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Non-Dry Dock Stormwater Monitoring Report for Puget Sound Naval Shipyard, Bremerton, Washington 2010-2013

FINAL

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August 2018

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Non-Dry Dock Stormwater Monitoring Report for Puget Sound Naval Shipyard, Bremerton, Washington 2010-2013

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August 2018

Prepared for
PSNS Project ENVVEST Study Area
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Executive Summary

Stormwater is a significant source for non-point source pollution in Puget Sound, WA and has been identified as a concern for endangered salmonid species, shellfish harvesting, and human health (e.g. swimming beach closures) (Puget Sound Partnership 2014). The Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK) are committed to a culture of continuous process improvement for all aspects of shipyard operations, including reducing the release of hazardous substances in stormwater discharges. This report summarizes the findings from the three year study on non-dry dock stormwater (NDDSW) chemistry within the PSNS&IMF and NBK, herein after referred to as the Shipyard. The overall goal of the NDDSW study was to characterize the stormwater quality in Shipyard drainage basins, provide a benchmark from which to measure past and future process improvements, and compare the current stormwater chemistry to a variety of regional stormwater data to provide a contextual understanding stormwater runoff quality from the Shipyard. The study sampled 16 storm events discharging from 13 different stormwater basins chosen to represent various activities across the Shipyard. The storms samples were representative of storm events occurring in the region from November through April 2010 -2013.

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.

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). Continuous monitoring at each site included precipitation, vault water level, temperature, conductivity, salinity, and autosampler operations. The Event Mean Concentration (EMC) for stormwater samples were collected using automated water samplers installed at each site. Autosampler setup included Teledyne-Isco® 6700 series samplers, a Teflon™-lined polyethylene sampler line, and siliconized Tygon™ pump and distributor arm tubing. Autosamplers were deployed in an off-the-shelf configuration, internally equipped with 24 1-L polypropylene wedge bottles. The samples were then composited to represent the chemistry during the entire storm event.

The storm events sampled during the study ranged from 0.21 – 4.33 in/24 hr and resulted in sampling 3 small = <0.5 in/24 hr, 4 medium = 0.5–1.0 in/24 hr, 7 large = 1.0–2.0 in/24 hr, and 2 extra-large = ≥2.0 in/24 hr storm events. Many stormwater sampling locations recorded tidal water reaching the sampling point during the storm events, therefore water-level and conductivity data were used in ensure that the EMC composite sample represented the freshwater runoff and not the tidal water intrusion.

The stations were grouped by those located within NBK and CIA to designate the outfalls draining the industrial operations versus the base's support activities located in NBK. For the total recoverable (TR) concentrations of Cu and Zn the highest EMCs were measured within the CIA where the EMCs for Cu (31.9 µg/L) were about 3 times higher than the NKB sites (13.5 µg/L) and Zn EMCs were about 1.5 time higher at the CIA stations (132 µg/L) than the NBK stations (94 µg/L). The TR Hg EMCs were significantly higher at the PSNS015 station within NBK than all the other stations, the average TR Hg EMC at PSNS015 was about 20 times higher (0.08 ug/L) than all the other stations (0.004 ug/L). On average, the EMCs contained 43±17% dissolved Cu with the highest fraction of dissolved Cu (87%) recorded during SW10, which was a small storm with an event rainfall of 0.57". For Zn, the average percent dissolved was 64±17% with the highest fraction of dissolved Zn also recorded during SW10 (92%). The high fraction of dissolved metals suggests that activities within the drainage basins of PSNS124 and PSNS126 should be reviewed to determine what might be releasing fine dust particles that easily dissolve Cu and Zn that are mobilized during small storm events. For Hg, the average percent dissolved was 27±17%.

Since the Shipyard is committed to process improvement, they have been benchmarking activities since 1995 to provide a metric by which to associate the measured water quality improvements with the activities that provided the benefit. Although this project did not detect statistical differences between EMCs based on primary work activity (residential, material laydown, loading, metal work, and high traffic), it did identify that the best discriminator of the EMCs was whether the outfalls drained NBK or CIA basins. This is a coarse breakdown of work activity between Shipyard supporting services (i.e. residential, parking, etc.) and the industrial activities such as metal work, metal recycling, materials laydown, and ship maintenance. Over the past two decades, activity based improvements and repairs have significantly reduced the concentrations of Cu, Pb, and Zn in stormwater. Converting the steam plant to reverse osmosis along with the other activities in NBK have significantly reduced the Hg concentrations at PSNS015. The mean of this study provides a benchmark from which to measure process improvement in the future.

The metal load was calculated for each storm as the EMC times the storm discharge volume. The load was calculated for both the TR metal and the dissolved fractions to provide both the total metal load for the mass balance calculations and allow an evaluation of the concentration that has the highest potential to be bioavailable (dissolved fraction). The general pattern shows that large storms contribute the largest loads, with the exception of Hg. The loading data was used to estimate the 2012 annual load of metals from the Shipyard into Sinclair Inlet. The calculations using the 2010-2013 data from this study showed significant reductions of metal loads from the Shipyard compared to loads estimated using older data. The annual loads were reduced by a factor of 57 for Cu (72 lbs/yr in 2012 compared to 798 lbs/yr previously), a factor of 37 for Pb (26 lbs/yr in 2012 compared to 516 lbs/yr previously), and a factor of 267 for Zn (346 lbs/yr in 2012 compared to 3742 lbs/yr previously). The results clearly show increased improvement in runoff quality since implementation of Best Management Practices (BMPs) and the value of using high quality collection and analytical chemistry techniques when calculating the loads.

To determine potential impairments to beneficial uses and identify appropriate stormwater BMP recommendations, the data from this study were considered within a regional context and specifically from a Sinclair/Dyes inlets watershed perspective to help prioritize stormwater management actions within the context of other activities within the watershed. Therefore, the results from this 2010−2013 stormwater study at the Shipyard are synthesized with the existing regional data to provide an assessment of overall stormwater quality and recommendations to address knowledge gaps and inform the NPDES process. It can be difficult to compare stormwater data between studies due to different collection (i.e. grab vs composite) and analytical methods (i.e. salt correction or simple dilution). This study was compared to the ENVVEST 2003–2005 stormwater study with the same collection methodology for urban outfalls and streams discharging into Sinclair Inlet and also the Ecology Phase I permit data which had different collection methods, but were still representative of the total storm contribution. The medians from the various studies were quite comparable to the industrial LULC medians from the Phase I permit data (4,423 samples from permittees). This provides a reasonable benchmark from which to compare future stormwater studies in the industrial and commercial/residential side of the Shipyard.

The overall goal of the NDDSW study was to characterize the stormwater quality in Shipyard drainage basins, provide a benchmark from which to measure past and future process improvements, and compare the current stormwater chemistry to a variety of regional stormwater data to provide a contextual understanding of the quality of stormwater runoff from the Shipyard. Over the past two decades, activity based improvements and repairs have significantly reduced the concentrations of Cu, Pb, and Zn in stormwater. Overall the study demonstrates the value of high quality collection and analytical methods within any stormwater program. A couple of key considerations for the Shipyard can be drawn from this study. Any stormwater collection within the Shipyard must consider tidal intrusion into the storm drains during both sample collection and analysis. In addition, stormwater sampling at the Shipyard should include collection and analytical methods that compensate for the tidal intrusion into the drainage system because the tide "holds" up the stormwater, thereby resulting in a delay in the freshwater runoff independent of precipitation trends. The detailed chemistry as a function of rainfall, volume of stormwater runoff, and tide further highlighted the need to collect composite samples rather than only grab samples during the "first flush". Finally, field collection procedures for the Shipyard stormwater outfalls must include specific methodology to limit the potential for post collection contamination. Cu and Zn are ubiquitous in shipyard operations and thus trigger the need to ensure the water collected during sampling adequately represents the water flowing in the drain and not contamination introduced to the sample itself during or after collection.

Acronyms and Abbreviations

Ag	silver
Al	aluminum
As	arsenic
BLM	biotic ligand model
BMP	Best Management Practice
BNC	Bremerton Naval Complex
°C	degree(s) Celsius
C&I	Commercial and Industrial Land-Use and Land-Cover
CaCO3	calcium carbonate
CAS	Columbia Analytical Laboratory Services
CIA	Controlled Industrial Area
Cd	cadmium
CDMA	Code Division Multiple Access
COC	chain of custody
Cr	chromium
Cu	copper
DI	deionized water
DME	dissolved metals
DOC	dissolved organic carbon
DOD	U.S. Department of Defense
DRO	diesel range organics (TPH)
DUP	laboratory duplicate
EB	equipment blank
Ecology	Washington State Department of Ecology
EMC	Event Mean Composite
ENVVEST	Project Environmental Investment (U.S. Navy)
EPA	U.S. Environmental Protection Agency
FC	fecal coliform
FSP	field sampling plan
ft	foot(feet)
ft2	square foot(feet)
ft3	cubic foot(feet)
GFF	glass fiber filter
µg/L	microgram(s) per liter
Hg	mercury
hr	hour(s)

ICP-MS	inductively coupled plasma mass spectrometery
ID	identification (number)
in.	inch(es)
INW	Instrumentations Northwest Inc.
L	liter(s)
LCS	laboratory control sample
LDPE	low-density polyethylene
LISST	Laser In-Situ Scattering and Transmissiometry
LULC	land-use and land-cover
MDL	method detection limit
min	minute(s)
mL	milliliter(s)
MS	matrix spike
MSD	matrix spike duplicate
MLLW	mean lower low water
NA	not available or not applicable
NBK	Naval Base Kitsap
NDDSW	Non-Dry Dock Stormwater
ng	nanogram(s)
NPDES	National Pollutant Discharge Elimination System
NPOC	non-purgeable organic carbon
NWTPH-Dx	Northwest Total Petroleum Hydrocarbons – Diesel fraction
PAHs	polycyclic aromatic hydrocarbons
Pb	lead
PME	Particulate Metals
PNNL	Pacific Northwest National Laboratory
PP	polypropylene
ppt	parts per thousand
PSNS&IMF	Puget Sound Naval Shipyard & Intermediate Maintenance Facility
PVDF	polyvinylidene fluoride
PWP	Project Work Plan
QAPP	Quality Assurance Project Plan
QA/QC	quality assurance/quality control
RCM	Runoff Coefficient Method
RL	reporting limit
RPD	relative percent difference
RRO	residual range organics
SRM	standard reference material

TDSR	Telemetry Data Summary Report
TMDL	Total Maximum Daily Load
TME	total metals
TOC	total organic carbon
TPH	total petroleum hydrocarbon
TR or TRM	total recoverable metals
TSS	total suspended solids
µm	micron(s)
µmho/cm	micromho(s) per centimeter
V	volt(s)
W	watt(s)
WDOE	Washington Department of Ecology
Zn	zinc

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1.0 Introduction

Stormwater is a significant source for non-point source pollution in Puget Sound, WA and has been identified as a concern for endangered salmonid species, shellfish harvesting, and human health (e.g. swimming beach closures) (Puget Sound Partnership 2014). The Puget Sound Naval Shipyard & Intermediate Maintenance Facility (PSNS&IMF) and Naval Base Kitsap-Bremerton (NBK-Bremerton) are committed to a culture of continuous process improvement for all aspects of shipyard operations, including reducing the release of hazardous substances in stormwater discharges. The facilities, collectively known as the Bremerton Naval Complex (BNC), are herein referred to as the Shipyard, for brevity. The U.S. Environmental Protection Agency (EPA) Region 10, the Washington State Department of Ecology (Ecology), and the Shipyard are working to renew the National Pollution Discharge Elimination System (NPDES) permit for discharges into Sinclair Inlet, Puget Sound, Washington (EPA 2008a, b). The discharge of stormwater from Shipyard operations is permitted by EPA Region 10 under the Clean Water Act of 1977 (National Pollutant Discharge Elimination System [NPDES] permit WA-00206-2, 1994). Under the NPDES program, the Shipyard is required to implement best management practices (BMPs) designed to reduce, treat, and control discharges of contaminants from Shipyard operations (Jabloner et al. 2009) and conduct stormwater monitoring from representative storm drains within the Shipyard to ensure compliance with the NPDES.

Regulatory agencies are currently specifying low discharge "benchmarks" or "limits" to stormwater outfalls and requiring arbitrary monitoring requirements (monthly or seasonally) that are not tied to the driving forces within the watershed such as hydrology (flow regime), weather (storm events and antecedent dry periods), land use and cover, and pollutant loading to the receiving waters. The result is expensive data collection efforts that provide little information on the impact to beneficial uses in the receiving waters. There is a significant compliance liability when permit required samples are not obtained, therefore it is imperative to ensure that development of new permit requirements are scientifically defensible. New permits must consider the complexity of sampling a highly heterogeneous media such as stormwater (i.e. timing of grab samples vs composites) and the challenges with collecting stormwater that is “representative of an end of pipe discharge” prior to the discharge point in tidally influenced stormwater outfalls located in industrial operations. All of these complexities require specific collection and analytical methods to ensure the data are representative of the quality of stormwater being discharges. Adequate representation allows an informed discussion on the influence stormwater has on the beneficial uses of the receiving water.

Therefore, the Navy commissioned a three year study (2010-2013) of Non-Drydock Stormwater (NDDSW) quality to provide a scientifically defensible characterization of the stormwater quality of representative Shipyard drainage basins, assess the probability of permit compliance, and to provide contextual data to assist the U.S. Navy, EPA, Ecology, and other stakeholders in understanding the nature and condition of stormwater discharges from the Shipyard both historically and currently to evaluate the realized benefits of process improvements already accomplished and help inform the permitting process (EPA 2008a, b). The project was conducted in three phases with Phase I in 2010, Phase II in 2011, and Phase III in 2013. Stormwater outfalls sampled in each Phase were selected based on the results of the previous Phases, representativeness of the sampling location (e.g., ensure that all major work activities within the Shipyard are represented), and planned construction activities. Cumulative annual reports were produced each year.

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). To determine potential impairments to beneficial uses and identify appropriate stormwater BMP recommendations, the data from this study are considered within a regional context and specifically from a Sinclair/Dyes inlets watershed perspective to help prioritize stormwater management actions within the context of other activities within the watershed. Therefore, the results from this 2010−2013 stormwater study at the Shipyard are synthesized with the existing regional data to provide an assessment of overall stormwater quality and recommendations to address knowledge gaps and inform the NPDES process.

1.1 Study Objectives

The overall goal of the NDDSW study was to characterize non-drydock stormwater quality as a function of several primary work activities within the Shipyard and identify representative outfalls for future permit requirements. This included the representation of industrial activities within the confined industrial area (CIA) compared to the more residential activities within the Naval Base Kitsap (NBK) to provide preliminary data in support of the (Working Draft) NPDES Permit Number WA-00206-2 (USEPA 2008a, b). In addition, these data support the development of the ENVVEST land-use and land-cover stormwater relational model (Brandenberger et al. 2007a, b; Cullinan et al. 2007) as part of the contaminant mass balance for Sinclair and Dyes Inlet (Brandenberger et al. 2008).

The study was conducted over three years to allow an adaptive approach (learning from each previous year) to characterize stormwater quality associated with representative activities in the Shipyard and provide a current measure to evaluate the value of past process improvement and a benchmark to assess effectiveness of future BMPs. The objectives were to:

(1) Conduct chemical analyses using appropriate collection and analytical techniques to ensure data are representative of stormwater quality and are comparable to previous studies; and

(2) Validate and report the sampling results to the EPA in monthly Discharge Monitoring Reports (per Permit §III.B), Annual Report of Progress (per Permit §I.E.2.c), and an NDDSW Study Report.

The objectives for each Phase of the project are listed below:

Phase I Specific Objectives (2010-2011):

(1) Identify primary land uses and activities of the Shipyard non-dry dock properties;

(2) Identify basins and outfalls to sample that are representative of the primary land uses and operations; and

(3) Collect storm event mean composite (EMC) samples during three qualifying storm events at each of the seven representative stormwater outfalls consistent with methodology reported by ENVVEST (Brandenberger et al. 2007a, b; Cullinan et al. 2007; per Permit §I.C.3 and §III.A).

Phase II Specific Objectives (2011-2012):

(1) Maintain stormwater EMC collections at two Phase I stations (PSNS015 and PSNS126) to provide additional data on identified anomalies at these stations (e.g. Hg and Cu, respectively);

(2) Identify and setup automated samplers at four new stormwater sampling locations to represent specific work activities within the CIA;

(3) Collect storm EMCs during four qualifying storm events at each of the six representative stormwater outfall sampling locations consistent with methodology from Phase I; and

(4) Collect a storm event profile at PSNS015 to represent storm dynamics in one-hour composite samples over the entire storm period and add in-situ particle size characterization to this event.

Phase III Objectives (2012-2013):

(1) Maintain stormwater EMC collections at four stations previously sampled including one in NBK(PSNS015) and three in the CIA (PSNS084.1, PSNS115.1 and PSNS126) to provide additional data on these areas of interest (e.g. Hg and Cu/Zn, respectively);

(2) Identify and setup automated samplers at two new stormwater sampling locations to represent the newly constructed stormwater system at Pier B and additional NBK activities; and

(3) Collect storm EMCs during four qualifying storm events at each of the six representative stormwater outfall sampling locations consistent with methodology from Phase I.

1.2 Stormwater Policy Overview

The Federal Clean Water Act of 1972 regulates the discharge of pollutants into surface waters. Stormwater discharges (outfalls) are considered point sources and are managed under the NPDES program administered by the EPA. Most states, including Washington, have been delegated authority by the EPA to implement the NPDES program in their state. However, in all states the EPA retains NPDES permitting authority for federal facilities and in Indian Country. Therefore, in the case of the Shipyard, the EPA is the permitting agency for the NPDES permit(s) that govern discharge of pollutants into surface waters[3]. However, it is critical to consider the regional stormwater policies for other similar industries such as boatyards being addressed under the Regional Stormwater Management Program (RSMP), discussed in more details below.

1.2.1 Background on Stormwater Policy in Puget Sound

The Puget Sound Partnership (PSP), established in 2007, is the current oversight agency for Puget Sound-wide water quality protection and recovery. State water quality regulatory authority rests with Ecology and EPA for federal facilities. Thus, policy regarding regulation of stormwater quality is influenced by PSP (through the Puget Sound Action Agenda), the EPA as the federal administrator of the NPDES program, and Ecology as the state environmental quality agency. The Washington State Pollution

[3] EPA NPDES permits in WA and OR are listed here
http://yosemite.epa.gov/r10/water.nsf/NPDES+Permits/CurrentOR&WA821

Control Hearings Board also sets policies by making legal decisions pertaining to orders and decisions from Ecology and other state agencies[4].

The focus of the PSP includes water quality recovery in fresh and marine waters around the Puget Sound. Starting with the 2012 Action Agenda[5], prevention of pollution from urban stormwater runoff was highlighted as one of three strategic initiatives of the PSP. This initiative encompasses five themes:

- Take a watershed approach to management (i.e, link funding to broader context and vision to more effectively manage stormwater at the watershed scale). A key action is to evaluate the feasibility of transitioning the existing municipal stormwater general permit approach to a watershed based municipal stormwater management approach.

- Prevent new problems (primarily focused on increasing funding for the Ecology-administered NDPES permit program). This would include providing incentives to NPDES permittees who carry out watershed scale NPDES implementation as described above.

- Fix existing problems (focused on identifying high priority stormwater retrofit projects)

- Control sources of pollution. A key action is to establish accurate new Fish Consumption Rates for vulnerable populations to inform human exposure to toxins from fish. These rates will inform new Sediment Management Standards and Water Quality Standards for Surface Water. Another key action is increased inspections, technical assistance, and enforcement.

- Education. This includes training and certification programs for local government staff on Low Impact Development and also a Phase 2 “Puget Sound Starts Here” educational campaign.

Urban runoff collected in MS4s (municipal separate storm sewer systems) and discharged into surface waters requires a NPDES permit. A general permit has been developed by EPA that divides permit holders into two groups (or Phases). The Phase 1 Municipal Stormwater General Permit covers MS4s owned or operated by Clark, King, Pierce and Snohomish Counties; and the cities of Seattle and Tacoma (incorporated cities with a population over 100,000 and unincorporated counties with populations of more than 250,000 according to the 1990 census. The second phase for western Washington covers at least 80 cities and portions of five counties with an effective date of September 1, 2012. The updated 2013-2018 permit became effective on August 1, 2013[6]. Other federal mandates addressing stormwater quality are listed below.

➢ Energy Independence and Security Act (EISA) of 2007, Section 438: EISA establishes stormwater runoff requirements for federal development projects in Section 438. This provision requires any projects involving a federal facility with a footprint that exceeds 5,000

[4] http://www.eho.wa.gov/Boards_PCHB.aspx
[5] 2012 Action Agenda http://psp.wa.gov/downloads/AA2011/083012_final/Action%20Agenda%20Book%202_Aug%2029%202012.pdf
[6] Municipal Stormwater General Permit page at Ecology http://www.ecy.wa.gov/programs/wq/stormwater/municipal/PermitsPermittees.html

square feet to use site planning, design, construction, and maintenance strategies that maintain or restore the predevelopment hydrology of the property, as feasible[7].

- Executive Order 13514 of 2009: EO 13514 requires federal agencies to implement and achieve the objectives identified in the stormwater management guidance developed by EPA that provides implementation guidelines on stormwater requirements in EISA 2007 section 438[8].

- EPA Technical Guidance on Implementing the Stormwater Runoff Requirements for Federal Projects: This guidance provides two technical approaches for meeting the stormwater runoff requirements of EISA section 438 along with key definitions to help guide agencies in meeting requirements[9].

1.2.2 Shipyard NPDES and Draft Stormwater Permit

The Shipyard's first NPDES permit was issued in September 1986 and then reissued in April 1994 (#WA-003716-8 or WA00206-2)[10] and covers dry dock discharges, steam plant discharges, and stormwater from non-dry dock areas. This 1994 permit is the current effectual stormwater discharge guidance for the Shipyard. The EPA, Ecology, and the Shipyard are working together to renew the PSNS &IMF's current NPDES permit for discharges into Sinclair Inlet, Puget Sound, Washington (EPA 2008a, b). The permit specifies conditions and concentration limits for discharge of several pollutants as well as required and recommended BMPs to guide Shipyard activity and pollution control and monitoring. The Shipyard is responsible for monitoring discharges at specified locations and reporting findings to the EPA. In accordance with the NPDES permit, PSNS&IMF has monitoring activities in place for all three of these operations including: dry dock discharges (Johnston et al. 2009), steam plant discharges (Johnston et al. 2009), and stormwater and miscellaneous runoff from non-dry dock areas (reported herein).

In May 2008, the EPA issued a Working Draft NPDES Permit for the Shipyards' consideration, review, and preparation. In the 2008 Working Draft NPDES Permit, one stipulation addresses the characterization and assessment of NDDSW runoff. Table 1-1 compares the 1994 (effectual) NPDES Shipyard Permit and the U.S. Navy General Permit to the Proposed Non-Dry Dock Stormwater Outfall Effluent Limits; Ecology Boatyard Permits, Vessel Deconstruction, and the EPA 2015 Multi-Sectoral General Permits. This provides a point of comparison within the region for the existing U.S. Navy General Permit limits and the proposed permit requirements (per Permit §I.C.3 and §III.A) for NDDSW monitoring assessment parameters. The proposed permit requirements recommend the sample collection frequency changes from weekly to quarterly, and provides for the option of either 2 hour time-proportionate composite sampling or the current grab sampling method.

[7] http://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf
[8] http://www1.eere.energy.gov/femp/pdfs/eo13514.pdf
[9] http://water.epa.gov/polwaste/nps/section438.cfm
[10] Current (1994) NPDES permit for the Shipyard
http://yosemite.epa.gov/R10/water.nsf/95537302e2c56cea8825688200708c9a/e0594922e7a282bc882568010055812a/$FILE/WA0002062_FP.pdf

Table 1-1 Permitted Maximum Daily Effluent Limits and Comparative Benchmarks

Shipyard Maximum Daily Benchmarks				Comparative Benchmarks		
				WSDOE		EPA
Parameter	1994 (effectual) NPDES	U.S. Navy General Permit	2008 DRAFT PERMIT NPDES	2014 Vessel Deconstruction General Permit	2016 Boatyard General Permit	2015 MSG Permit
Copper (Cu)	33 µg/L	14.0 µg/L	5.8 µg/L	5.8 µg/L	147 µg/L	4.8 µg/L
Lead (Pb)	--	--	221 µg/L	14 µg/L	--	210 µg/L
Mercury (Hg)	--	--	2.1 µg/L	--	--	1.8 µg/L
Zinc (Zn)	1000 µg/L	117 µg/L	95 µg/L	95 µg/L	90 µg/L	90 µg/L
Arsenic (As)	--	--	69 µg/L	--	--	69 µg/L
Total Suspended Solids (TSS)	100 mg/L	--	--	30 mg/L	--	100 mg/L
Turbidity	--	--	5 NTU above background	25 NTU	--	50 NTU
All metals are reported as total recoverable. MSG = Multi-Sector General						

Discharges from non-federal vessel repair and deconstruction sites in Washington State are regulated under Ecology's Vessel Deconstruction General Permit, the NPDES Boat Building and Repair Facilities General Permit for small boats (≤65ft in length)[11], or under individual NPDES permit for large boatyards. The Vessel Deconstruction General Permit, 2014, covers staging yards for over-water tasks; while the Boatyard General Permit, 2016, covers permanent industrial facilities. In response to technology improvements and policy advancements in Puget Sound, the Boatyard General Permit was reissued in 2011 with revised benchmarks for Cu and Zn based on past performance of stormwater treatment and water quality based limits; the current 2016 version of the permit, effective August 8th, made no modification to maximum daily benchmarks.[12]

Another opportunity for comparison of pollutant limits is the new Multi-Sector General Permit (MSGP) issued by the EPA in 2015 that covers federal facilities in Washington and regulates stormwater discharge from 29 different industrial sectors, including Ship and Boat Building and Repairing Yards (Sector R)[13]. The Working Draft NPDES Permit proposes Cu limits that are much more stringent than the 147µg/L maximum daily benchmark found in the Boatyard General Permit, but do align with effluent levels in the Vessel Deconstruction Permit and the MSGP. The 2011 calculation of the Boatyard General Permit values were based on effluent values from several boatyards in Puget Sound (averaging 24±26µg/L Cu – total recoverable) [14] with modern stormwater filtration. This approach gives a technologically feasible target for comparable land uses in the region. However the Working Draft NPDES permit uses waste-load allocation calculated from aquatic life acute criteria for setting benchmarks. This approach to setting benchmarks may make reaching them unattainable after AKART

[11] Small boatyards are all boatyards in Washington State which engage in the construction, repair and maintenance of small vessels, 85% of which are 65 feet or less in length, or revenues from which constitute more than 85% of gross receipts.
[12] Boatyard General Permit http://www.ecy.wa.gov/programs/wq/permits/boatyard/index.html
[13] EPA Multi-Sector General Permit page http://cfpub.epa.gov/npdes/stormwater/msgp.cfm
[14] Fact Sheet for NPDES Boatyard General Permit Reissuance April 21. 2010 http://www.ecy.wa.gov/programs/wq/permits/boatyard/permitdocuments/boatyardfs030211.pdf

implementation. This is seen in similar Industrial NPDES such as McFarland Cascade Permit No. WA0037953 Cu benchmark of 92µg/L effective 2014 and Dakota Creek Industries Permit No. WA0031411 Cu benchmark of 75µg/L Cu effective 2016. The Water Quality Permitting and Reporting Information System (PARIS) provides searchable access to a majority of Industrial NPDES information. Although PARIS provides Cu and Zn concentrations, it does do not have benchmarks.

1.3 Regional Stormwater Data Overview

There are three primary sources of stormwater quality information within the context of boatyard operations that would be relevant to the region: 1) U.S. Navy Project ENVironmental inVESTment (ENVVEST); 2) this report on the Non-Dry Dock Stormwater study and 3) Ecology's Regional Stormwater Monitoring Program (RSMP and Hobbs et al. 2015).

In 2000, ENVVEST was created in partnership with the Shipyard, EPA, Ecology, and local stakeholders to support the development of Total Maximum Daily Loads (TMDLs) [15] for fecal coliform (FC) and other contaminants entering the Sinclair and Dyes Inlets (ENVVEST 2002a, b, 2006). The ENVVEST Study area (Figure 1-1) was delineated as the watersheds draining into both Sinclair and Dyes Inlet to allow the study to achieve five key objectives:

1) Identify current sources of pollution within the watershed;

2) Assess the pollutant loadings to the receiving waters that may be associated with risks to a range of sensitive beneficial uses;

3) Collect and analyze water-quality samples to establish watershed-wide pollutant concentrations in relation to watershed characteristics and land-use land-cover (LULC) metrics;

4) Recommend implementation priorities for protecting the more sensitive beneficial uses and/or ecosystem components within the basin; and

5) Ensure that there is meaningful public involvement in the process and that the water clean-up efforts are coordinated to an extent that helps build the overall capacity of the community to successfully participate in these and related watershed protection activities.

The integrated watershed assessment approach of Project ENVVEST provided data on the current quality of the water, sediment, and biota present in both Sinclair and Dyes inlets. The objective was to establish a solid baseline and understand the variability on a spatial and seasonal scale to provide a means by which to assess process improvements within the Shipyard and bound the data in terms of regional sources of the contaminants present in stormwater runoff. ENVVEST previously sampled 13 stormwater drainage basins within the watershed, including 3 basins within the Shipyard that were monitored for flow and sampled during storm events (Brandenberger et al. 2007a, b). The stormwater outfalls selected for

[15] Total Maximum Daily Load (TMDL) means a calculation of the maximum amount of a pollutant that a water body can receive and still meet state water quality standards. Percentages of the total maximum daily load are allocated to the various pollutant sources. A TMDL is the sum of the allowable loads of a single pollutant from all contributing point and nonpoint sources. The TMDL calculations must include a "margin of safety" to ensure that the water body can be protected in case there are unforeseen events or unknown sources of the pollutant. The calculation must also account for seasonable variation in water quality.

flow monitoring were determined by a technical evaluation of 35 stormwater outfalls (including streams and other urbanized natural drainage areas) located within the City of Bremerton, City of Port Orchard, City of Bainbridge Island, Kitsap County, and the Shipyard (TEC 2003a, b, c). This work resulted in a calibrated and verified Hydrological Simulation Program Fortran (HSPF) watershed model for drainage basins within the watershed including the Shipyard (Skahill and LaHatte 2007) and estimates of stream and storm event runoff quality as a function of upstream LULC and storm intensity (Brandenberger et al. 2007a, b; Cullinan et al. 2007). This provided data to develop a contaminant mass balance for heavy metals, polycyclic aromatic hydrocarbons, polychlorinated biphenyls, and nutrients where all sources and sinks were considered to allow a relative evaluation of the dominant sources (Brandenberger et al. 2008).

One gap identified by ENVVEST was the characterization of stormwater quality within the various basins of the Shipyard. This study fills that gap by providing an initial characterization of the stormwater quality from both the industrial and residential sides of the Shipyard. An evaluation of existing stormwater monitoring data for the Shipyard and a review of technical and regulatory requirements was conducted and reported in the Quality Assurance Project Plan (QAPP) for non-dry dock stormwater monitoring conducted under the NPDES permit (Taylor Associates Inc. 2009). The data from Phase I, II, and III (reported herein) of this Non-Dry Dock Stormwater sampling improves the estimate of ENVVEST stormwater loading, the mass balance of chemical contaminants from the Shipyard, and augments the ambient monitoring to demonstrate ongoing environmental performance in support of NPDES requirements (Johnston et al. 2010). This provides the region with data on the range of contaminants in stormwater discharging from an industrial shipyard facility.

Figure 1-1 Location of the Puget Sound Naval Shipyard & Intermediate Maintenance Facility (Naval Shipyard) on Sinclair Inlet, Washington. The study region for the U.S. Navy project ENVironmental inVESTment (ENVVEST) is the watershed boundary supporting the receiving waters of Sinclair Inlet, Dyes Inlet, and the passage ways to the main basin of Puget Sound.

The third source of information is the Regional Stormwater Monitoring Program (RSMP) in the Puget Sound. The RSMP is a partnership between Ecology and PSP designed to compile technical expertise across the agencies to assess the effectiveness of stormwater monitoring techniques in Puget Sound. Ecology leads an independent stakeholder committee to assess effectiveness of, and standardize the use of, stormwater mitigation technologies and BMPs. This working group is funded by the regional permittees via equitable factor based cost pooling. A key component of the RSMP is the standardization and central listing of approved monitoring and analytical methods for source identification and diagnostic monitoring based on regional findings. This study falls under the committee's adaptive management recommendations of treating monitoring activities as experimental components within compliance efforts in order to target observed uncertainties and determine feasibility of effluent limit implementation to each corresponding land type/use covered.

One key recommendation from the RSMP that is relevant to the Shipyard is the recognized need to understand the potential for tidal intrusion into the storm drains prior to implementing RSMP and EPA recommended stormwater sampling methodologies (e.g. grab samples). However, the RSMP does not specify if randomly timed or targeted sampling is optimal, while the shipyard's Draft Permit stipulates grab samples be taken within the first 60 minutes of a storm event or time-proportional composites started within the first 30 minutes and extend 2 hours into the storm event. Understanding the timing of the first flush and the potential for tidal influence inside the storm drain system are critical elements for any stormwater program in order to represent the true discharge of metals and their chemical or phase speciation (e.g. dissolved versus particulate).

Ecology set the NPDES General Permit (GP) effluent benchmarks for boatyards by considering regional stormwater discharges to marine waters using data from 2011-2015[16] (Table 1-1). Future benchmarks may use effluent data from boatyards that have installed multimedia filtration stormwater treatment devices. The summary of current data available are provided in Table 1-2, but the data set is still limited and has not been utilized for the development of post-treatment benchmarks.

Table 1-2 Data used to develop Regional Stormwater Benchmarks.

Regional Stormwater Outfalls that Discharges to Marine Waters			
Analyte	Maximum Daily Benchmark (µg/L)	Over Benchmark	*n*
Cu	147	30%	773
Zn	90	46%	775

Post RSMP Recommended Stormwater Treatment Data					
Analyte	Mean (µg/L)	± (µg/L)	Minimum	Maximum	*n*
Cu	24.4	26.2	2.5	113	48
Zn	85.4	83.3	0.1	442	46

[16]Fact Sheet for NPDES and State Waste Discharge General Permit for Boatyards, July 6, 2016; http://www.ecy.wa.gov/programs/wq/permits/boatyard/permitdocuments/Boatyard-FactSheet-Final-20160706.pdf

2.0 BNC Study Area Description

The Shipyard is located in Bremerton, Washington which is surrounded by the watersheds draining into both Sinclair and Dyes Inlet (Figure 1-1). The Shipyard is located along the northern shore of Sinclair Inlet, a sub-basin of Puget Sound, and is bounded by the City of Bremerton. It covers approximately 350 acres of land and an additional 340 acres of tidelands along 11,000 ft. of shoreline. There are over 300 buildings and structures consisting of industrial, supply and base facilities, a steam plant, six dry docks, piers, and numerous moorings. The predominant land cover within the Shipyard is rooftops, paved areas (roads, parking areas, sidewalks, and concrete working areas), and piers.

The Shipyard and other industrial facilities have a number of unique attributes that make the identification of stormwater pollutant problems and their associated solutions difficult to determine. Stormwater contains a broad variety of pollutants whose concentrations can vary widely depending on storm event size, intensity, predominant industrial activities, LULC, and a number of other local and regional factors. The quality of stormwater runoff can often be difficult to manage due to the seasonal, sporadic nature of surface water discharges and the character and unpredictability of storm events. Monitoring stormwater discharges within the Shipyard presents the following additional challenges unique to a facility located within an industrial waterfront:

- Stormwater runoff from all BNC non-dry dock properties drains directly into adjacent marine receiving water;
- Most of the drainage basins are tidally influenced;
- The non-dry dock stormwater drainage systems are relatively short in length (from head to bay outfall), and many systems have limited access, eliminating the opportunity to conduct monitoring in non-tidally influenced areas; and
- Industrial processes occurring within the sampling area must be isolated from the water sampled in the stormwater conveyance. Contamination of the sample during or after collection would not be representative of the concentration of such contaminants at the point of discharge to the bay.

The Shipyard is divided into two areas (see figure 2-2): 1) Controlled Industrial Area (CIA) and 2) Naval Base Kitsap - Bremerton (NBK). The CIA is one of Washington State's largest industrial installations and is responsible for overhaul, maintenance, docking, refueling, and decommissioning of naval vessels, as well as, dismantling of ships and submarines. The NBK area provides base operating services, including support for home-ported surface ships and submarines. Support areas include housing, parking, shopping, entertainment, and recreation facilities. The stormwater system draining these two areas includes 156 distinct storm drainage systems, many of which serve small drainage areas.

As described in the All Known, Available, and Reasonable Methods of Treatment (AKART) study (Jabloner et al. 2009), the Shipyard stormwater system is composed primarily of clay pipe with a mixture of concrete, polyvinyl chloride, steel, and cement-asbestos pipe. Stormwater is collected from buildings and roofs by rain gutters and roof drains, which then discharge into storm drainage pipes or into catch basins located around the buildings. The depth of the stormwater system ranges 1–20 ft. below ground surface. Most of the stormwater outfalls discharge to Sinclair Inlet below mean lower low water (MLLW) allowing tidal water to push up into the storm drain system even as far as many sampling points.

There are more than 1,000 catch basins and track drains on piers that drain into Sinclair Inlet and an extensive rail system provides a pathway for stormwater to seep through the subsurface. Depending on the flow rate and whether the track drains become clogged, this runoff may drain directly into Sinclair Inlet (Jabloner et al. 2009). On the piers and other surfaces located directly over the water there are drain holes in the deck that allow rainwater to drain directly into Sinclair Inlet. The ground surfaces around the buildings are generally impervious, made up of either asphalt, concrete, or concrete base with asphalt over it. The Shipyard is not 100% impervious. There are various cracks, breaks, and holes in some of the surface cover, as well as crane track pathways and a sloped vegetated hillside (the northern boundary of the CIA) that allows infiltration of a small portion of precipitation and surface runoff. However, because the vast majority of the CIA contains no pervious areas, stormwater infiltration is assumed to be minimal.

2.1 Outfall Selection

The first objective of this study was to document the technical strategy and procedures needed to monitor stormwater basins in both the residential (NBK) and industrial (CIA) areas of the Shipyard. Taylor Associates Inc. (2009) evaluated existing stormwater monitoring data for the Shipyard, reviewed technical and regulatory requirements and conducted a pilot study to test methodologies for collecting representative freshwater samples from tidally influenced stormwater drainage systems (see Field Sampling Plans [FSP]; TEC and PNNL 2011, 2012a and 2012b). The technical strategy provided the basis for selecting a subset of representative outfalls from the 158 stormwater outfalls at the Shipyard. The selection criteria included the following categories: 1) representative of the seven main work activity categories, 2) representative of the upstream drainage area, 3) minimal tidal intrusion at the sampling location, and available solutions to operational constraints at the sampling point.

This study implemented the selection criteria and identified 13 distinct storm drainage systems to be monitored in during the 2010-2013 study. The 13 storm drainage basins were monitored during the three phases (Phase I, II, and III) and represent the main industrial operations and processes at PSNS&IMF and the support functions in the surrounding NBK. The selected drainage basins collectively represent all seven of the primary work activities 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; and because they contained unique and/or representative land use. Figure 2-1 illustrates the locations of the selected outfall manholes in both the CIA and NBK.

Table 2-1 provides a summary of the selected stormwater drainage basin characteristics, the Phase of the project and their associated stormwater outfall number, geographical area, and primary work activity. Taylor Associates Inc. (2009) provides a summary of the characteristics for all the Shipyard drainage basins. Table 2-2 provides the specific attributes of the selected drainage basins with additional details provided in the various FSPs (TEC and PNNL 2011, 2012a and 2012b).

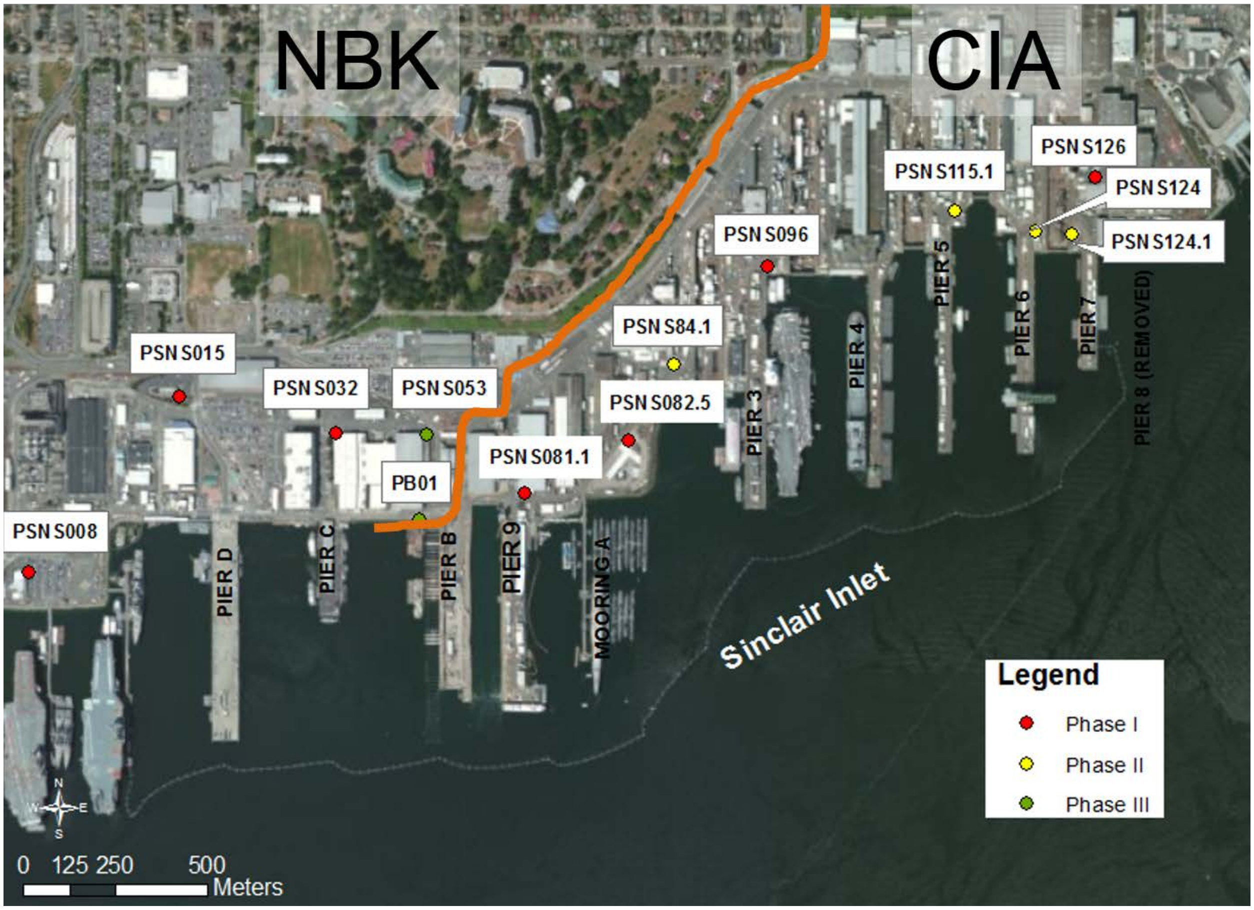


Figure 2-1. Sampling Locations for Non-Dry Dock Stormwater Outfall Study

Table 2-1. Drainage Basins Selected for Monitoring and Their Primary Work Activity

Location	PSNS Outfall #	Geographical Area [(a)]	Primary Work Activity	Phase I	Phase II	Phase III
NBK	008	West NBK, east side of Inactive Fleet B550	Parking/steam plant/truck traffic	X		
NBK	015	Mid NBK, south side of McDonalds, east side of drive-through lane	Municipal/commercial/residential services	X	X	X
NBK	032	East NBK, NW corner of B514	Aircraft carrier support services	X		
NBK	053	East NBK, Northeast corner of B449, inside perimeter fence along “T” Street	Vehicle and equipment movement and parking, material storage, air comp. facility, mixed waste storage facility and general warehousing.			X
NBK	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			X
CIA	081.1	West CIA, NE of DD6 and NW of Pier 9, south side of Bldg 462	Non-aircraft carrier support services	X		
CIA	082.5	West CIA, southeast of B851, RMTS Area	Vessel, equipment and materials recycling	X		
CIA	084.1	Western CIA, Southeast section of Bldg 983, west of DD5	Vehicle and equipment traffic, radiological work builds, outside equipment storage, paint shop, recycling, industrial waste pretreatment		X	X
CIA	096	Mid CIA, west of DD4, southeast of Bldg 457 along “N” St	Vessel maintenance	X		
CIA	115.1	Mid-CIA, South-southeast of Bldg 879, east of DD4	Materials storage (outdoors), various shops and training center, water front support activities		X	X
CIA	124	Eastern CIA, Northwest corner of Bldg. 357, west of DD3	Material storage, pipe/boiler/forge/nuclear repair shops, Chem Lab, DD3 cutting facility		X	
CIA	124.1	Eastern CIA, Southwest of Bldg 460, west of Bldg 495, east of DD3	Dry-dock support activities, crane, vehicle and equipment traffic, laydown and staging areas		X	
CIA	126	East CIA, Southwest B460 along “C” Street, east of DD3	Materials storage (outdoor)	X	X	X
	(b) Drydock 1 through 6 denoted as DD1, DD2, etc.					

Table 2-2. Stormwater Drainage Basin Attributes

PSNS Outfall No.	Outfall Location	Monitoring Location(a)	Total Basin Area (acres)(b)	Basin Impervious Surface Area (acres)	Basin Pervious Surface Area (acres)	Monitoring Location Manhole ID	Manhole Rim Elevation (ft)(c)	Approx. Elev. of Sampling Intake (ft)(c)	Effective Tide Height (ft)(d)
008	47°33'15"N, 122°39'17"W	47°33'19"N, 122°39'16"W	12.71	11.95	0.76	2179	17.95	5.33	+5.5
015	47°33'21"N, 122°39'02"W	47°33'29"N, 122°39'03"W	92.26	46.13	46.13	A42	17.21	1.96	+2
032	47°33'21"N, 122°38'50"W	47°33'27"N, 122°38'49"W	4.79	4.65	0.14	5961	18.46	9.46	+9.5
053	Relocated, ~same location as PB01	47°33' 27.3"N, 122°38'41.4"W	4.91	4.83	0.08	2749	17.90	9.51	+10.5
PB01	No data available	47°33'22.2"N 122°38'41.9"W	3.00	3.00	0	SDMH1D	17.54	11.02	Not Effected[f]
081.1	47°33'21"N, 122°38'31"W	47°33'23"N, 122°38'32"W	22.16	21.51	0.65	SD-1	17.71	3.85	+4
082.5	47°33'28"N, 122°38'20"W	47°33'26"N, 122°38'23"W	2.00	[e]2.00	0.00	CBS-6	17.91	9.87	+12[e]
084.1	47°33'30"N, 122°38'20"W	47°33'31.3"N, 122°38'20"W	0.55	0.55	0.0	551	17.69	5.61	+5.5
096	47°33'35"N, 122°38'11"W	47°33'37"N, 122°38'11"W	16.48	15.99	0.49	3878	17.46	2.94	+3.0
115.1	47°33'39"N, 122°37'54"W	47°33'40.4"N, 122°37'55"W	9.50	9.22	0.28	4860	17.72	1.27	+1
124	47°33'36"N, 122°37'47"W	47°33'39.2"N, 122°37'48"W	10.42	9.85	0.57	5881	17.75	5.27	+5
124.1	47°33'36"N, 122°37'44"W	47°33'39"N, 122°37'45"W	2.66	2.52	0.14	5880	17.15	8.19	+8
126	47°33'37"N, 122°37'36"W	47°33'42"N, 122°37'42"W	15.22	15.00	0.22	5110	18.22	8.60	+9

(a) Coordinates for the monitoring location were determined using a Trimble global positioning system and differentially corrected.
(b) Total basin areas are included in the Basin Description Table and were determined based on calculations supplied by the U.S. Navy.
(c) Referenced to mean lower low water (historical PSNS&IMF documents 1994–2008).
(d) Expected tidal height based on NOAA tide predications where tidewater, under non-storm conditions, would be detected at the monitoring location.
(e) The effective tide height at 082.5 is significantly higher than the approximate elevation of the sampling intake due to the design of the piping system. A TideFlex® valve is located in the manhole downstream from CBS-6, which allows tide water to back up into CBS-6 only during higher tides.
(f) Basin outfall has been retrofit with a Tideflex® valve. It's exact operation and subsequent effect on tidal height relation is unknown at this time. In the case of PB01, the Tideflex value and adjacent pump vault effectively keep out seawater.

3.0 Field Collection Methods

Consistent with the requirements specified in the draft NPDES permit, grab samples for total petroleum hydrocarbon [TPH] and fecal coliform and automated, tidally compensated, time-paced composite samples for the other heavy metals and physiochemical parameters were collected at 13 representative outfalls during the study from 2010-2013. Sixteen individual storm events were sampled and identified as SW01 through SW16. The field sampling logistical guidance for the Shipyard was described by Taylor Associates (2009) and an annual FSP was prepared for each of the Phases I through III (TEC and PNNL 2011, 2012a and 2012b). A brief description of the overall field collection methodologies and significant anomalies are provided below. For each of the storm events a Storm Event Report (see Appendix A) was produced to document the storm characteristics, sampling logistics, field activities, anomalies, and notes.

3.1 Stormwater Monitoring System/Equipment

A generalized schematic of the stormwater outfall monitoring systems is illustrated in Figure 3-1. Each system included a telemetric communication modem, antenna, central datalogger/system controller, autosampler, rain gauge, pressure (water level)/temperature transducer, conductivity sensor (typically integrated into the pressure transducer unit), solar panel charger, batteries, equipment housings and various mountings and sample tubing. All of the sensors and gauges were frequently calibrated and maintained (typically twice or more per month during their operational periods) to ensure accurate water level and conductivity data. A brief description of these components is provided below. For a detailed description of the sampling system at each of the selected outfalls see the FSP for each year of the study.

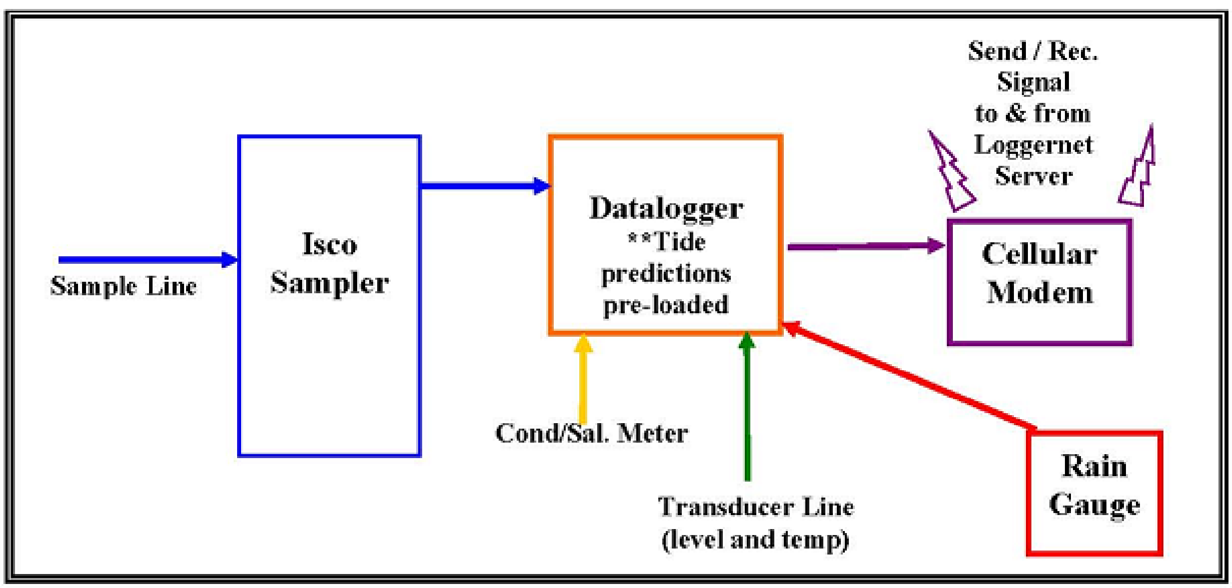


Figure 3-1. Generalized schematic of the stormwater outfall monitoring station components.

ISCO Autosampler. Stormwater samples were collected using automated water samplers (autosamplers) installed at each site. Autosamplers included Teledyne-Isco® 6700 series samplers (Lincoln, Nebraska), a Teflon™-lined polyethylene sampler suction line, and siliconized Tygon™ pump and distributor arm tubing. Autosamplers were deployed in an off-the-shelf configuration, internally equipped with 24 1-L polypropylene wedge bottles. Each sampler was identically programmed (with variations to account for duplicate collection or for use of other sensors [e.g. YSI multimeter used at one station]) (TEC and PNNL 2011, 2012a and 2012b). The associated dataloggers controlled activation and sample collection pacing. Autosampler reports (programming, sampler enable date/time, aliquot date/time and subsequent success or error codes) were also remotely downloaded and are included in Appendix A.

Datalogger/system controller. Campbell Scientific, Inc. CR1000 (Logan, Utah) custom programmable dataloggers were used as the central "brains" of each monitoring system. The CR1000 is capable of storing large quantities of time-series data, as well as performing a wide range of system control functions. All of the system components, including sensors, autosamplers, and peripherals (e.g., batteries and solar charging system), were connected through the datalogger. Calibration of all project sensors, as well as controlling the enabling conditions for the autosampler, was facilitated through the datalogger. Connection to the datalogger could be accomplished either directly (in-field) or remotely via proprietary software. All field data were automatically stored on the CR1000 datalogger at 5-minute intervals. Dataloggers were programmed to routinely download, via the telemetry system, to a base station computer at the TEC, Inc. office on a schedule of at least once per day; more frequent elective downloads occurred during times of need (e.g., storm events, calibrations, etc.).

Enabling conditions were developed for each system to determine when storm runoff reached the sampling location and there was little or no tidal influence at the location. These enabling conditions included rainfall, water level, and conductivity. For the rainfall conditions to be met, the rain gauge must detect a rain intensity of at least 0.03 inches of precipitation in a one-hour time period. The autosampler will remain inhibited until the rainfall produces adequate stormwater runoff based on an increase in the water level as measured by the pressure transducer installed at the monitoring site. The enabling water level will be determined from background water level measurements taken when the site was not affected by storm runoff or tides plus an upward water level change beyond the sensitivity (i.e., noise) of the instrument. This water level change value is typically 0.03 to 0.1 ft. For the conductivity condition to be met, the conductivity meter must measure a reading of less than 2,000 μmho/cm. The sampler can also be programed with a "repeatable enable" condition. This is where the sampler program will be toggled on and off based on a determined conductivity threshold of 2,000 μmho/cm. This threshold was defined as the definition between fresh and salt water. This conductivity threshold is also used to reflect the point at which higher levels of conductivity significantly interferes with Cu measurements using Inductively Coupled Plasma Mass Spectrometry (EPA 1638).

Conductivity. Specific conductivity was continuously measured at each station by two different sensor types: 1) INW CT2X (Kirkland, Washington) and YSI (Yellow Springs, Ohio) 6820 multi-meter sonde. The CT2X was the primary transducer/ conductivity meter used during the study, while the YSI6820 was only used in conjunction with one monitoring system during execution of Phase I and Phase II storm events. The INW CT2X specific conductivity sensor was integrated into its associated transducer (each CT2X measured pressure, temperature, and specific conductivity). The YSI 6820 is a standalone unit that was used in combination with the CS450 transducer. The YSI 6820 also provided redundant temperature data. Both specific conductivity probes recorded values to the nearest 1/100 micro-omhs/cm (μmho/cm), but were reported to the nearest whole number. Conductivity was also measured at the monitoring stations during non-storm periods to determine a relationship between conductivity and the tidal backwater conditions at that station. Salinity values were generated based on temperature-compensated conductivity measurements and temperature readings. For the CT2X units, salinity was derived from conductivity and temperature readings post-calculated by the Campbell datalogger. For the YSI, salinity was reported directly from the meter itself. Calculations for both units were based on similar algorithms derived from the *Standard Methods for the Examination of Water and Wastewater* 2520B. Salinity values from both sensors were recorded to the nearest 1/100 of a part/thousand (ppt) and reported as a whole number.

Water level and temperature. Transducers were used at each monitoring station to record water level and temperature within the outfall pipe or vault. Two different types of transducers were used for monitoring and sample collection: 1) Campbell Scientific CS450 and 2) Instrumentations Northwest Inc. (INW, Kirkland, Washington) CT2X. Each of these units measured pressure and temperature to similar specifications. Water level and temperature were both measured and reported to 1/100 of a foot and 1 degree Celsius, respectively.

Rain gauge. Teledyne-Isco® 674 (Lincoln, Nebraska) tipping bucket rain gauges were used to collect rainfall data. These instruments measured rainfall at 0.01-in. increments. Rainfall data were downloaded via telemetry at least once each day and more frequently during and following targeted storm events. Each rain gauge was connected to its associated datalogger, which recorded rainfall data at 5-minute intervals.

Telemetric communication modem. A telemetry communication system was installed at each monitoring station and provided remote communication access through the modem to the datalogger. Sierra Wireless AirLink Raven XT cellular modems (Campbell Scientific Inc., Logan, Utah), with Code Division Multiple Access (CDMA) digital technology, were used as the communication link between the remote user or server and the datalogger. This allowed for either transmission of collected data to an offsite computer and system status checks on a scheduled or on-demand basis or for execution of automated or elective system commands (e.g., setting or correcting enabling condition thresholds, changing a sample pacing rate, etc.). The use of the Raven XT modem in its project-specific configuration provided highly secure data transmissions, which was of the utmost importance to PSNS&IMF. Formal security permission was obtained for the possession and use of modems and dataloggers, especially within the CIA. Telemetry and datalogger equipment security permission forms and other pertinent information were stored in each monitoring station telemetry box and are available in the FSPs.

Solar panel charger and batteries. The telemetry system, datalogger, and all associated water-quality monitoring components were powered by 12-V deep cycle marine batteries. Typically, each station used two batteries—one to power the datalogger, sensors, and telemetry system and one to power the autosampler. Campbell Scientific SP20 regulated 20-W solar panels were used to recharge the battery associated with the datalogger and its connected components. Depending on available sunlight exposure at a particular station, it was sometimes necessary to have two batteries connected in parallel to power the datalogger.

Housings and mountings. Monitoring stations were designed with modularity and mobility as a key element. Sturdy steel, lockable equipment enclosures were used to house the various monitoring system components and to provide a stable platform from which to mount open-air items. Attached 10-ft tall masts supported the solar panels, omni-directional antennas, and rain gauges at each station. Each housing was placed as close to the outfall monitoring location as possible. All stations were above-ground with conduit lines leading from the housing to the vaults. A number of monitoring system components were installed underground at all of the sites. Transmission cables/lines for the transducers, conductivity meters, and sample collection tubing ran from the equipment housings into the associated vaults through heavy-duty plastic conduit. Inside each vault, the sample collection tubing ran along the wall, anchored at various points, and terminated at the intake point, which was generally installed in the invert of the outlet pipe. All in-vault mountings and most above ground hardware were constructed of stainless steel or non-reactive plastic.

In situ particle size and volume. For SW12, a Laser In-Situ Scattering and Transmissometry (LISST) analyzer from Sequoia Scientific (www.sequoiasci.com) was deployed at PSNS015 on April 13, 2012 to collect baseline data prior and then storm data during SW12 (only event where this instrument was utilized). The LISST-StreamSide unit was used to generate real-time data on the particle size distribution and volume through the progression of a storm (see Appendix A, SW12 Storm Report for more details).

Prior to the start of the storm, the field team visited each sampling location to prepare the monitoring equipment for data and stormwater collection. During the pre-storm site visit, the field team checked/ modified the autosampler programs as detailed in each storm event report, conducted necessary maintenance and calibration activities, and placed sample bottles into the autosamplers. All setup, maintenance, and calibration activities were recorded on field data sheets, along with associated notes of other relevant site conditions (Appendix A).

3.2 Qualifying Storm Events

The 2010-2013 study sampled 16 storms from 13 outfalls (8 CIA and 5 NBK). The size of storms sampled were 3 small = <0.5 in., 4 medium = 0.5–1.0 in., 7 large = 1.0–2.0 in., and 2 extra-large = ≥2.0 in. The project targeted larger storm events November through April to fill data gaps in previous ENVVEST stormwater projects (Brandenberger et al. 2007a; b and Cullinan et al. 2007). Qualifying storm events were targeted based on small modifications from the original ENVVEST criteria for wet season sampling (Brandenberger et al. 2007a). The qualifying storm criteria were modified to provide data to fill the gap identified in the ENVVEST (2003–2005) data set, which was missing larger storm events (≥1.0 in.) in urban and industrial drainage basins. Table 3-1 lists the qualifying criteria for Phases I through III; the modification was the addition of a conditional criterion for the 24-hour antecedent dry period requirement. The conditional qualification allows for the capture of discrete storm events during the more intensive wet season when the frequency of rain events is high and obtaining a 24-hour antecedent dry period during the wet season severely limits the sampling window. For example, with this qualifier the lack of a 24-hour dry period is overwhelmed by the total storm event rainfall depth, as long as the antecedent period is 10-20% or less of the total storm event volume. The larger storm volumes would have the potential to release and/or expose sources that otherwise might not occur during smaller events. This conditional antecedent qualification was applied on a station specific basis for each event.

Storm targeting procedures were detailed in each annual FSP and are briefly outlined here:

1. Weather forecasts for the Pacific Coast, Puget Sound Region and Bremerton, Washington local area were checked weekly to determine if a qualifying storm event may develop during the next 7 days.
2. If a forecast suggested a qualifying storm, the project team conferred to decide if the storm should be considered for targeting and continued tracking. If yes, then forecasts were reviewed at least daily for the next 3-4 days.

3. Precipitation forecasts were reviewed at 72–24 hours prior to the targeted storm and the project team made the final “go/no-go” decision.
4. If a “go” decision was made, then a field sample event lead was designated for each field team and a Storm Event Controller identified.
5. The Storm Controller scheduled field team pre-storm site setup activities and was responsible for event operations until all samples were delivered to the laboratory.
6. Internet-based forecasts were archived to document targeting decisions and are available in each of the Storm Event Reports in Appendix A.

Phase I included the collection of samples from seven qualifying storm events (SW01 - SW07) at seven monitoring stations. Phase II collected four qualifying storm events (SW08–SW11) at each of the six monitoring stations and a fifth storm event (SW12) at PSNS015 to target the storm chemistry dynamics. Phase III collected samples from four qualifying storm events (SW13-SW16) at each of the six monitoring stations. Sampling was conducted at only one station during SW14, as this was a “makeup” event for a station malfunction that occurred during SW13. See Table 3-3 for a summary of the characteristics of the storms sampled during the entire study.

Unlike the Phase I sampling season, where monitoring sites were split into two distinct sampling groups, samples from all six Phase II and Phase III monitoring stations were collected concurrently during each of the targeted storm events (except during SW12 and SW14). Typically equipment was mobilized and installed at all of the selected monitoring stations between October and November during each project Phase and generally demobilized between April and May.

Table 3-1. Qualifying Storm Event Criteria

Criteria	Wet Season	Dry Season
Seasonal Period	October 1–April 30	May 1–September 30
Targeted Storm Size and Probability	≥0.20 in. in 24 hours ≥70% forecasted probability of occurrence 24 hours prior	≥0.10 in. in 24 hours ≥50% forecasted probability of occurrence 24 hours prior
Qualifying Storm Size	≥0.10 in. or a sufficient amount for sampling to have occurred for at least 2 hours during stormwater runoff	≥0.10 in., or a sufficient amount for sampling to have occurred for at least 2 hours during stormwater runoff
Antecedent Precipitation Conditions	Less than or equal to 0.1 in. rain in previous 24 hours No rain in previous 6 hours	Less than or equal to 0.02 in. rain in previous 72 hours No rain in previous 6 hours
Conditional 24-hour Antecedent Qualification[(a)]	If there is more than 0.1 in. rain in a 24-hr antecedent period, the combined overage should not exceed 10-20% of the overall storm event rainfall total. The 6-hr condition is unchanged	Does not apply for Dry Season
Inter-Event Dry Period[(b)]	6 hours minimum, 12 hours maximum	6 hours minimum, 12 hours maximum

Criteria	Wet Season	Dry Season
(a) The concept of the "*Conditional 24-hr Antecedent Qualification*" was first adopted during Phase II (2011-12) efforts and was set as a 10% exceedance of the overall storm event rainfall depth. The conditional qualification was relaxed further to 20% of the total event rainfall depth during Phase III (2012-13). (b) A storm event can be considered completed once there has been a 6-hour period with no precipitation. However, water sampling could continue, as long as runoff is occurring or the station hydrograph is elevated above pre-storm conditions, for up to a 12-hour period with no precipitation, at which time the storm would be considered complete.		

3.3 In Situ Data Collection

At each of the monitoring stations, a variety of in situ data were collected. Data types included precipitation (rainfall depth and intensity), water level in the associated piping systems (level responses due to both runoff/process inputs and tidal influences), temperature, conductivity, salinity, and sample collection information. In situ data were collected with sensors, gauges, and autosamplers as described above. These equipment were connected to, logged by, and/or controlled with a station-specific datalogger and telemetric control system (see Figure 3-2). The in situ data collection, storage, and management procedures are described in detail in the associated FSP and in the individual Storm Event Reports. A brief description is provided below.

3.3.1 Precipitation Monitoring

Precipitation was monitored via a network of rain gauges installed at each monitoring station and atop Building 427 (official PSNS gauge) within the CIA. Precipitation amounts (depth) and intensity were continuously monitored at each site. Data from the rain gauges at each station were collected and stored on dataloggers then downloaded and synthesized in each storm report. A continuous rainfall record allowed for the establishment of a rainfall/runoff relationship at each site. This relationship was used to calculate the discharge volume for the specific sampling period at each station using a variation of the Runoff Coefficient Method (RCM). Each station's rainfall totals were used to classify the storm event size based on criteria consistent with ENVVEST (Brandenberger et al. 2007a). The RCM was previously used for volume estimation purposes during implementation of the 1994 PSNS NPDES permit compliance monitoring and for all three current project Phases. The RCM is an accepted industry standard and an effective tool for providing an estimate of storm flow volumes in the absence of dedicated flow monitoring equipment. Section 7.4 of each annual FSPs for this study (TEC and PNNL 2011, 2012a and 2012b) details the application, selection of coefficients, and calculation of the RCM.

Briefly, the RCM method uses the rainfall for a specified period (e.g specific sampling event duration), total pervious and impervious areas within a particular drainage basin, and land-cover runoff coefficients, applied individually to those pervious and impervious areas, to calculate the total runoff volume in cubic feet. Runoff coefficients for the selected monitoring sites where chosen from published values for the following surface types: heavy (0.6–0.9) and light (0.5–0.8) industrial areas, railroad lines (0.2–0.4), continuous concrete or asphalt cover (0.7–0.95), heavy soil (0.18–0.22), and residential/suburban (0.25–0.4). The coefficient range gives latitude for consideration of particular basin characteristics. Typically, the upper end of the coefficient range values were applied to both the impervious portions and the pervious portions of a certain surface type when calculating runoff volumes. The formula below was slightly modified from the standard RCM so that it accounts for the effective runoff from both pervious and impervious areas from each monitored drainage basin (U.S. Navy 1996):

$$\text{Total Runoff Volume } (V) = R \times [(A_i \times C_i) + (A_p \times C_p)] \quad (2.1)$$

where

	V	=	total runoff volume (ft^3)
	R	=	total rainfall depth (ft)
	A_i	=	total impervious drainage area (ft^2)
	A_p	=	total pervious drainage area (ft^2)
	C_i	=	runoff coefficient for impervious area of the drainage basin
	C_p	=	the runoff coefficient for pervious area of drainage basin.

Table 3-2 presents this information for the monitored drainage basins, their percent pervious and impervious areas, runoff coefficient value for the basin surface types, and the total discharge volume estimation equations. In addition, the rain gauges were used for storm event tracking and identifying the event start (to schedule grab sampling for TPH) and end (to retrieve composite samples). Rain data (at least in part) were also used to enable the autosamplers and validate the storm events based on the criteria presented above. Rain gauges were maintained in accordance with established methods of data assessment and comparison, scheduled maintenance, and appropriate calibration. The official PSNS rain gauge was maintained, serviced, and downloaded by the U.S. Navy.

Table 3-2. Stormwater Outfall Basin Attributes and Total Discharge Volume

PSNS Drainage Basin ID	Total Basin Area (ft^2)	Type of Surface	Percentage of Drainage Basin Surface Type	Area of Basin Surface Type (ft^2)	Runoff Coefficient [a]	Area of Basin Surface Type with Maximum Coefficient Value Applied (ft^2)	Total Discharge Volume (ft^3)[b]
008	553,650	Impervious	94	520,431	0.8	416349	R(429,637)
		Pervious	6	33,219	0.4	13,288	
015	4,018,862	Impervious	50	2,009,431	0.8	1,607,549	R(2,411,321)
		Pervious	50	2,009,431	0.4	803,772	
032	208,653	Impervious	97	202,393	0.9	182,154	R(184,658)
		Pervious	3	6,260	0.4	2,504	
053	214,000	Impervious	98	209720	0.9	188,748	R(190,460)
		Pervious	2	4,280	0.4	1,712	
PB01	130,681	Impervious	100	130,681	0.9	117,613	R(117,613)
081.1	965,294	Impervious	97	936,335	0.9	842703	R(849,074)
		Pervious	3	28,959	0.22	6,371	
082.5	87,120	Impervious	100	87120	0.95	82,764	R(82,764)
084.1	23,958	Impervious	100	23,958	0.9	21,562	R(21,562)
096	717,872	Impervious	97	696,336	0.9	626,702	R(635,317)
		Pervious	3	21,536	0.4	8,615	
115.1	463,042	Impervious	97	449,104	0.9	361,422	R(366,390)
		Pervious	3	13,938	0.4	4,968	
124	454,000	Impervious	94.56	429,302	0.9	386,372	R(396,251)
		Pervious	5.44	24,698	0.4	9,879	
124.1	116,000	Impervious	94.56	109,690	0.9	98,721	R(101,245)
		Pervious	5.44	6310	0.4	2,524	
126	662,986	Impervious	98.55	653,373	0.9	588,036	R(591,881)
		Pervious	1.45	9,613	0.4	3,845	

(a) These values are derived from various published sources regarding the RCM.
(b) Rainfall (R) is in feet for calculation of total discharge volume.

3.3.2 Other Monitoring Data

Water level, temperature, conductivity, salinity, and autosampler operation data were also recorded. Water level data were used for several key functions including autosampler enabling, stormwater hydrograph assessment, and tidal inundation assessment. Transducers were inspected and serviced as recommended by the manufacturer at least once each month and/or prior to targeted storm events, whichever was more frequent.

Autosampler units were connected to a Campbell Scientific datalogger and telemetry system, which allowed sample processing information to be immediately available to the storm lead. Information from the autosamplers served as a record of setup and unit operation and was included in the individual storm reports (Appendix A). The autosampler downloads included programming data, enable date and time, sample marker designations, bottle information, pump cycle counts, aliquot success and associated source error codes, and sample completion date and time. For SW12 only, a LISST analyzer was deployed in situ 6 days prior to the event and provided a nearly continuous log of the particle size and volume at PSNS015. Thirty-two size classifications were collected by the LISST. These data were post-processed to aggregate them into the following size fractions: clay/silt (<63 μm), very fine/fine grain sand (64–234 μm), and medium grain sand (235–386 μm).

During the Phase III storm events (SW13 - SW16) there were two transducers installed at PSNSPB01 water quality treatment vault. One transducer measured the water level, temperature and conductivity within the treatment vault under-drain sump (just prior to the vaults' discharge point). Another transducer was used to measure water level and temperature from within the vault itself, prior to water flow entering the filter cartridges. Since samples were collected from the under-drain sump the transducer in this area provided data on water quality condition and was linked to sampler enabling functions. The transducer placed within the vault (vault floor area, among the filter canisters) provided general filter performance and rainfall/runoff response data.

3.4 Stormwater Sample Collection

All sample collection and management followed the guidance contained in the annual FSPs (TEC and PNNL 2011, 2012a and 2012b). In brief, two types of stormwater samples were collected at each monitoring site: 1) manual grab samples and 2) time-proportionate composite samples (example setup Figure 3-2). See Table 3-5 for the parameters, container types, and holding times. All non-metal sample containers and (non-metal) equipment such as the collection containers, pump tubing, and other tubing connectors were pre-cleaned and packaged to maintain cleanliness (e.g., they were double bagged and ends of sampling tubing were closed together using silicon tubing). Equipment blanks and field blanks were periodically collected to ensure sampling equipment and collection methods were not a source of contamination (see Section 4.1.2).

Sixteen validated stormwater events were sampled during the study. Table 3-3 provides a summary of the storms sampled during each Phase, storm characteristics, date, stations sampled, and the rainfall from both the station gauge and the Navy's gauge atop Building 427. Rainfall information included minimum and maximum antecedent dry period, minimum and maximum sampling duration, average station rainfall and the total storm event rainfall. The antecedent dry period was defined as the last recorded rainfall (≥0.01") prior to the onset of a qualifying targeted sampling event.

The NDDSW Study collected a total of 123 samples (67 composite and 56 grabs). In addition, 16 field duplicates were collected (9 composite and 7 grab) which is 13% of the data set. This frequency of field duplicates satisfied the quality control requirement to provide 10% or greater representation of the normal sample set. Phase I included the collection of samples from seven qualifying storm events (SW01 - SW07) from seven stations. Phase II included four qualifying events (SW08 - SW11) among six stations and one qualifying event (SW12) from one station. Phase III included three qualifying storm events (SW013, SW15 and SW16) among six stations and one qualifying event (SW14) from a single station. The following sections summarize the collection procedures for each storm event and any major anomalies encountered. Additional details for each event can be found in Appendix A.

Figure 3-2 Composite sampler ring with 1-hr composite wedge bottles labeled 1 through 24. On the left the field sampling box with the rain guage and telemetry system.

Table 3-3. Storm Event Summary for All Phases Includes Station Identification, Antecedent Dry Period, Sampling Duration and Total Rainfall

Study Phase	Storm Event ID	Event Date	PSNS Station IDs	Antecedent Dry Period Minimum (hrs)	Antecedent Dry Period Maximum (hrs)	Sampling Duration Minimum (hrs:min)	Sampling Duration Maximum (hrs:min)	Ave. Station Rainfall (in)	Storm Period Rainfall @ B427 (in)
Phase I	SW01	11/17/2010	126, 081.1, 082.5, 096	17	42	9:45	23:45	0.37	0.57
	SW02	11/29/2010	126, 081.1, 082.5, 096	69	71	23:45	23:45	1.08	1.32
	SW03	12/11/2010	126, 081.1, 082.5, 096	23	37	22:07	23:45	3.92	4.79
	SW04	3/1/2011	096, 032, 015, 008, PB01	7	9	17:30	23:45	0.40	0.60
	SW05	3/8/2011	032, 015, 008, PB01	77	77	4:30	6:45	0.07	0.19
	SW06	3/9/2011	096, 032	17	18	23:45	23:45	1.67	2.60
	SW07	4/13/2011	096, 032, 015, 008, PB01	62	63	7:45	21:45	0.61	0.78
Phase II	SW08	11/21/2011	126, 124, 124.1, 115.1, 084.1, 015	81	84	25:51	28:21	1.59	5.68
	SW09	1/20/2012	126, 124, 124.1, 115.1, 084.1, 015	72	239	10:42	23:44	1.16	1.74
	SW10	2/28/2012	126, 124, 124.1, 115.1, 084.1, 015	89	90	1:44	20:44	0.41	0.57
	SW11	3/14/2012	126, 124, 124.1, 115.1, 084.1, 015	18	34	26:06	31:13	1.42	1.79
	SW12	4/19/2012	015	34	34	17:05	17:05	0.46	0.47
Phase III	SW13	12/16/2012	126, 084.1, 053, 015, PB01	18	20	11:44	23:29	1.32	1.52
	SW14	1/8/2013	115.1	25	25	23:44	23:44	1.10	1.54
	SW15	2/22/2013	126, 115.1, 084.1, 053, 015, PB01	34	36	8:59	23:44	0.47	0.49
	SW16	3/19/2013	126, 115.1, 084.1, 053, 015, PB01	42	74	16:30	23:44	1.30	1.44

3.4.1 Storm Event Summaries

The storm event reports provide a detailed overview of the field activities including any deviations from the annual FSP, field anomalies and any corrective actions. Notable anomalies are summarized below. Detailed discussions of all recognized methodology deviations, field anomalies and corrective actions are reported in the individual Storm Event Reports in Appendix A. Data anomalies were described and discussed in the Telemetry Data Summary Report sections of the Storm Event Reports.

No major anomalies were observed or otherwise noted during any Phase of the stormwater sampling events. Minor anomalies such as labeling corrections, changes to start and stop conditions, and grab sample collection timing were documented in each storm report, see Appendix A. Below is a summary of key minor anomalies experienced during the Phases.

Phase I SW04: The pacing rate of the autosampler is typically set to collect 250 mL every 15 minutes. A default pacing rate of 0 minutes was mistakenly used to collect bottles 1-9. A correction factor was applied to the pacing rate (increased to 22.5 minutes/sample aliquot or 1.5 hours/bottle) starting at bottle 10. The remaining 15 bottles (#'s 10-24) collected water for another 22.5 hours, which provided time to properly characterize the runoff at this station.

Phase I SW06: Two rapidly moving fronts SW05 and SW06 led to the need to do a rapid station reset at the end of SW05 to prepare to collect SW06. Due to technical issues with the rapid reset, stormwater was only collected at two stations: PSNS032 and PSNS096.

Phase I SW07: Normal and duplicate composite samples were collected at PSNS008 during this event. Several discrete one-hour bottles with conductivity measurements above the threshold of ≤2000μS/cm were mistakenly included in the storm event composite. This resulted in the conductivity of both the normal and duplicate samples (4700μS/cm and 6802μS/cm, respectively) exceeding the conductivity threshold. The error was noted and the laboratory was phoned immediately. The decision was made to process the two samples via alternate/additional methods to remove the salinity interference.

There were two key changes implemented in Phase II. First in Phase I the rainfall statistics were calculated on static 1-hour segments. During Phases II and III (starting with SW08), the statistics were calculated on a "rolling 1-hour data window" to provide a more accurate and representative assessment of the actual rainfall conditions. Second, the CT2X transducers and associated stainless steel pipe rings showed signs of saltwater corrosion and components were upgraded to titanium, which is less susceptible to corrosion. To strengthen the earth grounds of all monitoring systems and to electrically isolate the transducers from all other metal components additional grounding connections were made to various sensitive system components and inert non-ferrous materials were used to insulate in-vault equipment against any dielectric effects. These maintenance items did not affect data collection or quality.

Phase II SW10: The composite sample for PSNS124.1 was comprised of only one discrete sample. Freshwater conditions occurred at this monitoring station during a very brief collection period with all other periods / bottles dominated by seawater. The FSP stipulates that composite samples should represent at least 2 hours of duration and contain a minimum of eight aliquots. The resulting sample represented 1 hour of duration and four aliquots. The sample was conditionally accepted and analyses progressed as this was considered representative of the stormwater conditions that existed at the station and did not include dilution from incoming tidal water.

Phase II SW11: The storm characteristics included two fronts in rapid succession. To capture the bulk of the second front, the pacing rates were adjusted to 30 minutes after the first front had passed through the project site. The pacing rates were adjusted back to 15 minutes prior to the arrival of the second front (during the intra-event period). Composite sample formulation for each station accounted for these changes accordingly (see SW11 Report in Appendix A). Table 3-4 provides pacing rates changes.

Table 3-4 The SW11 Composite Sample Pacing Rate Information

Station ID	Pacing Rate Changed to 30 min. (Date/Time)	Bottle Where Change Occurred	Pacing Rate Switched Back to 15 min. (Date/Time)	Bottle Where Change Occurred
PSNS015[(a)]	3/14/12 1600	7/8	3/15/12 0430	13/14
PSNS084.1	3/14/12 1530	6	3/15/12 0500	13
PSNS115.1	3/14/12 1530	7	3/15/12 0500	14
PSNS124	3/14/12 1540	5	3/15/12 0500	12
PSNS124.1	3/14/12 1530	4	3/15/12 0500	11
PSNS126	3/14/12 1730	8	3/15/12 0430	14

(a) The field duplicate collected at PSNS015 was also affected.

Phase II SW12: No grab samples were targeted during this event. SW12 was a “bonus” event to install a LISST Analyzer to provide *in-situ* particle size analysis during this event. The data form Phase I and II data for PSNS015 suggested a detailed understanding of particle size variation during the storm would provide a better understanding of changes seen in Cu and Hg concentrations. The modifications from the FSP were documented in the addendum (see Appendix B chemistry report for SW12) and included: 1) sampling only at PSNS015; 2) collecting 18 samples from the individual wedge bottles prior to creation of the composite; and 3) reducing the parameter list to total and dissolved metals, DOC, TSS, salinity, and turbidity. All other collection and compositing procedures remained consistent with the FSP (TEC and PNNL 2012a).

Phase III SW16: An error in autosampler program setting at PSNS084.1 resulted in a continuous sampling after the planned 96 aliquots were collected. This allowed the sampler to add additional water to bottles 1 and 2 after the storm event had completed. Bottles 1-3 were disqualified and the error was noted on the *Stormwater Field Sampling Form* (SW16 Report).

3.4.2 Grab Sampling

Fecal coliform (results reported separately) and TPH samples were collected using manual grab sampling methodologies as described in the annual FSPs. Precipitation, conductivity and water level data were used to guide the field team to collect grabs during the rising limb of the storm if possible. In some cases, the grab samples were collected on the falling limb due to tidal conditions (see Table A-1 from each of the SW Event Reports for specific details as to hydrograph stage). After runoff commenced and conductivity levels were less than 2,000 µmho/cm, grab samples were collected. Qualifying stormwater conditions (runoff occurrence/hydrograph response and water quality) were also verified prior to grab sample collection at each station. A sterilized and pre-cleaned stainless steel cup was dipped into the flow stream (typically by using an extension pole) at each monitoring station. A separate laboratory cleaned stainless steel cup was used at each station. The TPH samplers were poured into two separate pre-cleaned amber glass containers each containing preservative (see Table 3-5). Fecal coliform samples were collected and managed as described in the *Fecal Coliform Monitoring Assessment and Control - Water Year 2011 Quality Assurance Project Plan* (Johnston et al. 2010). Samples were stored in a cooler at 4°C until transport to the analytical laboratories. Grab and composite samples were collected as an associated pair during each storm event.

Specific times and details are provided in the individual storm event reports along with the event hydrographs for each station and storm combination (Appendix A). Grab samples were not collected during SW07, SW12, SW13, and SW14 due to the timing of the high tide relative to the peak stormwater flow. These details are contained in individual Storm Event Reports (Appendix A). In all, 50 samples and 7 duplicate grab samples were collected during 13 of the 16 targeted storm events, from all 13 monitoring stations between Phases I through III.

Table 3-5. Sample Container Types, Preservatives, Recommended Handling, and Holding Times

Parameter	Container Type	Handling / Preservation	Holding Time
Chemicals of Concern			
TPH (grab)	(2) 1-L Amber Glass	4°C ± 2°C, H_2SO_4	7 days for extraction, 40 days for analysis
Total Recoverable Metals (Al, As, Cu, Cr, Cd, Pb, Zn, Hg)	1 L Teflon	4°C ± 2°C; pH < 2.0 with nitric acid	90 days Hg and 6 months for all others
Dissolved Metals (Cu, Cr, Cd, Pb, Zn, Hg)	500 mL Teflon	4°C ± 2°C; pH < 2.0 with nitric acid after filtration	Filter (0.45 µm) within 48 hours of composite; once preserved same as above
Conventional Parameters			
Turbidity	10 L Glass	4°C ± 2°C	48 hours
TSS	1 L LDPE	4°C ± 2°C	7 days
Hardness, Total (as $CaCO_3$)	250 mL LDPE	4°C ± 2°C	14 days
TOC	250 mL LDPE w/Pres. or glass	4°C ± 2°C, H_2SO_4 or frozen	28 days
DOC	250 mL LDPE w/Pres. or glass	4°C ± 2°C, H_2SO_4 or frozen	After field filtration using GFF filter, 28 days

Low Density Polyethylene (LDPE) and Glass Fiber Filter (GFF)

3.4.3 Automated Time-Proportionate Composite Sampling

Time-proportionate composite samples were collected using autosamplers at each station during qualifying storm events as described above. Autosamplers were configured to begin sampling based on the enabling conditions discussed above were reached (rain, and/or water level, and/or conductivity conditions). Composite samples were collected for at least the first 2 hours of non-tidally affected runoff and up to 24-hours or until the storm precipitation dropped below 0.03 inches in an hour. Time-paced composites were collected into pre-cleaned polypropylene (PP) containers (discrete wedge bottles) using Isco autosampler pumps equipped with siliconized Tygon pump head tubing, Teflon-lined suction tubing, and various connectors/fittings. The FSPs details the collection, handling, analytical, and quality control procedures associated with the composite sampling. Further, the individual SW Event Reports provide additional details regarding the collection and formulation of the composite samples and any issues encountered. The following sections briefly described these procedures.

The autosamplers were programmed to collect sequential samples over the course of a targeted event. A 24-bottle configuration was used to provide adequate sampling resolution (see Figure 3-2). In this configuration, each of the individual wedge bottle contained up to four aliquots, which were paced at 15 minutes apart to provide a 1-hour discrete sample. The conductivity of each discrete sample was measured and only samples with conductivity concentrations of less than 2,000 µmho/cm were included in the formulation of the station's overall composite sample, i.e. EMC. The acceptable discrete samples were then equally composited in a 10-L pre-cleaned glass jar. Details on the specific compositing plans are contained within each of the SW Event Reports in Appendix A. The SW12 event was the only example of where individual discrete samples were collected and analyzed along with an EMC composite sample.

3.4.4 Field Sample Validation, Preservation, and Handling

Prior to creating the storm EMC samples, the grab samples and individual discrete samples (one of up to 24 wedge bottles per autosampler) were validated against the following criteria:

1. Review field forms and the precipitation, water level, and conductivity data to ensure the grab samples were collected during storm runoff;
2. Review field notes to determine whether anomalous conditions were encountered that would disqualify the grab or discrete samples;
3. Inspect the grab, discrete samples, and EMC sample containers to ensure they were properly filled and labeled;
4. Review the storm event hyetograph, hydrograph, and timing of the sample aliquot collection to ensure that the discrete samples were collected within the first 2 hours of non-tidally influenced runoff;
5. Test the conductivity of each discrete wedge bottle to ensure <2,000 µmhos/cm;
6. Test the turbidity of each discrete wedge bottle; and
7. Confirm the EMC consisted of at least eight sample aliquots (two 1-L discrete wedge bottles).

The EMC samples (final composite) were prepared in a 10-L pre-cleaned glass jar stored at 4±2°C until hand delivered to PNNL. Grab samples collected for TPH were stored at 4±2°C and hand delivered to PNNL. Table 3-5 lists the sample containers, preservatives, and analytical holding times for each parameter. Upon receipt at PNNL, the condition of all the samples was verified as acceptable and tracked back to the field chain of custody (COC). In the clean laboratory at PNNL, each EMC was shaken vigorously (prior and between aliquot removal) the create the following samples.

1. Total Metal (TME) samples in a pre-cleaned Teflon bottle.
2. Dissolved metals (DME) samples in a 500-mL precleaned Teflon bottle after filtration with a 0.45-µm polyvinylidene fluoride (PVDF) filter unit in a class 100 clean bench.
3. Total Organic Carbon (TOC) samples stored in 250-mL LDPE bottles precharged with sulfuric acid preservative.
4. Hardness samples stored in 250-mL LDPE bottle precharged with nitric acid preservative.

5. Dissolved Organic Carbon (DOC) stored in 250-mL LDPE containers with sulfuric acid preservative after filtrations using a pre-cleaned 60-mL syringe with an ashed glass fiber filter (GFF).
6. Total suspended solids (TSS) stored in 500-mL or 1-L LDPE bottles.

The TME and DME fractions were acidified inside a Class 100 clean bench to a pH of <2.0 with double distilled nitric acid. The TPH grab samples and composites for TOC, DOC, hardness, and TSS were all forwarded to Columbia Analytical Laboratory Services (CAS) for analyses. The only exception was the SW12 samples for TOC, DOC, and TSS were analyzed at PNNL because lower detection limits were required. See Appendix B for the detailed chemistry reports for each storm event.

4.0 Laboratory Methods and Quality Control Results

The chemicals of concern for this project included total recoverable and dissolved Al, As, Cu, Cr, Cd, Pb, Zn, Hg, and TPH (see Table 3-5). Ancillary parameters included turbidity, TSS, hardness, TOC, and DOC. Table 4-1 lists the sample preparation and analytical methods along with the method detection limit (MDL) and reporting limit (RL). Collectively, these methods incorporate aspects of the EPA Method 1669 (EPA 1995) for clean hands sample collection and ambient water quality analyses methods (Method 1638 for metals [EPA 1996a] and Method 1631 for Hg [EPA 2002b]) to adequately represent ambient water chemistry. Although stormwater is not considered ambient water, it was critical to incorporate these protocols because industrial areas often have other sources of contamination at the outfall sampling locations. Once a sample is collected, it must be isolated from the industrial processes occurring around the manhole because contamination of the sample would mean the sample would no longer represent the chemistry of the stormwater transferred through the piped conveyance.

The following sections summarize the field quality control, laboratory quality control, and the overall usability of the data. The objective for the usability, quality, type, and output of data collected are to both achieve the requirements specified in the draft NPDES permit and provide sufficiently low-level detection methods to support a measure of process improvement at the shipyard. The data will also provide comparable data for the ENVVEST runoff model. The quality and usability of laboratory data generated in this investigation were evaluated for precision, accuracy (bias), representativeness, comparability, completeness, and sensitivity. The data were found to have acceptable measures of each of these variables. The overall precision was evaluated using the field duplicates, laboratory duplicates, and duplicate matrix spikes. The accuracy was evaluated using the equipment blank results, matrix spikes (MS), laboratory control sample (LCS), and standard reference material (SRM). The representativeness, comparability, and sensitivity were derived from the laboratory method blanks, MDLs, RLs, and comparable methodology in collection and analytical procedures (e.g., time-paced composites vs. grab samples). To provide more sensitive measurements of TSS and TOC/DOC, the methods were modified starting with SW12. The more precise measurements allow the assessment of the bioavailability of the metals and the application of the biotic ligand model (BLM). The BLM has been developed to account for ancillary parameters like TSS and DOC that affect Cu bioavailability in freshwater (EPA 2007) and saltwater (DOD/EPA 2011; Hydroqual 2011).

Table 4-1. Preparation and Analytical Methods for the Non-Dry Dock Stormwater Samples

Parameter	Preparation Method	Analytical Method	Method Detection Limit (MDL)[a]	Reporting Limit (RL)
TSS	NA	EPA 160.2[b] SM2540D[b]	5.0 mg/L 0.49 mg/L[b]	5.0 mg/L 0.49 mg/L[b]
Turbidity	NA	180.1	0.1 NTU	0.1 NTU
Hardness (as $CaCO_3$)	NA	STM2340C	0.8 mg/L	2 mg/L
TOC/DOC	DOC: Ashed GFF filtration	SM5310C[c] HTCO[c]	0.07 mg/L 0.03 mg/L[c]	0.50 mg/L 0.095 mg/L[c]
TPH (DRO)	EPA 3510C	NWTPH-Dx	11–13 µg/L[d]	250 µg/L
TPH (RRO)	EPA 3510C	NWTPH-Dx	19–22 µg/L[d]	500 µg/L
Al	TRM EPA 1640m	EPA 1638m	0.3 µg/L	1.0 µg/L
As	TRM EPA 1640m	EPA 1638m	0.03 µg/L	0.1 µg/L
Cu	TRM EPA 1640m	EPA 1638m	0.007 µg/L	0.02 µg/L
Cr	TRM EPA 1640m	EPA 1638m	0.08 µg/L	0.3 µg/L
Cd	TRM EPA 1640m	EPA 1638m	0.004 µg/L	0.01 µg/L
Pb	TRM EPA 1640m	EPA 1638m	0.002 µg/L	0.006 µg/L
Zn	TRM EPA 1640m	EPA 1638m	0.05 µg/L	0.2 µg/L
Hg	EPA 1631 Rev E	EPA 1631 Rev E	0.1 ng/L	0.3 ng/L

a) The MDL was reported from the annually verified MDL study as determined by seven replicates of deionized water spiked at appropriate concentrations and prepared using the Total Recoverable Metals (TRM) method. The RL = 3.18 × MDL.
b) For SW01-SW11 the TSS samples were analyzed by EPA Method 160.2. For SW12 – SW16 the method was changed to a more sensitive method SM2540D, which uses a gravimetric analysis with a modification to use a nucleopore membrane filter to obtain lower detection limits and prevent false positives due to glass fiber filters. The more accurate TSS measurement is needed for modeling and BLM calculations.
c) For SW01 – SW11 the TOC/DOC method was EPA 5310C. For SW12- SW16 the method changed to a more sensitive High Temperature Catalytic Oxidation (HTCO) more appropriate for supporting BLM calculations.
d) MDLs were sample-specific based on the volume extracted. See data table for individual MDLs.

Storm drain particulates were collected during setup, recovery, and maintenance of the autosamplers installed in the stormwater vaults. The sediments were collected and analyzed per the existing ENVVEST sediment sampling and analysis plan (Johnston et al. 2011) and also detailed in each FSP for this study. Table 4-2 lists the analytical methods for each parameter. The storm drain particulates were collected using pre-cleaned plastic spatulas to scoop available particulates from 3-5 locations within the sediment vault that were composited in a pre-cleaned 8oz. glass jar. Due to the potential for high concentrations of contaminants, the sample collection team wore disposable boot covers and used a new set of equipment at each outfall location. This ensured no cross contamination between outfalls and no tracking of particulates outside of the vault area. Appendix F provides the details for each batch of samples.

Table 4-2 Storm drain particulate analytical methods.

Parameter	Analytical Method[1]
Total Organic Carbon	ASTM D4129-82 M
Metals	EPA 1638/1640m[2]
Hg	DMA[2]
PAH	GC-MS[2]
PCB	GC-ECD[2]

[1]Sediment Methods, detection limits, and reporting limits are provided in Johnston et al. (2011) sediment verification study sampling and analysis plan.

[2]Sediment will be analyzed for metals, Hg, PAH, and PCB following the methods detailed in Johnston et al. (2011) and will remain consistent with the ENVVEST protocol to ensure comparability across projects.

4.1 Field Quality Control

Field quality control (QC) included documented procedures specific to field activities, including calibrating field equipment, sample collection documentation, QC samples, data review and verification, field team performance, and system audits and possible corrective actions for activities. These elements were described in detail during each of the three FSPs (TEC and PNNL 2011; 2012a; 2012b). Field event preparation and sampling records were included in each of the storm event reports (see Appendix A).

Field QC samples were used to assess sample collection procedures, environmental conditions during sample collection, storage, and transport to the laboratory, and the cleanliness of the equipment and sampling containers. The types of field QC samples collected were field duplicate samples and equipment blanks (including tubing, discrete wedge bottles, composite bottles and sample bottles). Field QC samples were labeled and tracked as individual samples. The collection frequency was greater than the target of 10% of the environmental samples collected for chemicals of concern (e.g., metals and TPH). In addition, other field QC procedures used to ensure consistency, reduce contamination, and ensure representative samples were as follows:

- Collect composite samples using automatic samplers for all parameters except TPH (grabs due to container requirements) consistent with previous studies.
- Collected samples in certified contaminant-free or properly decontaminated containers as demonstrated by the equipment blank samples.
- Store sampling containers in clean, sealed boxes, coolers or bags prior to use.
- Use "clean hands/dirty hands" sampling techniques (e.g., one team member performs "dirty tasks" such as lifting manhole covers and handling samplers with batteries, while the other member performs "clean tasks" such as handling sample intake lines and sample collection bottles).

- Periodically clean or replace Teflon-lined sampler tubing and sampler strainers.
- Backflush sampler tubing with deionized water prior to each sampling event.
- Deliver samples to laboratory with proper COC forms, appropriate preservation and within recommended holding times.

4.1.1 Field Duplicates

Field duplicates provided a measure of field specific variability. All field duplicate samples were collected in an identical manner to the “parent” sample and were treated as independent samples. Field duplicates consisted of an “internal” duplicate, which included a replicate collected at the same time using a single autosampler configuration. The autosampler was programmed to collect sequential aliquots of stormwater and deliver them to two separate sets of bottles. In addition, field duplicates were collected for those parameters that required grab samples (i.e., TPH, fecal coliform) by filling an additional set of grab sample bottles in rapid succession. The field duplicate samples were used to evaluate whether environmental conditions were more variable than the sampling design could accommodate.

The project created 67 EMCs that included 8 EMC field duplicates collected at PSNS126 (3), PSNS008 (2), PSNS015, PSNS084.1, and PB01. Table 4-3 provides a summary of the project quality control samples. For the metals of concern (Cu, Pb, Zn, Hg, As, Ag, Cd, Cr, Al) the relative percent differences (RPDs) between field duplicates ranged 0-40% RPD with an average of 8% RPD. This meets the data quality objective of ≤40% RPD suggesting the methodology accurately captures variability at a particular station within a given storm event. There were two outliers (40% and 39% RPD) noted for Hg at stations PSNS015 and PSNS126. All other field duplicates met the QC criterion for laboratory duplicates of ≤30%. The variability appeared to be driven by the particulate fraction of Hg and is discussed further in Section 5.3.

Field duplicate for all other parameters were ≤40% RPD. The one high RPD (67%) was noted for TSS during SW09 at station PSNS126. A second field duplicate was collected at this station during SW10 with 10% RPD for TSS. The SW09 event was a large storm (>1 in.) and larger storms would be expected to have higher TSS variability.

4.1.2 Equipment Blanks

Equipment blanks (EBs) exceeded a frequency of 1 out of every 10 samples for metals and 1 per sample container lot for TPH. EBs were used to check for possible contamination of laboratory-cleaned grab sample equipment, autosampler equipment, and sample containers for the chemicals of concern (TPH and metals). Table 4-2 summarizes the EBs and records if there were samples potentially impacted by EBs with detectable metals or TPH. The EBs were also used to detect contamination from the surroundings at the sampling location or cross-contamination during transportation and/or storage. For TPH, EBs were collected by pouring deionized water (DI) into the stainless steel sampling cup and then into an amber glass sample container while at randomly selected outfall location. The TPH concentration in the EBs were not detected above the Reporting Limit (RL).

For the metals, there was a total of 30 EBs for the 134 samples. The autosampler equipment used to collect EBs included the Teflon sample tubing, autosampler pump and distributor arm tubing, glass composite jars, and sample containers (aka wedge bottles). DI was pumped through the deployed tubing, autosampler, laboratory cleaned sample intake line and strainer, and into the pre-cleaned glass composite jar. The EB samples were assigned a unique sample identification code, labeled, and delivered to the laboratory as a sample. At the laboratory, they were handled as a sample and split into pre-cleaned Teflon bottles for total metals. All the EBs were less than the RLs except Cr, Cu, Pb, and Zn. This triggered the corrective action, which included a review of the analytical method blanks to rule out laboratory contamination, a review of the clean hands sampling protocol, and all data were evaluated if the storm event concentrations were <5 times the EB concentrations. Table 4-2 summarizes the mean EB concentrations compared to the MDL, RL, and shows the percentage of the data set potentially impacted by the detected blanks. The priority metals, Cu, Pb, and Zn were not impacted by the detected blanks. The Cr data are considered potentially impacted by the equipment blanks. However, Cr is not a metal of concern, but an indicator that the corrosion of stainless steel may be compromising the samples.

Table 4-3. Summary of 30 Equipment Blank Concentrations for the Metals and any Sample Impacts

	MDL	RL	EB Mean	Standard Deviation	% Samples <5 times EB Mean (number) out of 134 samples
Hg (ng/L)	0.1	0.3	0.2 J	0.05	NA
Ag (µg/L)	0.002	0.006	< MDL	--	NA
As (µg/L)	0.03	0.1	< MDL	--	NA
Cd (µg/L)	0.004	0.01	0.007 J	0.004	NA
Cr (µg/L)	0.08	0.3	0.4	0.8	66% (89)
Cu (µg/L)	0.007	0.02	0.1	0.2	0
Pb (µg/L)	0.002	0.006	0.02	0.02	2% (3)
Zn (µg/L)	0.05	0.2	0.5	0.4	0

NA – not applicable; U value not detected above the MDL; and J estimated concentration below the RL.

4.2 Laboratory Quality Control

The FSPs detailed the laboratory procedures necessary to achieve the data quality objectives through appropriate analytical methods, quality assurance (QA)/QC, and data validation. The QC samples analyzed with each batch of 20 or fewer field samples included method blanks, laboratory control samples (LCSs), matrix spikes (MSs), matrix spike duplicates (MSDs), laboratory duplicate (DUP), and SRM for the metals. The TPH samples included method blanks, LCSs, and DUPs. The QC data were provided in the individual storm chemistry reports (Appendix B) and summarized in Table 4-3 for all the parameters. The summary included both freshwater and seawater methods required for SW12, because both discrete intervals of the storm and the EMC were analyzed.

The FSPs provide details about the sample preparation and analytical methods, which can also be found in Appendix B for each of the storm events. The following is a brief description of the methods, quality control samples, and a discussion on any impacts to the data quality. The methods were either standard methods or modifications of EPA methods where quality control is assessed through SRMs. A short synopsis of method modification is provided below. PNNL maintains a National Environmental

Laboratory accreditation for the modified methods. Methods not described below follow the EPA methods exactly (i.e., Hg).

Samples were analyzed for TME and DME metals (except Hg) by inductively coupled plasma-mass spectrometry (ICP-MS) in accordance with standard operating procedure (SOP) MSL-I-022, "Determination of Elements in Aqueous and Digestate Samples by ICP/MS." The base methods for this procedure are EPA Method 1638 and EPA Method 1640 (EPA 1996a, b). Freshwater samples (defined as salinity <2 ppt) were digested by following the total recoverable metals (TRM) method established in EPA Method 1640 (EPA 1996b) prior to analysis by ICP-MS. Both the filtered and unfiltered fractions were prepared using this method to destroy any colloidal particles.

Seawater samples were preconcentrated via a precipitation step followed by reconstitution in a salt-free solution in accordance with SOP MSL-I-025, "Methods of Sample Preconcentration: Iron and Palladium/APDC Coprecipitation and Borohydride Reductive Precipitation for Trace Metals Analysis in Water." Preconcentrated seawater samples were analyzed for Al, Ag, Cd, Cr, Cu, Pb, and Zn by ICP-MS. Seawater data were reported as reagent corrected for the metals requiring Fe/Pd preconcentration (Al, Ag, Cd, Cr, Cu, Pb, and Zn) and denoted with a b-flag. The required preconcentration procedure for seawater samples analyzed by ICP-MS includes the addition of chelating agents to induce precipitation of metals under specific conditions. Subsequently, reagents added to the samples should be of the purest quality to result in zero addition of metals to the seawater samples. Unfortunately the reagents have trace impurities of these metals and the data must be reagent blank corrected for Al, Ag, Cd, Cr, Cu, Pb, and Zn. Results were corrected using the mean batch reagent blank (≥3 blanks) identified for each preparation batch (identified as BMRB_analysis date) and provided in Appendix B for each storm.

The TOC/DOC method for SW01 through SW11 was the Standard Method for wet oxidation (SM5310C). For SW12 through SW16 the method changed to a new highly precise High Temperature Catalytic Oxidation (HTCO) method. The instrument is specially equipped with a high-salt sample combustion tube kit and halogen scrubber for seawater analysis. Seawater samples were acidified to pH <2 by concentrated hydrochloric acid prior to analysis then sparged for 2 minutes to remove inorganic carbon. The non-purgeable organic carbons (NPOC) in samples were further converted to CO_2 by oxidation at 680°C with a platinum catalyst. A non-dispersive infrared detector was used to detect the converted CO_2 for quantification of NPOC.

Overall the data met the QC requirements. The only consistent issue was that the Hg concentrations at PSNS015 were highly variable both in the laboratory and the field duplicates. High RPDs in laboratory duplicates for Hg are highly unusual unless elemental Hg is present (i.e. silver beads). The RPDs for laboratory duplicates ranged from 1 to 93% RPD for PSNS015. In each case, the samples were re-analyzed to verify that the issue was not associated with the laboratory procedure. Lab duplicates of the dissolved fraction yielded acceptable RPDs from PSNS015. In fact, the average RPD for TME Hg at PSNS015 was 36% from 11 duplicates while the DME average was 2% RPD. All stormwater samples collected at this site should be duplicated to understand the variability.

Table 4-4. Laboratory Quality Control Sample Summary

QC Type		Hg	As	Ag	Cd	Cr	Cu	Pb	Zn	TPH DRO	TPH RRO
MB	n =	64	19	19	19	19	19	19	19	9	9
MB	Mean	<RL	<MDL	<MDL	<MDL	<RL	<MDL	<MDL	<RL	<RL	< RL
MB	Stdev	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
Percent Recovery (%)											
LCS	n =	32	16	16	16	16	16	16	16	10	10
LCS	Mean	102%	98%	98%	100%	102%	99%	100%	98%	104%	97%
MS	n =	48	31	29	31	31	31	31	31	NA	NA
MS	Mean	102%	101%	96%	100%	100%	98%	102%	101%	NA	NA
SRM[(a)]	n =	14	17	17	17	17	17	17	17	NA	NA
SRM[(a)]	Mean	96%	97%	92%	98%	97%	97%	98%	96%	NA	NA
Relative Percent Difference (RPD)											
Lab Dup	n =	19	17	15	16	16	16	16	16	8	8
Lab Dup	Mean	22%	3%	11%	4%	3%	1%	1%	1%	13%	13%
Field Dup[(b)]	n =	16	16	13	16	16	16	16	16	7	7
Field Dup	Mean	13%	7%	11%	8%	6%	4%	11%	4%	21%	31%

Ancillary Parameters[(c)]

QC Type		DOC 5310	DOC HTCO	TOC 5310	TOC HTCO	TSS 160.2	TSS SM2540D	Hardness
MB	n =	12	11	15	11	16	10	9
MB	Mean	< RL	< RL	<MDL	< RL	<MDL	<MDL	<MDL
Percent Recovery (%)								
LCS	n =	12	27	17	27	13	8	12
LCS	Mean	98%	100%	98%	100%	97%	90%	105%
MS	n =	8	NA	6	NA	NA	NA	NA
MS	Mean	100%	NA	100%	NA	NA	NA	NA
SRM	n =	NA	12	NA	12	NA	NA	NA
SRM	Mean	NA	96%	NA	96%	NA	NA	NA
Relative Percent Difference (RPD)								
Lab Dup	n =	31	11	36	11	1	2	9
Lab Dup	Mean	5%	6%	3%	6%	4%	10%	2%
Field Dup	n =	6	2	6	2	6	2	9
Field Dup	Mean	11%	2%	9%	2%	17%	24%	10%

Storm Drain Particulate Parameters

QC Type		Hg	Metals[(d)]	PAHs	PCBs	TOC
MB	n =	2	2	1	1	2
MB	Mean	<MDL	<MDL	<MDL	<MDL	<RL
Percent Recovery (%)						
LCS	n =	2	16	1	1	NA
LCS	Mean	102%	101%	109%	96%	NA
MS	n =	2	16	NA	2	NA
MS	Mean	98%	94%	NA	99%	NA
SRM	n =	2	16	1	1	NA
SRM	Mean	93%	89%	74%	80%	NA
Relative Percent Difference (RPD)						
Lab Dup	n =	2	16	NA	NA	NA
Lab Dup	Mean	3%	14%	NA	NA	NA

(a) Includes SRMs 1640 and 1641d.
(b) Field duplicate count for metals includes both total and dissolved fractions.
(c) Includes the QC samples for the original DOC/TOC method for SW1-11 (5310) and the more sensitive method for SW12-SW16 (HTCO). The original method for TSS was 160.2 for SW 1-11, which changed to a more sensitive method

(HTCO) for SW12-16.
(d) As, Ag, Cd, Pb, Cr, Cu, Ni, Zn
EB = equipment blank; MB = method blank; LCS = laboratory control sample; MS = matrix spike
SRM = standard reference material; Lab Dup = laboratory duplicate; Field Dup = field duplicate; TPH = total petroleum hydrocarbons; DRO = diesel range organics; RRO = residual range organics.

Storm drain particulate samples were analyzed for Ag, As, Cd, Cr, Cu, Pb, Ni and Zn. Samples were freeze-dried and homogenized using a ball-mill prior to digestion. Sediment samples were digested in accordance with Battelle SOP MSL-I-006, Mixed Acid Sediment Digestion. An approximately 200-mg (dry weight) aliquot of each sample was combined with nitric and hydrochloric acids (aqua regia) in a Teflon bomb and heated in an oven at 130ºC (±10ºC) for a minimum of eight hours. After heating and cooling, deionized water was added to the sediment digestate to achieve analysis volume.

Storm drain particulates were extracted for PCBs and PAHs following general National Atmospheric and Oceanic Administration (NOAA) National Status and Trends (NS&T) methods. Approximately 10 g of wet sediment was mixed with pre-cleaned anhydrous sodium sulfate, spiked with surrogates and extracted with methylene chloride using accelerated solvent extractor (ASE). For PCBs, the extract was processed through an alumina cleanup column, concentrated, and further cleaned up by Florisil cleanup column. The extract was finally concentrated via gentle nitrogen stream and fortified with internal standard (IS) before analysis. PCB congeners were analyzed using gas chromatography with electron capture detection (GC/ECD). For PAHs, the extract was concentrated and processed through an alumina cleanup column. The extract was finally concentrated via gentle nitrogen stream and fortified with internal standard (IS) before analysis. PAHs were analyzed using gas chromatography mass spectrometry (GC/MS). Sample data were quantified by the method of internal standards using the surrogate compounds.

5.0 Results and Discussion

Over the course of this study, 16 qualifying storm events were sampled in Phase I 2010-11, Phase II 2011-12 and Phase III 2012-13 (see Table 3-3). The field collection details for each storm are reported in Appendix A. The chemistry data are reported in Appendix B. Each event report (field and chemistry) contained a summary of storm event-specific qualification parameters, sample collection criteria, QC information, and storm and sample validation checklist items. The following sections combine the results from the individual annual reports into a synoptic view of the study and a discussion on the findings.

5.1 Rainfall and Runoff Data

Rainfall data were collected from each monitoring station and from the PSNS Navy gauge (B427) continuously during the project and the sixteen qualifying storm events. Figure 5-1 illustrates the total event rainfall from each station for the 16 storm events sampled from 2010-2013. Table 5-1 through 5-3 provide a summary of the rainfall data collected during each Phase and the calculated runoff for each storm event (used to calculate the load). The tables also provide the average and range of rainfall across the PSNS sampling locations to illustrate the variability even within PSNS during a given storm. The total event rainfall was used to classify the storm size based on the ENVVEST storm size classification (Brandenberger et al. 2007a). The project sampled stormwater during the following size distribution of storms: 3 small = <0.5 in., 4 medium = 0.5–1.0 in., 7 large = 1.0–2.0 in., and 2 extra-large = ≥2.0 in. Classifying the storms based on size, basin LULC, and water quality parameters provides a means of further developing relationships between metrics that are easily acquired, such as LULC data and the associated contaminant concentrations. This data also helps to fill the gaps in stormwater characterization of high density urban outfalls identified in the previous ENVVEST reports (Brandenberger et al. 2007a, b; Cullinan et al. 2007). This is discussed further in the sections on stormwater chemistry.

A rainfall and runoff relationship for each station was established using the continuous rainfall record. These relationships were used to estimate the total volume of discharge during the sampling period using the RCM calculations discussed previously in Section 3. This method uses the sampling period rainfall, pervious and impervious drainage area size, and a runoff coefficient to calculate the total runoff volume in cubic feet. Runoff coefficients for the selected stations where chosen from published values and were provided in Table 3-2 along with the descriptive information for each basin (e.g., basin area, type of surface, etc.). The coefficient ranges give latitude for consideration of particular basin characteristic. The maximum coefficient range was applied to both the impervious portions and the pervious portions of a surface type to provide the maximum volume discharged for an environmentally conservative estimate. The maximum coefficient values were also used because of the high proportion of impervious surface in each drainage basin.

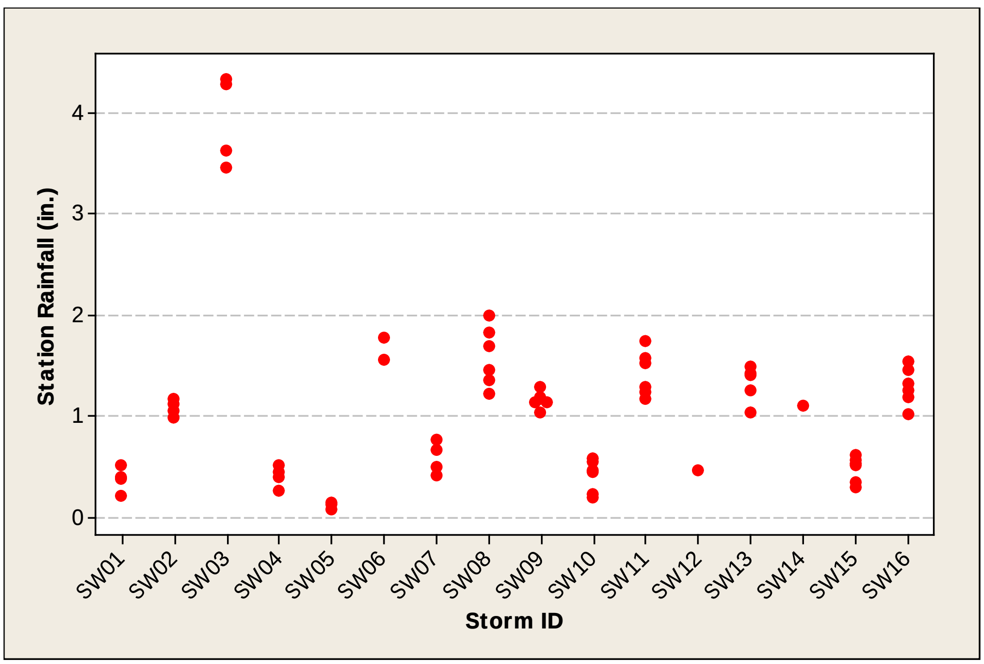


Figure 5-1 Total even rainfall at each station sampled during the 16 storm events from 2010-2013.

Table 5-1. Phase I Total Rainfall (inches) for Each Storm Event, Calculated Runoff, and the ENVVEST Storm Size Classification

Station	SW	1	2	3	4	5	6	7
	Date	11/17/10	11/29/10	12/10/10	3/1/11	3/8/11	3/9/11	4/13/11
B427 – Navy Gauge		0.57	1.32	4.79	0.60	0.19	2.60	0.78
PSNS126	Rainfall (in.)	0.39	1.05	3.62	--	--	--	--
	Runoff (ft^3)	19,236	51,790	178,551	--	--	--	--
PSNS096	Rainfall (in.)	0.21	1.12	4.29	0.26	--	1.78	0.41
	Runoff (ft^3)	11,118	59,296	227,126	13,765	--	94,239	21,707
PSNS82.5	Rainfall (in.)	0.51	1.17	4.33	--	--	--	--
	Runoff (ft^3)	3,518	8,069	29,864	--	--	--	--
PSNS81.1	Rainfall (in.)	0.38	0.98	3.45	--	--	--	--
	Runoff (ft^3)	26,887	69,341	244,109	--	--	--	--
PSNS032	Rainfall (in.)	--	--	--	0.40	0.12	1.56	0.49
	Runoff (ft^3)	--	--	--	6,155	1,847	24,006	8,925
PSNS015	Rainfall (in.)	--	--	--	0.44	0.08	--	0.67
	Runoff (ft^3)	--	--	--	88,415	16,075	--	134,632
PSNS008	Rainfall (in.)	--	--	--	0.51	0.15	--	0.76
	Runoff (ft^3)	--	--	--	18,260	5,370	--	27,210
Storm Average Rainfall (in.)[(a)]		**0.37**	**1.08**	**3.92**	**0.40**	**0.12**	**1.67**	**0.58**
Min (in.)		0.21	0.98	3.45	0.26	0.08	1.56	0.41
Max (in.)		0.51	1.17	4.33	0.51	0.15	1.78	0.76
ENVVEST Storm Size[(b)]		S	L	XL	M	S	XL	M

(a) Rain total averages do not include data from the B427 gauge.

(b) Storm size classification (Brandenberger et al. 2007a): Small (S) = <0.5 in., Medium (M) = 0.5–1.0 in., Large (L) = 1.0–2.0 in., Extra-large (XL) = ≥2.0 in.

-- Not sampled.

Table 5-2. Phase II Total Rainfall (inches) for Each Storm Event, Calculated Runoff, and the ENVVEST Storm Size Classification

Station	SW	08	09	10	11	12
	Date	11/21/11	1/20/12	2/28/12	3/14/12	4/19/12
B427 – Navy Gauge		1.83	1.74[a]	0.57	1.42	0.47
PSNS126	Rainfall (in.)	1.36	1.03	0.45	1.29	--
	Runoff (ft^3)	67,080	50,803	22,196	63,627	--
PSNS124.1	Rainfall (in.)	1.99	1.13	0.23	1.52	--
	Runoff (ft^3)	16,790	9,534	1,941	12,824	--
PSNS124	Rainfall (in.)	1.22	1.18	0.19	1.23	--
	Runoff (ft^3)	40,286	38,965	6,274	40,616	--
PSNS115.1	Rainfall (in.)	1.45	1.17	0.46	1.17	--
	Runoff (ft^3)	44,272	35,723	14,045	35,723	--
PSNS084.1	Rainfall (in.)	1.69	1.13	0.55	1.58	--
	Runoff (ft^3)	3,037	2,030	988	2,839	--
PSNS015	Rainfall (in.)	1.82	1.29	0.58	1.75	0.46
	Runoff (ft^3)	365,717	259,217	116,547	351,651	92,434
Storm Average Rainfall (in.)[b]		**1.59**	**1.16**	**0.41**	**1.42**	**0.46**
Min (in.)		1.22	1.03	0.19	1.17	0.46
Max (in.)		1.99	1.74	0.58	1.75	0.47
ENVVEST Storm Size Classification[c]		L	L	M	L	S

(a) The B427 rain gauge was likely initially clogged with snow pack. The gauge did not record its first tip until approximately 5 hours after the monitoring sites recorded their first tips and the total rain amount is much greater than any station.
(b) Rain total averages do not include data from the B427 gauge.
(c) Storm size classification (Brandenberger et al. 2007a): Small (S) = <0.5 in., Medium (M) = 0.5–1.0 in., Large (L) = 1.0–2.0 in., Extra-large (XL) = ≥2.0 in.
-- Not sampled.

Table 5-3. Phase III Total Rainfall (inches) for Each Storm Event, Calculated Runoff, and the ENVVEST Storm Size Classification

Station	SW	13	14	15	16
	Date	12/16/12	1/8/13	2/22/13	3/19/13
B427 – Navy Gauge		1.52	1.53	0.49	1.42
PSNS126	Rainfall (in.)	1.04	--	0.34	1.02
	Runoff (ft^3)	51,296	--	16,770	50,310
PSNS115.1	Rainfall (in.)	--	1.10	0.29	1.19
	Runoff (ft^3)	--	37,564	9,903	40,638
PSNS084.1	Rainfall (in.)	1.25	--	0.50	1.26
	Runoff (ft^3)	2,246	--	898	2,264
PSNS053	Rainfall (in.)	1.40	--	0.61	1.32
	Runoff (ft^3)	22,220	--	9,682	20,951
PSNS015	Rainfall (in.)	1.49	--	0.56	1.46
	Runoff (ft^3)	299,406	--	112,528	293,377
PSNSPB01	Rainfall (in.)	1.42	--	0.50	1.54
	Runoff (ft^3)	13,917	--	4,901	15,094
Storm Average Rainfall (in.)[(a)]		**1.32**	**1.10**	**0.47**	**1.30**
Min (in.)		1.04	1.1	0.29	1.02
Max (in.)		1.49	1.1	0.61	1.54
ENVVEST Storm Size Classification[(b)]		L	L	M	L

(a) Rain total averages do not include data from the B427 gauge.

(b) Storm size classification (Brandenberger et al. 2007a): Small (S) = <0.5 in., Medium (M) = 0.5–1.0 in., Large (L) = 1.0–2.0 in., Extra-large (XL) = ≥2.0 in.

-- Not sampled.

When identifying a representative outfall sampling location, several factors needed to be considered including typical rainfall intensity, volume of discharge at the sampling location, and tidal intrusion into the storm drain. Appendix C provides the descriptive statistics for all the in-situ parameters including rainfall (total and intensity), vault level, conductivity, salinity, and temperature. This includes the maximum 1-hour rainfall intensity and storm average 1-hour rainfall intensity (both in inches/hour). The in-situ parameters for the vault were also assessed in 5-minute intervals. These data illustrate the variability in the rainfall statistics across the PSNS stations. Detailed discussions for each storm are provided in Appendix A Strom Event Reports.

The rainfall and storm characteristics were compared to the average daily conditions during the project to determine the representativeness of the sampled storms. The average daily rainfall (in.) during sampled storm events (n = 16) was compared to the average daily rainfall from November-April 2010-2013 (n = 449). Descriptive statistics including the sample size, mean, standard deviation, quartiles, and range of the sampled storm characteristics were calculated. The average daily rainfall (in.) was significantly greater during sampled storms (95% CI: 0.43 – 1.47 in.) than during all daily rainfall between November-April 2010-2013 (95% CI: 0.19 – 0.27 in.). The daily rainfall during sampled storm events ranged from 0.08 to 3.25 in. The quartiles (Q1, Q2, and Q3) and maximum daily rainfall from all rainy days over the study period were 0.03 in., 0.15 in., 0.43 in., and 3.48 in. Thus, even though sampled storm events tended to be larger storms, the sampling included storms that were below the median rainfall of all rainy days. Figure 5-2 illustrates the relationship between the daily rainfall from B427 Navy Gauge during the project compared to the sampled storm events. Therefore the storms were considered representative of the annual storm conditions during the study.

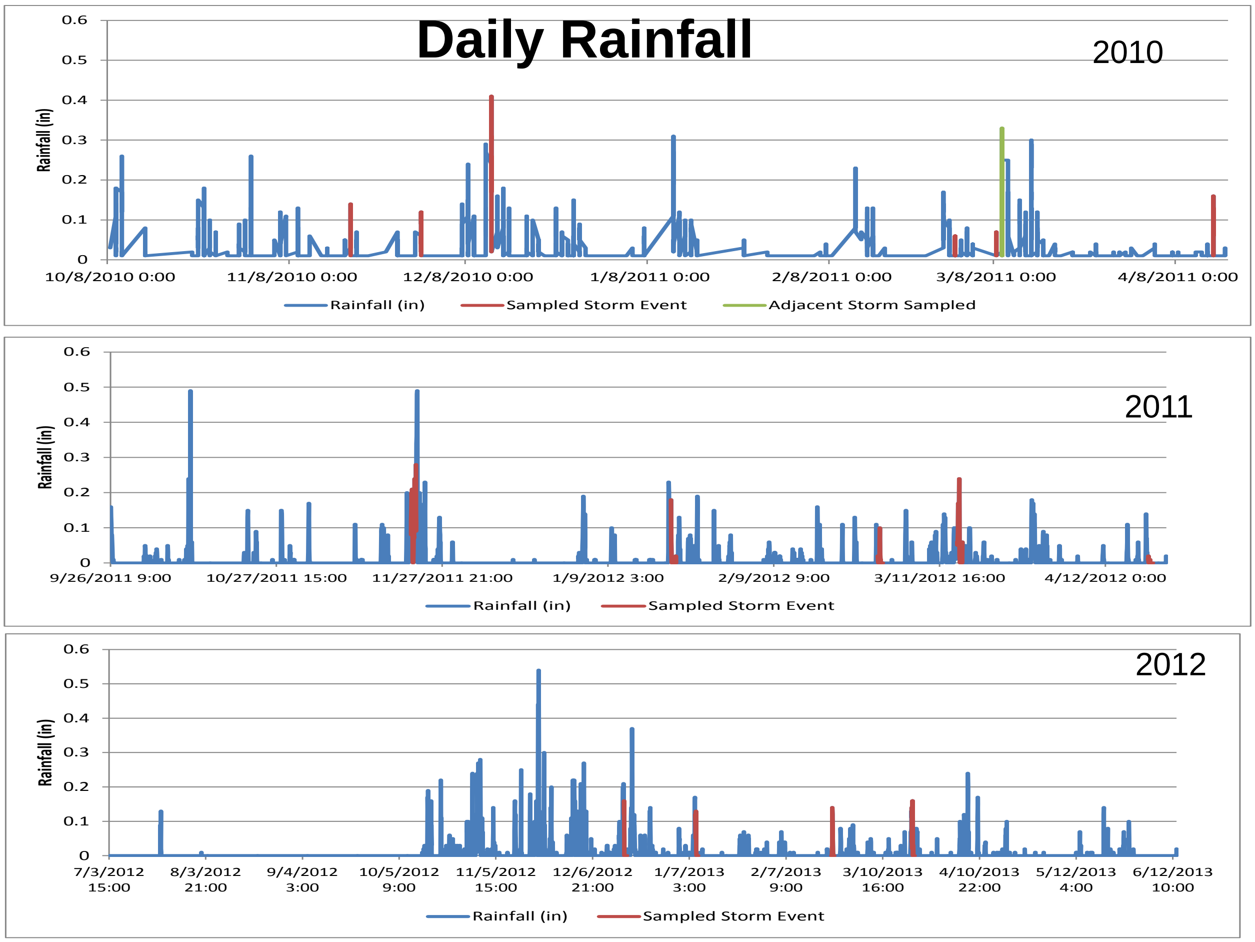


Figure 5-2 Daily rainfall compared to the sampled storms in each Phase 2010, 2011, and 2012.

The rainfall patterns within the Shipyard during the project were evaluated to determine whether they were representative of historical conditions beyond the study period. Project rainfall data were compared to historic rainfall records maintained for the Bremerton, Washington, area since 1899 to April 2013 and available through the Western Regional Climate Center (http://www.wrcc.dri.edu/). Table 5-4 presents monthly statistical rainfall summary data for Bremerton, Washington (station 450872), along with the PSNS monthly statistics for the project.

The "wet season" in western Washington is from October through April with an average annual precipitation in the Bremerton area of 48.26". During the project the sampling occurred from November through April. Bremerton has an average rainfall during this sampling of 38.68". In 2010 (Phase I) there were 106 days with at least 0.01" of rainfall in a 24-hour period at the PSNS B427 rain gauge. The monthly rainfall average was 6.16” and a total rainfall of 36.98” during the sampling season. Phase II experienced 80 days with at least 0.01” of rainfall in a 24-hour period at the PSNS B427 rain gauge; with a monthly rainfall average of 4.45” and a total rainfall of 26.67” during its sampling season. Phase III experienced 116 days with at least 0.01” of rainfall in a 24-hour period at the PSNS B427 rain gauge; with a monthly rainfall average of 5.59” and a total rainfall of 33.53” during its sampling season. The average daily rainfall at PSNS was consistently lower than the average daily rainfall for the Bremerton (e.g. ~5% below average during Phase I, ~31% below average during Phase II and ~13% below average during Phase III). Therefore outfalls draining areas outside of PSNS may discharge more volume than the rainfall characteristics at PSNS might suggest.

The overall findings of the rainfall statistics confirmed that the objective to characterize larger storms was statistically achieved and the study also was representative of “typical” average annual rainfall conditions as follows:

- The median daily rainfall for the collected storm data is significantly greater (Mann-Whitney; $p < 0.001$) than the median daily rainfall for all rainy days between Nov and April (2010-2013).

- The minimum daily rainfall for storms sampled is greater than the Q1 of all rainy days between Nov and April (2010-2013).

In addition to the rainfall characteristics, the correlation between the different storm characteristics was low ($|r| < 0.45$) except for the average conductivity and salinity ($r = 0.986$) confirming almost all the stations are tidally influenced. The *in-situ* data confirmed that a majority of the outfalls received some measure of tidal influence at each station. It is critical to design a stormwater monitoring program with a solid understanding of the potential influence of the tide at the specific sampling location. This ensures that the data represent the stormwater chemistry just prior to discharge. Even with tide gates, salt water intrusion into the drainage system can significantly influence the water chemistry and bioavailability of metals discharged during a storm event. The autosamplers were programmed to not sample waters with a salinity greater than 5 ppt and conductivity greater than 2000 µS/cm even during a storm event. Greater than 2 ppt salinity requires selecting a different analytical method for Cu (e.g., Cu by ICP-MS suffer salt interferences and methods must remove the salt to avoid false positives). Mostly all outfalls recorded tidal water reaching the sampling station during a particular storm event although there were a few exceptions (e.g. PSNSPB01 and PSNS126 during SW10). The waterlevel and conductivity (proxy for salinity) data were used in the storm composite formulation (e.g., EMC). In all cases, the EMC was formulated to represent only the freshwater or storm event runoff and not the incoming tidal water.

Table 5-4 Historical Monthly Total Rainfall (inches) for Bremerton, Washington (Station ID 450872), from May 1, 1899 to March 31, 2013 Compared to the PSNS Monthly Rain Gauge Rainfall Statistics for the Phase I (2010-11), Phase II (2011–2012) and Phase III (2012-2013) Sampling Periods

Bremerton Historical Monthly Rainfall Data (inches)													
	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Annual
Avg.[(a)]	4.02	7.36	7.74	7.20	5.28	4.65	2.73	1.83	1.44	0.73	0.86	1.65	48.26
Min.	0.16	0.83	0.44	0.61	0.27	0.27	0.26	0.13	0.04	0	0	0	22.73
Max.	14.12	21.64	16.22	20.08	18.03	12.19	7.67	5.46	4.52	3.11	3.97	7.09	75.81
No. Yrs.	103	96	98	97	102	101	106	107	108	105	106	108	65
PSNS B427 Rain Gauge Statistics for Phase I (2010-2011)													
Days of Rain		18	21	13	14	26	14	**106**	**Total Days of Rainfall ≥0.01" Phase I**				
Monthly Rainfall		5.81	12.27	4.04	4.16	9.35	1.35	**6.16**	**Ave Monthly Rainfall SW Events (in)**				
Daily avg.		0.32	0.58	0.31	0.30	0.36	0.10	**36.98**	**Total Rainfall During Phase (in)**				
Daily Min		0.01	0.01	0.01	0.01	0.01	0.01						
Daily Max		1.52	3.01	1.53	1.25	1.93	0.62						
Median		0.18	0.34	0.13	0.1	0.17	0.05						
PSNS B427 Rain Gauge Statistics[(b)] for Phase II (2011-2012)													
Days of Rain		12	2	18	15	23	10	**80**	**Total Days of Rainfall ≥0.01" Phase II**				
Monthly Rainfall		8.72	0.02	5.74	3.13	7.71	1.35	**4.45**	**Ave Monthly Rainfall SW Events (in)**				
Daily avg.		0.73	0.01	0.32	0.21	0.34	0.14	**26.67**	**Total Rainfall During Phase (in)**				
Daily Min		0.04	0.01	0.01	0.01	0.01	0.01						
Daily Max		2.88	0.01	1.50	0.39	1.53	0.39						
Median		0.47	0.01	0.15	0.21	0.16	0.10						
PSNS B427 Rain Gauge Statistics for Phase III (2012-2013)													
Days of Rain		22	26	18	15	18	17	**116**	**Total Days of Rainfall ≥0.01"PhaseIII**				
Monthly Rainfall		12.48	9.54	3.08	1.98	2.73	3.72	**5.59**	**Ave Monthly Rainfall SW Events (in)**				
Daily avg.		0.57	0.37	0.17	0.13	0.15	0.22	**33.53**	**Total Rainfall During Phase (in)**				
Daily Min		0.01	0.01	0.01	0.01	0.01	0.01						
Daily Max		3.25	2.19	0.86	0.53	0.88	0.89						
Median		0.33	0.11	0.07	0.06	0.07	0.02						

(a) Historical rainfall downloaded from Western Regional Climate Center http://www.wrcc.dri.edu/cgi-bin/cliMAIN.pl?wa0872.
(b) PSNS data included the following notes: only days with measurable rain were used in the statistical calculations, and from December 1 through December 23, 2011 the actual rainfall was higher but the rain gauge was obstructed by snow on some days.

5.2 Event Mean Composite Chemistry Data Summary

The stormwater samples consisted of both grab samples (TPH DRO, TPH RRO) and time-paced composite samples (Hg, Cu, Pb, Zn, As, Ag, Cd, Cr, DOC, TOC, TSS, and hardness) collected from 13 stations. For storm events SW12 and SW14, only one station was sampled, and for storm events SW05 and SW06 there were 3 and 2 stations sampled, respectively. All of the remaining storm events had four or more stations sampled. Stations PSNS-015 and PSNS-126 were sampled during 11 and 10 storm events, respectively. The full chemistry reports are available in Appendix B. The descriptive statistics were calculated on the pooled data by parameter from all stations and storms (Table 5-5) and then broken out into individual stations for the metals (Table 5-6 and Table 5-7). These data represent the storm composites only and not the 1-hr composites collected during SW12 (see Section 5-3). Overall TPH concentrations were less than the reporting limit or qualified due to spectral interferences. TPH was selected as it is a permit requirement for NPDES outfalls at the Shipyard. However a more specific method to characterize individual oil and grease compounds is recommended for future stormwater characterizations. Methods such as those for polycyclic aromatic hydrocarbons (PAHs) would provide a more detailed characterization of the specific organic compounds present in stormwater and the potential for impacts to beneficial uses.

Figure 5-3 provides a box plot of the pooled metal EMCs from all stations and all storms. As typical of stormwater chemistry, the data set is not normally distributed. Statistically significant outliers skewed the data for TR Hg, Ag, As, and Cu. The high variability noted for Ag results from the overall low concentrations, which are generally just a factor of 10 above the MDL. For As, a majority of the outliers were collected at PSNS126 (max 6.4 µg/L) and PSNS124 (max 7.7 µg/L). These values are still an order of magnitude below the Navy General Permit limit (69 µg/L). The only metals that could potentially exceed the existing Navy permits and/or the stormwater benchmarks discussed in Table 1-1 and Table 1-2 are Cu, Pb and Zn. The remaining analysis will focus on Hg, Cu, Pb, and Zn as they have the greatest relevance to both the sediment remediation projects at the Shipyard, NPDES compliance and development of future stormwater permits. Although the Hg data are three orders of magnitude below the reference permits, the data are included in the extended analysis as the concentrations were significantly higher at station PSNS015 ($p < 0.1$; Figure 5-7) compared to all other stations. The potential for sediment contamination from the cumulative release of the low concentrations of Hg in stormwater is discussed in Section 5.4.

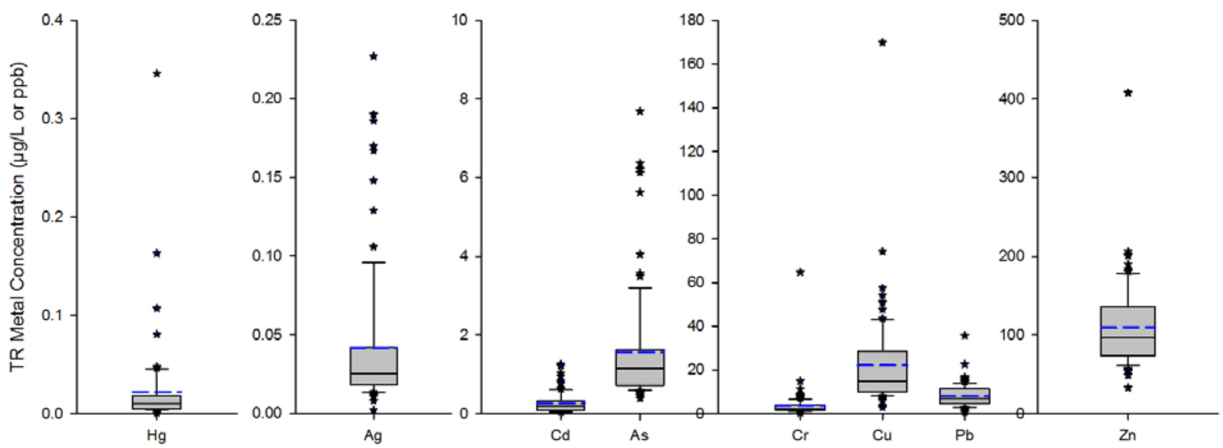


Figure 5-3. Total Event Mean Concentrations (EMCs) in Stormwater from the 16 storms sampled from 2010 through 2013. The top, middle, and bottom solid black lines of the box represent the 75th percentile, 50th, and 25th percentile, respectively. The whiskers are the 5th and 95th percentile and the asterisks fall outside the 5th and 95th percentiles (n = 67). The blue dashed line is the average.

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.

Table 5-6 Descriptive statistics by station for Event Mean Composites (EMC) stormwater samples for total recoverable (TR) and dissolved (Diss) Hg, Cu, Pb, and Zn. Storm specific data are in Appendix C.

Station		Hg	Hg	Cu	Cu	Pb	Pb	Zn	Zn
	Fraction	Diss	TR	Diss	TR	Diss	TR	Diss	TR
Units: µg/L									
MDL			**0.0001**		**0.007**		**0.002**		**0.05**
RL			**0.0003**		**0.02**		**0.006**		**0.2**
PSNS008	**Mean**	**0.00197**	**0.0109**	**5.45**	**14.3**	**0.228**	**5.11**	**99.6**	**141**
PSNS008	Stdev.	0.00025	0.00201	0.74	2.28	0.110	1.05	14.5	12.9
PSNS008	Min	0.00181	0.0087	4.92	12.9	0.139	3.95	82.8	132
PSNS008	Max	0.00226	0.0126	6.3	16.9	0.351	6.00	108	156
PSNS008	N	3	3	3	3	3	3	3	3
PSNS015	**Mean**	**0.00380**	**0.0777**	**4.36**	**10.0**	**1.37**	**10.8**	**42.7**	**67.1**
PSNS015	Stdev.	0.00184	0.0998	1.31	2.36	0.530	2.53	9.61	12.95
PSNS015	Min	0.00180	0.0119	2.34	5.94	0.393	7.73	21.1	33
PSNS015	Max	0.00785	0.346	6.89	14.4	2.35	15.9	57.2	78.4
PSNS015	N	11	11	11	11	11	11	11	11
PSNS032	**Mean**	**0.00391**	**0.0284**	**3.12**	**10.1**	**0.322**	**8.62**	**33.6**	**95.3**
PSNS032	Stdev.	0.00196	0.0349	0.85	2.58	0.207	3.61	2.71	24.0
PSNS032	Min	0.00246	0.00669	1.92	6.97	0.179	4.17	30.4	71.8
PSNS032	Max	0.00681	0.0806	3.9	12.4	0.623	11.8	37.0	118
PSNS032	N	4	4	4	4	4	4	4	4
PSNS053	**Mean**	**0.00157**	**0.00465**	**16.1**	**29.6**	**0.158**	**6.10**	**106.5**	**155**
PSNS053	Stdev.	0.00056	0.00165	10.4	16.7	0.1126	2.83	20.59	36.9
PSNS053	Min	0.00099	0.003194	5.93	14.6	0.079	4.09	83.4	113
PSNS053	Max	0.00211	0.006445	26.7	47.6	0.287	9.34	123.0	181
PSNS053	N	3	3	3	3	3	3	3	3
PSNS081.1	**Mean**	**0.00236**	**0.0167**	**13.9**	**34.8**	**0.367**	**10.8**	**82.2**	**138**
PSNS081.1	Stdev.	0.00028	0.00872	6.24	6.87	0.1793	4.54	10.27	31.4
PSNS081.1	Min	0.00216	0.00981	7.23	30.6	0.198	6.05	71.6	116
PSNS081.1	Max	0.00255	0.0265	19.6	42.7	0.555	15.1	92.1	174
PSNS081.1	N	2	3	3	3	3	3	3	3
PSNS082.5	**Mean**	**0.00189**	**0.00724**	**10.7**	**30.4**	**0.343**	**6.01**	**51.3**	**119**
PSNS082.5	Stdev.	0.00022	0.00401	6.79	18.0	0.318	4.16	1.65	38.9
PSNS082.5	Min	0.00164	0.0037	6.44	16.4	0.149	2.74	49.7	80.2
PSNS082.5	Max	0.00204	0.0116	18.5	50.7	0.710	10.7	53.0	158
PSNS082.5	N	3	3	3	3	3	3	3	3
PSNS084.1	**Mean**	**0.00117**	**0.00404**	**6.47**	**17.4**	**0.212**	**5.40**	**115**	**146**
PSNS084.1	Stdev.	0.000345	0.000277	2.57	2.6	0.0875	1.69	10.3	14.3
PSNS084.1	Min	0.00069	0.00367	3.07	14.7	0.087	3.88	106	133

Station	Fraction	Hg Diss	Hg TR	Cu Diss	Cu TR	Pb Diss	Pb TR	Zn Diss	Zn TR
Units: µg/L									
MDL			**0.0001**		**0.007**		**0.002**		**0.05**
RL			**0.0003**		**0.02**		**0.006**		**0.2**
PSNS084.1	Max	0.00171	0.00455	11.0	21.1	0.375	8.91	134	169
PSNS084.1	N	6	7	7	7	7	7	7	7
PSNS096	**Mean**	**0.00169**	**0.0092**	**5.37**	**25.5**	**0.279**	**9.47**	**53**	**98.5**
PSNS096	Stdev.	0.000641	0.00306	1.68	5.7	0.1213	2.77	5.1	15.3
PSNS096	Min	0.00100	0.00472	3.05	17.8	0.149	5.35	47.5	74.5
PSNS096	Max	0.00227	0.0133	7.7	32.5	0.453	12.2	60	116
PSNS096	N	3	5	5	5	5	5	5	5
PSNS115.1	**Mean**	**0.00245**	**0.0143**	**11.7**	**33.0**	**0.417**	**13.0**	**116**	**172**
PSNS115.1	Stdev.	0.000872	0.00622	3.80	10.8	0.0543	11.0	13.1	30.2
PSNS115.1	Min	0.00153	0.0075	7.47	20.4	0.339	2.59	98.3	127
PSNS115.1	Max	0.00357	0.0252	17.5	51	0.487	35.7	139	206
PSNS115.1	N	6	7	7	7	7	7	7	7
PSNS124	**Mean**	**0.00849**	**0.0227**	**39.5**	**84.5**	**0.348**	**9.62**	**83.2**	**188**
PSNS124	Stdev.	0.00936	0.0174	45.0	58.8	0.232	3.97	41.6	150
PSNS124	Min	0.00187	0.00727	15.3	39.5	0.193	4.95	54.5	76.6
PSNS124	Max	0.0151	0.0476	107	170	0.694	14.5	145	408
PSNS124	N	2	4	4	4	4	4	4	4
PSNS124.1	**Mean**	**0.00154**	**0.00563**	**13.1**	**42.8**	**0.601**	**11.9**	**105**	**172**
PSNS124.1	Stdev.	0.00034	0.00165	5.27	10.6	0.175	3.96	24.0	48.3
PSNS124.1	Min	0.00130	0.00330	7.65	34.6	0.371	6.04	71.1	100
PSNS124.1	Max	0.00178	0.00701	20.3	57.5	0.797	14.8	127	201
PSNS124.1	N	2	4	4	4	4	4	4	4
PSNS126	**Mean**	**0.00395**	**0.00977**	**12.8**	**18.7**	**0.314**	**4.32**	**52**	**73**
PSNS126	Stdev.	0.00297	0.00668	9.23	11.9	0.112	1.64	9.5	18.6
PSNS126	Min	0.00107	0.0030	3.35	7.64	0.159	2.60	34.7	49
PSNS126	Max	0.00982	0.0204	29.3	42.8	0.546	7.89	62	108
PSNS126	N	9	10	10	10	10	10	10	10
PSNS PB01	**Mean**	**0.00072**	**0.00162**	**7.14**	**13.2**	**0.0973**	**1.20**	**48**	**83**
PSNS PB01	Stdev.	0.00019	0.00085	3.28	6.7	0.0743	0.77	13.5	30.1
PSNS PB01	Min	0.00050	0.00096	4.25	7.85	0.0528	0.648	33.0	56
PSNS PB01	Max	0.00086	0.00258	10.7	20.7	0.183	2.08	58	115
PSNS PB01	N	3	3	3	3	3	3	3	3

Table 5-7 Descriptive statistics by station for Event Mean Composites (EMC) stormwater samples for total recoverable (TR) and dissolved (Diss) Ag, As, Cd, and Cr. The draft permit concentrations are included for reference. Storm specific data are in Appendix C.

Station		**Ag**	**Ag**	**As**	**As**	**Cd**	**Cd**	**Cr**	**Cr**
Fraction		**Diss**	**TR**	**Diss**	**TR**	**Diss**	**TR**	**Diss**	**TR**
Units: µg/L									
MDL			**0.002**		**0.03**		**0.004**		**0.08**
RL			**0.006**		**0.1**		**0.01**		**0.3**
PSNS008	**Mean**	**0.0029**	**0.0162**	**2.18**	**2.47**	**0.187**	**0.327**	**1.62**	**3.86**
PSNS008	Stdev.	0.0009	0.0125	3.05	3.17	0.0443	0.0344	0.771	0.675
PSNS008	Min	0.002U	0.002	0.38	0.586	0.148	0.300	0.946	3.2
PSNS008	Max	0.004	0.025	5.70	6.13	0.235	0.366	2.46	4.55
PSNS008	N	3	3	3	3	3	3	3	3
PSNS015	**Mean**	**0.00337**	**0.0327**	**0.626**	**0.793**	**0.0360**	**0.0861**	**1.20**	**2.31**
PSNS015	Stdev.	0.00131	0.0228	0.204	0.235	0.017	0.0453	0.729	0.929
PSNS015	Min	0.002U	0.014	0.356	0.583	0.0228	0.0518	0.443	1.03
PSNS015	Max	0.00579	0.0931	1.05	1.31	0.0847	0.207	2.94	4.46
PSNS015	N	11	11	11	11	11	11	11	11
PSNS032	**Mean**	**0.0033**	**0.0260**	**0.753**	**1.24**	**0.102**	**0.239**	**0.986**	**2.80**
PSNS032	Stdev.	0.0016	0.0060	0.221	0.29	0.0056	0.0608	0.486	0.769
PSNS032	Min	0.002U	0.0199	0.480	0.936	0.0931	0.184	0.412	1.74
PSNS032	Max	0.005	0.034	1.00	1.63	0.105	0.317	1.58	3.5
PSNS032	N	4	4	4	4	4	4	4	4
PSNS053	**Mean**	**0.0046**	**0.0168**	**0.893**	**1.05**	**0.120**	**0.219**	**0.78**	**1.98**
PSNS053	Stdev.	0.0028	0.0055	0.355	0.48	0.0501	0.0811	0.386	0.775
PSNS053	Min	0.002U	0.0109	0.499	0.521	0.0720	0.127	0.355	1.12
PSNS053	Max	0.008	0.022	1.19	1.44	0.172	0.28	1.11	2.62
PSNS053	N	3	3	3	3	3	3	3	3
PSNS081.1	**Mean**	**0.0104**	**0.0467**	**1.15**	**1.48**	**0.157**	**0.345**	**2.55**	**7.36**
PSNS081.1	Stdev.	0.0038	0.0221	0.411	0.43	0.0558	0.0703	1.54	1.385
PSNS081.1	Min	0.00624	0.0288	0.679	1.00	0.109	0.266	1.44	5.99
PSNS081.1	Max	0.014	0.071	1.40	1.85	0.218	0.4	4.31	8.76
PSNS081.1	N	3	3	3	3	3	3	3	3
PSNS082.5	**Mean**	**0.0029**	**0.0298**	**0.572**	**0.79**	**0.317**	**0.892**	**1.59**	**3.97**
PSNS082.5	Stdev.	0.0016	0.0184	0.268	0.39	0.0617	0.3314	0.351	1.595
PSNS082.5	Min	0.002U	0.012	0.292	0.383	0.2770	0.596	1.35	2.31
PSNS082.5	Max	0.005	0.049	0.827	1.17	0.388	1.25	1.99	5.49
PSNS082.5	N	3	3	3	3	3	3	3	3
PSNS084.1	**Mean**	**0.00414**	**0.0206**	**0.770**	**0.94**	**0.101**	**0.176**	**0.98**	**2.31**
PSNS084.1	Stdev.	0.00217	0.00434	0.353	0.329	0.00593	0.0363	0.576	0.933
PSNS084.1	Min	0.002U	0.0134	0.442	0.597	0.0956	0.150	0.511	1.36

Station		Ag	Ag	As	As	Cd	Cd	Cr	Cr
Fraction		**Diss**	**TR**	**Diss**	**TR**	**Diss**	**TR**	**Diss**	**TR**
Units: µg/L									
MDL			**0.002**		**0.03**		**0.004**		**0.08**
RL			**0.006**		**0.1**		**0.01**		**0.3**
PSNS084.1	Max	0.00795	0.0275	1.46	1.56	0.112	0.255	2.20	3.96
PSNS084.1	N	7	7	7	7	7	7	7	7
PSNS096	**Mean**	**0.0025**	**0.0258**	**1.25**	**1.73**	**0.183**	**0.363**	**2.44**	**17.35**
PSNS096	Stdev.	0.00066	0.0091	0.429	0.345	0.165	0.230	1.68	26.69
PSNS096	Min	0.002U	0.0138	0.730	1.38	0.085	0.208	1.10	2.71
PSNS096	Max	0.00341	0.0394	1.77	2.23	0.476	0.77	5.19	64.7
PSNS096	N	5	5	5	5	5	5	5	5
PSNS115.1	**Mean**	**0.0150**	**0.0712**	**0.953**	**1.37**	**0.188**	**0.391**	**2.44**	**4.54**
PSNS115.1	Stdev.	0.00810	0.0236	0.610	0.662	0.0458	0.129	4.48	4.85
PSNS115.1	Min	0.00354	0.0351	0.455	0.651	0.145	0.232	0.595	1.65
PSNS115.1	Max	0.02390	0.106	2.22	2.65	0.270	0.531	12.6	14.9
PSNS115.1	N	7	7	7	7	7	7	7	7
PSNS124	**Mean**	**0.0277**	**0.115**	**2.77**	**3.21**	**0.231**	**0.549**	**3.25**	**5.88**
PSNS124	Stdev.	0.0427	0.0997	3.05	3.01	0.0605	0.292	2.23	1.01
PSNS124	Min	0.002U	0.0179	0.851	1.37	0.181	0.286	1.05	4.65
PSNS124	Max	0.0913	0.227	7.32	7.69	0.319	0.945	5.33	7.08
PSNS124	N	4	4	4	4	4	4	4	4
PSNS124.1	**Mean**	**0.00347**	**0.0283**	**0.834**	**1.07**	**0.474**	**0.875**	**2.53**	**6.65**
PSNS124.1	Stdev.	0.00172	0.00922	0.480	0.386	0.115	0.288	0.871	1.71
PSNS124.1	Min	0.002U	0.0191	0.532	0.724	0.309	0.631	1.70	4.57
PSNS124.1	Max	0.00532	0.0399	1.55	1.62	0.566	1.21	3.62	8.07
PSNS124.1	N	4	4	4	4	4	4	4	4
PSNS126	**Mean**	**0.0453**	**0.0890**	**3.72**	**3.86**	**0.1276**	**0.216**	**1.08**	**1.77**
PSNS126	Stdev.	0.0450	0.0732	1.68	1.68	0.042	0.080	0.610	0.55
PSNS126	Min	0.002U	0.0175	1.64	1.80	0.071	0.13	0.371	0.91
PSNS126	Max	0.128	0.19	6.34	6.37	0.194	0.35	2.36	2.94
PSNS126	N	10	10	10	10	10	10	10	10
PSNS PB01	**Mean**	**0.00493**	**0.0160**	**1.01**	**1.08**	**0.0378**	**0.0793**	**0.69**	**1.22**
PSNS PB01	Stdev.	0.00217	0.00835	0.273	0.262	0.012	0.0403	0.252	0.58
PSNS PB01	Min	0.00243	0.00793	0.706	0.778	0.025	0.0458	0.506	0.804
PSNS PB01	Max	0.00629	0.0246	1.23	1.27	0.046	0.12	0.979	1.88
PSNS PB01	N	3	3	3	3	3	3	3	3

Overall the stormwater data from this three year study suggests that stormwater composite samples have a >50% probability of exceeding the 2008 draft permit and the U.S. Navy general permit for TR Cu and Zn (Figure 5-3). The stations were selected to represent various Shipyard activities and process improvements occurring across all operations at the Shipyard. Therefore, the data were evaluated for station level trends. Figure 5-4 illustrates the inter-storm and station variability for Cu and Zn compared to the storm size. The EMCs were not highly correlated with the storm characteristics (i.e. rainfall, antecedent dry period, etc. $|r| < 0.52$). Therefore, higher antecedent dry periods did not equate to higher stormwater concentrations for the metals as one might expect after a prolonged dry period. However, consistent with the previous ENVVEST studies, there were trends suggesting that small storms such as SW10 with a total event rainfall of 0.57” may have higher concentrations of metals. This is discussed further in the following section on storm event loading.

The stations were not highly correlated to each other ($|r| < 0.8$), which is to be expected since the stations were selected to represent various Shipyard activities and conditions. The strongest correlations were between Cd and Zn ($r = 0.66$), Cd and Cu ($r = 0.75$), and Cu and Zn ($r = 0.76$). The stations with significantly higher concentrations than the median were PSNS 115.1, 124, and 124.1 for TR Cu; PSNS 084.1, 115.1, and 124.1 for TR Zn; and PSNS 015 for Pb and Hg ($p< 0.1$). Stations with significantly lower concentrations were PSNS 015 and 032 for Cu; PSNS 015 and 126 for Zn, and PSNS 126 and PB01 for Pb ($p< 0.1$). PB01 is the newest stormwater outfall sampled during this study. The outfall is unique from all others as it includes a water quality treatment system in the stormwater vault. The vault is located on Pier B and required stormwater treatment prior to discharge. Detailed descriptions of each outfall were provided in the FSPs for each Phase (TEC and PNNL 2011, 2012a and 2012b).

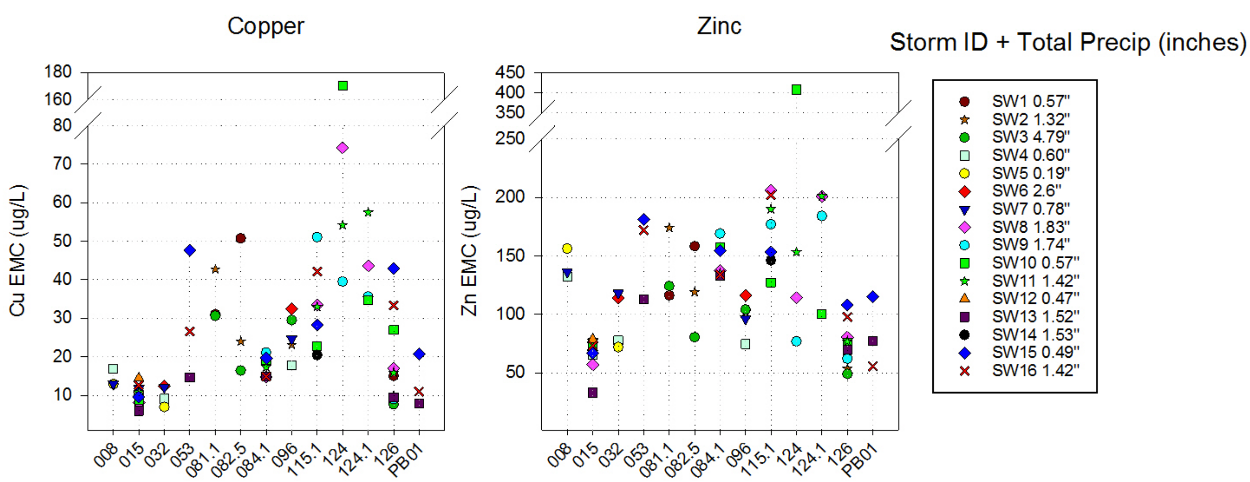


Figure 5-4 All storm event composite (EMC) samples by station and by storm with the associated total event rainfall for total recoverable Cu and Zn.

The stations can be grouped at the highest level by those located within NBK and CIA to designate the outfalls draining the industrial operations versus the base’s support activities located in NBK (see Figure 2-1). Figure 5-5, Figure 5-6, and Figure 5-7 illustrate the TR Cu, Zn, and Hg concentrations (top of each bar) for each storm and station. The mean of CIA stations was greater than the mean of NBK for Cu (31.9 µg/L vs. 13.5 µg/L, see Figure 5-8), but there was no significant difference seen for Zn (132 µg/L vs 94 µg/L). However for Hg, the mean of CIA stations was less than that of NBK stations (0.011 µg/L vs

0.046 µg/L). As was noted above, the Hg concentrations at PSNS015 were significantly higher than all other stations.

The graphs also illustrate the fraction of each stormwater composite that was dissolved. The measured values of TR and dissolved were then used to calculate the particulate fraction of the stormwater composite. This is important for the evaluation of the bioavailability and also for understanding the types of BMPs that would be most effective (e.g., particulate removal versus dissolved metal). On average, EMCs contained 43% ± 17% dissolved Cu with the highest fraction of dissolved Cu (87%) recorded during SW10, which was a small storm with an event rainfall of 0.57”. For Zn the average percent dissolved was 64% ± 17% with the highest fraction of dissolved also recorded during SW10 (92%). This suggests that activities within the drainage basins of interest, PSNS124 and 126, should be reviewed to determine what might be releasing fine dust particles of Cu and Zn that are easily mobilized during small storm events. For Hg the average percent dissolved was 27% ± 17%. The fraction of the TR Hg occurring as dissolved in the ambient waters of Sinclair/Dyes Inlets averages approximately 50% with a range of 30%–80%. The importance of the particulate fraction is discussed in Section 5.4.

The fraction of dissolved Cu can be used to identify the types of Cu entering the systems, predict the most effective BMPs for a particular drainage basin, and evaluate the fate of the Cu once it enters the marine receiving waters of Sinclair Inlet. The TR Cu concentrations in Sinclair Inlet ambient seawater range from 60% to 90% dissolved Cu (Brandenberger et al. 2008). In ambient seawater, Zn occurs as 90%–100% dissolved and would be expected to be highly soluble after entering seawater. In the stormwater the percent dissolved Zn ranged 29%-92%. Particulate BMPs would be effective only if there was no tidal intrusion. The increased conductivity and ionic strength of the seawater generally solubilized Zn. The stations with the highest particulate fractions were PSNS082.5, 096, 032, 124, and PB01.

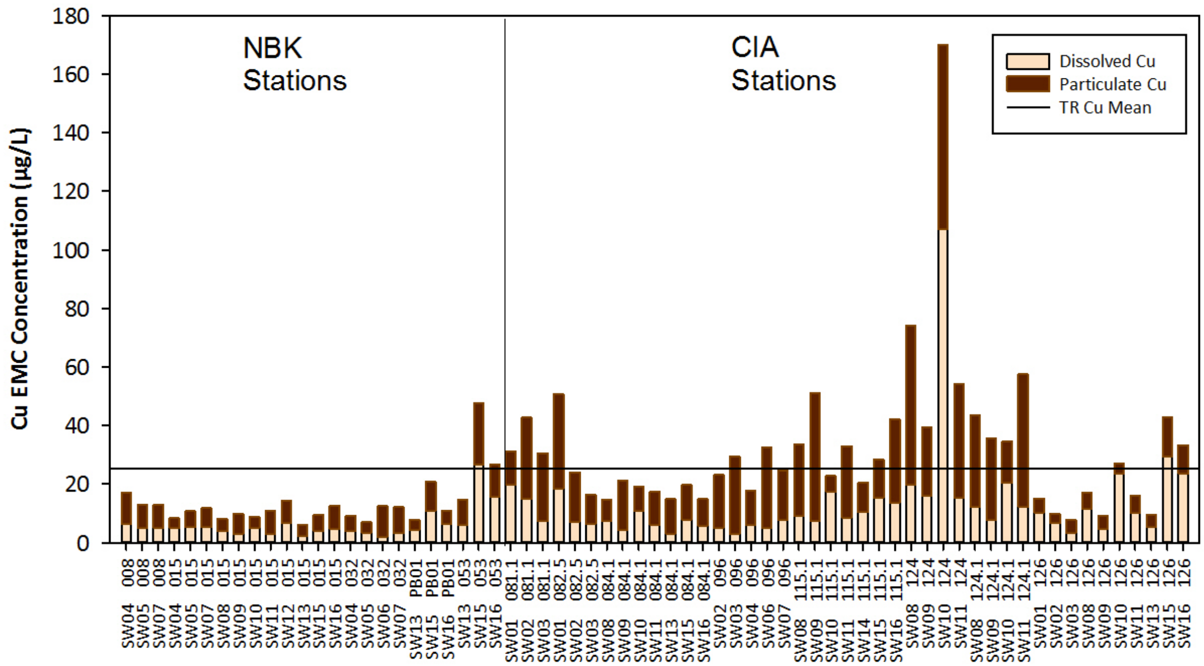


Figure 5-5. Stormwater composites with dissolved, particulate, and total recoverable (top of each bar) Cu concentrations from CIA (industrial) and NBK (residential) outfalls. The storm event number (1 through 16) and the station ID (PSNS X) are on the x-axis.

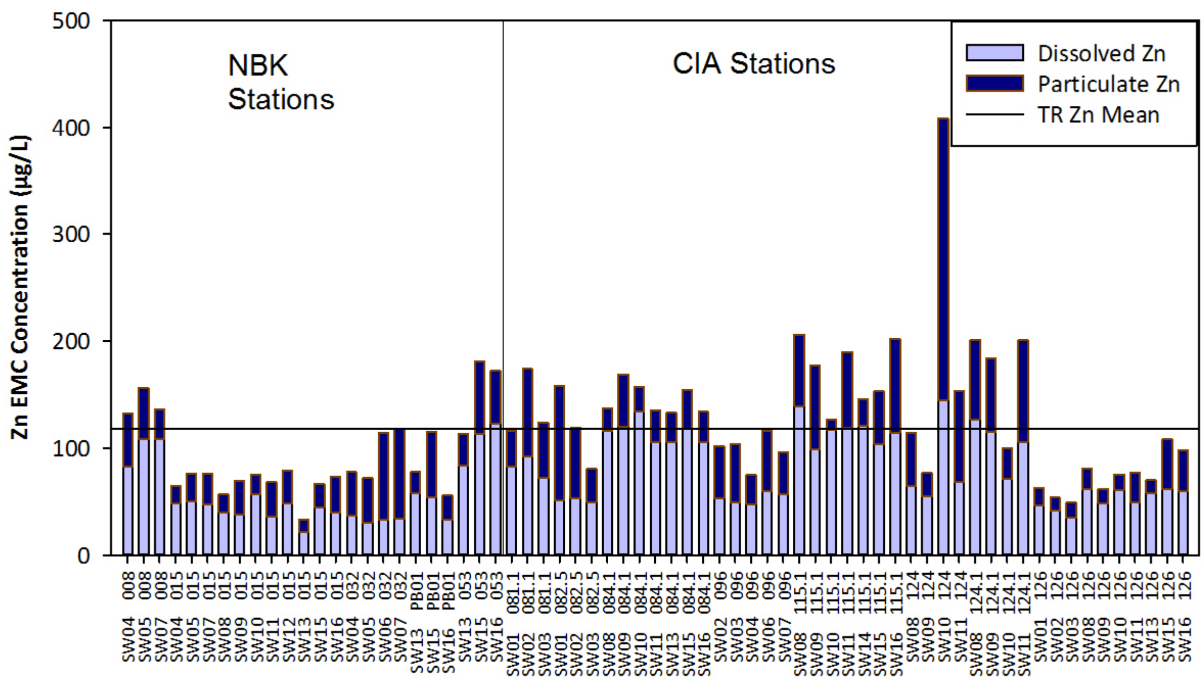


Figure 5-6. Stormwater composites with dissolved, particulate, and total recoverable (top of each bar) Zn concentrations from CIA (industrial) and NBK (residential) outfalls. The storm event number (1 through 16) and the station ID (PSNS X) are on the x-axis.

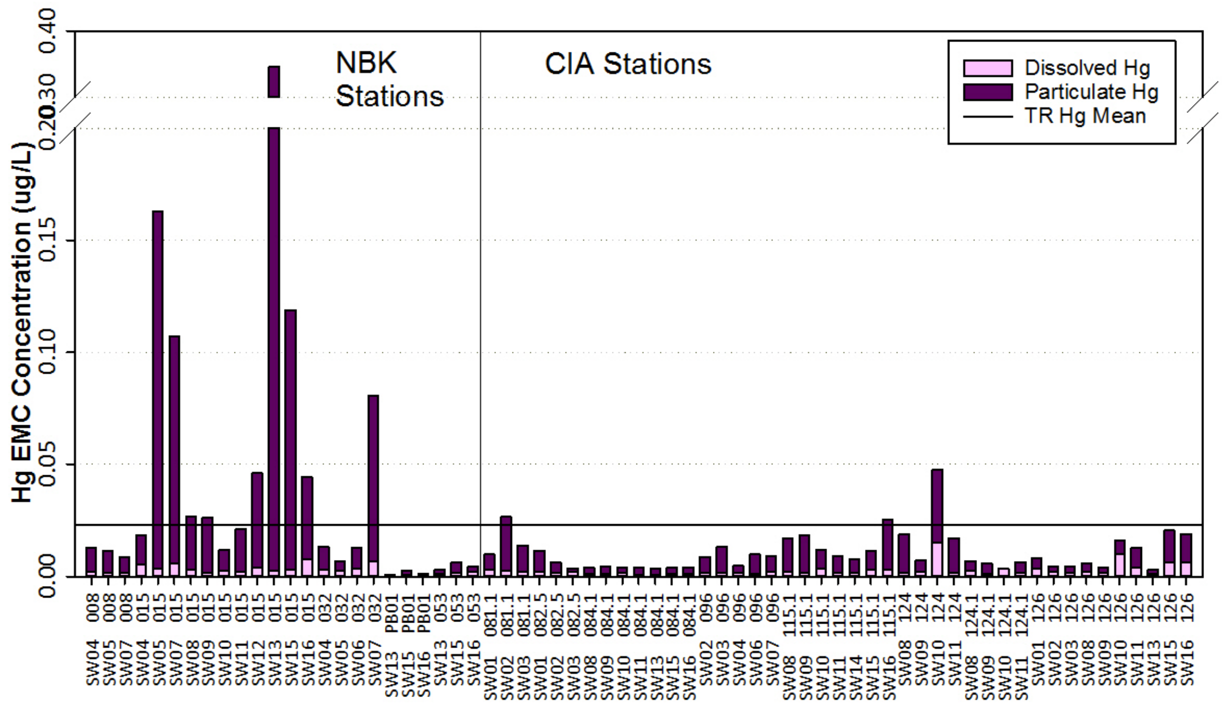


Figure 5-7. The Concentrations of dissolved and particulate Hg measured in event mean composites (EMCs) from CIA and NBK outfalls. The storm event number (SW08, etc.) and station code are on the x-axis. The tops of each bar represents the TR Hg concentration.

5.3 Primary Work Activity

Station characteristics including the primary work activity, basin area (acres), and %TIA were calculated and used to compare EMCs (see Table 2-1, Table 2-2, and Appendix E). Comparison of the median EMCs between stations and between primary work activities was conducted using the Kruskal-Wallis test. Stations classified by the primary work activity were not significantly different based on basin area or %TIA (Kruskal-Wallis; $p > 0.28$). The only residential site, Station PSNS015, had the largest basin area (92.3 acres) and the lowest %TIA (50%). All other stations had basin areas less than 25 acres and %TIA of at least 94%. This shows the primary difference between the industrial areas of the Shipyard with very little impervious surfaces compared to the residential side of the Shipyard with half of the landscape being permeable. The EMCs were not statistically different based on their primary work activity (residential, material laydown, loading, metal work, and high traffic; Kruskal-Wallis $p > 0.05$). The best discriminator of the EMCs was their location within the Shipyard as either NBK or CIA (Figure 5-8), as discussed above. The classification of stations based as NBK or CIA is a coarse breakdown of work activity between Shipyard supporting services (i.e. residential, parking, etc.) and the industrial activities such as metal work, metal recycling, materials laydown, and ship maintenance. Therefore, the work activities defined for the basins may be too specific for the comparison to stormwater quality.

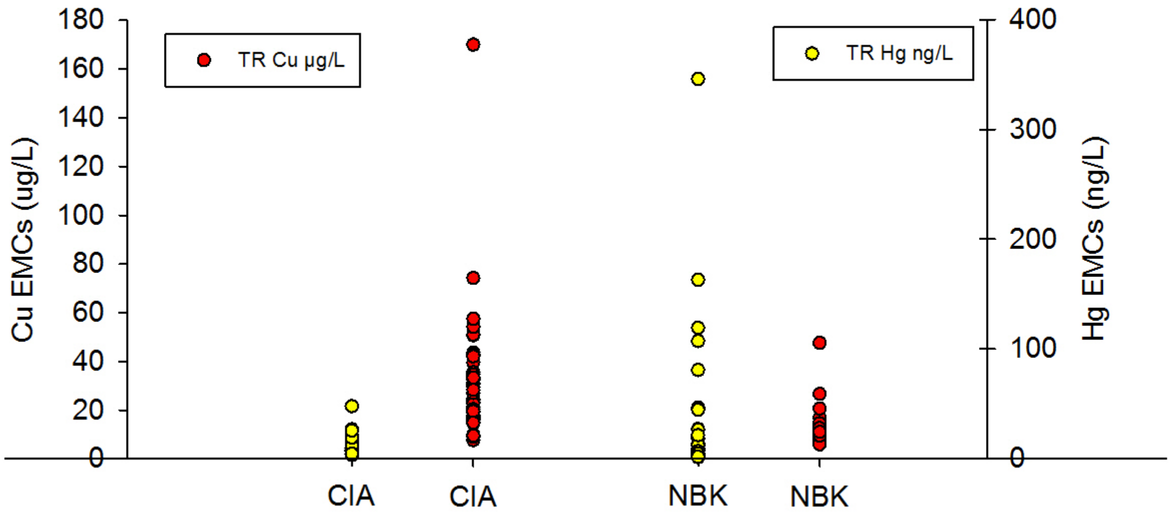


Figure 5-8 Distribution of EMCs categorized by location within the Shipyard including Confined Industrial Area (CIA) and Naval Base Kitsap (NBK).

As it was difficult to classify the primary work activity for a station, the data were pooled by station and a forward-stepping discriminant analysis was performed (Figure 5-9). Data were log10 transformed and then standardized by subtracting the mean and dividing by the standard deviation. Wilks' lambda provided a measure of the proportion of variance in the combination of modeled variables that was unaccounted for by the classification variable (station, activity, or storm). Total EMCs were able to discriminate stations with 97% correct classification and a Wilks' Lambda ($\lambda < 0.0001$, $p < 0.001$). Five eigenvalues were greater than 0 and the associated canonical variables explained 96% of the variability. The first two canonical variables, however, only explain 71% of the variability and only separate stations PSNS015 and PSNS126. The dissolved concentrations discriminated stations slightly better with the first two canonical variables explaining 76% of the variability which separated stations PSNS015, PSNS032, PSNS096, PSNS124.1, PSNS126, and PSNSPB01. This analysis provided a representative list of stations that could be sampled in future stormwater studies to represent the broader range of activities occurring at the Shipyard. The stations recommended for sampling include NBK stations PSNS015, PSNSPB01, and PSNS032 and CIA stations PSNS126, PSNS096, and PSNS124.1.

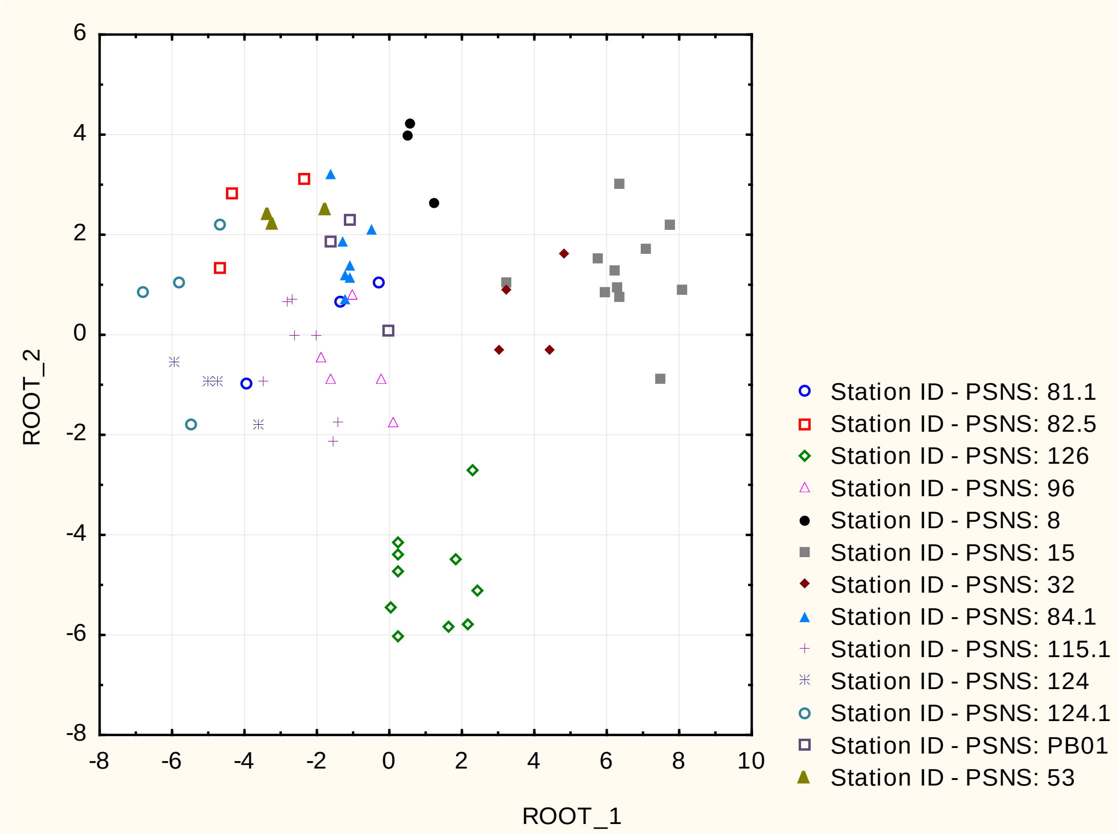


Figure 5-9 Forward-stepping discriminant analysis by station including basin characteristics and primary work activity show PSNS126 and PSNS015 can be uniquely identified.

5.4 PSNS015 Storm Chemistry

The Phase I study identified PSNS015 as a critical drainage basin for further Hg studies. Therefore, it was included in the subsequent two Phases and SW12 focused on understanding the detailed chemistry at PSNS015 during a single storm event. Figure 5-10 illustrates the results of the precipitation (inches), water level in the pipe (ft), total concentration of particles as measured by the LISST (µL/L) and mean particle size (µm) during the progression of the storm (SW12). The *in situ* sensors also collected conductivity and detailed particle size measurements (LISST) during the entire storm. The LISST data were captured as 32 size classifications then post processed to group the data into three size classes: <63 µm (silt/clay), 63–234 µm (very fine and fine sand), and 234–386 µm (medium sand). All the size classification data and the grouped data are available in Appendix D.

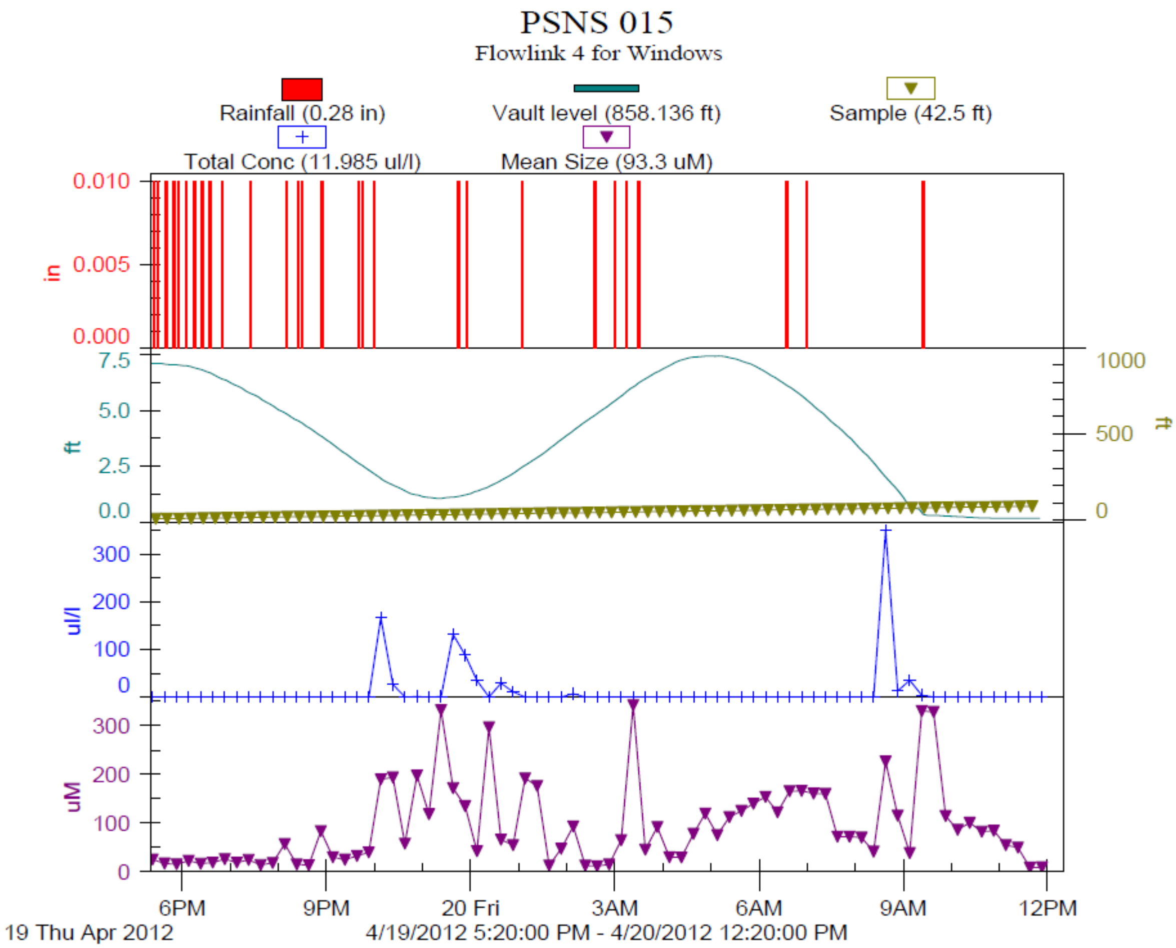


Figure 5-10. From top to bottom, graphs of the precipitation (inches; red), water level in the pipe (feet; green), total concentration of particles as measured by the Laser In Situ Scattering and Transmissometry (LISST; µL/L; blue) and mean particle size (µm; purple) for SW12.

The in situ measurements were plotted against the concentrations of DOC; particulate and dissolved Hg (Figure 5-11); and particulate and dissolved Cu (Figure 5-12) determined during the intervals of the storm. The TR Hg concentrations in the discrete samples of the storm are equal to the top of the stacked bars. The *in situ* measurements were collected at roughly 15-minute intervals, while the chemistry data were determined from the 1-hour composites collected by automated samplers. Table 5-8 provides the 1-hr composite sample chemistry for SW12 at PSNS015.

The Hg and Cu data show that as the rainfall begins smaller particles move through the outfall and the Hg concentrations begin to increase about 4 hours into the storm event compared to Cu where the peak is in the first hour of the storm. The first increase in Hg occurs around the time there is a peak in the size and volume of particles moving through the outfall around 23:00 to 24:00. By this time the precipitation volumes have begun to decrease and the tide begins to move into the pipe with conductivity rising around 03:00. While the denser saltwater is filling the pipe, the fresh stormwater is trapped behind the denser saltwater and the DOC concentrations are closer to those measured in the ambient seawater (~1–2 mg/L).

As the tide recedes, the DOC increases and there is a peak in the TR Hg and Cu concentration along with a peak in the silt/clay and fine sand size classifications. After this peak, the concentrations decrease. However, the portion of total Hg that is dissolved increases to as much as 57% compared to earlier in the storm (averages 23%). The pulse of particulates traveling through the pipe during the collection of discrete sample 16 around 0900 on April 20, 2012 contained elevated Hg, Cu and other metals as seen in Table 5-8. This highlights the need to understand the particulate bound metals in the storm drains.

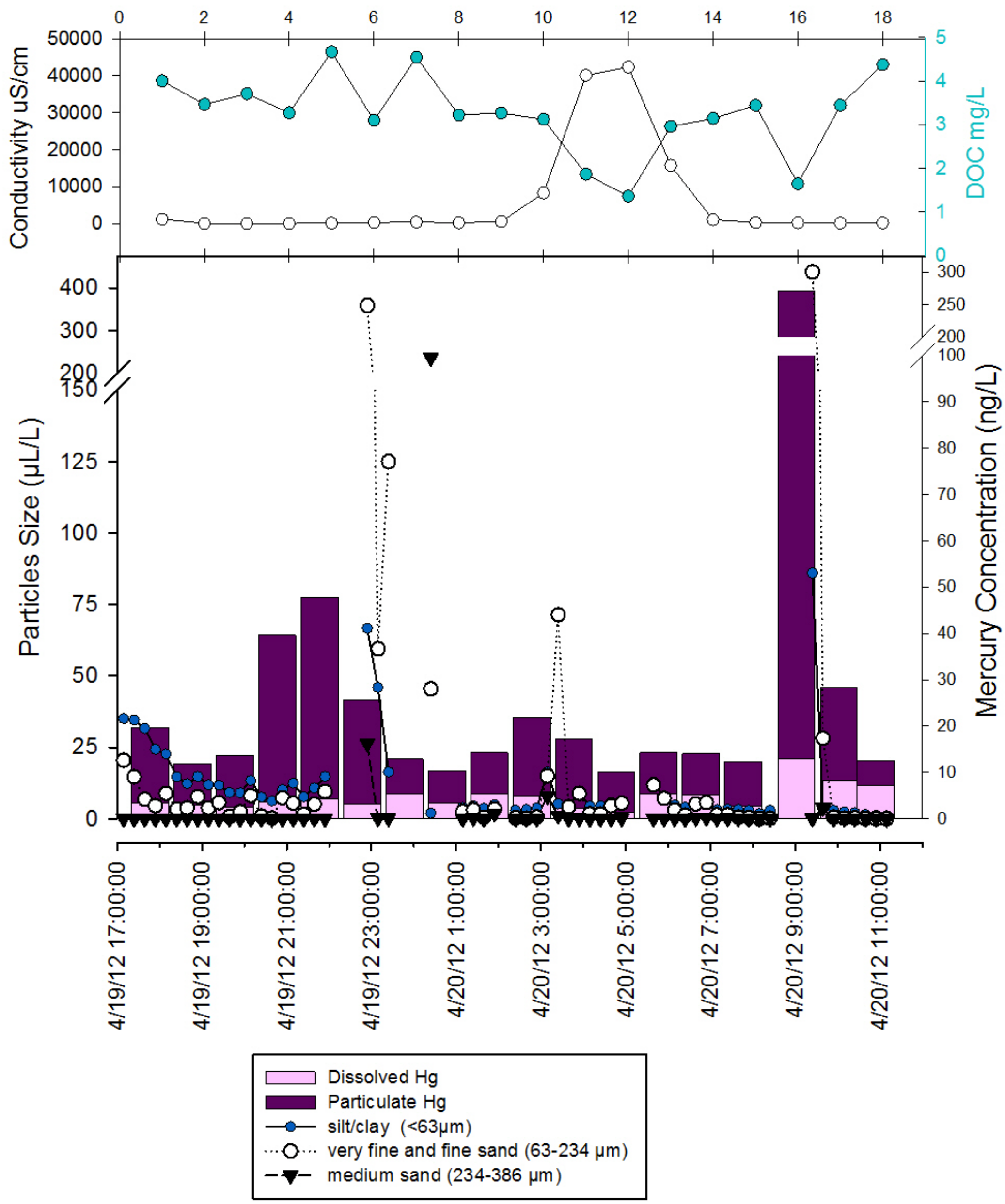


Figure 5-11.The conductivity and dissolved organic carbon (DOC) during SW12 (top graph) and discrete 1-hr composite concentrations of particulate and dissolved Hg (bottom graph). The silt/clay, fine sand, and medium sand data collected from the LISST are plotted. The top of the bar represents TR Hg.

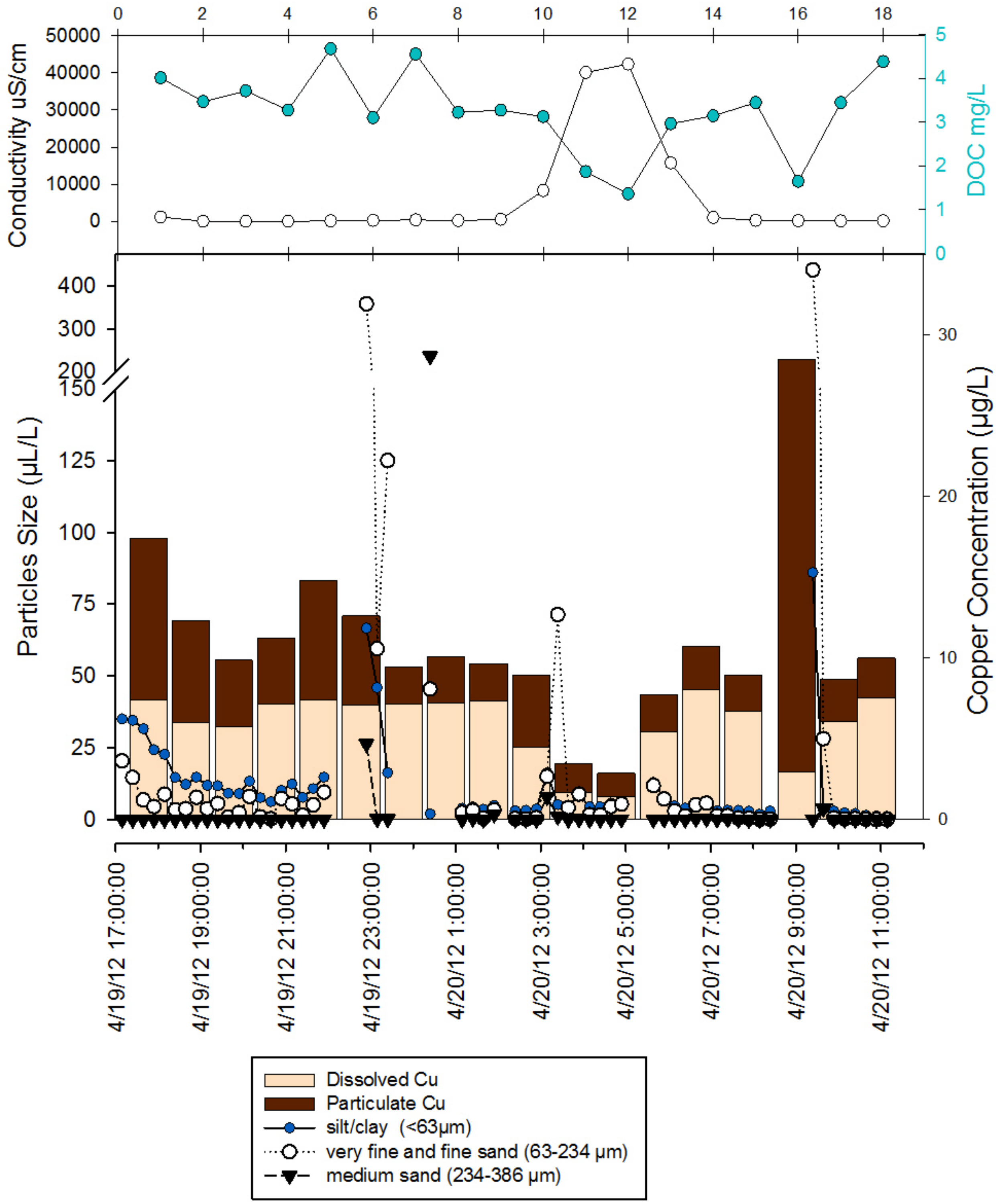


Figure 5-12.The conductivity and DOC during SW12 (top graph) and discrete 1-hr composite concentrations of particulate and dissolved Cu. The silt/clay, fine sand, and medium sand data collected from the LISST are plotted. The top of the bar represents TR Cu.

Table 5-8. The Event Mean Composite (EMC) and discrete 1-hr composite concentrations for SW12.

Station	Collected	Conductivity	TSS	DOC	Hg	Hg	Cu	Cu	Pb	Pb
Fraction	Date/Time				Dissolved	Total	Dissolved	Total	Dissolved	Total
Units		µS/cm	mg/L	mg/L	ng/L	ng/L	µg/L	µg/L	µg/L	µg/L
EMC		338	60.3	3.07	3.98	46.2	6.89	14.4	1.55	12.0
PSNS015-1	4/19/12 17:46	1200	41.8	4.01	3.40	19.7	7.43	17.4	0.872	14.4
PSNS015-2	4/19/12 18:46	70	23.3	3.47	3.04	11.9	6.02	12.3	1.18	9.77
PSNS015-3	4/19/12 19:46	42	14.6	3.71	2.58	13.7	5.77	9.9	1.54	9.39
PSNS015-4	4/19/12 20:46	67	11.9	3.27	3.71	39.6	7.18	11.2	2.28	9.73
PSNS015-5	4/19/12 21:46	168	58.3	4.67	4.34	47.8	7.38	14.8	1.67	12.3
PSNS015-6	4/19/12 22:46	304	13.8	3.10	3.09	25.7	7.08	12.6	1.84	9.75
PSNS015-7	4/19/12 23:46	417	3.34	4.55	5.27	12.9	7.13	9.5	2.22	6.12
PSNS015-8	4/20/12 0:46	228	6.34	3.22	3.43	10.3	7.22	10.1	2.32	7.06
PSNS015-9	4/20/12 1:46	581	5.70	3.27	5.29	14.2	7.32	9.67	2.18	6.45
PSNS015-10	4/20/12 2:46	8300	10.6	3.12	4.97	21.9	4.49	8.95	1.49	6.43
PSNS015-11	4/20/12 3:46	40,100	6.57	1.87	2.37	17.3	1.68	3.49	0.470	2.70
PSNS015-12	4/20/12 4:46	42,350	4.14	1.36	1.31	10.1	1.41	2.87	0.301	1.91
PSNS015-13	4/20/12 5:46	15,750	1.90	2.96	5.49	14.3	5.45	7.73	1.34	5.07
PSNS015-14	4/20/12 6:46	1065	2.95	3.14	5.25	14.0	8.06	10.7	1.79	6.08
PSNS015-15	4/20/12 7:46	311	5.57	3.44	2.83	12.4	6.71	8.95	3.55	8.34
PSNS015-16	4/20/12 9:01	236	181	1.65	13.0	271	2.96	28.5	0.350	22.5
PSNS015-17	4/20/12 10:01	158	8.41	3.45	8.35	28.4	6.07	8.69	1.58	5.40
PSNS015-18	4/20/12 10:54	186	8.90	4.38	7.23	12.6	7.51	10.0	2.29	5.70

Table 4.7. (cont.)

Station	Collected	Zn	Zn	Ag	Ag	Cd	Cd	Cr	Cr
Fraction	Date	Dissolved	Total	Dissolved	Total	Dissolved	Total	Dissolved	Total
Units	Time	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L	µg/L
EMC		48.7	78.4	0.00468	0.0445	0.0277	0.0610	0.888	2.32
PSNS015-1	4/19/12 17:46	43.7	76.2	0.00369	0.0296	0.0569	0.117	0.949	2.69
PSNS015-2	4/19/12 18:46	34.2	62.6	0.00200	0.0192	0.0183	0.0594	0.746	1.61
PSNS015-3	4/19/12 19:46	37.5	57.1	0.00311	0.0138	0.0146	0.0459	0.715	1.28
PSNS015-4	4/19/12 20:46	52.5	70.6	0.00241	0.0331	0.0260	0.0453	0.801	1.36
PSNS015-5	4/19/12 21:46	54.0	84.8	0.00249	0.0433	0.0198	0.0588	0.782	1.93
PSNS015-6	4/19/12 22:46	51.8	76.1	0.00448	0.0241	0.0261	0.0722	0.950	1.60
PSNS015-7	4/19/12 23:46	55.6	64.4	0.00427	0.0144	0.0284	0.0378	1.39	1.73
PSNS015-8	4/20/12 0:46	79.20	92.8	0.00474	0.0148	0.0314	0.0463	1.21	1.63
PSNS015-9	4/20/12 1:46	72.2	82.1	0.00531	0.0133	0.0332	0.0408	1.40	1.87
PSNS015-10	4/20/12 2:46	71.0	92.0	0.00526	0.0512	0.0732	0.0962	0.698	1.37
PSNS015-11	4/20/12 3:46	65.1	70.5	0.00420	0.0225	0.204	0.224	0.119	0.420
PSNS015-12	4/20/12 4:46	30.3	32.8	0.00420	0.0122	0.128	0.141	0.138	0.378
PSNS015-13	4/20/12 5:46	79.4	83.3	0.00519	0.0204	0.120	0.128	0.694	0.968
PSNS015-14	4/20/12 6:46	61.7	69.9	0.00493	0.0125	0.0301	0.0382	1.02	1.39
PSNS015-15	4/20/12 7:46	87.6	98.5	0.00332	0.0118	0.0329	0.0394	0.774	0.970
PSNS015-16	4/20/12 9:01	22.1	108	0.00200	0.129	0.0200	0.125	0.411	3.38
PSNS015-17	4/20/12 10:01	65.7	80.7	0.00926	0.0242	0.0279	0.0434	0.687	0.971
PSNS015-18	4/20/12 10:54	68.0	80.7	0.0103	0.0220	0.0282	0.0470	0.740	1.06

5.5 Stormwater Loading Calculations

The runoff volume was used to calculate the metal loads. The generalized equation for calculating the metal load is the EMC times the storm discharge volume. Appendix C details the equations to calculate the load and also summarizes the load for each outfall during each storm. The load is calculated for both the TR metal concentrations and the dissolved concentrations to provide both the total metal load for the mass balance calculations (Brandenberger et al. 2007a) and allow an evaluation of the fraction of the load that has the highest potential to be bioavailable. Figure 5-13 illustrates the distribution of the metal loads for Cu, Zn, Pb, and Zn categorized by the ENVVEST storm size classification. The general pattern appears to emerge that large storms contribute the largest loads, with the exception of Hg. However, the data set is skewed to represent larger storms as discussed above. When you add the ENVVEST stormwater outfall data from 2003-2005 to this study you can see a different picture. The relative importance of the small storms shows up. However the Hg continues to demonstrate that larger storms do not necessarily contribute larger loads. The small data set represents the challenges of predicting stormwater concentrations in a limited data set due to the highly variable nature of the storm chemistry.

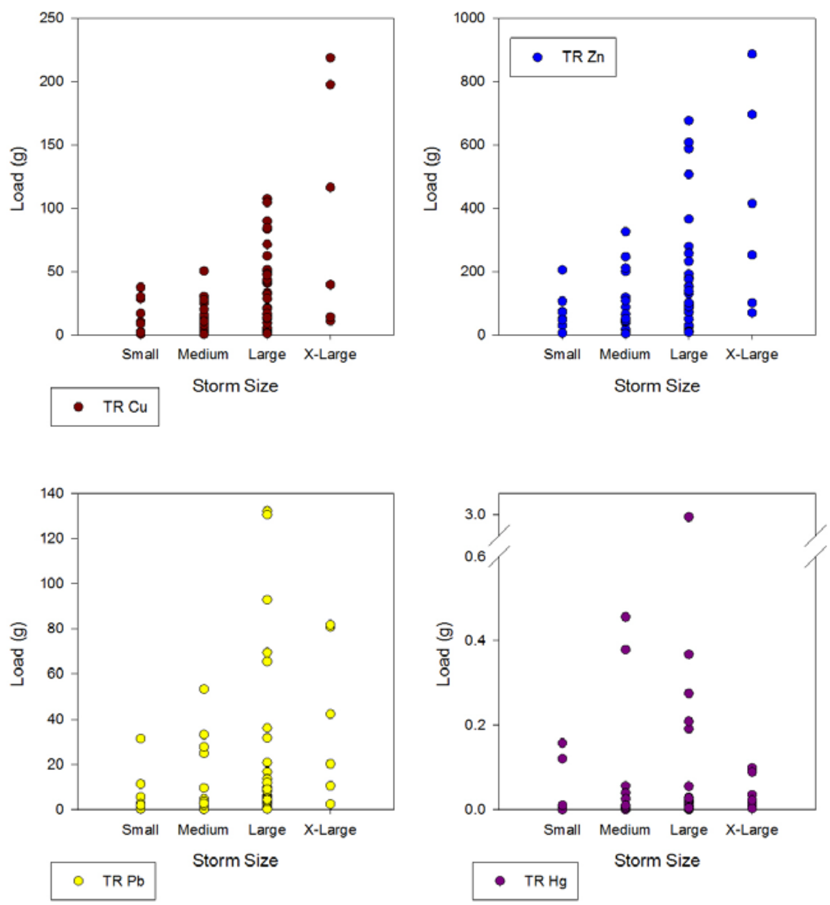


Figure 5-13 The load for each storm from the 2010-2013 study plotted base on the size classification.

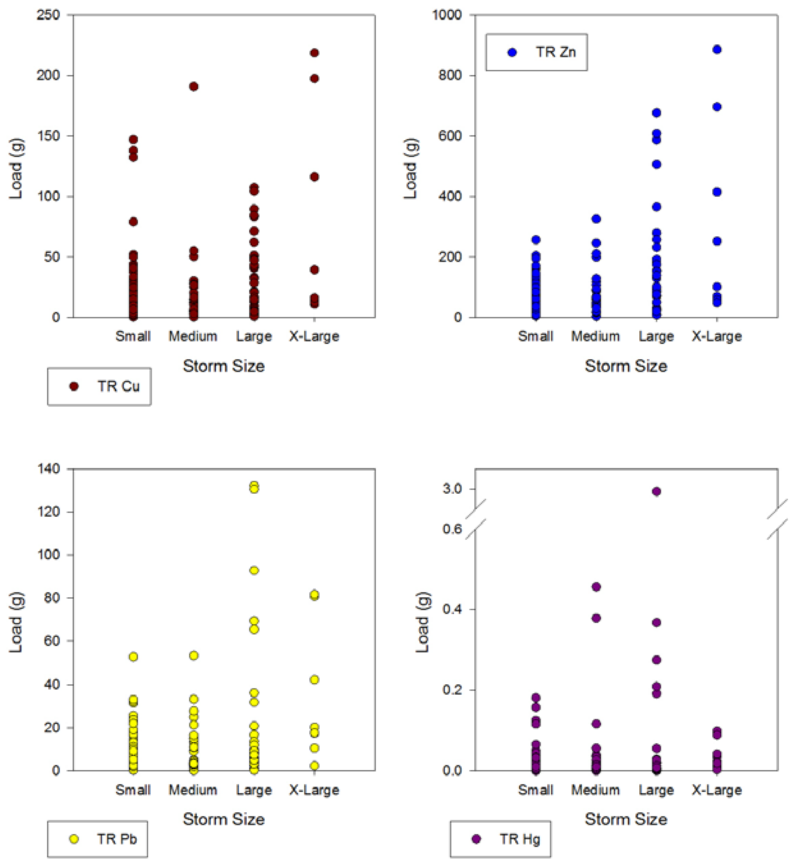
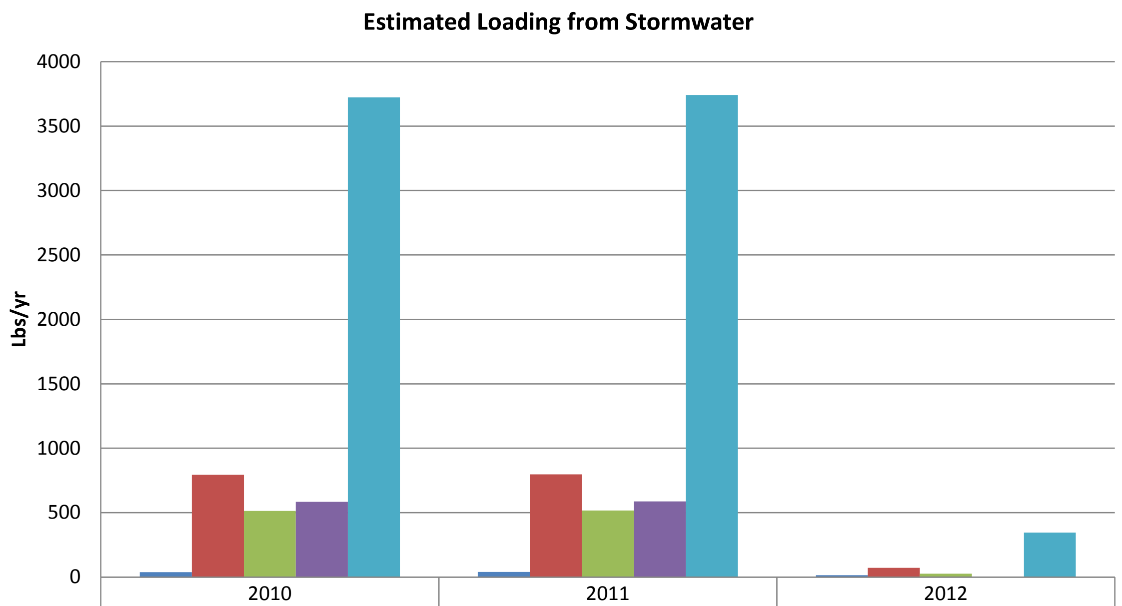


Figure 5-14 The loads of Cu, Zn, Pb, and Hg from the combined 2010-2013 PSNS outfall study and the ENVVEST 2003-2005 stormwater outfall study show the increase in the relative importance of the small storms.

This loading data can be used to calculate the estimated stormwater discharge for EPA form R for each year. Figure 5-15 summarizes the annual load for each metal by year for this study. The best available stormwater quality data are used to calculate the load. The data from this study was used to calculate the loads in 2012. The previous years used significantly older stormwater data, which illustrates the value of using high quality chemistry data when calculating the loads.



	2010	2011	2012
Cr	39	39	14
Cu	794	798	72
Pb	514	516	26
Ni	584	587	0
Zn	3723	3742	346

Figure 5-15 The estimated loading from stormwater calculated for each year with the data from this study used in the 2012 calculation compared to older data used in 2010 and 2011 when new stormwater quality data were not available.

5.6 Storm Particulate Chemistry

The metal, PAH, and PCB results from the storm drain particulates recovered from the storm vaults were highly variable and demonstrate the value of understanding the particulate chemistry in the stormwater system. Table 5-9 provides the descriptive statistics for the particulate samples collected from storm drains from 2010 -2013. At PSNS015 the 2011 concentration for Hg was 591 µg/g dry wt. compared to the 2012 8550 µg/g dry wt. In 2013, the particulates ranged from 60-1234 µg/g dry wt. Figure 5-16 illustrates the data from 2011-2013 storm particulate collection events. The data are reported in Appendix F. Although the data are not conclusive, they show the particulate metal and organic sources are higher at PSNS015 than the other stations. Although this basin has the lowest %TIA and is located on NBK where the support service activities and residential activities are located, the concentrations of TOC at PSNS015 (<1% TOC) were much lower than the other stations (15% TOC). Generally areas with more grass surfaces and higher levels of pervious surfaces (i.e. baseball fields, parks, etc.) have higher TOC.

It isn't appropriate to compare the particulate chemistry to sediment quality standards as the particulates have not mixed with seawater and been deposited in the marine sediment. Therefore, the data were compared to the regional Phase I permit data summarized by Ecology (Hobbs et al. 2015). This too isn't a perfect comparison as the sampling methods were quite variable. This study collected grab samples of particulates in the stormwater drain/vault area. The permit did not specify a collection methodology, but recommended that the sampling protocol use in-line sediment traps or other similar collection system.

The Permit data thus represents a variety of stormwater sediment sampling approaches from in-line traps to grab samples. Monitoring in-line stormwater solids using traps can be unpredictable and require long periods of submersion and/or deployment to adequately trap sediments sufficient for analysis. Other differences in methods could include decanted overlying water prior to laboratory analysis and the method used to analyze the sediment (e.g. leaching). However, the data does provide a rough comparison of chemistry between the Shipyard storm drains and other regional storm drains. The extremely low concentrations for the metals recorded as minimum concentrations under Phase I Permit Data appear to be anomalous compared to most pre-industrial sediment chemistry in Puget Sound (Brandenberger et al. 2008b; 2011). The pre-industrial concentrations for Sinclair and Dyes Inlet were provided by sediment cores and are included for comparison in Table 5-9 (Brandenberger et al. 2008b). It is unrealistic to have particles that represent the broader sediment conditions that have less metals than the concentrations prior to industrialization in Sinclair and Dyes Inlets.

Table 5-9 2010-2013 storm drain particulate chemistry concentrations. Units are µg/g dry wt for all metals and ng/g dry wt for PAHs and PCBs

	2010-2013 Shipyard Study					**Ecology Phase I Permit Data**			**Pre-industrial Concentrations of Metals in Sediment**[17]
Parameter	**Count**	**Median**	**Min**	**Max**		**Count**	**Min**	**Max**	**Mean (n=8)**
Cu	9	775	137	6018		78	0.16	1260	37
Zn	9	537	296	3465		80	0.37	9250	79
Pb	9	630	73	5030		80	0.36	1790	8.0
Hg	13	128	0.87	8550		68	0.01	0.44	0.048
As	9	13	5.7	156		NA			8.9
Ag	9	2.3	0.32	458		NA			0.24
Cd	9	1.3	0.39	8.1		80	0.008	4.9	
Cr	9	444	49	1861		NA			
Ni	9	122	45	1292		NA			
PAH	5	5716	1508	418407		86	4.1	2990960	
PCB	5	754	35	1151		33	8.5	770	

[17] Brandenberger et al. 2008

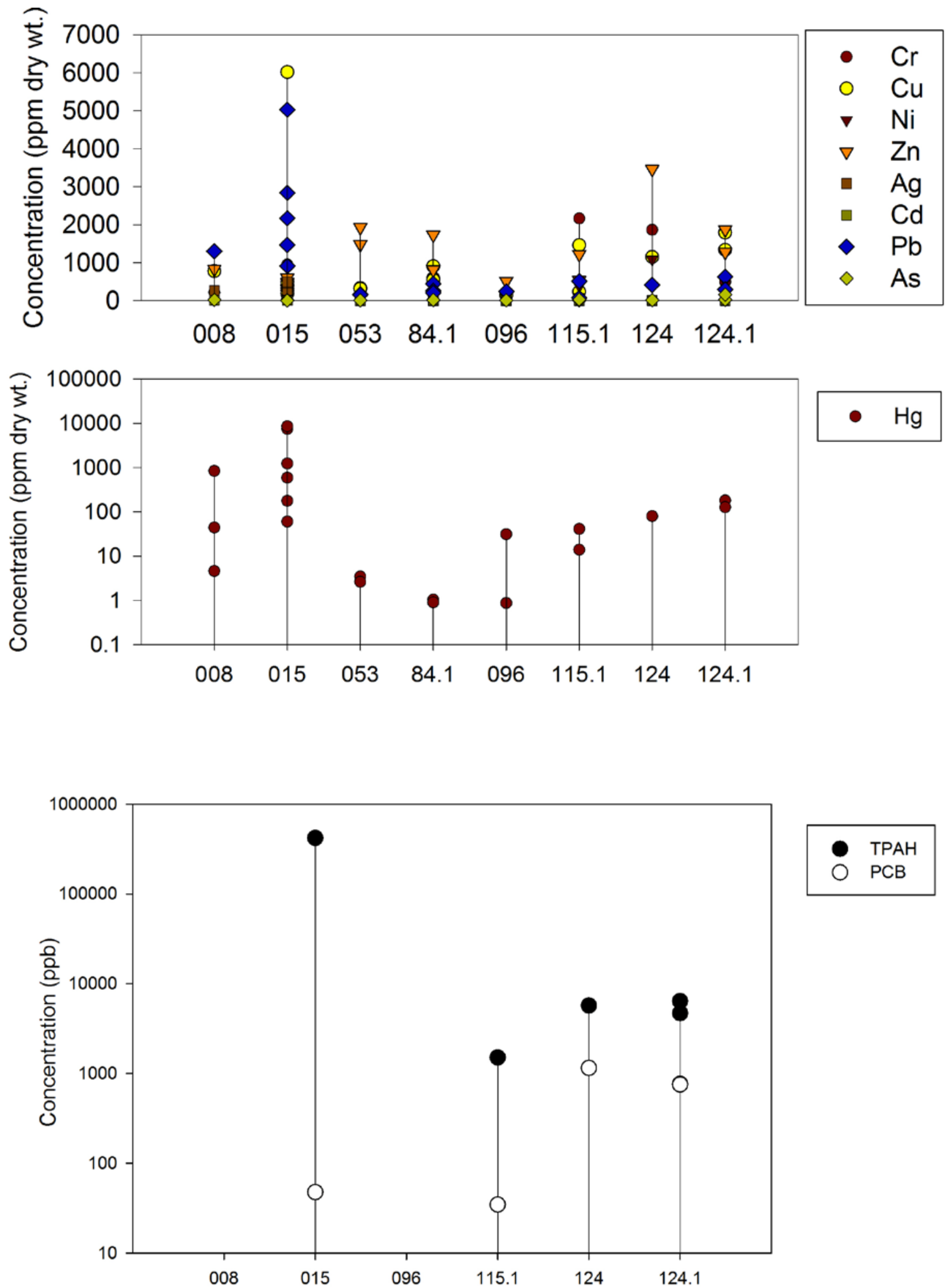


Figure 5-16 Stormwater outfall particulate chemistry during the 2010-2013 study.

6.0 Conclusion

Regulatory agencies are currently specifying low discharge "benchmarks" or "limits" to stormwater outfalls and requiring arbitrary monitoring requirements (monthly or seasonally) that are not tied to the driving forces within the watershed such as hydrology (flow regime), weather (storm events and antecedent dry periods), land use and land cover, and pollutant loading to the receiving waters. This report summarizes the findings from the three year study on non-drydock stormwater chemistry within the Shipyard. The overall goal of the NDDSW study was to characterize the stormwater quality in Shipyard drainage basins, provide a benchmark from which to measure past and future process improvements, and compare the current stormwater chemistry to a variety of regional stormwater data to provide a contextual understanding for the Shipyard. The study sampled 16 storm events discharging from 13 different outfalls chosen to represent various activities across the Shipyard. The storm samples were found to be representative of the typical size and frequency of storm events occurring in this region from November through April. The work activities were divided at the highest level into outfalls draining the industrial CIA region of the Shipyard and those draining the residential and support services on NBK. The only metals that could potentially exceed the existing Navy permits and/or the stormwater benchmarks discussed in Table 1-1 and Table 1-2 were Cu, Pb and Zn.

Based on this three year study, the probabilities for stormwater composites collected from outfalls in the Shipyard to exceed the 2008 draft NPDES stormwater permit limits were 100% for Cu, 62% for Zn, and 0% for all other metals (see permit limits in Table 1-1). The probability for the EMCs to exceed the U.S. Navy general permits for Cu and Zn were 67% and 43%, respectively. The probability for the EMCs to exceed the 1994 NPDES Permit (still in effect) for Cu and Zn were 25% and 0%, respectively. Although the stormwater appears to have the potential to exceed several different permit limits for Cu and Zn, the question remains: How do the Shipyard stormwater outfalls compare to Bremerton and Kitsap County stormwater outfalls that also discharge into Sinclair Inlet? Also how do they compare to the broader Puget Sound regional stormwater outfalls?

The following sections compare historical stormwater data along with tracked process improvements in the Shipyard, discusses various stormwater benchmarks or permits, and provides contextual stormwater data from Bremerton and Kitsap County that also drains into Sinclair Inlet. The potential for many sources of stormwater to enter Sinclair Inlet and potentially impair beneficial uses suggests the need for a mass balance or total maximum daily load (TMDL) type approach to management. In addition, the stormwater partitioning chemistry provided a means to develop recommended actions for each drainage basin and suggest potential BMPs for stormwater managers. This report addressed the following questions:

1. How does the water quality of stormwater runoff compare between various drainage basins in the Shipyard that support different types of activities (e.g., CIA versus NBK)?
2. What is the status and trend of stormwater quality relative to previous Shipyard sampling (e.g., ENVVEST in 2003–2005) and/or other Puget Sound industrial areas?

6.1 Process Improvement at the Shipyard

Since the Shipyard is committed to process improvement, they have been benchmarking activities since 1995 to provide a metric by which to associate the measured water quality improvements with the activities that provided the benefit. Although this project did not detect statistical differences between EMCs based on primary work activity (residential, material laydown, loading, metal work, and high traffic), it did identify that the best discriminator of the EMCs was whether the outfalls drained NBK or CIA basins. This is a coarse breakdown of work activity between Shipyard supporting services (i.e. residential, parking, etc.) and the industrial activities such as metal work, metal recycling, materials laydown, and ship maintenance. Over the past two decades, activity based improvements and repairs have significantly reduced the concentrations of Cu, Pb, and Zn in stormwater. Figure 6-1 provides specific improvements on the left compared to stormwater sample concentrations collected over the same period of time. The stormwater data was compiled from several Shipyard projects through the years and includes the 2010-2013 study reported herein. The mean of this study is plotted to provide another benchmark from which to measure process improvement in the future. Similar graphs could be prepared for Zn and Pb. The benefit of process improvements can also be assessed at the station level. Converting the steam plant to reverse osmosis along with the other activities in NBK have significantly reduced the Hg concentrations at PSNS015 (Figure 6-2). Similarly in the CIA, outfall PSNS126 drains metal work and laydown areas that have significantly benefited from process improvement (Figure 6-2).

It is difficult to definitively compare historical stormwater data due to the variety of methods used to collect and analyze the chemicals of concern. One data set directly comparable to this study is the ENVVEST 2003–2005 PSNS stormwater outfall study which also sampled PSNS015, 124, 008, and 101 using similar methodologies (Brandenberger et al. 2007a, b). In this 2010-2013 study, the median concentrations were all lower than the medians from the 2003–2005 data set. This suggests a measurable decrease in the overall concentration of these metals in the stormwater at the Shipyard and points to successes in process improvements.

Date	Action
1995	ESH Managers for Projects
1995	Non-Stormwater Discharge Permit Process
1998/1999	RMTS – Stormwater treatment installed
~ 2001	Environmental Coordinators for Projects
2001/2002	Pier Delta Oily Water Separator
2003	Inspection criteria developed for drydock and stormwater
2004	Effective inspections and reporting process set up
2004	Repair of major storm & sanitary sewer line on "R" street
2004	Portable Fuel Tank Usage Restrictions (IPI) - No topside fueling
~ 2004	Implement revised industrial process instructions
2004/2005	Steelyard – Vortech stormwater treatment device
2004/2005	265 Repairs after Clean and Inspect of Stormwater System
2005	Increase Env Management oversight; Catch Basin PMI
2006	Sanitary sewer and storm drain repair
2007	BMP briefs prior to docking; Establish stormwater inspection zones
2008	Containments for Blasting and Painting
2009	Disconnect Bremerton 21" stormwater line
2010/2011	BMP's updated to current processes
2011	Bremerton's separated their combined sewer system
2012	Monthly inspections of base, Storm sewer PMIs tracked
2012	Pier B – New stormwater treatment in vault
2013	98% Solid Waste Containers Covered

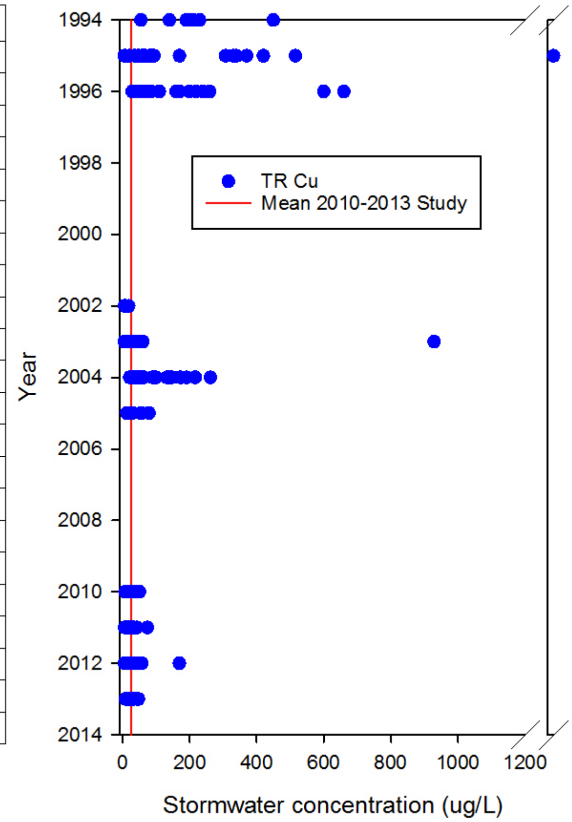


Figure 6-1 Key process improvement activities at PSNS from 1995 – 2013 (left) compared to stormwater concentrations from various projects conducted over this time period. The plot includes the current 2010-2013 NDDSW study and the red line is the 2010-2013 study mean for total recoverable (TR) Cu.

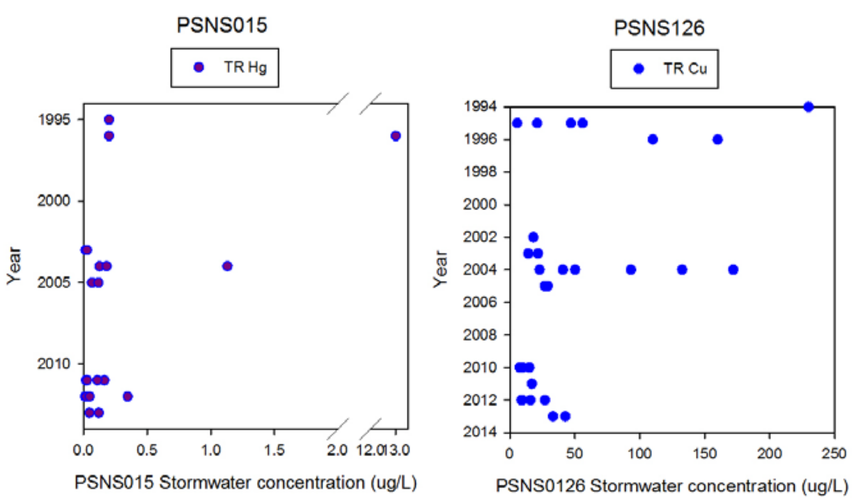


Figure 6-2 Historical stormwater Hg (left) and Cu (right) concentrations from 1995 – 2013 (left) collected at outfall PSNS015 located in NBK and PSNS126 in the CIA.

6.2 Regional Comparison

The data from this study were compared to other regional urban, commercial, and industrial stormwater data and benchmarks (Table 6-1). This provides reference points for other outfalls discharging directly into Sinclair Inlet and the Puget Sound region. The referenced studies were discussed in Section 1.3 and include the ENVVEST 2003–2005 stormwater data collected from PSNS outfalls, the ENVVEST stormwater data collected from urban outfalls in Kitsap County, a 2010 Puget Sound stormwater study of specific LULCs, and Ecology's Phase I stormwater permit data summary 2009-2013 (Hobbs et al. 2015). The stormwater concentrations can be compared to the Multi Sector General Permit (MSGP) (TR Cu 4.8 µg/L and TR Zn 90 µg/L, see Section 1.2.2) issued by the EPA in 2015 that covers federal facilities in Washington and regulates stormwater discharge from 29 different industrial sectors, including ship and boat building and repairing yards. The data could also be compared to the U.S. Navy general permit. Out of the 67 stormwater composite samples collected in this study, all stations and storms would exceed the MSGP for TR Cu, 45 (67%) would exceed the U.S. Navy general permit, and 17 (25%) would exceed the NPDES outfall permit of 33 µg/L TR Cu. However, it would be more appropriate to evaluate how the concentrations from this study compare to regional stormwater collected from industrial, commercial, and other urban outfalls.

It can be difficult to compare stormwater data between studies due to different collection (i.e. grab vs composite) and analytical methods (i.e. salt correction or simple dilution). The ENVVEST 2003–2005 stormwater study collected samples using the same composite methodology from urban outfalls and streams (during storm events) within the Sinclair Inlet study area. In many cases, the medians are very similar and the ranges overlap the stormwater data from this study. Figure 6-3 illustrates the data sets and suggests that for some metals their sources may not be specific to Shipyard activities and may be driven more by activities occurring in both urban and industrial settings (e.g., vehicles, roof runoff, etc.) across the region rather than just at the Shipyard. In fact, Brandenberger et al. (2010) found the Puget Sound concentrations of Cu and Hg in rainfall ranged from 0.29 to 5.5 µg/L and from 4.1 to 9.4 ng/L, respectively. For Hg, this is consistent with the data across all the studies where stream concentrations during storm events are within a factor of two of the industrial and urban stormwater outfall chemistry.

Outside of Kitsap County, the data can be compared to several studies conducted by Ecology to evaluate the concentrations of stormwater compared to the dominant LULC. The collection methodology is slightly different between all three studies, but they all provide a representation of the total storm contribution. In 2010, a stormwater study collected grab samples based on the hydrograph that were then composited to represent the storm concentrations measured in two basins of Puget Sound (Puyallup and Snohomish) that targeted specific LULC distributions (Herrera Environmental Consultants, Inc. 2011). The median for the commercial/industrial LULC provides a measure of regional comparison. Overall the concentrations from the PSNS outfalls were higher, but the data should be compared with caution. Herrera Environmental Consultants, Inc. (2011) reported data from only 6 samples; therefore, no conclusions could be drawn as the stormwater data are not normally distributed.

Then from 2009 – 2013 the stormwater Phase I permittees collected flow-weighted composite sampling to best represent storm event concentrations. Flow-weighted stormwater samples were collected by automatic samplers (such as ISCO samplers), which were triggered to begin sampling once either the rainfall criteria of 0.02" or a presence of flow in the conduit was detected. This was a very robust study with 4,423 samples from permittees with stormwater outfalls draining predominately industrial LULC and 20,045 from commercial LULC. The medians from NDDSW 2010-2013 stormwater study were quite comparable to the industrial LULC medians from the Phase I permit data. Predominately industrial stormwater drainage basins were reported from counties (Clark, King, Pierce, Snohomish), cities (Seattle and Tacoma) and the ports (Seattle and Tacoma) compiled from 2009 through 2013 (Hobbs et al. 2015). This provides a reasonable benchmark from which to compare future stormwater studies in the industrial and commercial/residential side of the Shipyard.

Table 6-1. Stormwater permit, benchmark, and study comparisons applicable to contextualize this study within the region and from both urban stormwater outfalls and commercial/industrial (C&I) activities. All concentrations are total recoverable (TR) metals.

TR Concentration	TR Cu (µg/L)	TR Zn (µg/L)	TR Pb (µg/L)	TR As (µg/L)	TR Hg (µg/L)
PSNS 2008 Draft NPDES Stormwater Permit	5.8	95	221	69	2.1
U.S. Navy General Permit	14.0	117			
NDDSW 2010–2013 PSNS Median EMCs (range) n=67	**17.8 (5.9-170)**	**114 (33-408)**	**7.2 (0.65-2.4)**	**1.2 (0.38-7.7)**	**0.010 (0.001-0.35)**
ENVVEST 2003–2005 PSNS Outfalls Median (range)[(a)] n=19	42.4 (12-123)	113 (35-257)	11 (4-32)	4.3 (1-12)	28 (12-123)
ENVVEST Urban Outfalls Median (range)[(a)] n=40	11 (5-27)	62 (18-140)	9.8 (3-25)	0.97 (0.5-14)	11 (6-56)
Puget Sound C&I[(b)] Median n= 6	3.84	37.2	1.68	0.92	7
Ecology Phase I Permit Data[c] (Median: Min - Max)					
LULC – Industrial n = 4,423	16 (5.56-64.3)	123 (27.7-420)	7.94 (2-60)	NA	(0.0219-0.062)
LULC – Commercial n = 20,045	19.6 (2.1-218)	102 (8.6-1290)	14.4 (0.1-294)	NA	0.01 (0.002-0.4)

(a) Brandenberger et al. (2007 a, b) and Cullinan et al. (2007).
(b) Herrera Environmental Consultants, Inc. (2011).
(c) Hobbs et al. (2015) for Puget Sound Counties, major cities and ports

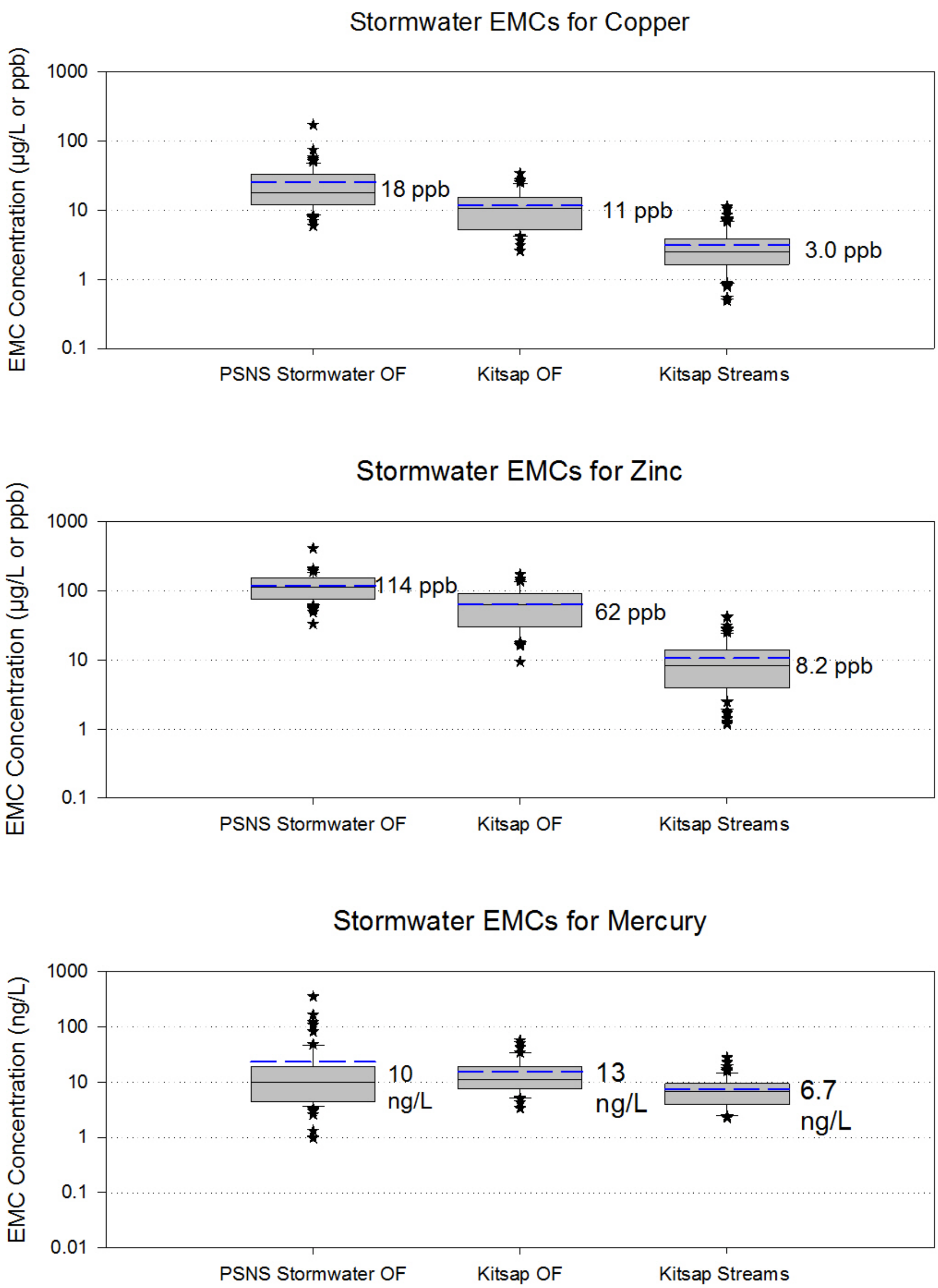


Figure 6-3. Data distributions from this study (PSNS Stormwater OF), the ENVVEST 2003–2005 Kitsap County Urban Stormwater Outfalls (Kitsap OF), and stormwater collected from Kitsap Streams from 2003-2005 (Brandenberger et al. 2007 a, b). The median concentrations are numerically noted on the graphs and the blue dashed lines are the average concentrations.

6.3 Key Stormwater Sampling Considerations

Overall the study demonstrates the value of high quality collection and analytical methods within any stormwater program. A couple of key considerations for the Shipyard can be drawn from this study. Any stormwater collection within the Shipyard must consider tidal intrusion into the storm drains during both sample collection and analysis. Although this is recognized by the regional guidance provided by RSMP, the RSMP does not specify if randomly timed or targeted sampling is optimal. This contrasts with the shipyard's Draft Permit which stipulates grab samples be taken within the first 60 minutes of a storm event or time-proportional composites started within the first 30 minutes and extended 2 hours into the storm event. Understanding the timing of the first flush and the potential for tidal influence inside the storm drain system are critical elements for any stormwater program in order to represent the true discharge of metals and their chemical or phase speciation (e.g. dissolved versus particulate). In addition, stormwater sampling at the Shipyard should include collection and analytical methods that compensate for the tidal intrusion into the drainage system. As was noted in the SW12 detailed storm analyses, the influence of the tide on the stormwater chemistry at PSNS015 was significant. Salinity, as low as 2 ppt, results in analytical artifacts and dilution of the runoff derived from a storm event. In addition, the tide "holds" up the stormwater, thereby resulting in a delay in the freshwater runoff independent of precipitation trends. The detailed chemistry as a function of rainfall, volume of stormwater runoff, and tide further highlighted the need to collect composite samples rather than grab samples during the "first flush".

The dominance of the particulate or dissolved metal fraction is also a function of the total precipitation during the storm and the eventual mixing with seawater from tidal intrusion. Table 6-2 lists the average percent dissolved for each metal as a function of storm size. As would be expected, the larger storms have a larger fraction of particulate copper than smaller storms. This is primarily a function of the runoff speed and the ability to erode landscapes during larger storms. The erosion brings particulate metals both from natural and Shipyard sources. However, Zn, Hg, and Pb do not have comparable trends.

Table 6-2. The Average Percent Dissolved Metal in Stormwater EMCs as a Function of Storm Size

	Cu	Zn	Hg	Pb
Small (<0.5 in.)	50%	60%	22%	8%
Medium (0.5–1.0 in.)	51%	65%	31%	9%
Large (1–2.0 in)	39%	66%	26%	6%
Extra-Large (>2.0 in.)	25%	53%	26%	3%

This study suggests additional studies are required to provide scientific evidence in support of, or to refute, the draft permit limits for Cu and Zn as a function of actual bioavailability instead of total recoverable metals (e.g., implementing the BLM for site-specific criteria) and to determine if there are truly impairments to beneficial uses within Sinclair/Dyes Inlets. specific outfalls with EMCs repeatedly above the NPDES permit for TR Cu (33 µg/L) should be targeted for further monitoring and process evaluation. The outfalls in priority order include PSNS124, 124.1, 115.1, and 081.1. In addition, NBK stations PSNS015 and PSNS032 should be evaluated for sources of Hg.

The final consideration is that field collection procedures for the Shipyard stormwater outfalls must include specific methodology to limit the potential for post collection contamination. Cu and Zn are ubiquitous in shipyard operations and thus trigger the need to ensure the water collected during sampling adequately represents the water flowing in the drain and not contamination introduced to the sample itself during or after collection (i.e., at the manhole). The concentrations of the draft permit are approaching levels measured in streams during storm conditions and rainfall directly. This means that even small amounts of contamination added to the sample after collection or from a localized activity may skew the stormwater results when you calculate the load of the metal entering the receiving water. Therefore it is critical that both stormwater collection and analytical methods take every precaution to prevent sample contamination. The chemistry of the 1L of stormwater collected from the storm drain must represent the chemistry of the water in the stormwater conveyance.

7.0 References

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