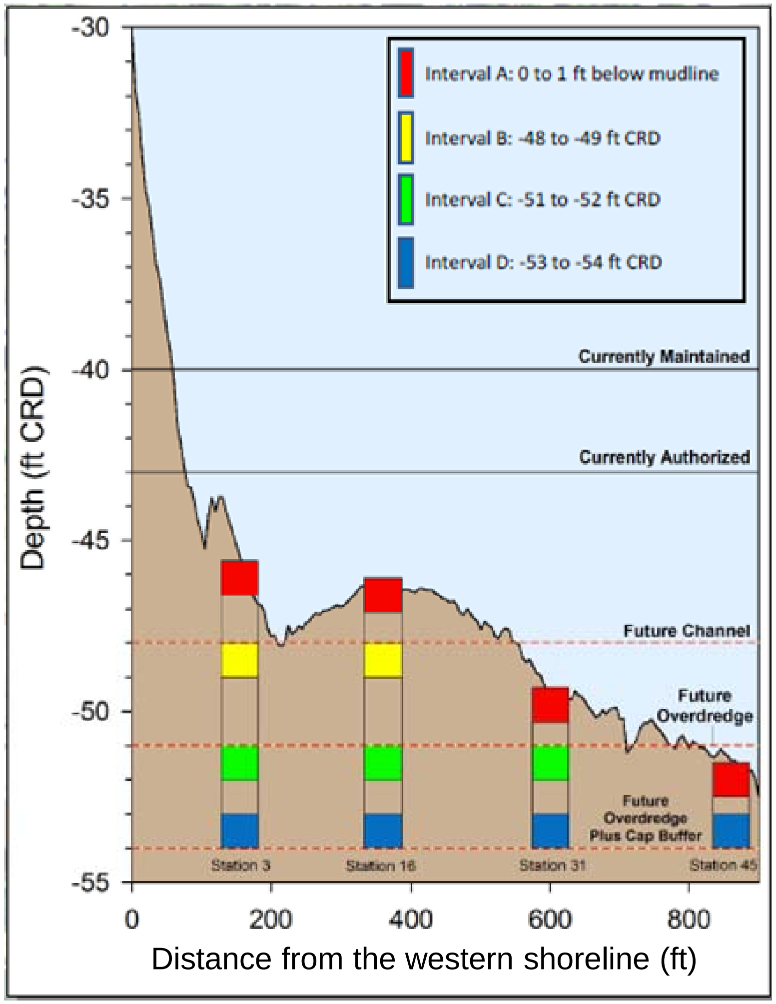


Figure 4. Depth horizons sampled in the NewFields 2015 Investigation.

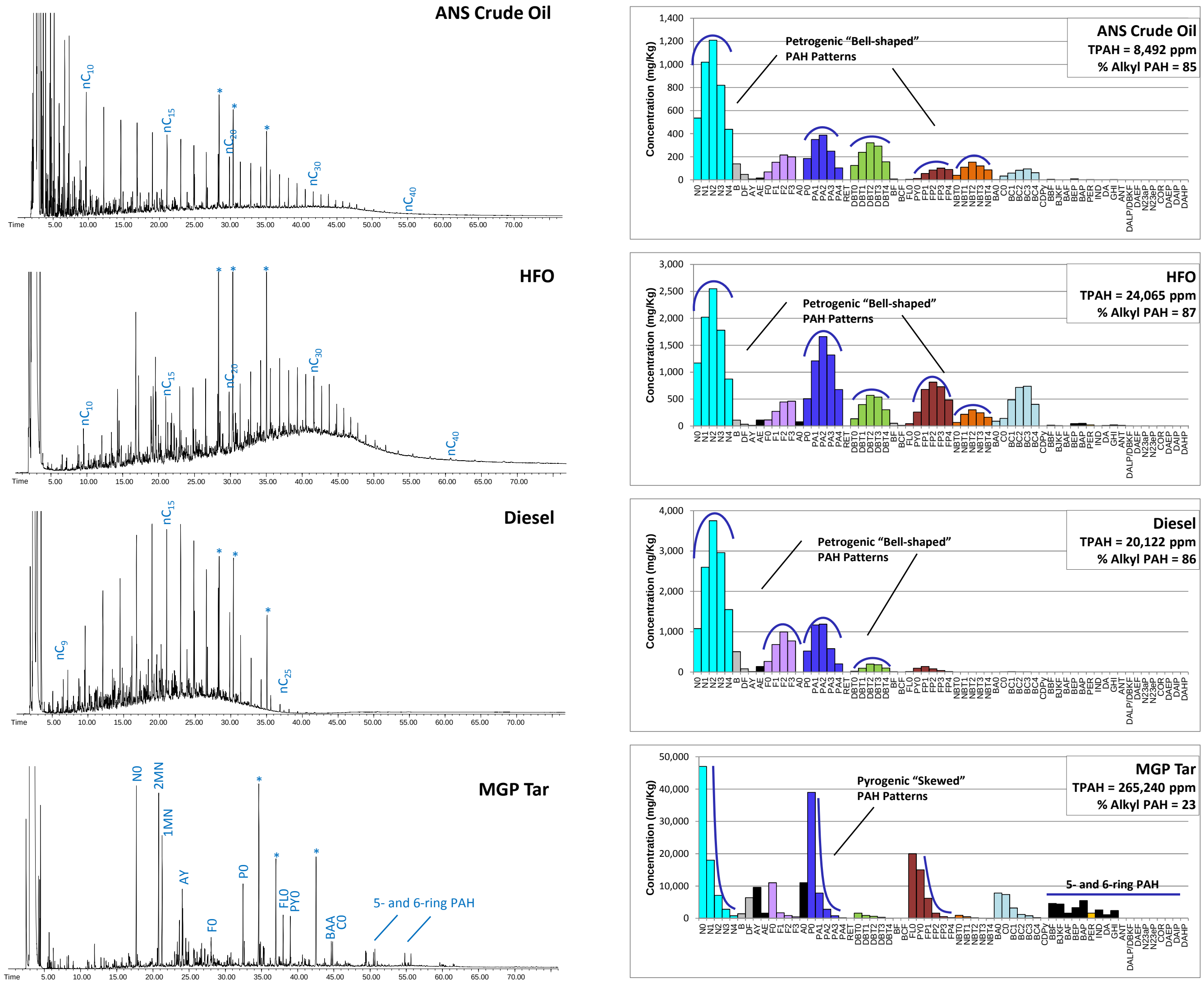
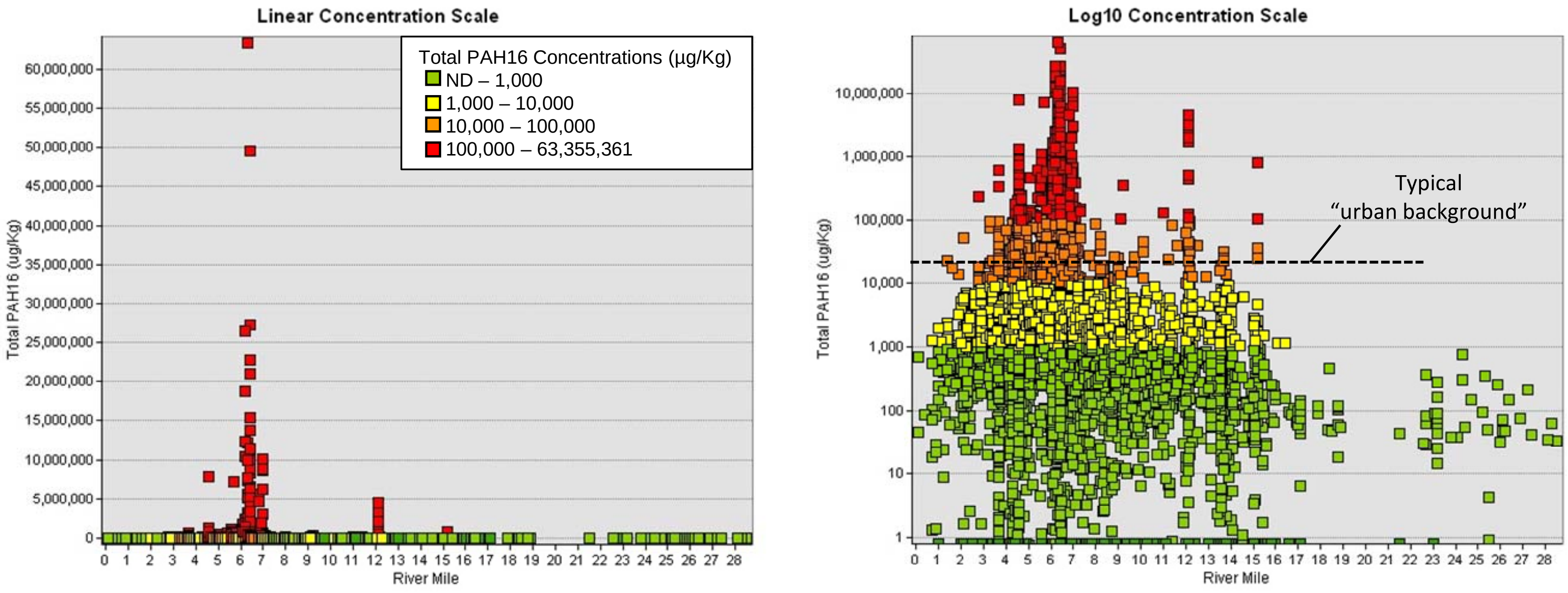


Figure 5. Gas chromatograms and PAH histograms for common petroleum products (crude oil, HFO, diesel fuel) and a representative pyrogenic MGP tar.

'*': laboratory added internal standards.


Linear Concentration Scale

Log10 Concentration Scale

Typical
“urban background”

Figure 6. Concentration of 16 Priority Pollutant PAH vs River Mile in the Portland Harbor Superfund Site Area.

Left panel: linear concentration scale; Right panel: Log10 concentration scale. Dashed line: upper limit of “urban background” sediments proposed by Stout et al. (2004).

Source: Lower Willamette Group RI Database.

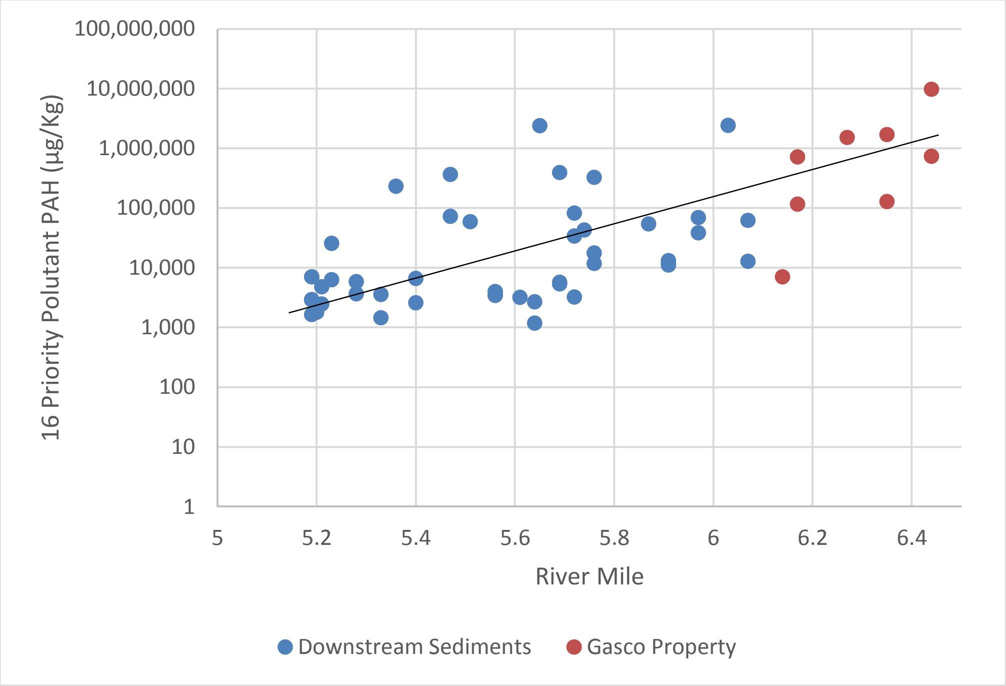
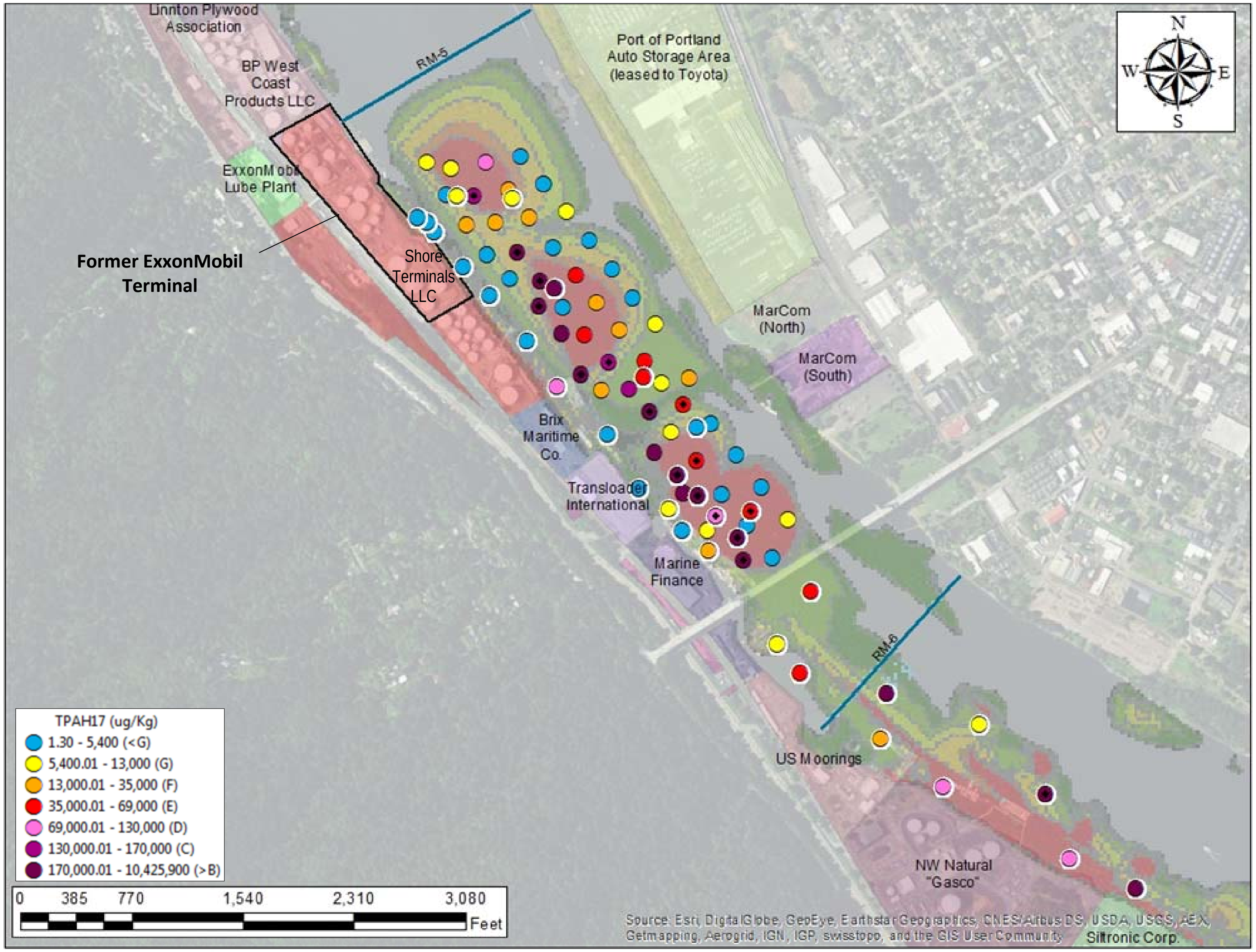


Figure 7. Surface and subsurface PAH concentrations versus River Mile in the vicinity of River Mile 5 and River Mile 6. PAH concentrations generally decrease downstream of the Gasco property.

Source: NewFields 2014 Investigation.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 8 (a). Surface sediment TPAH17 concentrations (by RAL).

Note: Symbols with white halos represent samples collected in 2014.
Black bullets represent locations where tar balls were observed.

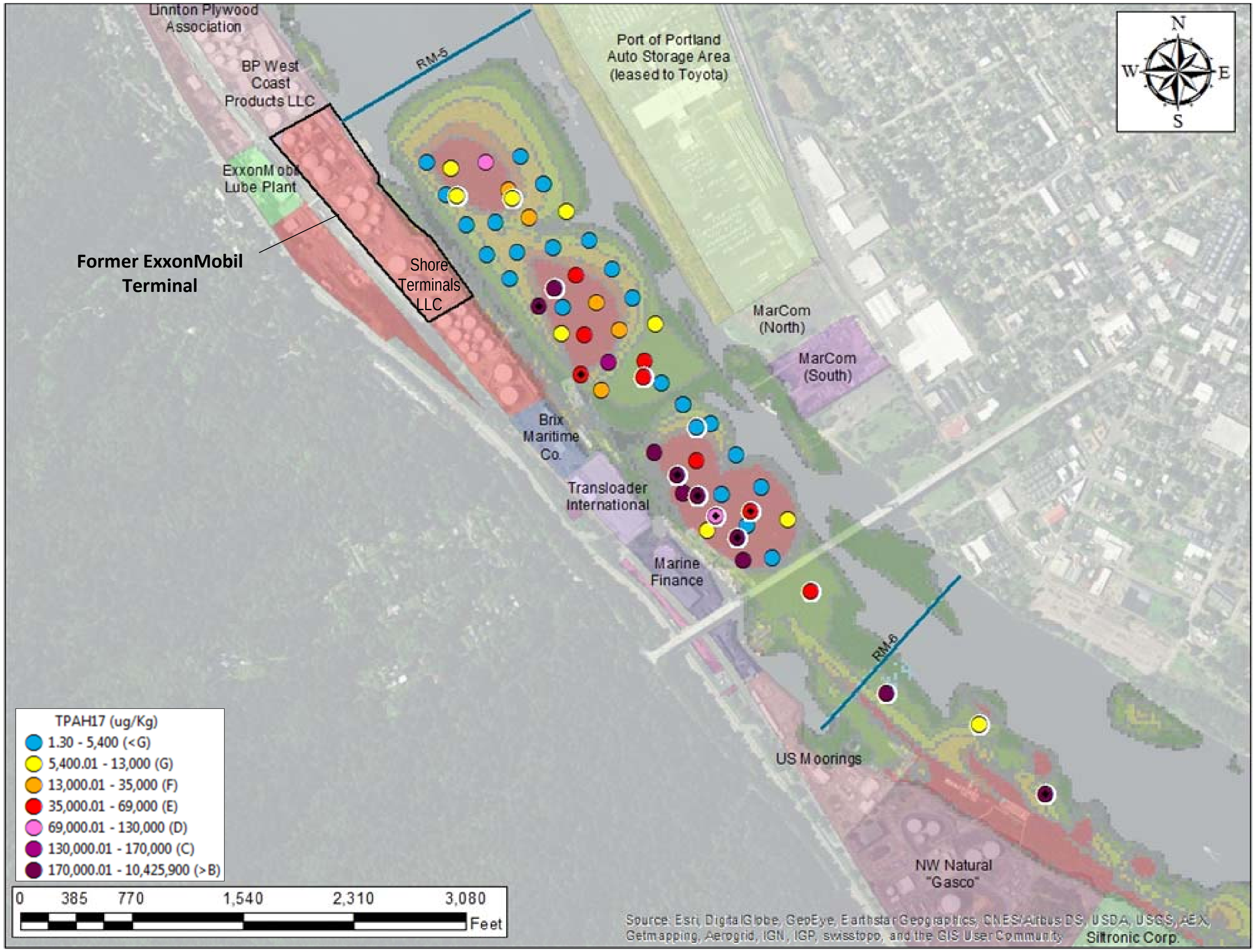
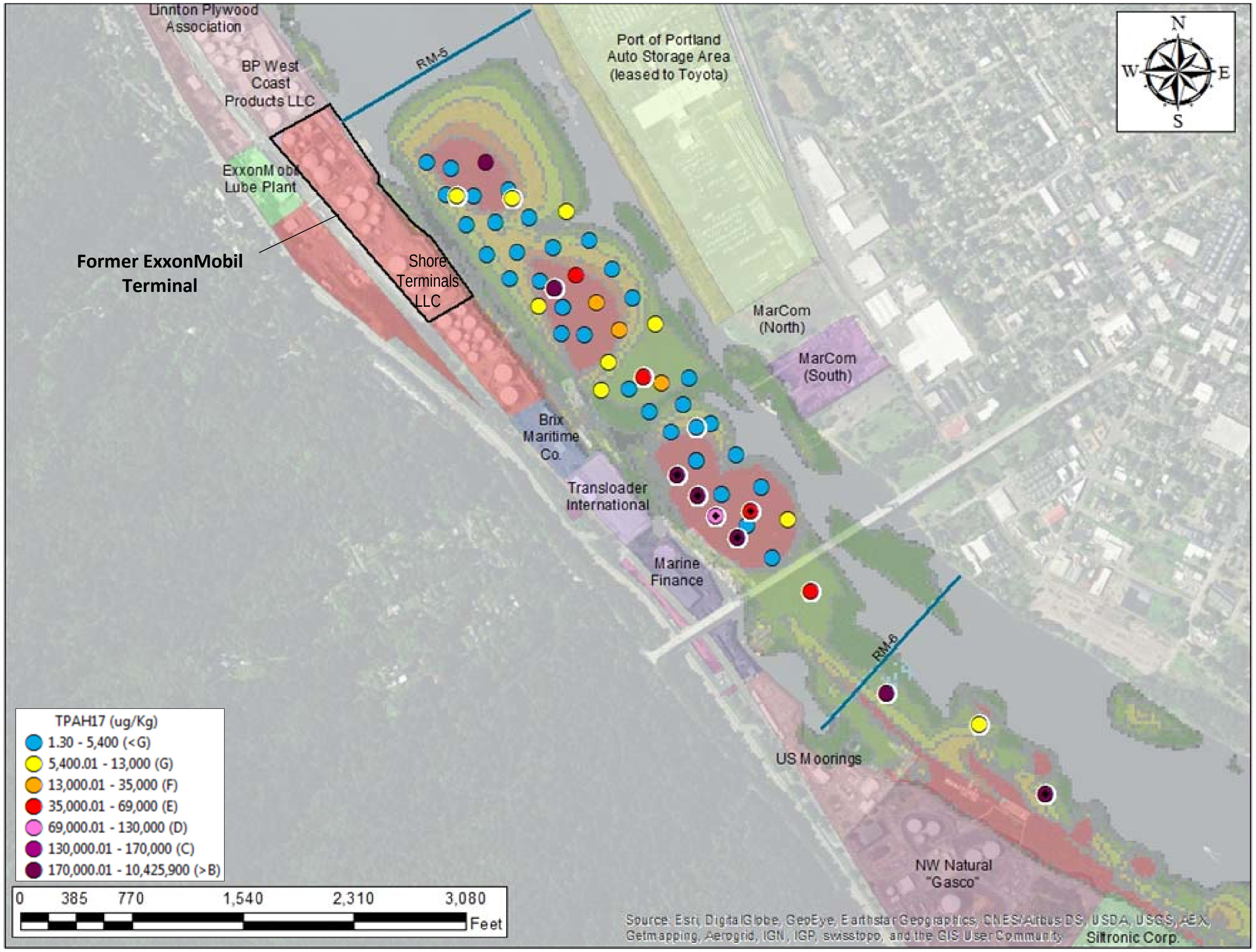


Figure 8 (b). Future channel (-48 to -49 ft) depth sediment TPAH17 concentrations (by RAL).

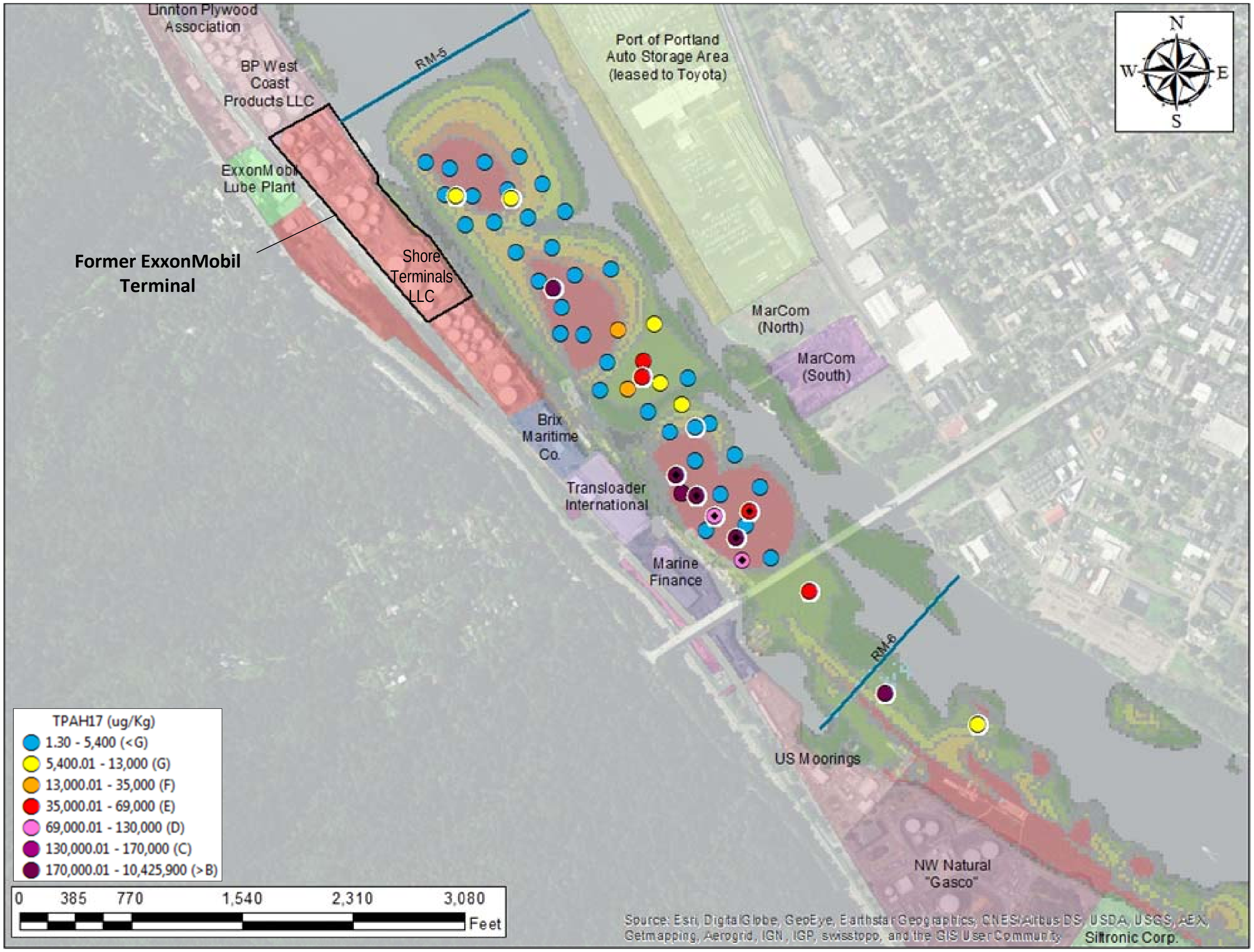
Note: Symbols with white halos represent samples collected in 2014.
Black bullets represent locations where tar balls were observed.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 8 (c). Future overdredge (-51 to -52 ft) depth sediment TPAH17 concentrations (by RAL).

Note: Symbols with white halos represent samples collected in 2014.
Black bullets represent locations where tar balls were observed.



Source: Esri, DigitalGlobe, GeoEye, Earthstar Geographics, CNES/Airbus DS, USDA, USGS, AEX, Getmapping, Aerogrid, IGN, IGP, swisstopo, and the GIS User Community

Figure 8 (d). Future channel plus cap (-53 to -54 ft) depth sediment TPAH17 concentrations (by RAL).

Note: Symbols with white halos represent samples collected in 2014.
Black bullets represent locations where tar balls were observed.

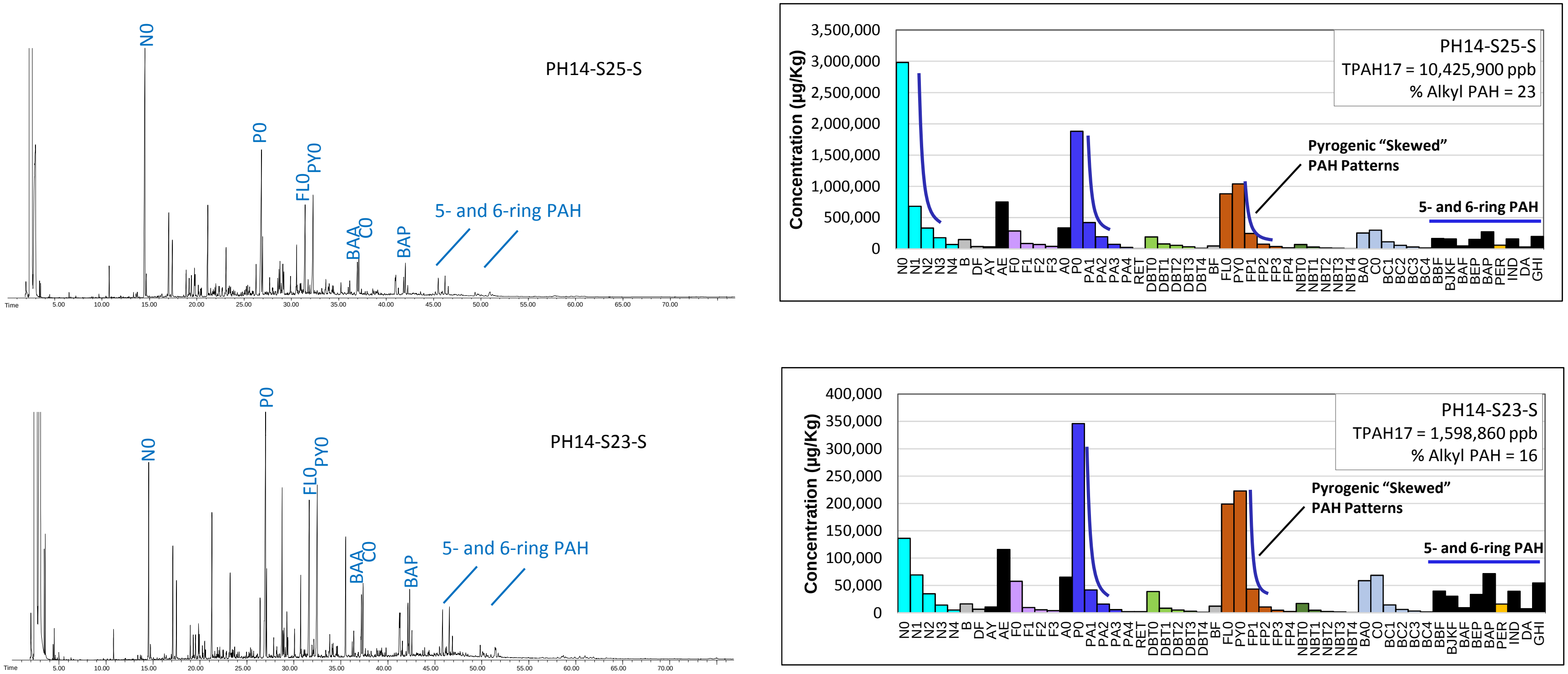


Figure 9. Representative gas chromatograms (left panel) and PAH histograms (right panel) of sediment samples collected in the vicinity of the Gasco Property.

Source: NewFields 2014 Investigation.

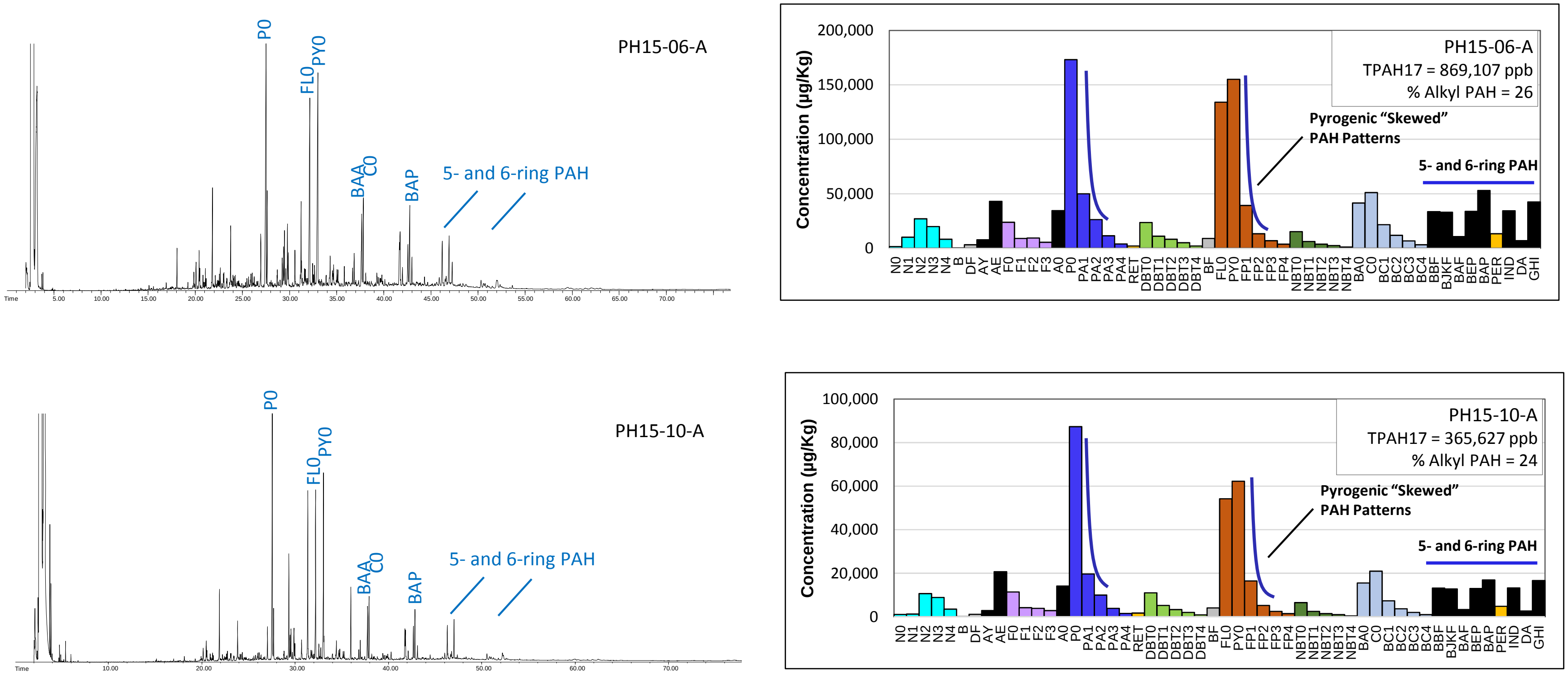


Figure 10. Representative gas chromatograms (left panel) PAH histograms (right panel) of sediment samples collected in the Remedial Alternatives Area, River Mile 5 and River Mile 6.

‘*’: laboratory added internal standards.

Source: NewFields 2015 Investigation.

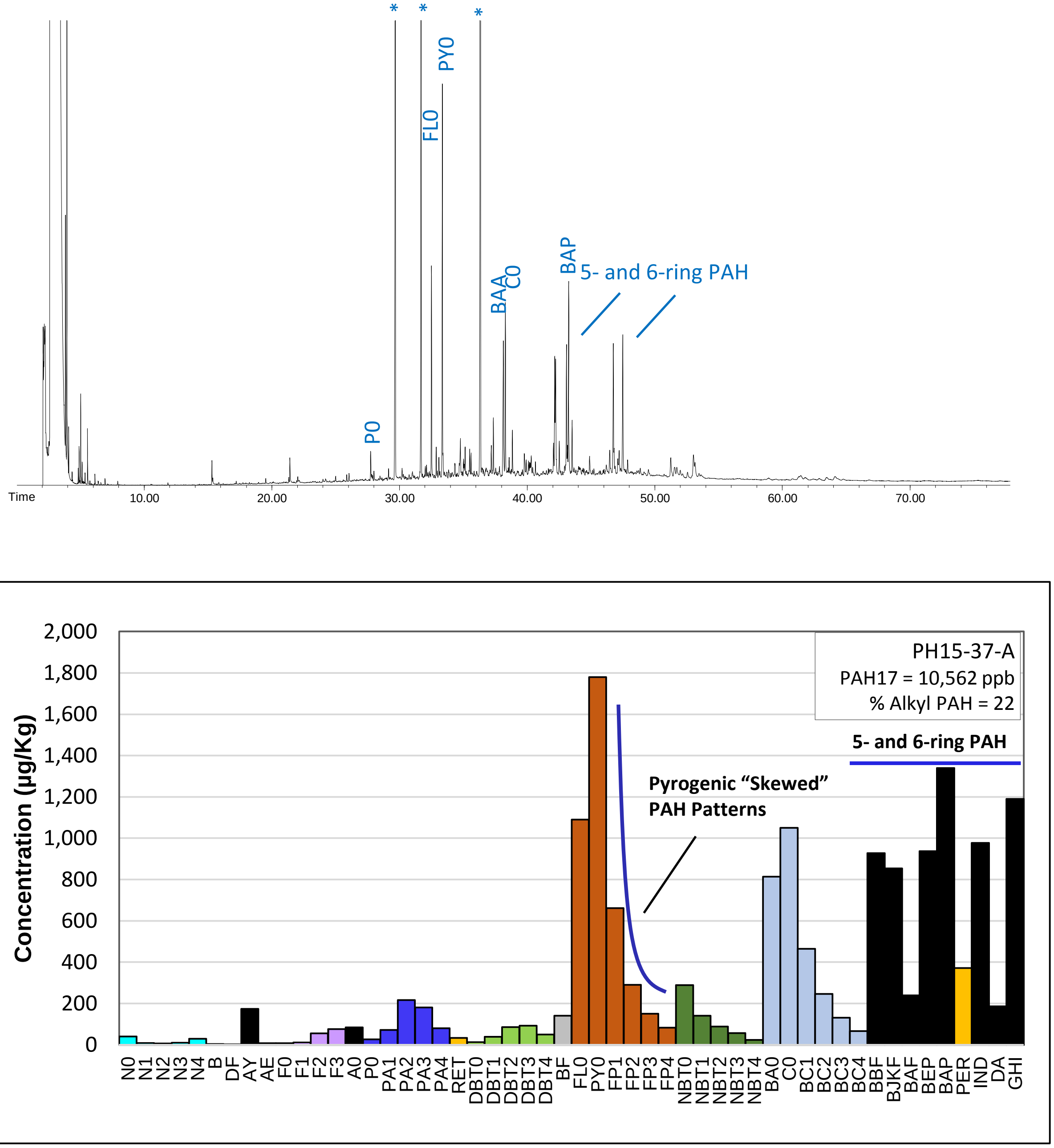


Figure 11. Gas chromatogram (top panel) and PAH histogram (bottom panel) of a surface sample collected in the Remedial Alternatives Area exhibiting characteristic of highly weather tar or tar pitch.

'*': laboratory added internal standards.

Source: NewFields 2015 Investigation.

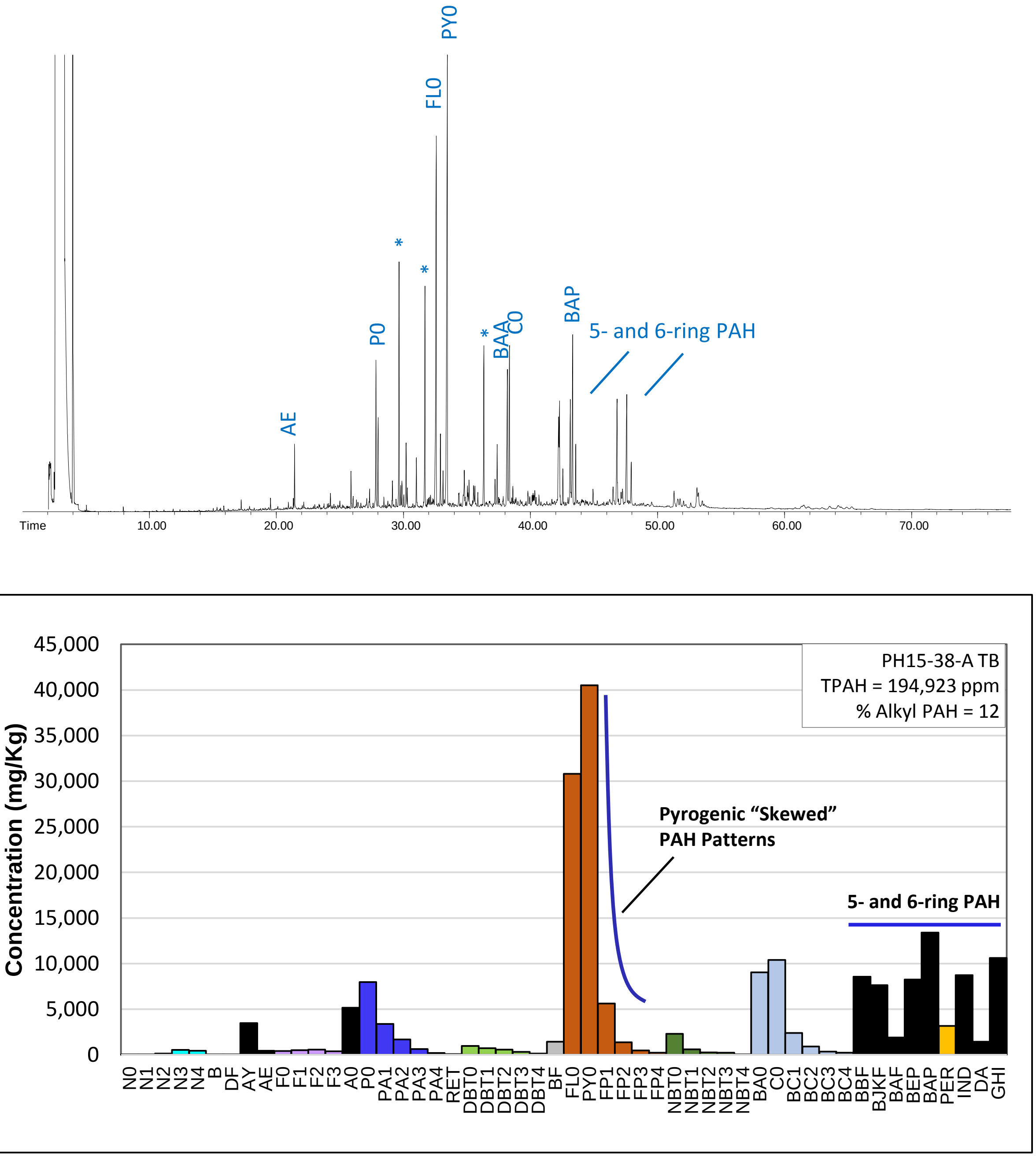


Figure 12. Gas chromatogram (top panel) and PAH histogram (bottom panel) of a tar ball sample collected from PH15-38.

'*': laboratory added internal standards.

Source: NewFields 2015 Investigation.

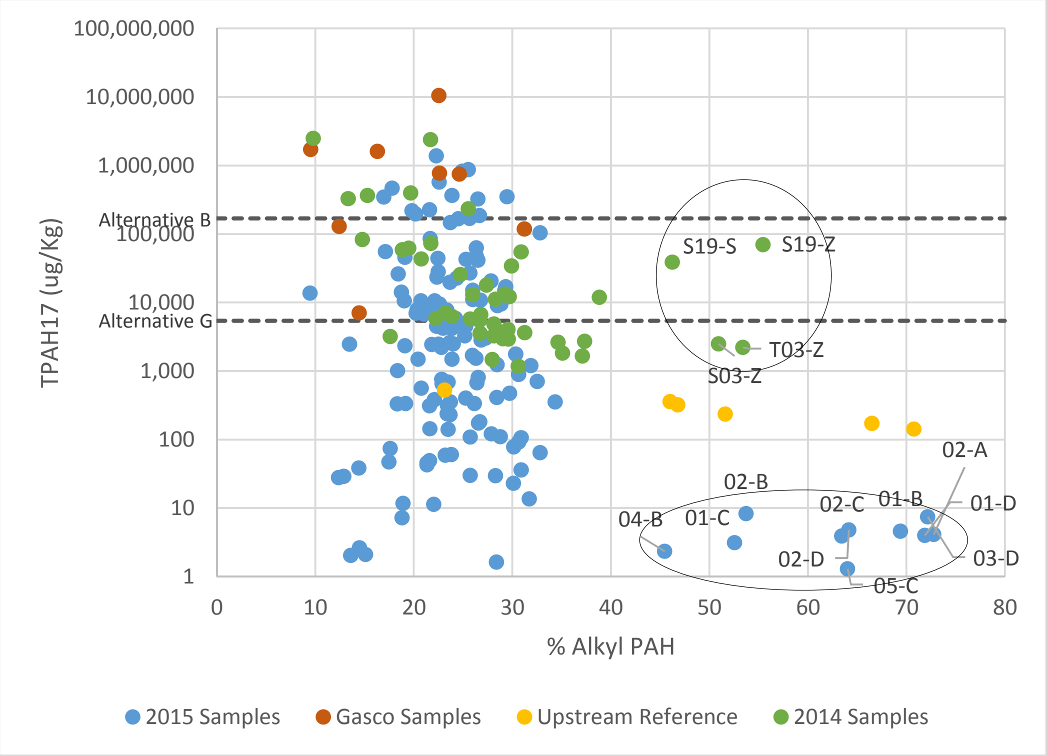


Figure 13. Cross-plot of % Alkyl PAH versus TPAH17 for 2014 and 2015 sediment samples. Samples collected offshore of Gasco depicted by red symbols.

Note: Prefixes for 2014 (PH14-) and 2015 (PH15-) sample IDs are truncated.

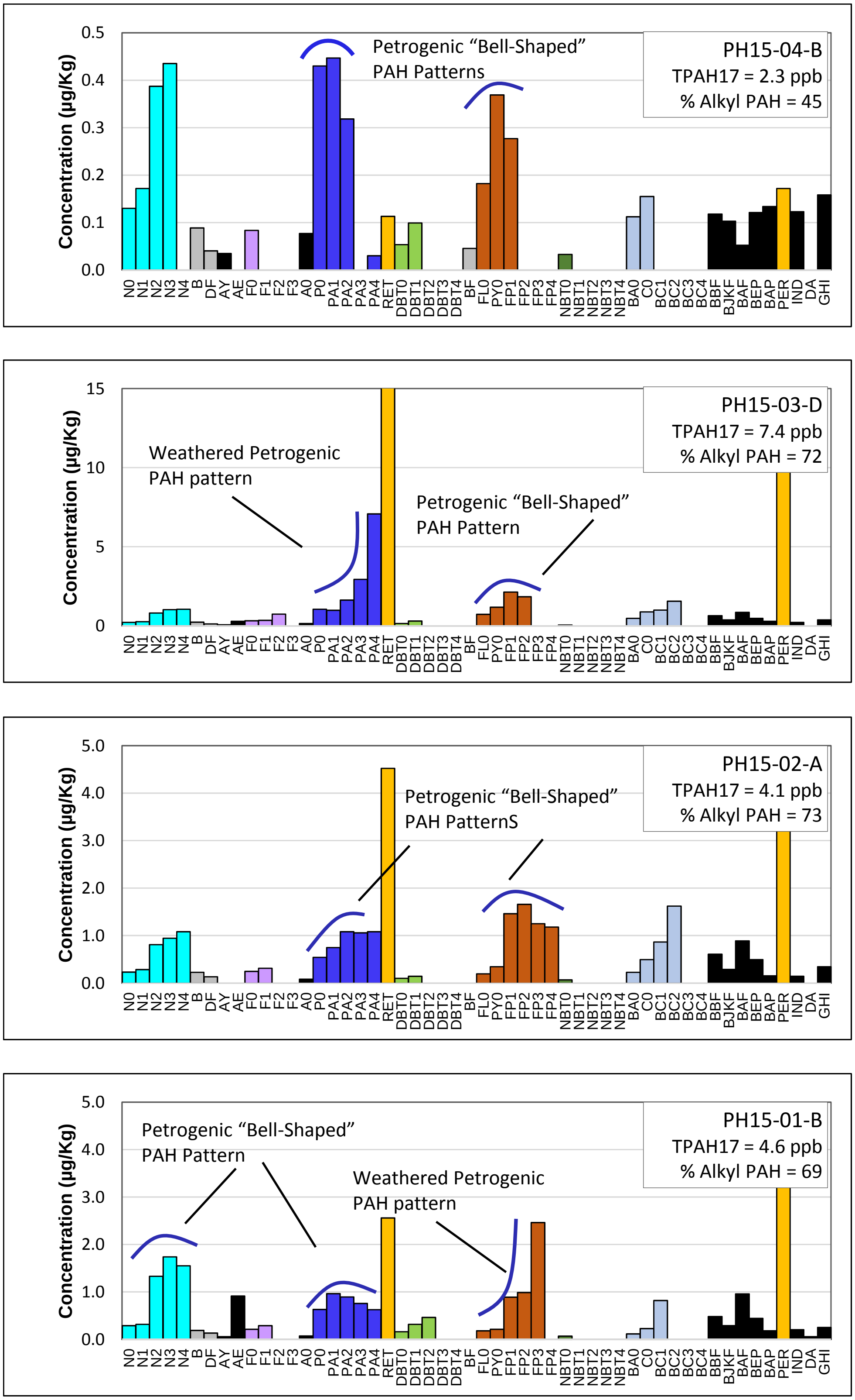
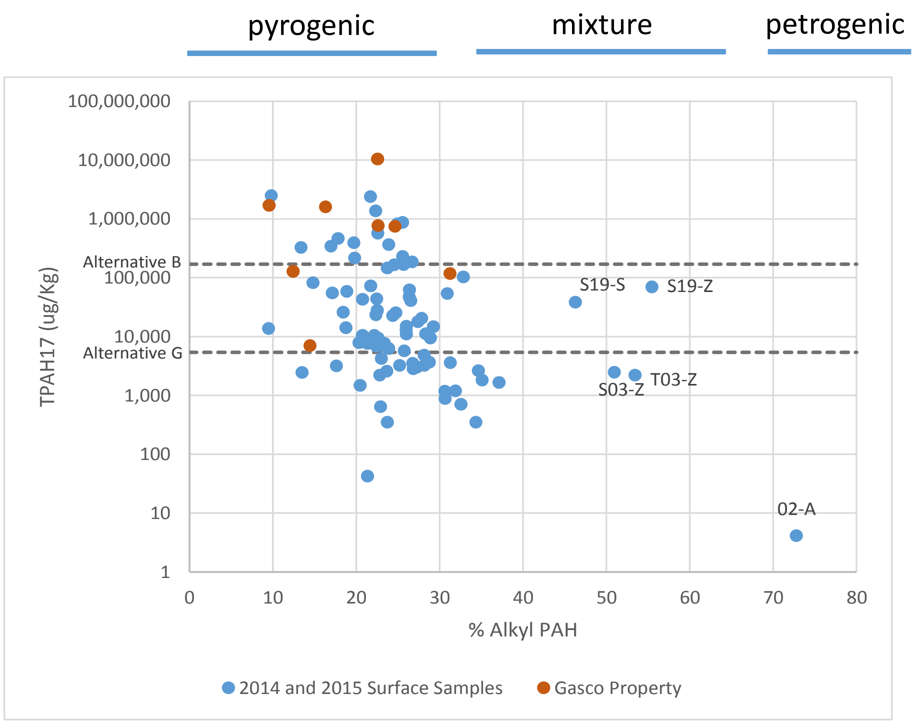
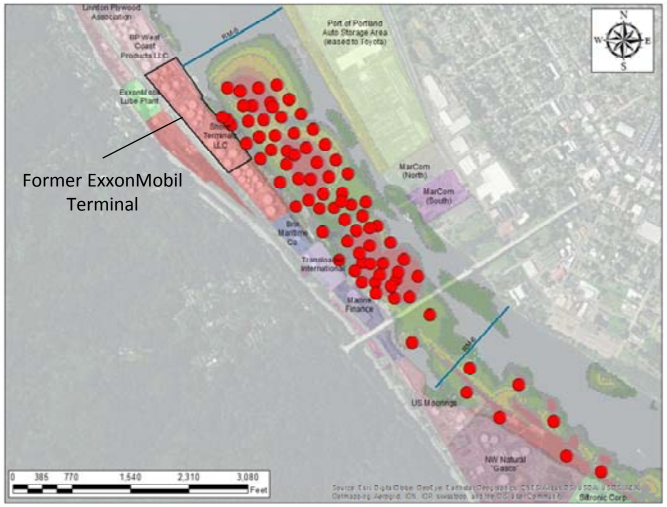


Figure 14. Representative PAH histograms of petrogenic influenced samples. Orange bars represent PAH compounds of biogenic (plant-derived) origin.

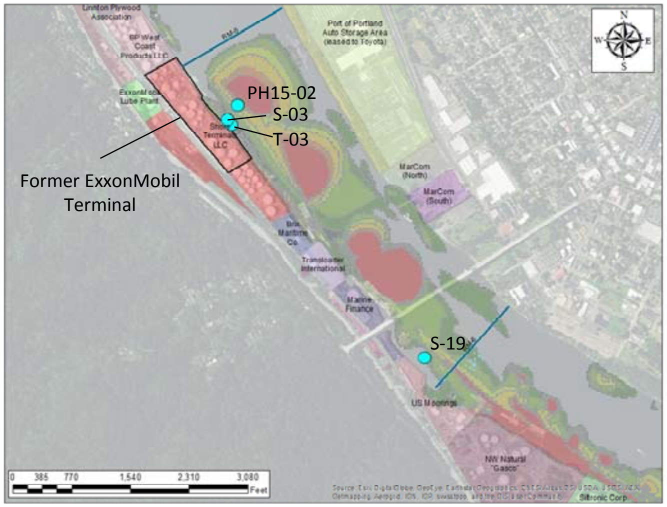
Source: NewFields 2015 Investigation.



Graph (above) depicts discrete samples. Maps (right) depict sample locations.
Prefixes for 2015 (PH15-) sample IDs in graph are truncated.

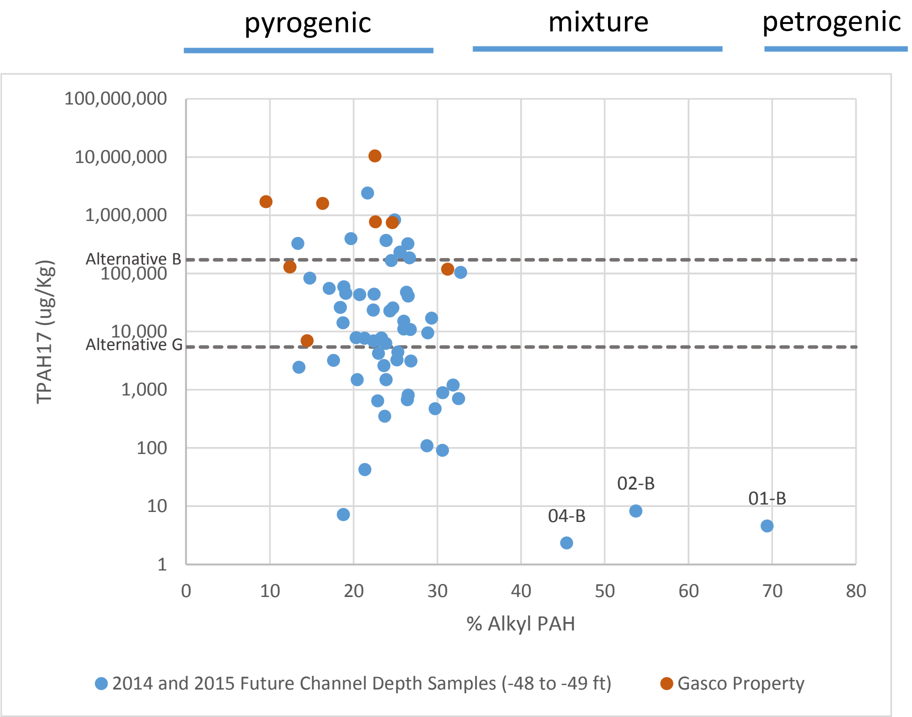


Locations where PAH are pyrogenic dominant.

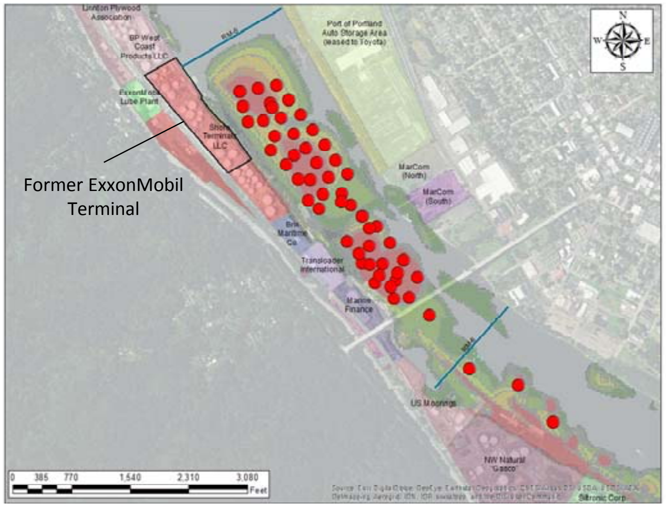


Locations where PAH are petrogenic dominant.

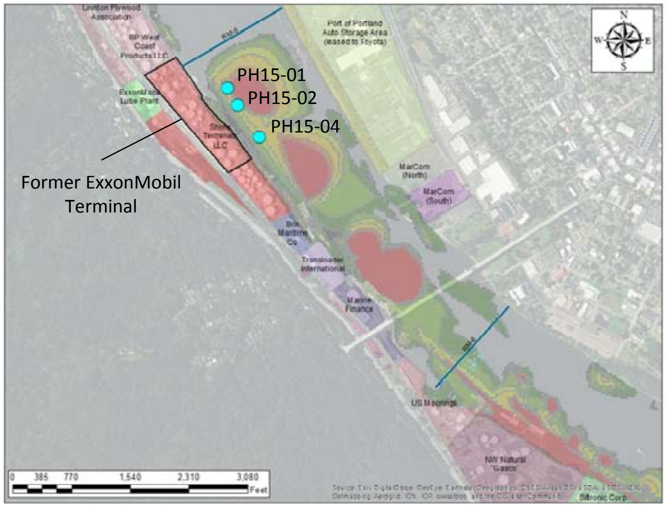
Figure 15 (a). The source character of PAH at the sediment surface (0 to -1 ft interval)
Top left panel: Locations of pyrogenic dominant PAH.
Bottom left panel: Locations of petrogenic dominant PAH.



Graph (above) depicts discrete samples. Maps (right) depict sample locations. Prefixes for 2015 (PH15-) sample IDs in graph are truncated.

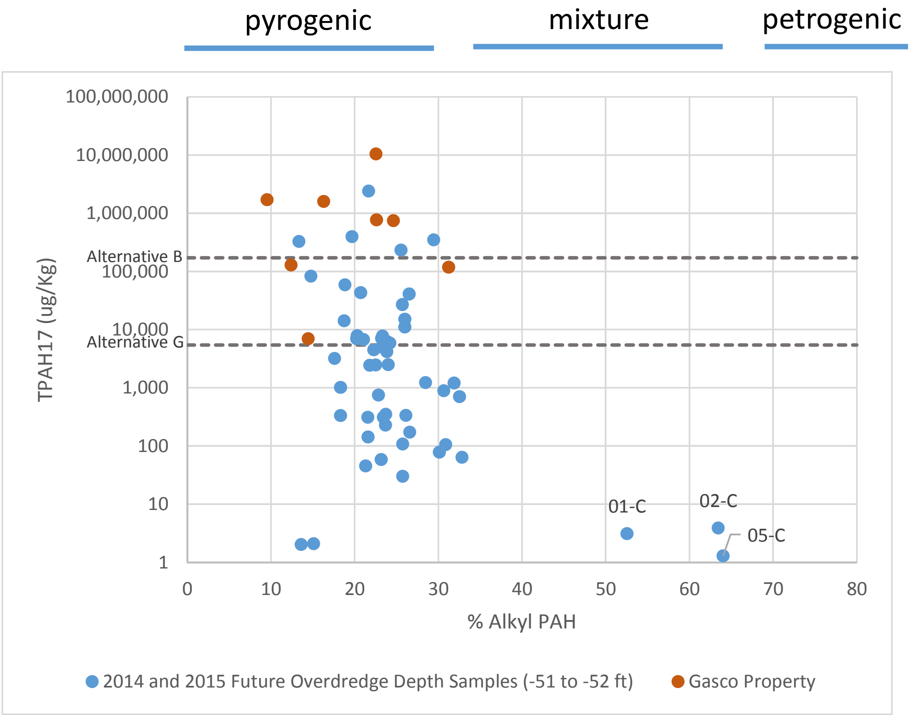


Locations where PAH are pyrogenic dominant.

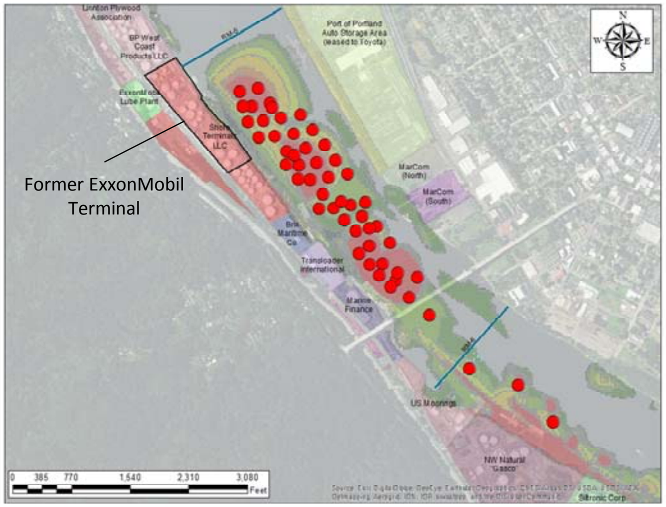


Locations where PAH are petrogenic dominant.

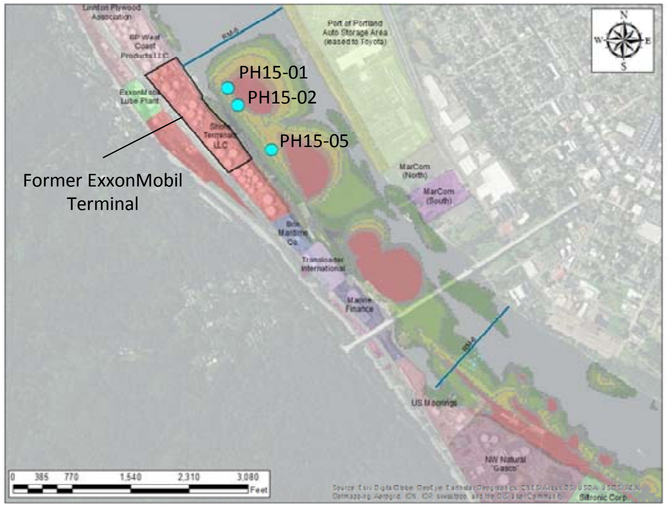
Figure 15 (b). The source character of PAH at the future channel depth horizon (-48' to -49' CRD interval)
Top left panel: Locations of pyrogenic dominant PAH.
Bottom left panel: Locations of petrogenic dominant PAH.



Graph (above) depicts discrete samples. Maps (right) depict sample locations.
Prefixes for 2015 (PH15-) sample IDs in graph are truncated.

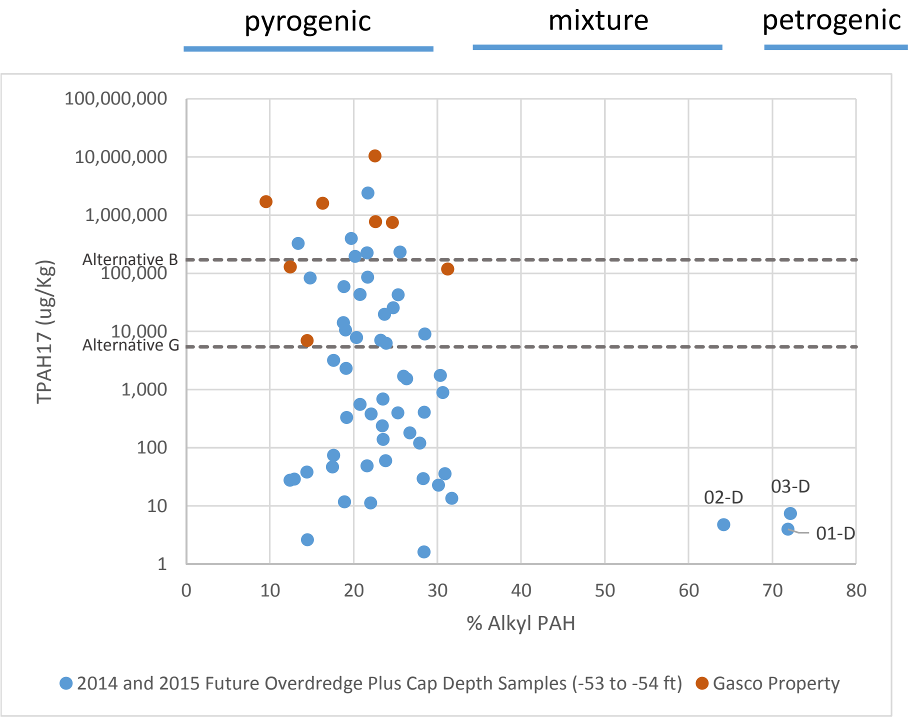


Locations where PAH are pyrogenic dominant.

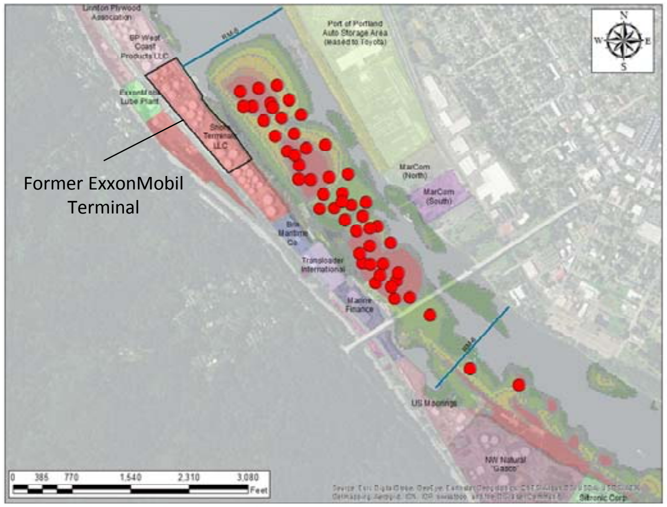


Locations where PAH are petrogenic dominant.

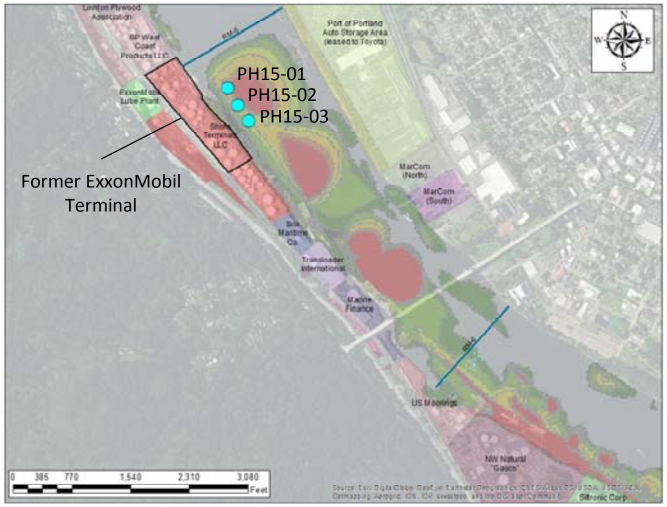
Figure 15 (c). The source character of PAH at the future overdredge depth horizon (-51' to -52' CRD interval).
Top left panel: Locations of pyrogenic dominant PAH.
Bottom left panel: Locations of petrogenic dominant PAH.



Graph (above) depicts discrete samples. Maps (right) depict sample locations.
Prefixes for 2015 (PH15-) sample IDs in graph are truncated.



Locations where PAH are pyrogenic dominant.



Locations where PAH are petrogenic dominant.

Figure 15 (d). The source character of PAH at the future overdredge plus cap depth horizon (-53' to -54' CRD interval).
Top left panel: Locations of pyrogenic dominant PAH.
Bottom left panel: Locations of petrogenic dominant PAH.