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Puget Sound Naval Shipyard and Intermediate Maintenance Facility (PSNS & IMF) Bremerton, WA, Pier B Stormwater Data Analyses and Preliminary Modeling Memo

Contents

Summary

This memo briefly summarizes the Pier B (Puget Sound Naval Shipyard and Intermediate Maintenance Facility, PSNS & IMF, Bremerton, WA) stormwater monitoring data supplied by the Texas Tech researchers, and the site description. These summaries were then evaluated and organized for use in WinSLAMM.

The Pier B site stormwater enters a proprietary hydrodynamic separator (CONTECH CDS) for pretreatment to remove coarse solids, followed by an oil-water separator and finally into a cartridge type media filtration unit consisting of 23 zeolite, perlite, and granular activated carbon (ZPG) cartridges. The monitoring data represents the influent and effluent of the oil-water separator/cartridge filter system, after the hydrodynamic separator. Two events were sampled and analyzed for contaminants of concern (CoCs) however, flow data were not available due to flow sensor malfunctions. The underground pump in the outlet chamber was also not operating during the sampling period due to maintenance, resulting in mixing of the outlet stormwater with seawater.

The Pier B drainage area is about 3.1 acres, including road and adjacent areas (0.4 acres), sheds on pier (0.6 acres), laydown storage areas on pier (0.6 acres), and the remainder of the pier (1.5 acres).

The metals with >70% of the total mass in the filtered inlet sample portion included manganese, nickel, zinc, arsenic, and cadmium, while the metals with >70% of the total mass in the filtered outlet sample portion included manganese, copper, arsenic, and lead. The outlet copper concentrations are much larger than the inlet copper concentrations, likely due to contamination of backflowing receiving waters in the sampling vault. Otherwise, the inlet and outlet concentrations do not show any expected pattern or much difference. The median particle size after the hydrodynamic separator was about 30 um and was reduced to about 12 µm after the media filters, although there were few consistent patterns for the other pollutants. Metals with the highest particulate strengths in the largest size category (>63 µm) were chromium, arsenic, and lead. Manganese and zinc had their largest particulate strengths in the smallest size category (0.45 to 5 µm)., while nickel, copper, and cadmium had their largest particulate strengths associated with intermediate size ranges.

None of the PAHs were seen to have >70% of the total mass in the filtered inlet sample portions, while naphthalene and 2-methylphthalene both have >70% of their mass in the filtered outlet sample portions. There were no patterns of apparent concentration reductions with the filter media treatment. Most of the PAHs had greater relative particulate strengths in the smallest size range (0.7 to 2.7 µm) compared to the other size ranges.

Most of the PFAS compounds had large associations with the filtered samples in both the inlet and outlet samples. Only FHxSA (inlet) had large (>70%) associations with particulate samples. All of the filtered and total sample PFAS concentrations had lower concentrations in the outlet samples compared to the inlet samples. PFOS has the largest concentrations and largest particulate strengths for the inlet and outlet samples.

The Pier B monitoring data were compared to previously collected stormwater data at the Bremerton location. The copper and lead total recoverable and filtered sample results were similar for the three sampling locations. However, the more recent Pier B zinc concentrations were several times greater than the older zinc data. The overall site zinc data were also substantially less than the observed Pier B observations. It is likely that greater amounts of exposed galvanized metals were present on the pier during the more recent monitoring period. TSS data were not shown in the monitoring report for the individual locations during the historical monitoring period. The overall site average TSS concentration was 19.7 mg/L (average of 67 samples), while the Pier B TSS average was 10.2 mg/L. Therefore, based on the limited data for comparisons, the recent Pier B are generally in agreement with the older site data, with the possible exception of the greater zinc concentrations at Pier B.

WinSLAMM was setup using the Pier B site data and the previously calibrated parameter files for comparison to the monitored data. The WinSLAMM calculated TSS average values are about half of the Pier B and historical site monitored values, but within the overall calculated range. The copper, lead, and zinc calculated average values are close to the monitored average values.

Fate and transport potential of the Pier B pollutants was also evaluated. The fate of discharged particulate stormwater pollutants in the receiving waters is mainly a function of their settling rates. Pollutants having about 70%, or more, of their particulate mass in the near field category included: chromium, lead, 2-methylnaphthalene, fluoranthene, and benzo(b)fluoranthene. Pollutants with about

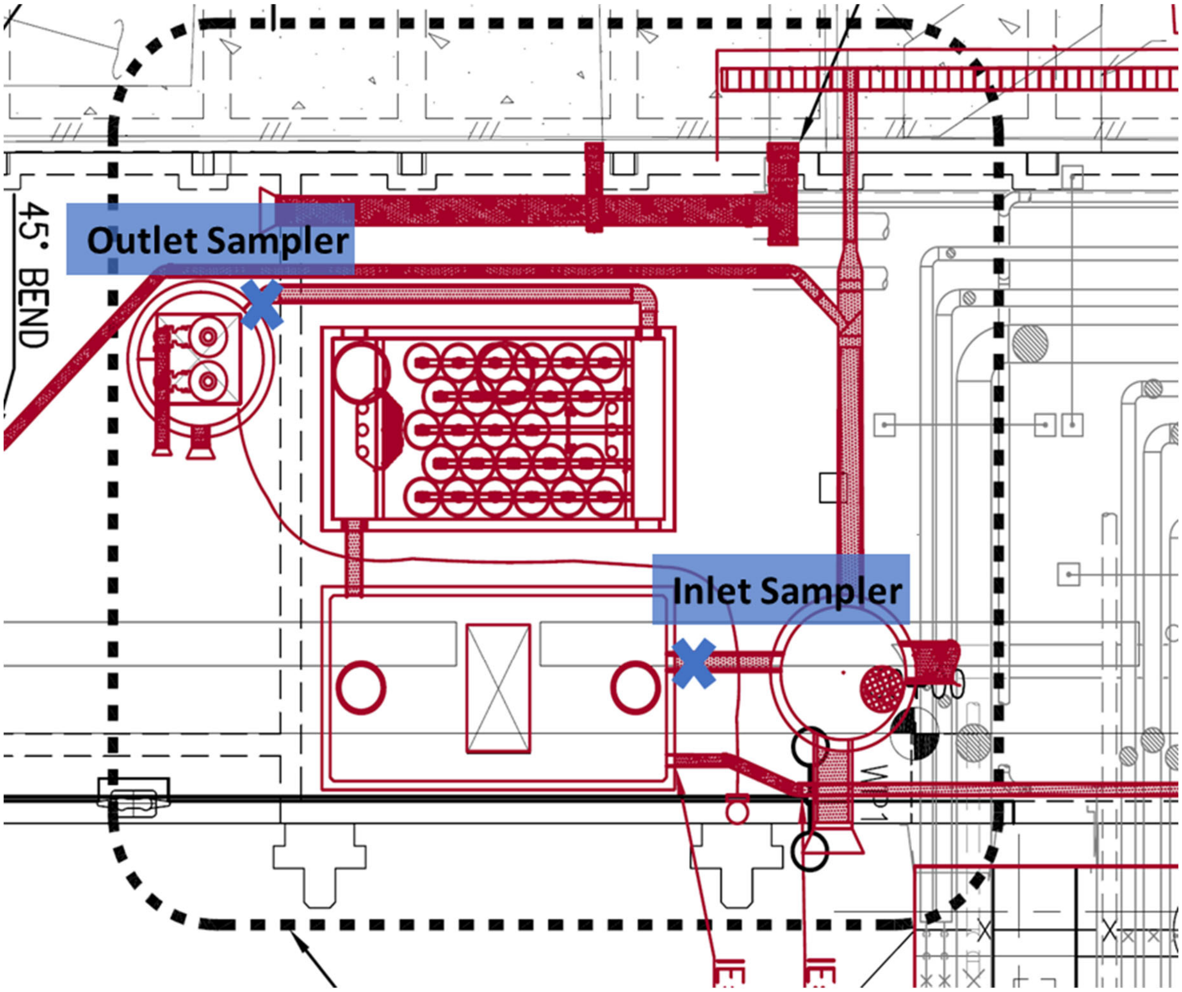
70%, or more, of their particulate mass in the widely dispersed category included: TSS, manganese, copper, and naphthalene. No PFAS data are available by particle size range due to low concentrations observed in the unfiltered samples. Again, these are only rough estimates and the final analyses incorporating data from the other monitoring locations will enable more reliable results.

Monitoring Effort and Stormwater Treatment Descriptions

This memo briefly summarizes the Pier B (Puget Sound Naval Shipyard and Intermediate Maintenance Facility, PSNS & IMF, Bremerton, WA) stormwater monitoring data supplied by the Texas Tech researchers, and the site description. These summaries were then evaluated and organized for use in WinSLAMM. The following site and monitoring description is an edited from the Texas Tech researchers information and from the site questionnaire form.

The Pier B site stormwater entered a proprietary hydrodynamic separator (CONTECH CDS) for pretreatment to remove coarse solids, followed by an oil-water separator and finally into a cartridge type media filtration unit consisting of 23 zeolite, perlite, and granular activated carbon (ZPG) cartridges. These were sized for the peak 6-month storm (1.87”).

The outlet flow from the media filtration unit was directed into the receiving water using an underground pump system as shown in the figure below. Two ISCO samplers were installed with one at the outlet of the hydrodynamic separator and other at the outlet of the cartridge filter. The monitoring data therefore represented the influent and effluent of the oil-water separator/cartridge filter system, after the hydrodynamic separator.



Layout of the stormwater control system and sample locations in Pier B. Note that the inlet was sampled after the hydrodynamic separator and the outlet after the oil/water separator and cartridge filters

Two events were sampled and analyzed for contaminants of concern (CoCs) however, flow data were not available due to flow sensor malfunctions. The underground pump in the outlet chamber was also not operating during the sampling period due to maintenance, resulting in mixing of the outlet stormwater with seawater, as indicated by high salinity and chloride results for the effluent samples.

Pier B Monitoring Area Description

The following aerial photograph shows Pier B and the drainage area outlined in yellow. The drainage area is about 3.1 acres from the Google Map scale for the site. The drainage area includes a short section of a frontage road and adjacent area, plus a portion of the pier. The following lists the approximate areas of the source areas on this map:

Road and adjacent areas:	0.4 acres
Sheds on pier:	0.6 acres
Laydown storage areas on pier:	0.6 acres
Remainder of pier:	1.5 acres

Aerial drainage map of Pier B site in PSNS with drainage represented by yellow lines

Monitoring Data Summary for Modeling

The following subsections summarize stormwater monitoring data for TSS, heavy metals, PAHs, and PFAS compounds at the Pier B location. With only two influent and effluent events sampled, the data are limited, and these results should be used with caution. The concentrations were also generally low, further hindering the ability to analyze particulate strengths for different particle size ranges, especially for the PFAS compounds. As noted above, the influent samples were obtained after the hydrodynamic separator and before the oil and grease separator and cartridge filters, while the effluent samples were obtained from the final effluent vault before discharge to the saline receiving water. It was also noted that the effluent samples may have been affected by backwater from the receiving water due to pump issues in the vault. Comparisons of the influent vs. effluent data were therefore not reliable due to the few samples and potential contamination; the concentration differences were also shown to be small in most cases. The data were most useful in describing the particulate strength values by particle size range for the metals and PAHs.

The data were organized showing the total and filtered sample concentrations (averaged for the two influent and two effluent samples), and the percentage of the total concentration in filtered and percentage particulate bound portions. Plots also show the mass cumulative distributions by particle size, for the influent and effluent samples. Particulate strength values by size range are shown for the heavy metals and selected PAHs. Some of the PAHs had too many non-detectable results by size range for the calculations, so only those with most of the data available are shown. The particulate strength values combined the influent and effluent samples by size range as the treatment system would not affect the particulate strengths. The treatment system would likely preferentially remove more of the larger particles than the smaller particles (not affecting their particulate strengths) in addition to capturing some of the filterable concentrations through ion exchange or sorption, along with some small particles. Bar plots also compare normalized particulate strengths by size range for the metals and some of the PAHs. These data were normalized by calculating the ratios of the individual size range particulate strengths to the total sample particulate strengths, and then normalizing the ratios to be equal to one.

TSS and Heavy Metals

The following tables and the plots summarize the total and filtered sample concentrations for TSS and heavy metals, along with the mass distributions of the particulate bound pollutants by particle size. These are shown for both the inlet samples (after the hydrodynamic separator) and the outlet (after both the hydrodynamic separator and media filters). As noted, only two events were monitored at each location, so these observations do not represent the likely overall range of conditions expected at the Pier B sampling location. The metals with >70% of the total mass in the filtered inlet sample portion included manganese, nickel, zinc, arsenic, and cadmium, while the metals with >70% of the total mass in the filtered outlet sample portion included manganese, copper, arsenic, and lead. Its highly unusual for most of the lead to be associated with filtered sample fractions, especially with marginal TSS removals. Pollutants with large portions of particulate bound pollutants included TSS (by definition) and chromium (for both inlet and outlet samples). The outlet copper concentrations were much larger than the inlet copper concentrations, likely due to contamination of backflowing receiving waters in the sampling vault (although these concentrations were higher than expected for the receiving waters). Otherwise, the inlet and outlet concentrations did not show any expected pattern or much difference.

Average concentrations and filterable vs. particulate bound portions of two inlet samples for TSS and heavy metals

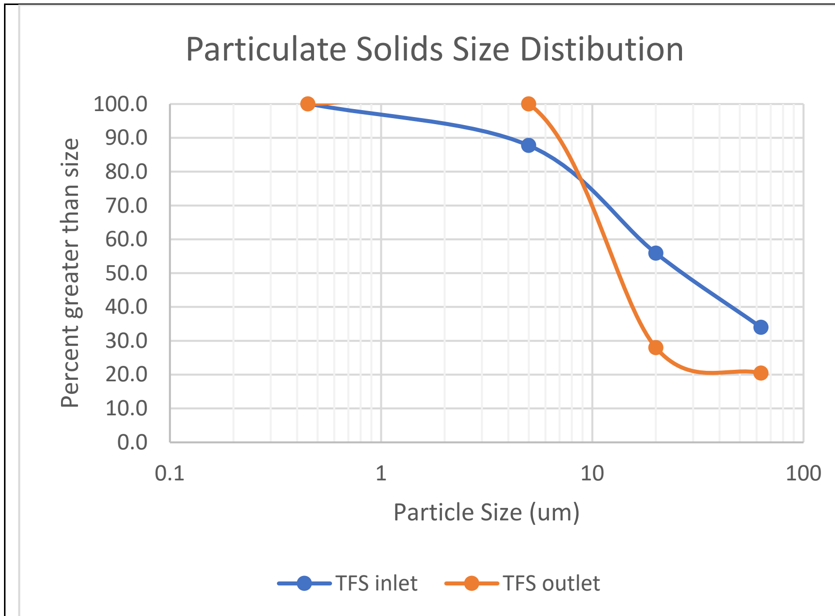
	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
Total conc (mg/L for TSS and µg/L for others)	10.2	1.26	36.6	4.0	22.0	305.3	1.91	0.50	1.40
Filtered conc (ug/L)	n/a[1]	0.29	33.6	3.5	12.4	236.9	1.87	0.41	0.46
% filtered	n/a	22.8	91.7	87.7	56.5	77.6	97.7	82.4	33.1
% particulate	100	77.2	8.3	12.3	43.5	22.4	2.3	17.6	66.9

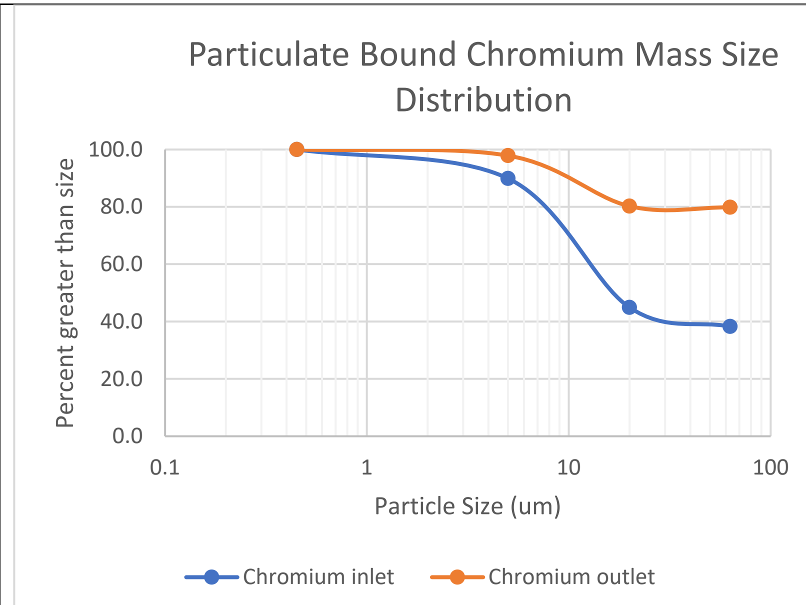
Note: TSS is only for total concentration and not applicable for filtered samples

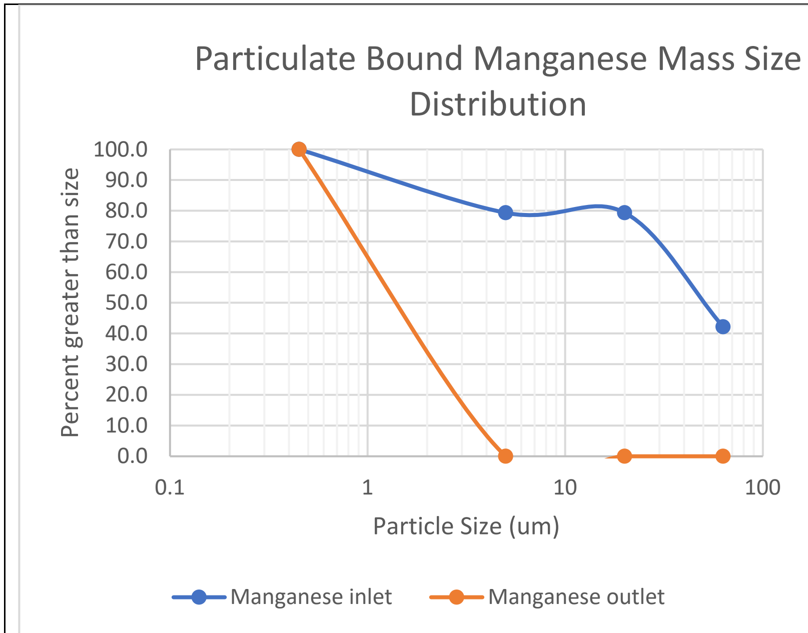
Average concentrations and filterable vs. particulate bound portions of two outlet samples for TSS and heavy metals

	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
Total conc (mg/L for TSS and µg/L for others)	7.3	5.03	37.2	11.6	205.5	264.0	6.15	0.58	1.44
Filtered conc (ug/L)	n/a	1.12	36.5	7.1	154.0	145.5	4.98	0.35	1.20
% filtered	n/a	22.2	98.1	61.2	74.9	55.1	81.1	61.0	83.4
% particulate	100	77.8	1.9	38.8	25.1	44.9	18.9	39.0	16.6

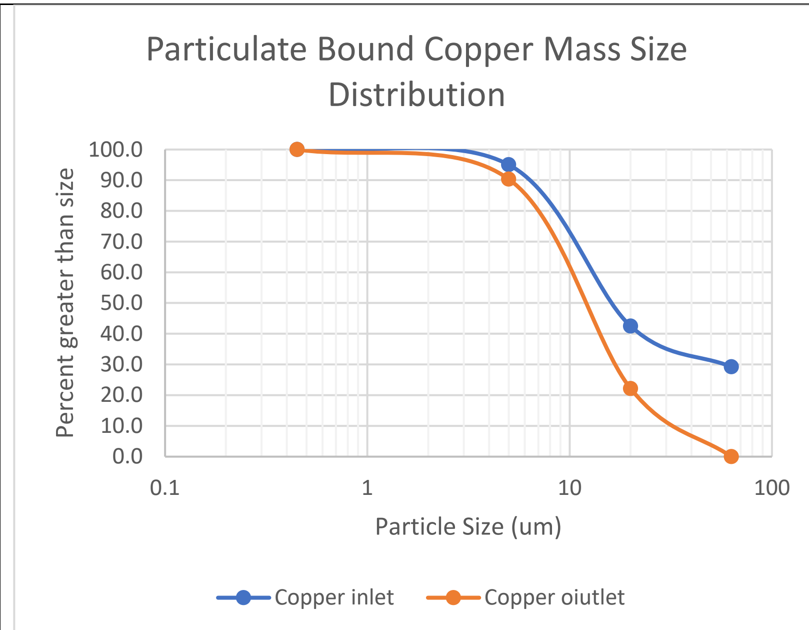
The following plots show the mass distributions of the particulate-bound pollutants by particle size, for the inlet samples (after the hydrodynamic separator) and the outlet samples (after both the hydrodynamic separator and oil/water separator and media filters). The hydrodynamic separator would have previously retained the largest particles (probably greater than about 100 µm), while the media filters (the process affecting these two sample sets) would mostly affect the filterable forms of the pollutants, along with some of the smaller particles. The median particle size after the hydrodynamic separator was about 30 µm and was reduced to about 12 µm after the media filters, although there were few consistent patterns for the other pollutants.



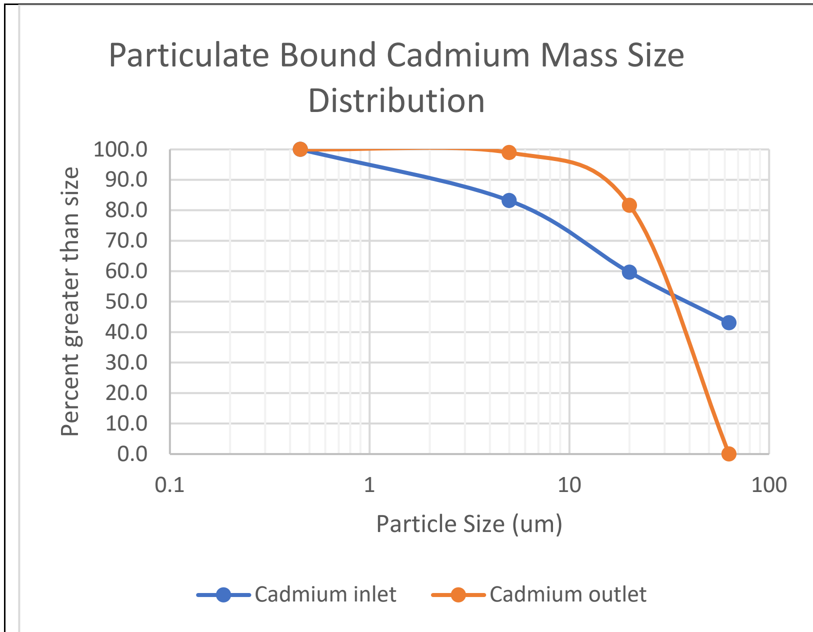
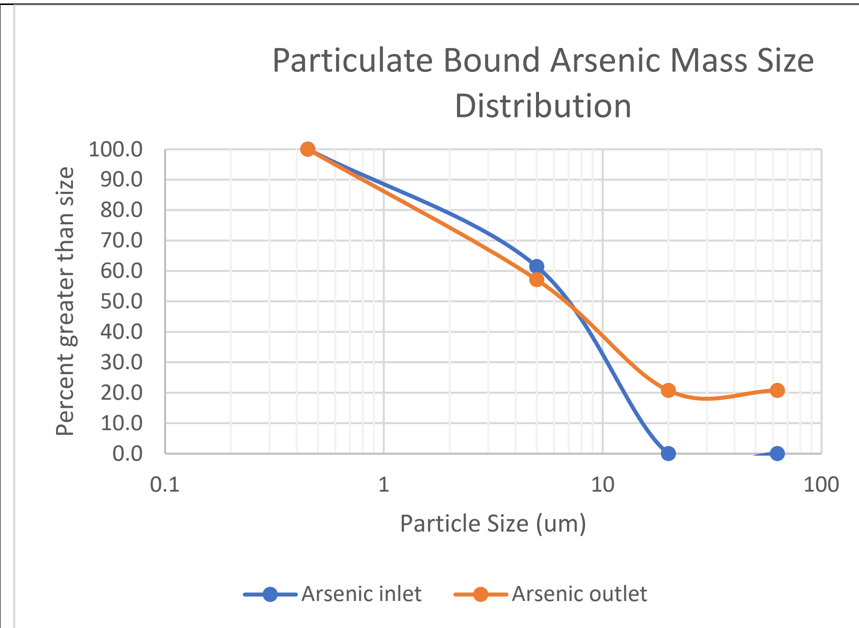


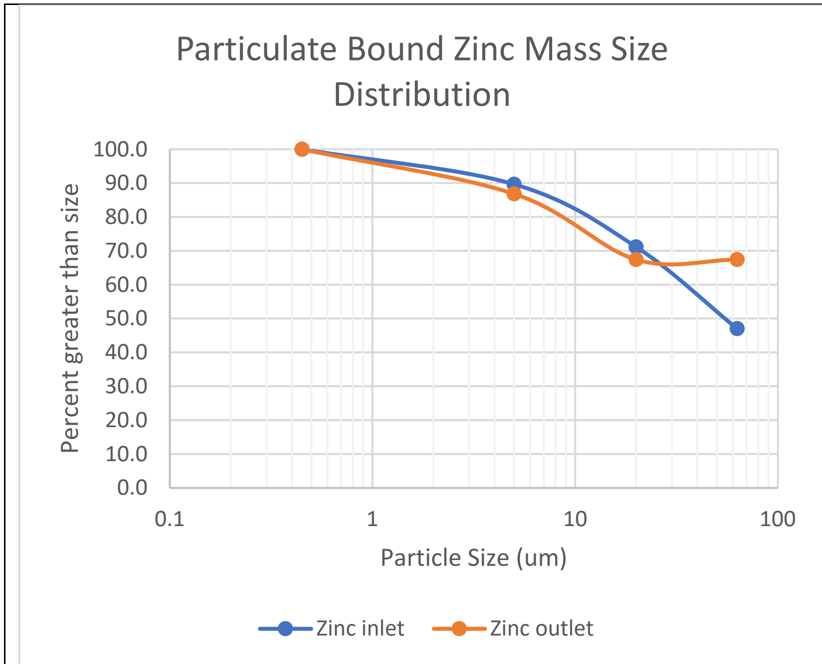


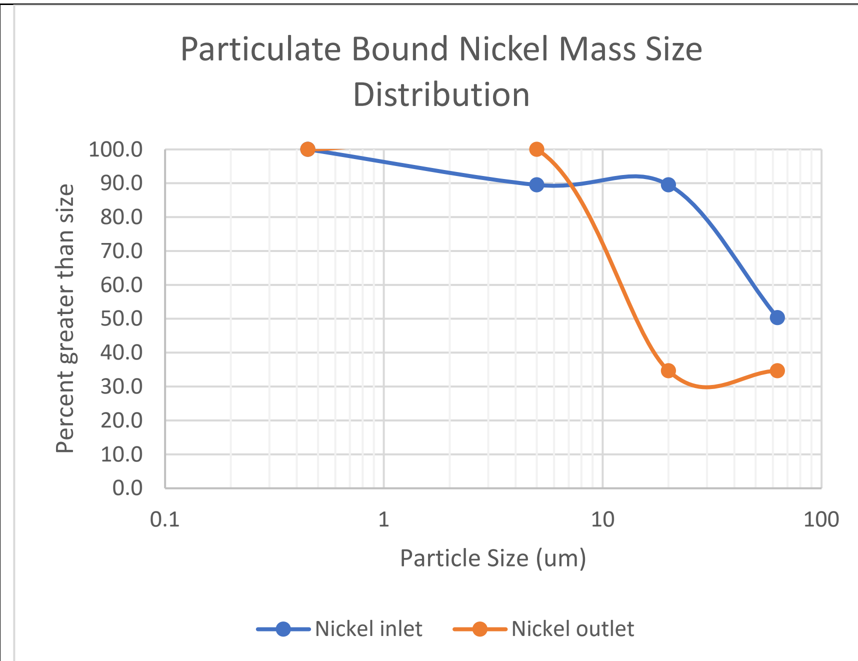
Particulate Bound Manganese Mass Size Distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
Manganese inlet
Manganese outlet

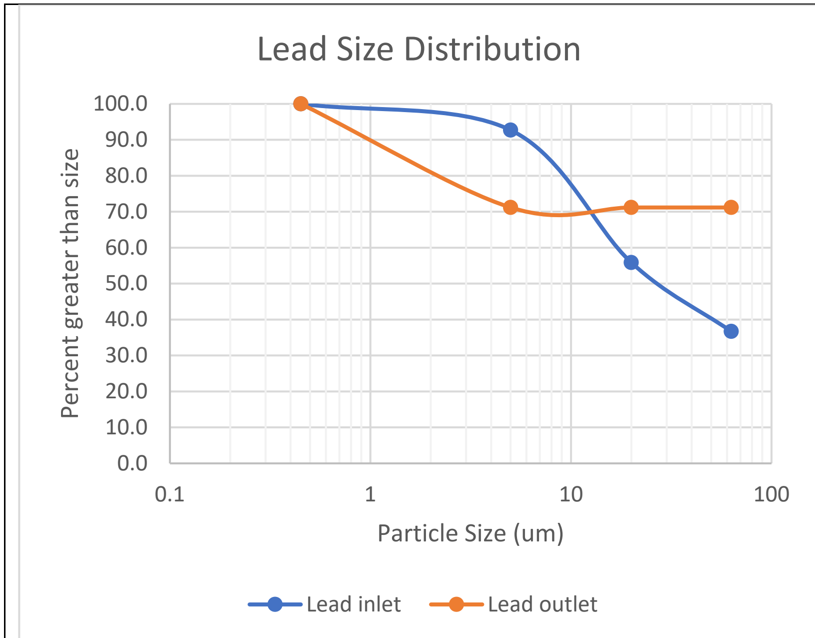


Particulate Bound Copper Mass Size Distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
Copper inlet
Copper oiutlet

Particulate Bound Cadmium Mass Size Distribution Percent greater than size 100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0 0.1 1 10 100 Particle Size (um) Cadmium inlet Cadmium outlet	Particulate Bound Arsenic Mass Size Distribution Percent greater than size 100.0 90.0 80.0 70.0 60.0 50.0 40.0 30.0 20.0 10.0 0.0 0.1 1 10 100 Particle Size (um) Arsenic inlet Arsenic outlet


Particulate Bound Zinc Mass Size Distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
Zinc inlet
Zinc outlet


Particulate Bound Nickel Mass Size Distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
Nickel inlet
Nickel outlet

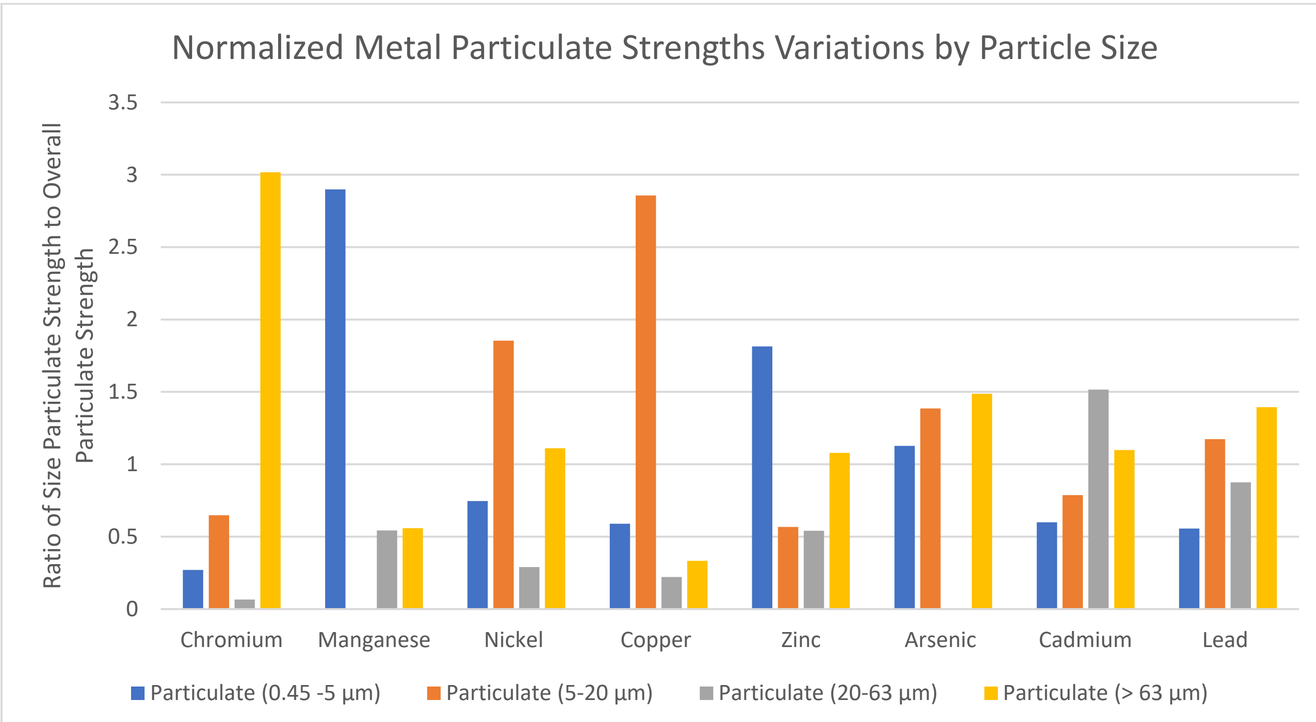


The following table and figure summarize the particulate strengths for the monitored metals, by particle size. Values for all four samples (2 inlets and 2 outlets) were averaged together for these summaries, as treatment would not affect the particulate strengths (only the mass of particulates in each size range would change with treatment). The bar plots show the particulate strengths normalized against the overall total particulate strengths, with an overall average of one. Metals with the highest particulate strengths in the largest size category (>63 µm) were chromium, arsenic (slightly larger than other categories) and lead. Manganese and zinc had their largest particulate strengths in the smallest size category (0.45 to 5 µm)., while nickel, copper, and cadmium had their largest particulate strengths associated with intermediate size ranges.

Average particulate strengths of all 2 inlet and 2 outlet samples, mg/kg

Size Interval	Chromium	Manganese	Nickel	Copper	Zinc	Arsenic	Cadmium	Lead
0.45 -5 µm	66	1,500	120	840	17,000	41	7.0	33
5-20 µm	160	nd	310	4,100	5,300	50	9.2	69
20-63 µm	16	280	50	320	5,000	nd	18	51

> 63 µm	740	290	190	480	10,000	54	13	81
Total Particulate (> 0.45 µm)	3100	200	440	4,300	15,000	86	29	73



PAHs

The following tables and the plots summarize the total and filtered sample concentrations for selected PAHs (those with fewer non-detectable observations by size range), along with the mass distributions of the particulate bound pollutants by particle size. These are shown for both the inlet samples (after the hydrodynamic separator) and the outlet (after both the hydrodynamic separator and oil/water separator plus media filters). As noted, only two events were monitored at each location, so these observations do not represent the likely overall range of conditions expected at the Pier B sampling location. None of these PAHs had >70% of the total mass in the filtered inlet sample portions, while naphthalene and 2-methylphthalene both had >70% of their mass in the filtered outlet sample portions. There were no patterns of apparent concentration reductions with the filter media treatment.

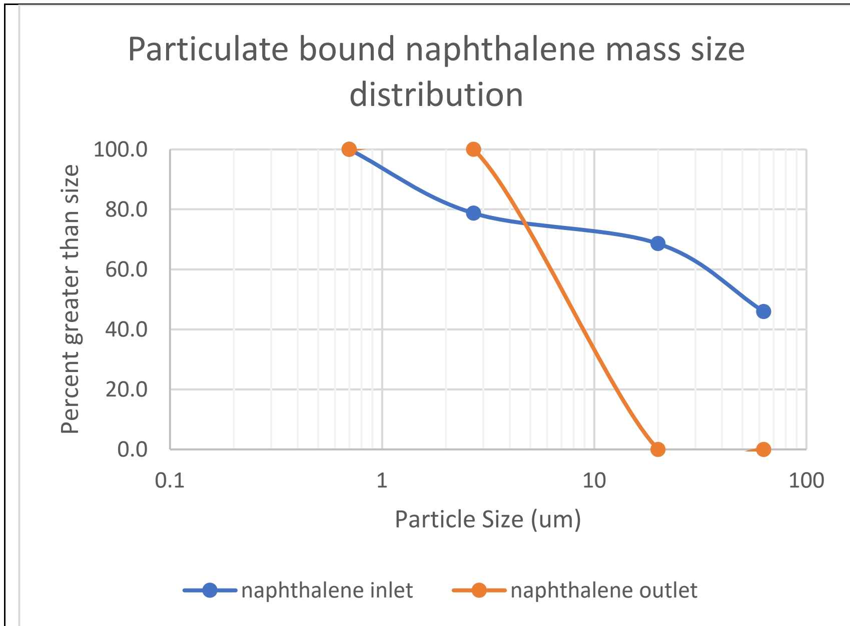
PAH concentrations and filterable and particulate bound values for the average of two inlet samples

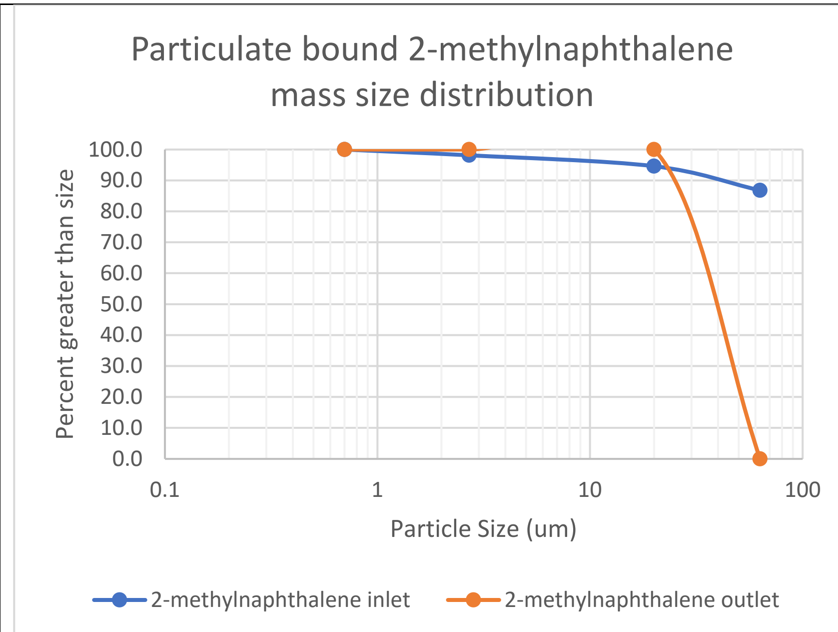
	naphthalene	2-methylnaphthalene	pyrene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
total conc (µg/L)	4.4	3.9	2.4	4.2	0.5	2.5	1.4	33.2
filtered conc (ug/L)	1.9	1.3	1.2	1.6	0.0	0.4	0.1	12.7
% filtered	41.9	33.2	48.8	37.4	9.2	15.5	4.0	38.1
% particulate	58.1	66.8	51.2	62.6	90.8	84.5	96.0	61.9

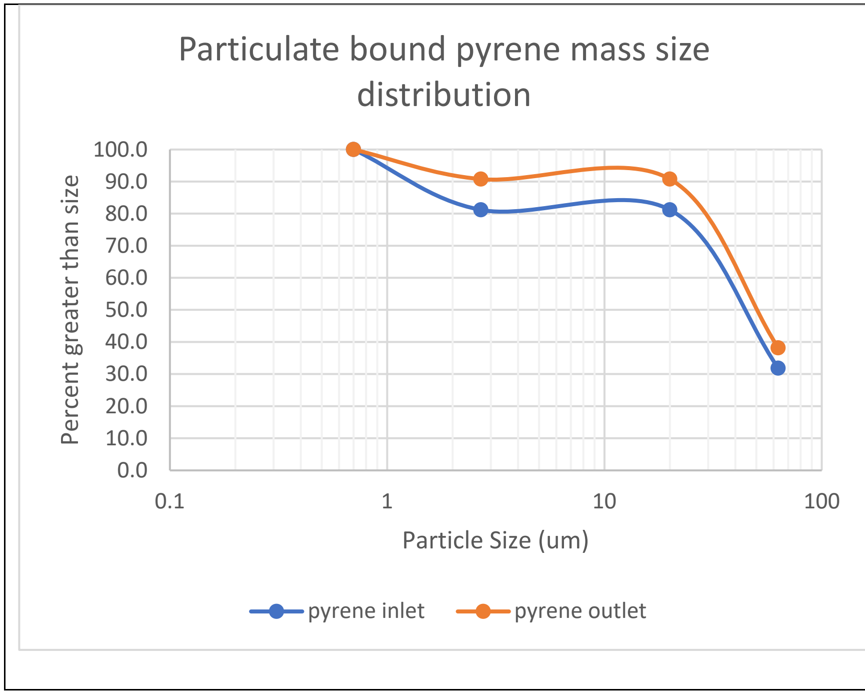
PAH concentrations and filterable and particulate bound values for the average of two outlet samples

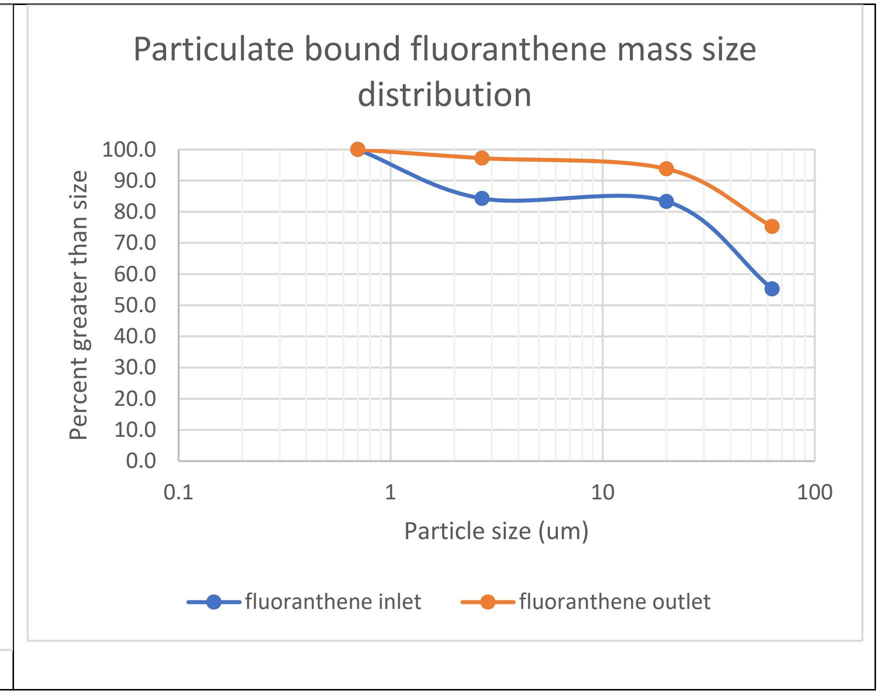
	naphthalene	2-methylnaphthalene	pyrene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
total conc (µg/L)	4.6	6.8	4.8	7.1	1.1	2.3	1.5	47.2
filtered conc (ug/L)	4.6	6.0	2.0	1.4	0.1	0.2	0.0	26.9
% filtered	99.7	87.9	42.9	20.2	5.3	10.5	2.3	57.1
% particulate	0.3	12.1	57.1	79.8	94.7	89.5	97.7	42.9

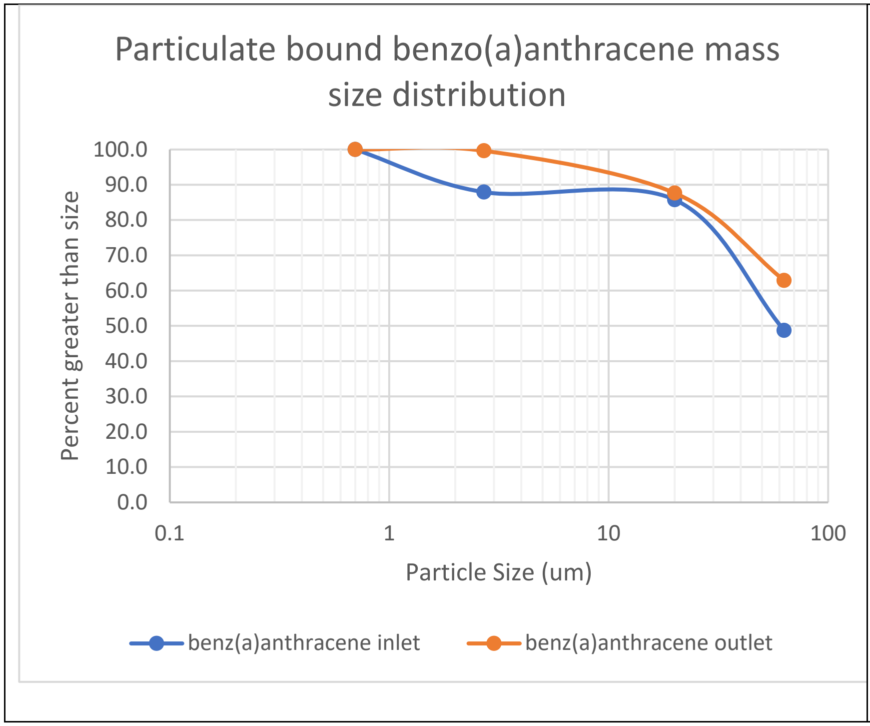
The following plots show the mass distributions of selected particulate-bound PAHs by particle size, for the inlet samples (after the hydrodynamic separator) and the outlet samples (after both the hydrodynamic separator and media filters). The hydrodynamic separator would have previously retained the largest particles (probably greater than about 100 µm), while the media filters (the process affecting these two sample sets) would mostly affect the filterable forms of the pollutants, and some of the smaller particles. There were few consistent patterns for the PAHs, with similar distributions for inlet and outlet samples for most shown (except for naphthalene and 2-methylnaphthalene, which were shown to have large filtered fractions in the outlet samples).


Particulate bound naphthalene mass size distribution
Percent greater than size
100.0
80.0
60.0
40.0
20.0
0.0
0.1
1
10
100
Particle Size (um)
naphthalene inlet
naphthalene outlet

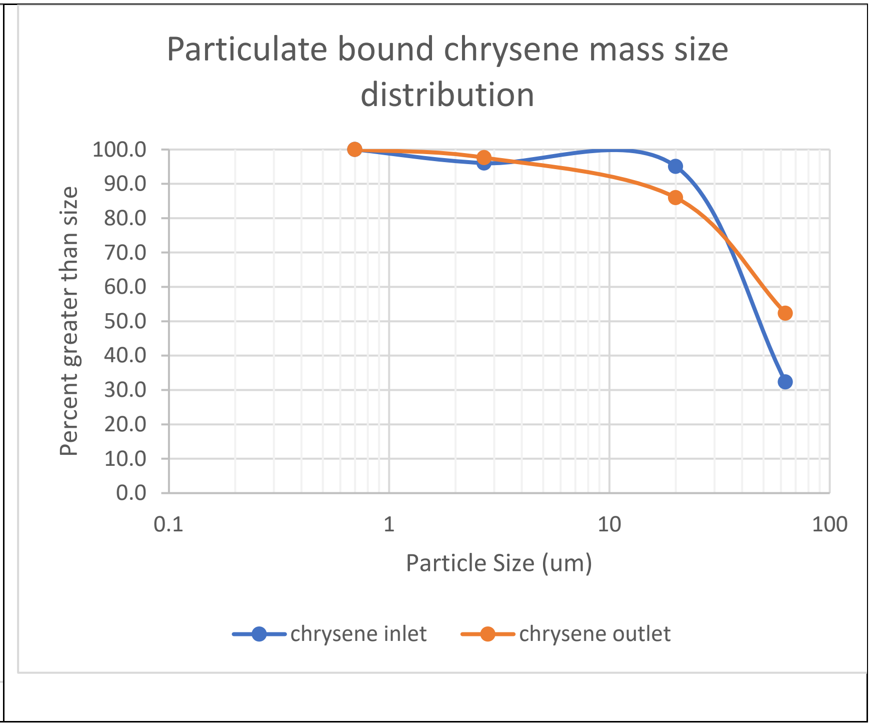

Particulate bound 2-methylnaphthalene mass size distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
2-methylnaphthalene inlet
2-methylnaphthalene outlet


Particulate bound pyrene mass size distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
pyrene inlet
pyrene outlet

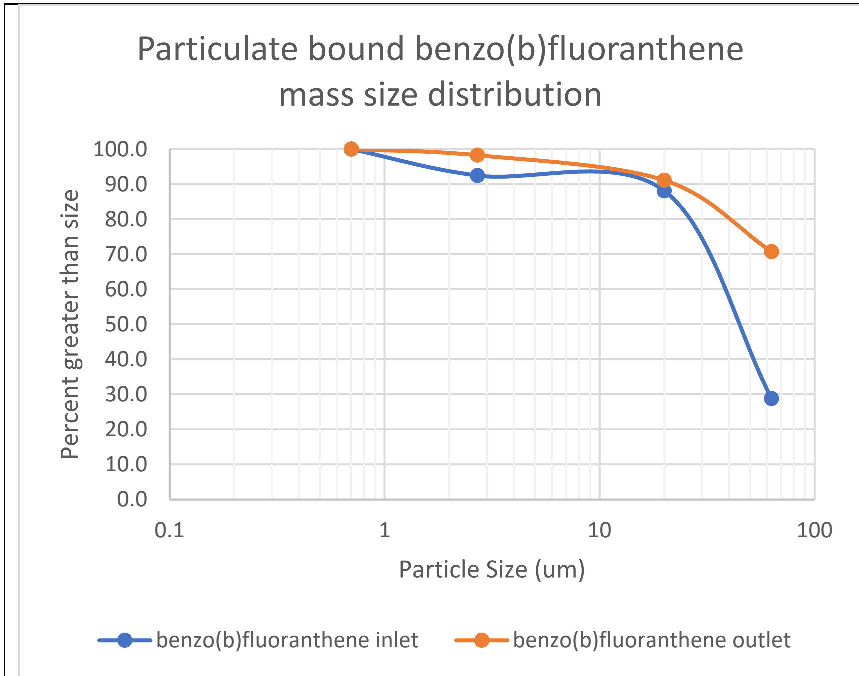

Particulate bound fluoranthene mass size distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle size (um)
fluoranthene inlet
fluoranthene outlet

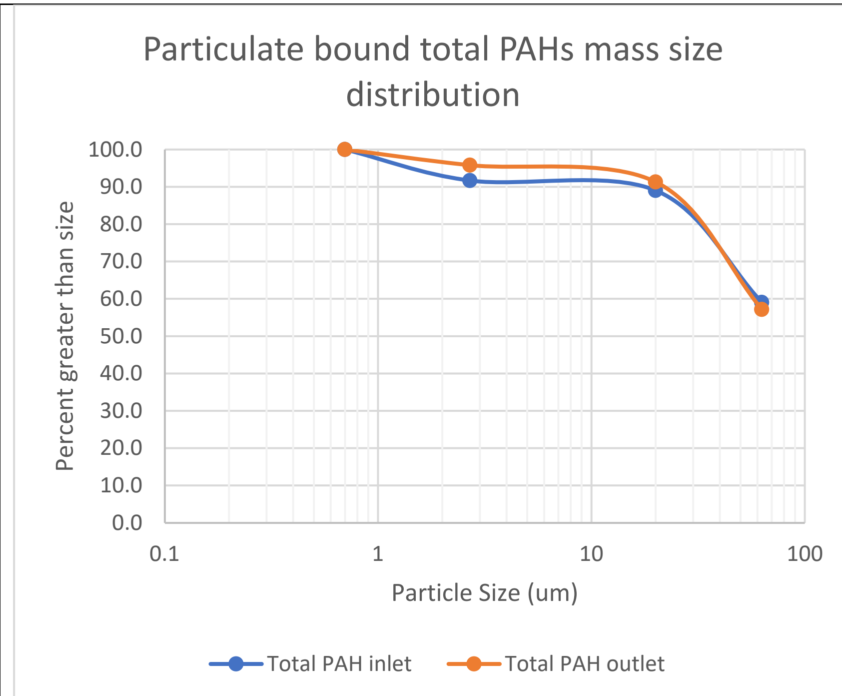


Particulate bound benzo(a)anthracene mass size distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
benz(a)anthracene inlet
benz(a)anthracene outlet



Particulate bound chrysene mass size distribution
Percent greater than size
100.0
90.0
80.0
70.0
60.0
50.0
40.0
30.0
20.0
10.0
0.0
0.1
1
10
100
Particle Size (um)
chrysene inlet
chrysene outlet



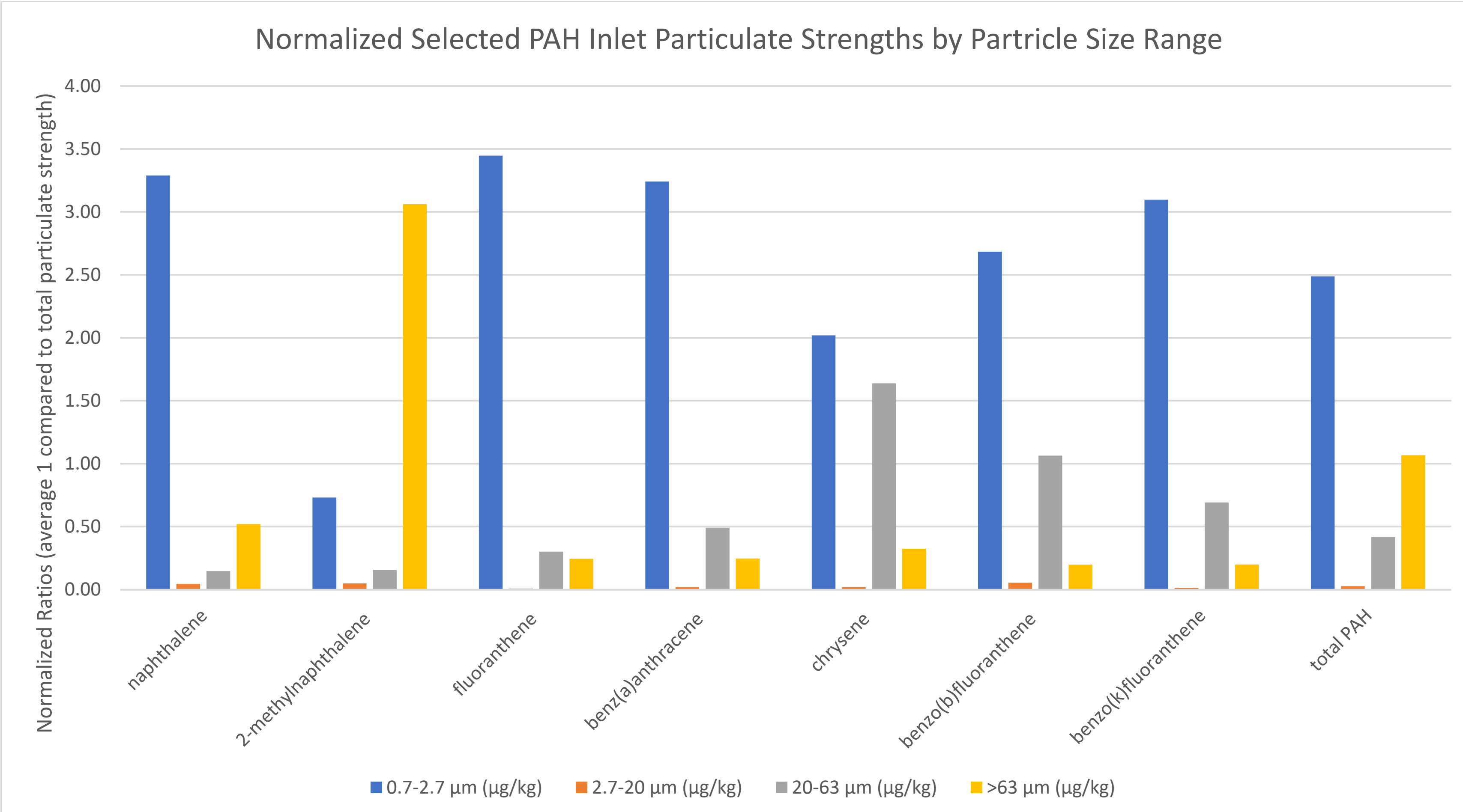


The following table and figure summarize the particulate strengths for the selected monitored PAHs, by particle size. Values are only used for the inlet samples as many particle size range PAH data were not detected. The bar plots show the particulate strengths normalized against the overall total particulate strengths, with an overall average of one. Most of the PAHs shown had greater relative particulate strengths in the smallest size range (0.7 to 2.7 µm) compared to the other size ranges (the only exception is for 2-methylnapthalene that had the highest particulate strength for the largest size range (>63 µm).

Selected PAH Inlet Sample Particulate Strengths by Particle Size Range (µg/kg)

	naphthalene	2-methylnaphthalene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	benzo(k)fluoranthene	total PAH
0.7-2.7 µm	5.4	0.4	3.5	0.5	0.7	0.8	0.6	15.1

2.7-20 µm	0.1	0.0	0.0	0.0	0.0	0.0	0.0	0.2
20-63 µm	0.2	0.1	0.3	0.1	0.5	0.3	0.1	2.5
>63 µm	0.9	1.7	0.2	0.0	0.1	0.1	0.0	6.5
Total Particulate (>0.7 µm)	0.3	0.4	0.3	0.0	0.2	0.2	0.1	2.5



PFAS

The following tables and the plots summarize the total and filtered sample concentrations for selected PFAS compounds, along with the mass distributions of the particulate bound pollutants by particle size. These are shown for both the inlet samples (after the hydrodynamic separator) and the outlet (after both the hydrodynamic separator and media filters). As noted, only two events were monitored at each location, so these observations do not represent the likely overall range of conditions expected at the Pier B sampling locations. Most of the PFAS compounds show high associations with the filtered samples in both the inlet and outlet samples. Only FHxSA (inlet) had large (>70%) associations with particulate samples. All of the filtered and total sample PFAS concentrations had lower concentrations in the outlet samples compared to the inlet samples. Since particle range data were not available, only the particle strengths for the total sample were available and shown. PFOS had the largest concentrations and largest particulate strengths for the inlet and outlet samples.

Average PFAS concentrations and filterable and particulate bound percentages for two inlet samples

	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFHxS	PFOS	FHxSA
total (ng/L)	3.61	5.07	7.40	7.35	4.03	0.69	0.94	2.65	45.93	4.89
filtered <0.7µm (ng/L)	2.07	3.33	7.14	6.90	2.19	0.42	nd	nd	24.12	1.42
% filterable	57.4	65.7	96.4	94.0	54.3	60.3	nd	nd	52.5	29.1
% particulate	42.6	34.3	3.6	6.0	45.7	39.7	nd	nd	47.5	70.9
particulate strength (mg/kg)	0.19	0.22	0.03	0.05	0.20	0.03	0.10	0.27	2.41	0.43

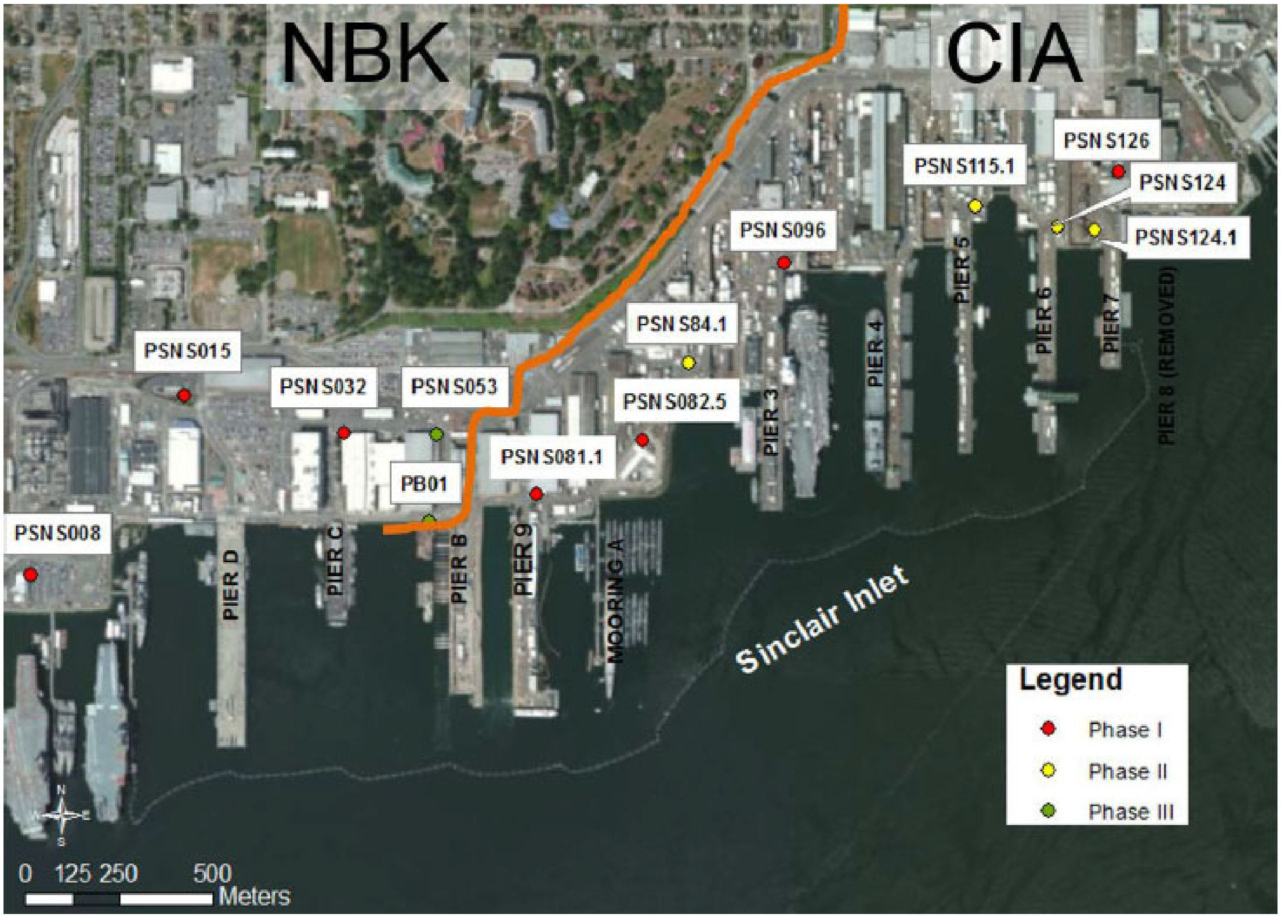
Average PFAS concentrations and filterable and particulate bound percentages for two outlet samples

	PFBA	PFPeA	PFHxA	PFHpA	PFOA	PFNA	PFDA	PFHxS	PFOS	FHxSA
total (ng/L)	0.63	2.06	3.72	2.76	1.60	nd	0.74	nd	26.11	nd
filtered <0.7µm (ng/L)	0.54	2.06	3.06	1.82	1.15	nd	nd	nd	15.56	nd
% filterable	84.7	100.0	82.3	66.1	71.4	nd	nd	nd	59.6	nd
% particulate	15.3	na	17.7	33.9	28.6	nd	nd	nd	40.4	nd
particulate strength (mg/kg)	0.01	nd	0.14	0.09	0.07	nd	0.07	nd	1.05	nd

Pier B SERDP Stormwater Monitoring Data Compared to Historical Bremerton Stormwater Data

Brandenberger, *et al*. (2018) presents a summary of Bremerton stormwater data (*Non-Dry Dock Stormwater Monitoring Report for Puget Sound Naval Shipyard, Bremerton, Washington 2010-2013*, August 2018. Pacific Northwest National Laboratory). As they stated:

> "This report summarizes the overall collection, chemical analyses, and water quality results of 16 storm events sampled from 13 different outfalls within the Shipyard from 2010 through 2013. The chemicals of concern included heavy metals (Hg, Cu, Pb, Zn, As, Ag, Cd, and Cr), organics (RRO and DRO), and physiochemical parameters (DOC, TOC, TSS, and hardness)."
>
> "The NDDSW study characterized non-dry dock stormwater quality as a function of primary work activities within the Shipyard stormwater basins. The representative activities included industrial activities within the confined industrial area (CIA) and the residential activities within the NBK. These data provide a comprehensive evaluation of stormwater discharge to support of the Shipyard's National Pollutant Discharge Elimination System (NPDES) Permit (WA-00206-2) and future Draft permits. The selected drainage basins collectively represented all seven of the primary work activities for the Shipyard including materials storage (outdoors); vessel, equipment, and materials recycling; vessel maintenance; non-aircraft carrier vessel support services; aircraft carrier support services; parking/steam plant (stormwater discharges only)/truck traffic; and municipal/commercial/residential services. These basins were selected because of their relatively large size (in comparison to other basins with similar activity); heavy industrial use (for applicable primary work tasks); close proximity to previous sampling sites; unique and/or representative land use; and the ability to obtain viable samples at the sampling point."



Sampling locations for non dry dock stormwater outfall study (Brandenberger, et al. 2018)

The closest sampling stations to Pier B were PSN PB01 and CIA PSN S081.1, as shown on the aerial photograph from the report, and are described as:

- CIA PSN 081.1. West CIA, NE of DD6 and NW of Pier 9, south side of Bldg 462. Non-aircraft carrier support services

- NBK PSN PB01. East NBK, south-southeast of B449, south side of Wyckoff Ave, northwest of Mooring Pier B, along quay wall Section 729 (at treatment vault). Aircraft carrier / vessel support services

The following table summarizes the heavy metal monitoring data for these two sampling locations. Only 2 to 3 events were sampled at each location, so the actual concentrations variations are expected to be larger than indicated.

Reported historical heavy metal data for two closest stations to Pier B

		Mercury (filtered)	Mercury (total)	Copper (filtered)	Copper (total)	Lead (filtered)	Lead (total)	Zinc (filtered)	Zinc (total)

PSNS 081.1	Mean, µg/L	0.00236	0.0167	13.9	34.8	0.367	10.8	82.2	138
	COV	0.1	5.2	0.5	0.2	0.5	0.4	0.1	0.2
	number	2	3	3	3	3	3	3	3
PSNS PB01	Mean, µg/L	0.00072	0.00162	7.14	13.2	0.097	1.2	48	83
	COV	0.3	0.5	0.4	0.5	0.8	0.6	0.3	0.4
	number	3	3	3	3	3	3	3	3

The following table summarizes all of the site monitoring data combined. Only the above listed heavy metal data are available for the two specific sampling locations. 56 to 67 events were sampled. The variations indicated is expected to be a reasonable representation of the overall conditions at the site.

Table 5-5 Descriptive statistics for all stormwater data collected during the study from 2010-2013.

	Units	n	Mean	Stdev	Min	Max	25th	Median	75th
TR Cu	µg/L	67	25.3	23.2	5.94	170	12.0	17.8	32.8
Diss Cu	µg/L	67	10.6	13.5	1.92	107	4.92	6.89	12.2
TR Zn	µg/L	67	118	57.5	33.0	408	75.9	114	153
Diss Zn	µg/L	67	73.5	33.4	21.1	145	48.3	59.6	106
TR Pb	µg/L	67	8.15	5.23	0.648	35.7	4.42	7.19	11.5
Diss Pb	µg/L	67	0.487	0.472	0.0528	2.35	0.194	0.339	0.551
TR Hg	µg/L	67	0.0228	0.0486	0.000961	0.346	0.00446	0.00981	0.0184
Diss Hg	µg/L	67	0.00278	0.00233	0.000498	0.0151	0.00165	0.00204	0.00312
TR As	µg/L	67	1.71	1.55	0.383	7.69	0.800	1.19	1.80
Diss As	µg/L	67	1.45	1.55	0.292	7.32	0.555	0.838	1.49
TR Ag	µg/L	67	0.0459	0.0479	0.002U	0.227	0.0194	0.0280	0.0448
Diss Ag	µg/L	67	0.0127	0.0245	0.001U	0.128	0.00215	0.00434	0.0103
TR Cd	µg/L	67	0.315	0.267	0.0458	1.25	0.145	0.254	0.368
Diss Cd	µg/L	67	0.154	0.122	0.0228	0.566	0.0846	0.113	0.188
TR Cr	µg/L	67	4.39	7.91	0.804	64.7	1.83	2.56	4.56
Diss Cr	µg/L	67	1.62	1.76	0.355	12.6	0.748	1.09	1.70
TPH-DRO	µg/L	56	227 J	410	13 J	2900 H	84 J	115 J	200 J
TPH-RRO	µg/L	56	812	2170	22 J	16000 O	225 J	325 J	623
Conductivity	µS/cm	67	365	640	36	4700	94	209	328
Turbidity	NTU	66	16	8.9	3.0	43	9.0	16	22
TSS	mg/L	67	19.5	12.0	2.71	60.3	9.75	17.5	26.0
TOC	mg/L	67	3.36	4.69	0.900	33.9	1.51	2.19	3.02
DOC	mg/L	67	3.21	4.26	0.639	31.5	1.44	2.25	3.06
Harness (as $CaCO_3$)	mg/L	66	41	62	9.7	494	20	28	39

Acronyms: Total Petroleum (TPH); Diesel Range (DRO); Residual Range (RRO); Total Organic Carbon (TOC); Dissolved Organic Carbon (DOC); Total Suspended Solids (TSS)

Data Qualifiers:

H = The chromatographic fingerprint of the sample resembles a petroleum product, but the elution pattern indicates the presence of a greater amount of heavier molecular weight constituents than the calibration standard.

O = The chromatographic fingerprint of the sample resembles an oil, but it does not match the calibration standard.

J = Analyte detected above the mean MDL, but less than the mean RL for the project. MDL/RLs are sample specific.

Note: TR is total recoverable and diss is filtered

The above data are compared to the Pier B monitoring data below. Since only 2 or 3 samples are represented in each of these data categories, larger variations are expected than indicated on this table.

Average concentrations (2 to 3 samples in each category) for Pier B and historical data (µg/L)

	Copper	Zinc	Lead
Pier B Total conc	22.0	305	1.4
PSNS 081.1	34.8	138	10.8
PSNS PB01	13.2	83	1.2
Pier B Filtered conc	12.4	237	0.46
PSNS 081.1	13.9	82.2	0.37
PSNS PB01	7.1	48	0.1

The copper and lead total recoverable and filtered sample results were similar for the three sampling locations. However, the more recent Pier B zinc concentrations were several times greater than the older zinc data. The overall site zinc data were also substantially less than the observed Pier B observations. It is likely that greater amounts of exposed galvanized metals were present on the pier during the more recent monitoring period.

TSS data were not shown in the monitoring report for the individual locations during the historical monitoring period. The overall site average TSS concentration was 19.7 mg/L (average of 67 samples), while the Pier B TSS average was 10.2 mg/L.

Therefore, based on the limited data for comparisons, the recent Pier B are generally in agreement with the older site data, with the exception of the greater zinc concentrations at Pier B, possibly due to increased exposed galvanized metal during the more recent monitoring period.

Preliminary WinSLAMM Modeling

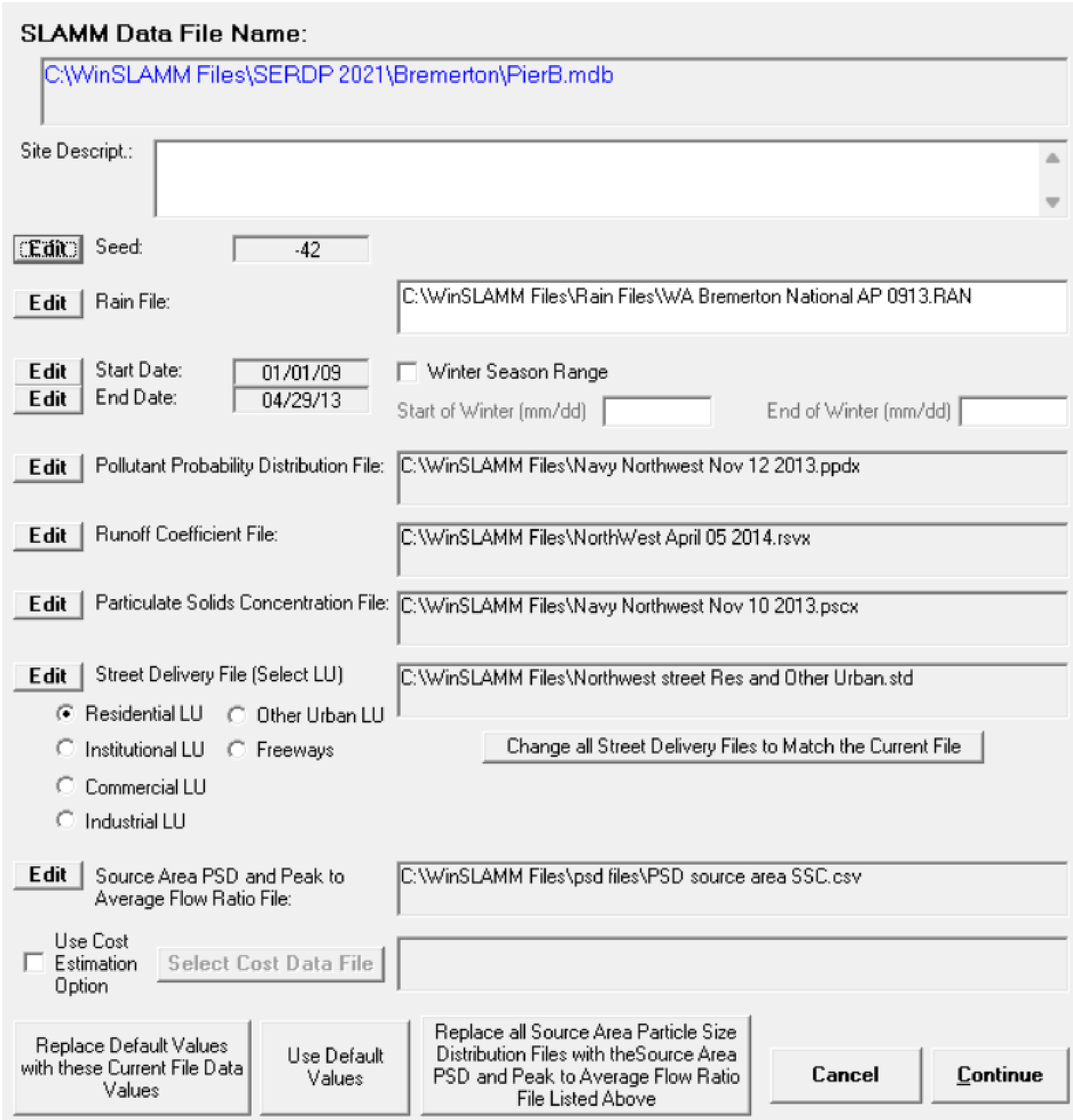
WinSLAMM used the previously calibrated Puget Sound naval base parameter files, with three industrial source areas (galvanized metal shed roofs, and light and moderate concrete laydown areas), in addition to the road and adjacent paved area. The following special source areas to describe these areas (in addition to the street and adjacent paved areas (0.11-acre road at 40 ft wide and 0.29-acre adjacent paved parking/storage areas):

WinSLAMM other impervious areas for Pier B area

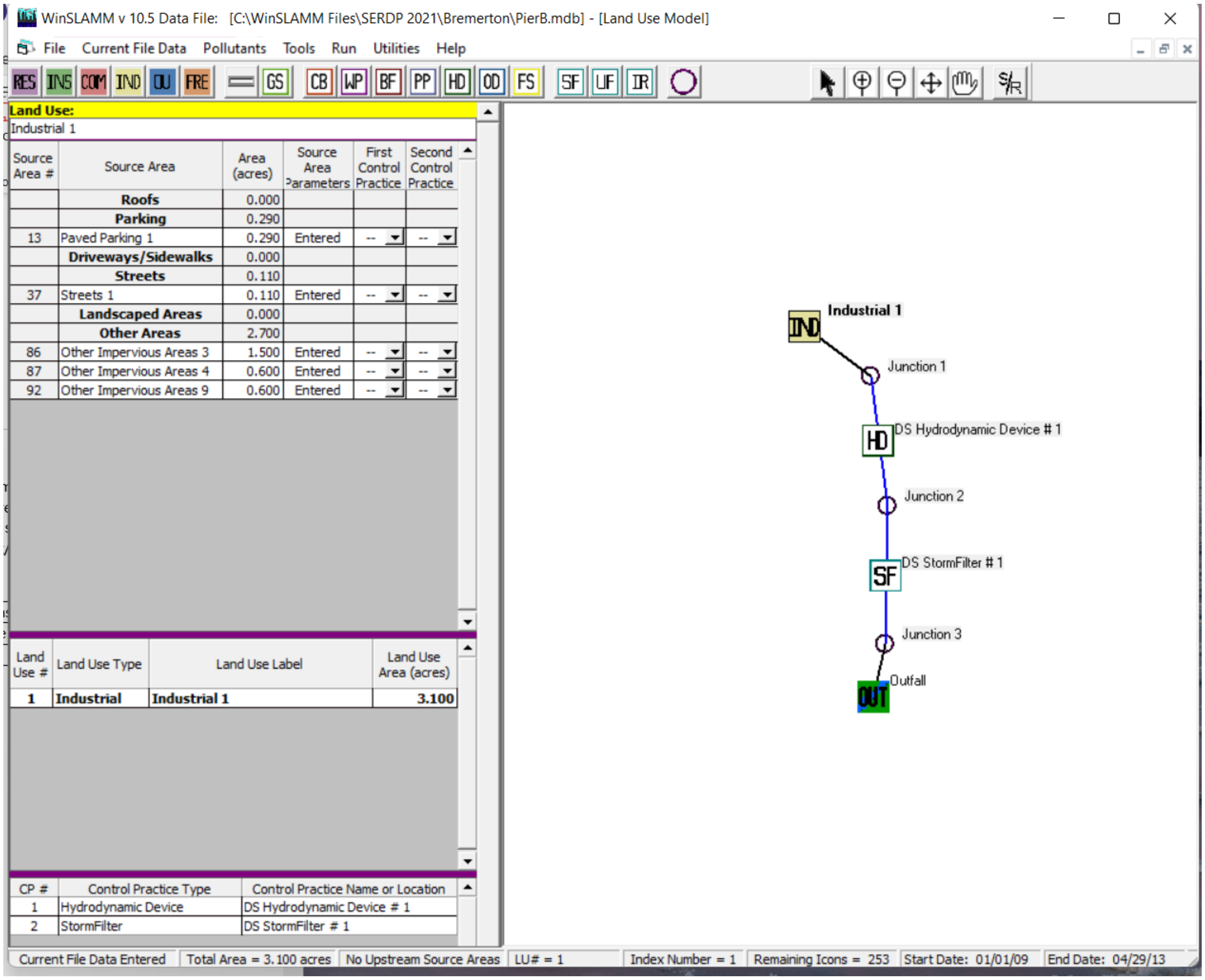
86	Other Imp Area 3	OIA3 - Light laydown concrete areas	1.5
87	Other Imp Area 4	OIA4 - Moderate laydown concrete areas	0.6
92	Other Imp Area 9	OIA9 - Galvanized metal roofs	0.6

The following figure shows the current file data (previously calibrated parameter files).

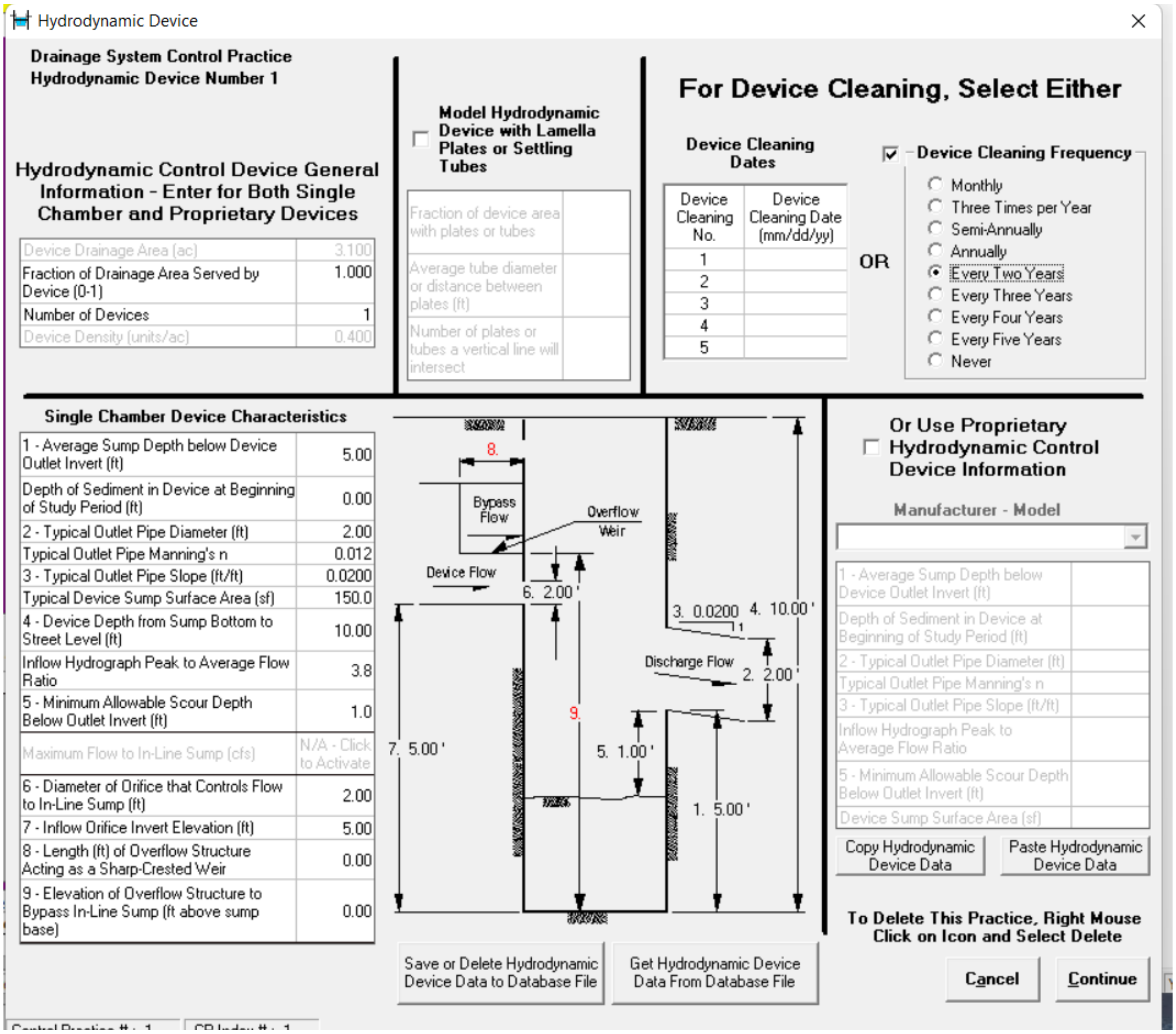
Current File Data

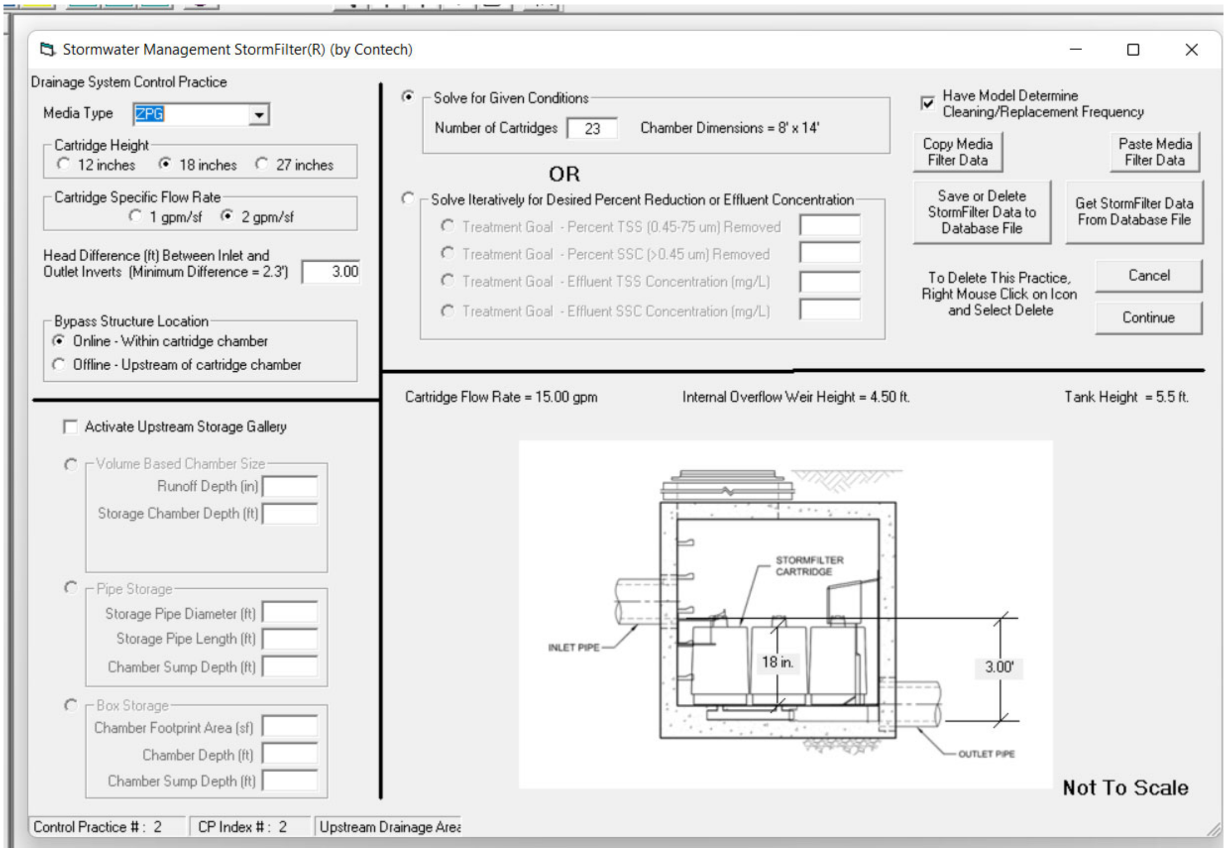


The following figure shows the source areas and the layout for the Pier B area.

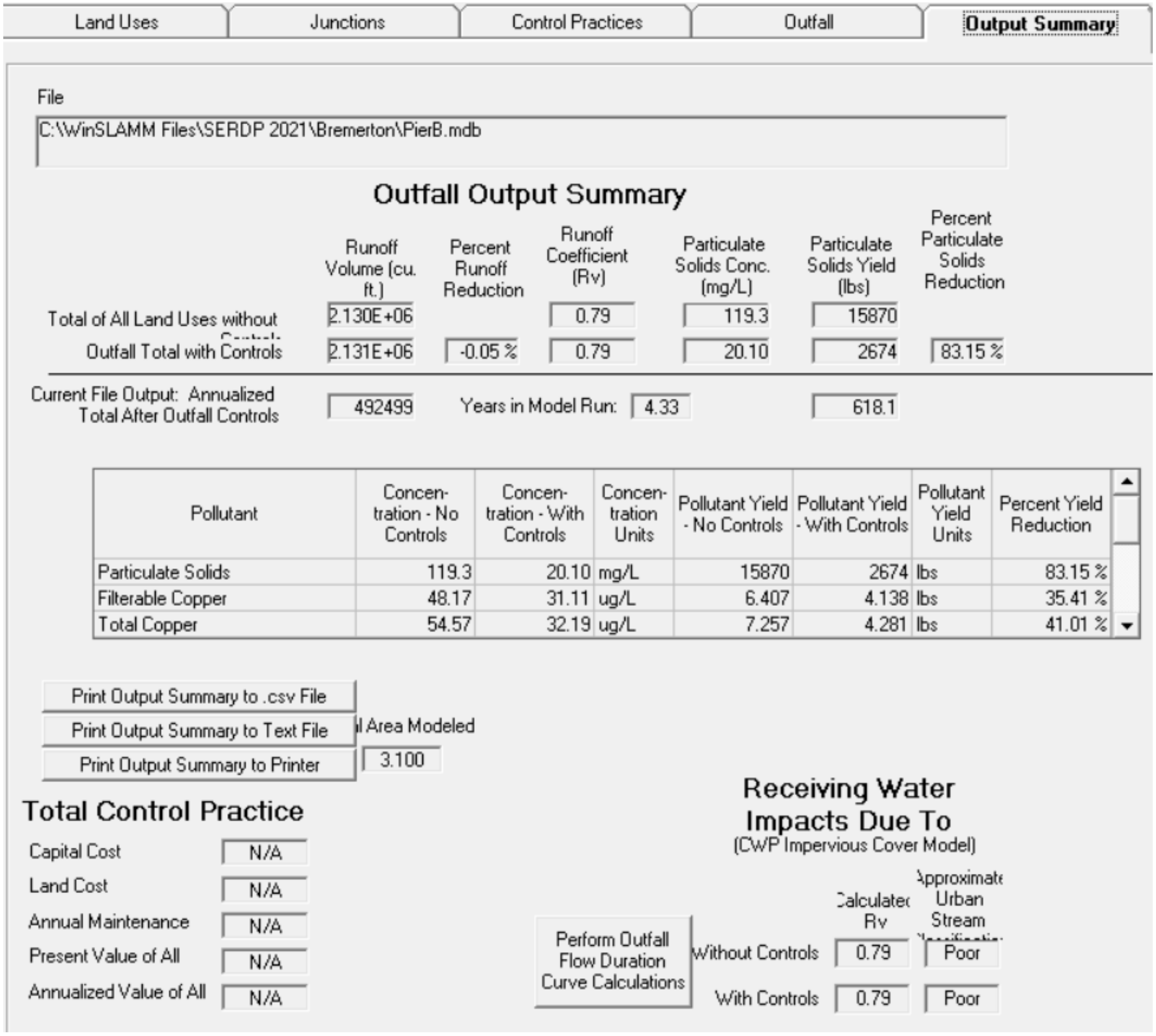


The following screens show the stormwater controls used at Pier B.

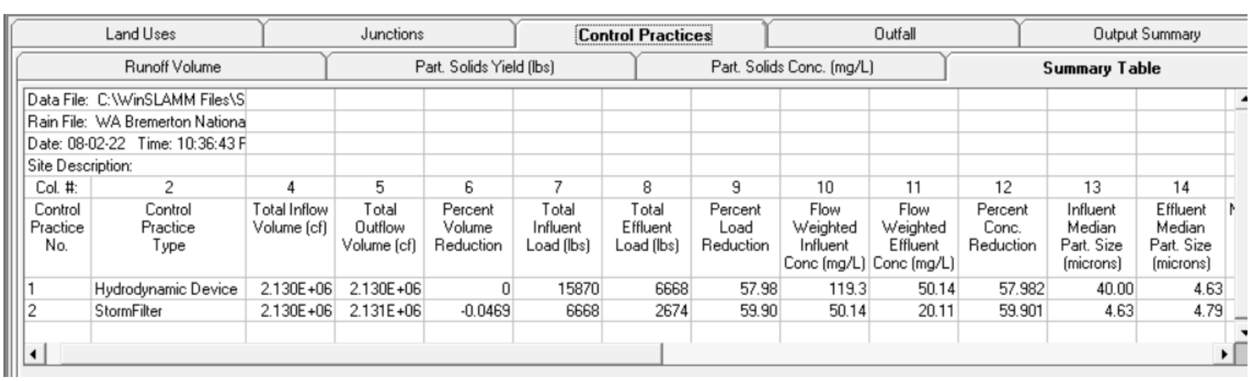

Hydrodynamic Device
Drainage System Control Practice
Hydrodynamic Device Number 1
Hydrodynamic Control Device General Information - Enter for Both Single Chamber and Proprietary Devices
Device Drainage Area (ac) 3.100
Fraction of Drainage Area Served by Device (0-1) 1.000
Number of Devices 1
Device Density (units/ac) 0.400
Model Hydrodynamic Device with Lamella Plates or Settling Tubes
Fraction of device area with plates or tubes
Average tube diameter or distance between plates (ft)
Number of plates or tubes a vertical line will intersect
For Device Cleaning, Select Either
Device Cleaning Dates
Device Cleaning No.
Device Cleaning Date (mm/dd/yy)
1
2
3
4
5
OR
Device Cleaning Frequency
Monthly
Three Times per Year
Semi-Annually
Annually
Every Two Years
Every Three Years
Every Four Years
Every Five Years
Never
Single Chamber Device Characteristics
1 - Average Sump Depth below Device Outlet Invert (ft) 5.00
Depth of Sediment in Device at Beginning of Study Period (ft) 0.00
2 - Typical Outlet Pipe Diameter (ft) 2.00
Typical Outlet Pipe Manning's n 0.012
3 - Typical Outlet Pipe Slope (ft/ft) 0.0200
Typical Device Sump Surface Area (sf) 150.0
4 - Device Depth from Sump Bottom to Street Level (ft) 10.00
Inflow Hydrograph Peak to Average Flow Ratio 3.8
5 - Minimum Allowable Scour Depth Below Outlet Invert (ft) 1.0
Maximum Flow to In-Line Sump (cfs) N/A - Click to Activate
6 - Diameter of Orifice that Controls Flow to In-Line Sump (ft) 2.00
7 - Inflow Orifice Invert Elevation (ft) 5.00
8 - Length (ft) of Overflow Structure Acting as a Sharp-Crested Weir 0.00
9 - Elevation of Overflow Structure to Bypass In-Line Sump (ft above sump base) 0.00
8.
Bypass Flow
Overflow Weir
Device Flow
6. 2.00 '
3. 0.0200
4. 10.00 '
1
1
Discharge Flow
2. 2.00 '
9.
7. 5.00 '
5. 1.00 '
1. 5.00 '
Or Use Proprietary Hydrodynamic Control Device Information
Manufacturer - Model
1 - Average Sump Depth below Device Outlet Invert (ft)
Depth of Sediment in Device at Beginning of Study Period (ft)
2 - Typical Outlet Pipe Diameter (ft)
Typical Outlet Pipe Manning's n
3 - Typical Outlet Pipe Slope (ft/ft)
Inflow Hydrograph Peak to Average Flow Ratio
5 - Minimum Allowable Scour Depth Below Outlet Invert (ft)
Device Sump Surface Area (sf)
Copy Hydrodynamic Device Data
Paste Hydrodynamic Device Data
To Delete This Practice, Right Mouse Click on Icon and Select Delete
Save or Delete Hydrodynamic Device Data to Database File
Get Hydrodynamic Device Data From Database File
Cancel
Continue



The following screen is the overall modeling output summary.



And the following screens show some of the detailed performance information for the stormwater control practices.



Land Uses | Junctions | **Control Practices** | Outfall | Output Summary

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | **Summary Table**

Data File: C:\WinSLAMM Files\S												
Rain File: WA Bremerton Nationa												
Date: 08-02-22 Time: 10:36:43 F												
Site Description:												
Col. #:	2	15	18	21	22	23	24	40	41	42	43	44
Control Practice No.	Control Practice Type	Notes	Maximum Stage (ft)	% Device Volume Full	Bypass Volume (cf)	Treated Volume (cf)	Number of Cartridges	Number of Tank Overflows (Count)	Number of Device Height Exceedance	Bypass Volume (cf)	Bypass Conc. (mg/L)	Bypass Mass (lbs)
1	Hydrodynamic Device		5.34	3.5 %	0	2130445						
2	StormFilter		2.45				23	#> 2.25' = 14	#> 5.5' = 0	0	0.00	0.0

Land Uses | Junctions | **Control Practices** | Outfall | Output Summary

Runoff Volume | Part. Solids Yield (lbs) | Part. Solids Conc. (mg/L) | **Summary Table**

Data File: C:\WinSLAMM Files\S													
Rain File: WA Bremerton Nationa													
Date: 08-02-22 Time: 10:36:43 F													
Site Description:													
Col. #:	2	45	46	47	48	49	50	51	52	54	55	56	91
Control Practice No.	Control Practice Type	Overflow Volume (cf)	Overflow Conc. (mg/L)	Overflow Mass (lbs)	Cartridge Flow Volume (cf)	Cartridge Effluent Conc. (mg/L)	Cartridge Effluent Mass (lbs)	Final Device Sediment Depth (ft)	Average Cleaning Frequency (yrs)	Residence Time in Media (hrs)	Max. Filter Number	Max. Filter Treatment Goal mg/L or %	Runoff Producing Events/ Ttl. Rains
1	Hydrodynamic Device												522/522
2	StormFilter	29100	64.66	117.5	2101464	19.49	2556.7	0.00	0.71	0.121	0	0.00	522/522

The following table compares the calculated WinSLAMM TSS, Cu, Pb, and Zn concentrations, using the Monte Carlo options in the model to better represent the overall range of expected concentrations.

WinSLAMM Monte Carlo Calculated TSS and heavy metal concentrations for Pier B (J2 is the junction before the media filter treatment and J3 is the junction after the treatment, corresponding to inlet and outlet monitored locations)

	min	max	average
J2 TSS after CDS, mg/L	20.3	68.9	50.1
J3 TSS after filters, mg/L	1.1	37.2	20.1

J2 Cu total after CDS, µg/L	11.3	193	55
J2 Cu filtered after CDS, µg/L	9.4	189	52
J3 Cu total after filters, µg/L	2.3	114	35
J3 Cu filtered after filters, µg/L	2.2	111	34

J2 Pb total after CDS, µg/L	0.3	4.2	1.5
J2 Pb filtered after CDS, µg/L	0.03	1.4	0.2
J3 Pb total after filters, µg/L	0.04	1.9	0.7

J2 Pb filtered after filters, µg/L	0.003	1.4	0.2

J2 Zn total after CDS, µg/L	16	1680	160
J2 Zn filtered after CDS, µg/L	2.2	1650	119
J3 Zn total after filters, µg/L	2.4	950	102
J3 Zn filtered after filters, µg/L	1.0	942	85

The WinSLAMM calculated TSS average values were about half of the Pier B and historical site monitored values, but within the overall calculated range. The copper, lead, and zinc calculated average values were close to the monitored average values.

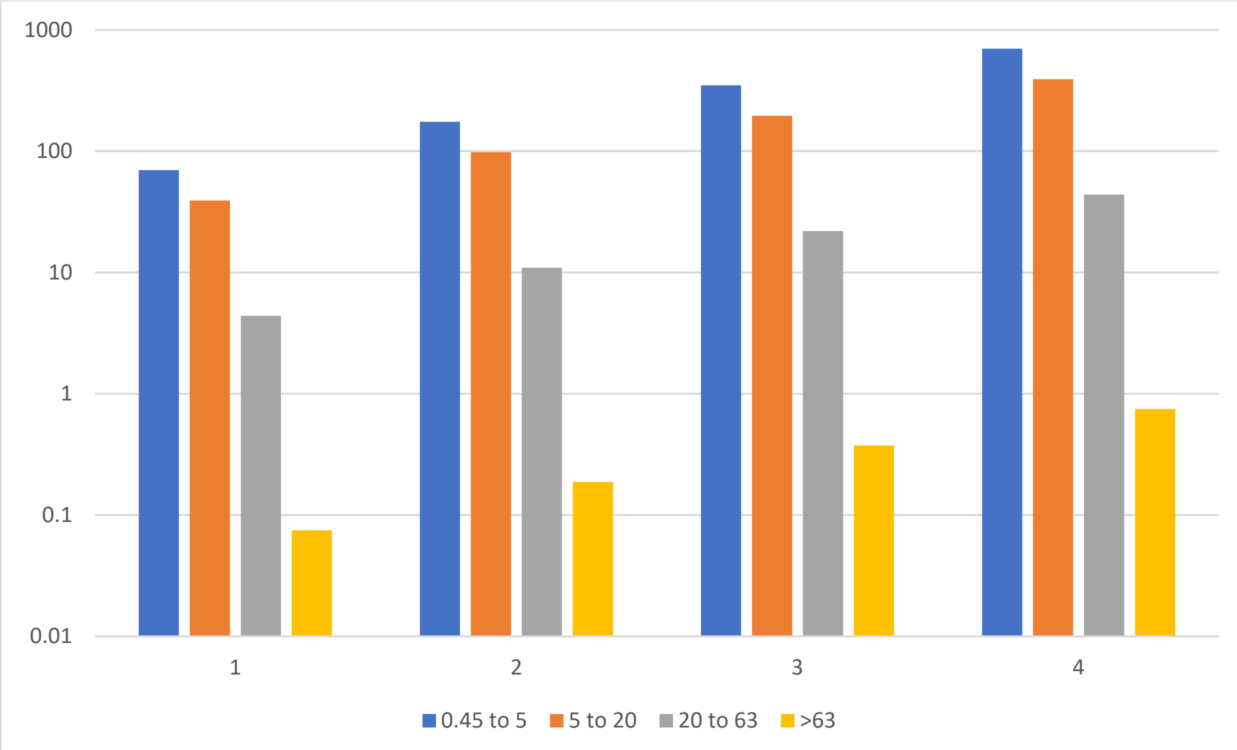
Fate of Discharged Stormwater Pollutants in Receiving Waters

The fate of discharged particulate stormwater pollutants in the receiving waters is mainly a function of their settling rates. Currents and water depths will determine where the pollutants may settle to the receiving water sediments. In these analyses, settling rates were calculated using Newton's (turbulent) and Reynold's (laminar) settling equations. For the specific gravities associated with typical stormwater particulates (1.5 to 2.5), turbulent flow would only be associated with particles larger than about 0.5 cm (highly unlikely in stormwater), while laminar flow would be associated with particles smaller than about 100 µm (most common). Transitional settling would affect intermediate sized particles, resulting in slightly reduced settling rates compared to laminar settling (but still quite fast). The following table summarizes example settling rates (50^{o}F, or 10^{o} C) for stormwater particulates.

Calculated Settling Rates and Settling Times for Stormwater Particulates

	settling rates (cm/sec) for		time (min) to settle 10 ft (305 cm)		time (min) to settle 25 ft (762 cm)		time (min) to settle 50 ft (1,520 cm)		time (min) to settle 100 ft (3,050 cm)	
size (µm)	1.5 sp gr	2.5 sp gr	1.5 sp gr	2.5 sp gr	1.5 sp gr	2.5 sp gr	1.5 sp gr	2.5 sp gr	1.5 sp gr	2.5 sp gr
0.45	colloidal	colloidal	never	never	never	never	never	never	never	never
5	0.0008	0.0025	6,350	2,032	15,875	5,080	31,750	10,160	63,500	20,320
20	0.006	0.03	847	169	2,117	423	4,233	847	8,467	1,693
63	0.2	0.5	25	10	64	25	127	51	254	102
106	0.3	1	17	5.1	42	13	85	25	169	51
256	2	3	2.5	1.7	6.4	4.2	13	8.5	25	17
1000	10	23	0.51	0.22	1.3	0.55	2.5	1.1	5.1	2.2

The following figure plots the approximate settling times needed for the four particle size ranges examined, for 10 ft (3 m) to 100 ft (30 m) water depths.



Approximate settling times (hours) for 10, 25, 50, and 100 ft water depths for different particle size ranges.

- Near field effects: The largest particles (>63 µm) would require about 1 hour to settle in 100 ft (30 m) of water, and only about 5 minutes to settle in 10 ft (3 m) of water. These particles have the greatest potential of affecting areas close to the discharge locations and would not be widely dispersed. These particles are also most readily removed by most stormwater controls.

- Far field effects: The intermediate particles (20 to 63 µm) would require about 50 hours to settle in 100 ft (30m) of water and 5 hours to settle in 10 ft (3 m) of water. These would affect sediments further from the discharge location, or closer, if slow moving and/or shallow water. These particles require more advanced and larger stormwater controls for effective reductions.

- The smallest particles (<20 µm) would require even longer times to settle: about 500+ hrs in 100 ft (30 m) of water and 50+ hours to settle in 10 ft (3 m) of water. Unless impounded, these particles would likely be transported a large distance beyond the discharge locations. These particles are the most difficult to control with conventional stormwater treatment.

The following tables summarize the percentages of the monitored TSS, heavy metals, and PAH pollutant particulate-bound masses in each of these three transport and fate categories. These are shown for the two monitoring locations representing initial treatment by the hydrodynamic separator and after the hydrodynamic separator plus the media filters. These values are uncertain due to the few samples available with detectable concentrations. Also, it would be expected that the treatment by the hydrodynamic separator plus the media filters would have smaller portions in the near field particle size (>63 µm) than for the hydrodynamic separator alone, but that relationship was inconsistent in the monitored data. Pollutants having about 70%, or more, of their particulate mass in the near field category (irrespective of treatment) included: chromium, lead, 2-methylnaphthalene, fluoranthene, and benzo(b)fluoranthene. Pollutants with about 70%, or more, of their particulate mass in the widely dispersed category (irrespective of treatment) included: TSS, manganese, copper, and naphthalene. No PFAS data are available by particle size range due to low concentrations observed in the unfiltered samples. Again, these are only rough estimates and the final analyses incorporating data from the other monitoring locations will enable more reliable results.

Percentage of mass of Pier B TSS and heavy metal particulate pollutants in size ranges affecting transport and fate in receiving waters

after hydrodynamic separator	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Cadmium	Lead
>63 µm (near field)	34.0	38.3	42.2	50.3	29.2	47.0	43.1	36.7
20 to 63 µm (far field)	21.9	6.6	37.2	39.2	13.3	24.1	16.6	19.1
<20 µm (widely dispersed)	44.2	55.1	20.6	10.5	57.5	28.9	40.4	44.1
after hydrodynamic separator and media filters	TSS	Chromium	Manganese	Nickel	Copper	Zinc	Cadmium	Lead
>63 µm (near field)	20.5	79.9	0.0	34.6	0.0	67.4	0.0	71.2
20 to 63 µm (far field)	7.5	0.4	0.0	0.0	22.1	0.0	81.6	0.0
<20 µm (widely dispersed)	72.0	19.8	100.0	65.4	77.9	32.6	18.4	28.8

Percentage of mass of Pier B PAH particulate pollutants in size ranges affecting transport and fate in receiving waters

after hydrodynamic separator	naphthalene	2-methylnaphthalene	pyrene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
>63 µm (near field)	45.9	86.8	31.8	55.2	48.7	32.4	28.8	59.1
20 to 63 µm (far field)	22.7	7.8	49.4	28.1	37.0	62.7	59.3	30.0
<20 µm (widely dispersed)	31.4	5.4	18.8	16.7	14.3	5.0	11.9	11.0
after hydrodynamic separator and media filters	naphthalene	2-methylnaphthalene	pyrene	fluoranthene	benzo(a)anthracene	chrysene	benzo(b)fluoranthene	Total PAH
>63 µm (near field)	0.0	0.0	38.2	75.3	62.9	52.3	70.7	57.1
20 to 63 µm (far field)	0.0	100.0	52.6	18.5	24.8	33.7	20.4	34.2
<20 µm (widely dispersed)	100.0	0.0	9.3	6.2	12.3	14.0	8.9	8.7