North Boeing Field/ Georgetown Steam Plant Site Remedial Investigation/Feasibility Study

Expanded Stormwater Sampling

Interim Data Report (Updated)

Prepared for

Washington State Department of Ecology
Toxics Cleanup Program
Northwest Regional Office
Bellevue, WA

Prepared by

Science Applications International Corporation
18912 North Creek Parkway, Suite 101
Bothell, WA 98011

January 2011

LIMITATIONS

SAIC's investigation was restricted to collection and analysis of a limited number of environmental samples, visual observations, and field data, in addition to summarizing available information from previous site documents. Because the current investigation consisted of evaluating a limited supply of information, SAIC may not have identified all potential items of concern. This report is intended to be used in its entirety; taking or using excerpts from this report is discouraged.

Table of Contents

Figures

Tables

List of Acronyms

µg	microgram
µm	micron
2LAET	second lowest apparent effects threshold
ARI	Analytical Resources, Inc.
CSL	Cleanup Screening Levels
DOC	dissolved organic carbon
EAP	Environmental Assessment Program
Ecology	Washington State Department of Ecology
EOF	emergency overflow
EPA	U.S. Environmental Protection Agency
FC	freshwater criteria
ft/s	feet per second
g	gram
gpm	gallons per minute
GTSP	Georgetown Steam Plant
HHO	human health for consumption of organisms
HPAH	high molecular weight polycyclic aromatic hydrocarbon
KBFI	Seattle Boeing Field-King County International Airport rain gauge
KC	King County
KCIA	King County International Airport
kg	kilogram
L	liter
LAET	lowest apparent effects threshold
LDW	Lower Duwamish Waterway
LPAH	low molecular weight polycyclic aromatic hydrocarbon
LS	lift station
m/s	meters per second
mg	milligram
MH	manhole
mL	milliliter
MLLW	mean lower low water
mm	millimeter
MWC	marine water criteria
NBF	North Boeing Field
NOAA	National Oceanic and Atmospheric Administration
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyl
pg	picogram
QAPP	Quality Assurance Project Plan
RI/FS	Remedial Investigation/Feasibility Study
SAIC	Science Applications International Corporation

List of Acronyms (continued)

SAP	sampling and analysis plan
SD	storm drain
SIM	Selective Ion Monitoring
SMS	Sediment Management Standards
SOP	standard operating procedure
SQS	Sediment Quality Standard
SVOC	semi-volatile organic compound
TEF	toxic equivalency factor
TEQ	toxic equivalent quotient
TOC	total organic carbon
TSS	total suspended solids
USEPA	U.S. Environmental Protection Agency
VOC	volatile organic compound
WAC	Washington Administrative Code
WHO	World Health Organization

1.0 Introduction

Stormwater discharge from the North Boeing Field-Georgetown Steam Plant (NBF-GTSP) Site is a potential source of contaminants to Slip 4 on the Lower Duwamish Waterway (LDW). The Washington State Department of Ecology (Ecology) and the U.S. Environmental Protection Agency (USEPA) identified cleanup of contaminated sediment in Slip 4 as a high priority for the LDW Superfund Site. Cleanup of Slip 4 has been delayed because of concerns about the potential recontamination of sediments in Slip 4 from releases of contaminants from this site. A Remedial Investigation/Feasibility Study (RI/FS) and cleanup of this site is necessary to allow sediment cleanup in Slip 4 to proceed. Because of the long time frame associated with completing the RI/FS, USEPA asked Ecology to investigate options that might allow the cleanup of Slip 4 to proceed.

To facilitate this process, Ecology tasked Science Applications International Corporation (SAIC) with the collection of stormwater and continuous flow measurements from the storm drain (SD) line upstream of the King County International Airport (KCIA) SD#3/PS44 emergency overflow (EOF) outfall to Slip 4. In September 2009, stormwater sampling systems were installed at two locations on the NBF-GTSP site: a manhole on the downstream side of the King County lift station (LS431), and manhole MH108 on the north lateral SD line. Whole water and filtered suspended solids samples were collected at both locations during five storm events as part of the preliminary stormwater sampling task. Sampling results were documented in a Preliminary Stormwater Sampling Interim Data Report (SAIC 2010a).

Based on a preliminary conceptual site model (SAIC 2010b) and input from Ecology, USEPA, Boeing, the City of Seattle, and King County, additional sampling needs were identified. The original stormwater sampling task was expanded to include an additional five storm events at these two locations, plus sampling at new locations in the north lateral SD line and in each of the other lateral SD lines at NBF. Base flow sampling was also included to assess the contribution of contaminants in base flow to discharges from the KCIA SD#3/PS44 EOF outfall. Additional samples were collected to determine the concentrations of various chemicals of concern in different particle size fractions, in support of Slip 4 sediment recontamination modeling.

This report includes the chemical analysis results for filtered suspended solids and whole water samples collected at 13 locations during the course of the expanded stormwater sampling phase (February through July 2010). Results from the *Preliminary Stormwater Sampling Interim Data Report* (SAIC 2010a) are included in the discussion of results to present a comprehensive account of stormwater data collected at NBF-GTSP.

In addition, continuous flow measurements collected over the duration of sampling are reported. These measurements will be used in conjunction with the chemistry data to calculate contaminant loadings to Slip 4. These loadings will be reported in a separate technical memorandum. Sampling was conducted following the study design and methods described in the August 2009 *Sampling and Analysis Plan and Quality Assurance Project Plan for Preliminary Stormwater and Filtered Suspended Solids Sampling* (SAIC 2009a) and the April 2010 *Work Plan and SAP/QAPP Addendum Expanded Stormwater Monitoring* (SAIC 2010b).

1.1 Site Description

The NBF-GTSP Site is located east of Slip 4 and approximately 4 miles south of downtown Seattle. NBF is located at 7500 East Marginal Way S and occupies approximately 130 acres primarily within the Seattle and Tukwila city limits (Figure 1). The site is leased by Boeing from King County, with the exception of a few acres on either side of the former GTSP flume, which is leased from the City of Seattle, and Building 3-390 and an adjacent parcel used for parking, which are owned by Boeing. The head of Slip 4 is approximately 150 feet from the northwestern boundary of NBF.

The NBF SD system drains a total area of approximately 328 acres; this includes stormwater flow from 171 acres of KCIA, which enters the site from the north and east at four locations (SAIC 2009b). Most areas of NBF drain to one of four lateral SD lines (the north, north-central, south-central, and south lateral SD lines), which are directed to a trunk line that passes through a King County (KC) lift station, under East Marginal Way S, and to the 60-inch KCIA SD#3/PS44 EOF outfall at Slip 4 (Figure 2). Stormwater from a smaller area near Building 3-380 (which previously discharged to Slip 4 via a separate SD line) and a parking area downstream of the lift station also drain to Slip 4.

1.2 Project Scope and Study Objectives

The purpose of the expanded stormwater sampling effort was to collect samples of whole water and filtered suspended solids during five storm events at LS431 and MH108. During three of these events, filtered solids were collected near the downstream end of each lateral SD line and from up to six locations in the north lateral SD line. Filtered suspended solids and whole water were collected from base flow during two time periods near the beginning and end of the expanded sampling task. Specific objectives for sampling are as follows:

- Obtain a larger data set for whole water and filtered suspended solids at LS431 and MH108 to allow for a better determination of the relationship between these two sample types. Continued sample collection at these two locations will allow for a more accurate calculation of contaminant loadings from the north lateral SD line relative to the entire site.
- Conduct base flow sampling at LS431 and MH108 to assess contaminant loadings due to infiltration of groundwater to the SD system.
- Collect filtered suspended solids samples from the north-central lateral SD line, south-central lateral SD line, south lateral SD line, Building 3-380 drainage, and parking lot area to assess contaminant contribution (polycyclic aromatic hydrocarbons [PAHs], metals, polychlorinated biphenyl [PCBs], dioxins/furans) from areas outside the north lateral SD area, to assess whether PCB source control actions taken in the north lateral SD line are sufficient to reduce the potential for Slip 4 sediment recontamination.
- Collect filtered suspended solids samples at six locations upgradient of MH108 in the north lateral SD line to identify and trace sources of PCBs in the north lateral SD line and allow any needed interim actions to focus on specific sub-drainages of concern.

- Determine concentrations of PCB Aroclors, metals, and PAHs in four different particle size fractions.
- Compare chemistry results from all SD lines to relevant surface water or sediment criteria.

1.3 Document Organization

The primary purpose of this report is to summarize and evaluate the results of the expanded phase of the 2009–2010 NBF-GTSP stormwater investigation. Results from the preliminary stormwater investigation are discussed in this document for overall comparisons of results. Section 1.0 describes the NBF-GTSP site and document organization. Section 2.0 describes sampling methods that differed from the preliminary stormwater investigation or the SAP/QAPP Addendum (SAIC 2010b). Flow measurement data are summarized in Section 3.0. Analytical results for filtered suspended solids and whole water are presented in Section 4.0. Section 5.0 summarizes the data validation reports. A summary of findings is presented in Section 6.0. References are listed in Section 7.0. The appendices include totalizer logs, event flow and precipitation summaries, laboratory results, and data validation reports.

2.0 Data Collection and Analytical Methods

This section describes the collection of flow measurement data and the sampling and analytical methods associated with filtered suspended solids, whole water, and base flow samples.

Samples were collected at 13 locations described below (Figure 3):

- LS431, located on the discharge (southwest) side of the KC lift station. All four major SD lines plus the Building 3-380 line drain to the lift station prior to entering Slip 4.
- MH108, located along the north lateral SD line, north of Building 3-380 and near the corner of Building 3-350. MH108 was selected to represent stormwater drainage from the north lateral SD line. MH108 is located 85 meters (275 feet) upstream of the connection between the north and north-central lateral SD lines.
- MH226, located in a flight apron 58 meters (190 feet) north of MH369. MH226 is on the north-central lateral SD line, 107 meters (350 feet) upgradient of the junction with the north lateral SD line.
- MH369, located at the north end of the small parking lot on the northwest side of Building 3-390. This location is 210 meters (700 feet) upgradient of the lift station on the south-central lateral SD line.
- MH356, located on the southwestern corner of Building 3-369, approximately 45 meters (150 feet) upgradient of the lift station. This location is near the downstream end of the south lateral SD line.
- CB423, located between Building 3-380 and the lift station. Flow through CB423 is representative of the Building 3-380 drainage.
- MH434, located 23 meters (75 feet) downstream of the lift station. MH434 is representative of flow from a section of parking lot bordering East Marginal Way S and additional parking spaces within NBF. MH434 was the only drainage area sampled that does not drain to the lift station.
- MH133D, on an extension of the north lateral SD line southwest of Building 3-315.
- MH152 and MH138 are southwest of Building 3-626.
- CB165 is northwest of Building 3-322. This location was adjacent to the March 2010 soil excavation area near Buildings 3-322 and 3-302.
- MH178 and CB173, in the parking lot west of Building 3-323 and about 23 meters (75 feet) southwest of the GTSP boundary. These locations are the farthest upgradient structures sampled as part of the expanded stormwater sampling program. CB173 drains NBF property. Flow at MH178 enters from off site.

Two locations proposed in the SAP/QAPP Addendum (SAIC 2010b) could not be sampled. Proposed sampling at MH160 was not possible due to insufficient stormwater flow. MH169 is within the fuel test area. Sampling at this location would have required explosion-proof sampling equipment. Designing and implementing this equipment was cost prohibitive.

There were two other substantial deviations from the SAP/QAPP Addendum. Up to 20 grab samples were to have been collected at various locations. Between March and May 2010, Landau collected grab samples at all NBF SD structures that contained sufficient material to sample (Landau 2010). Boeing subsequently cleaned out all catch basins in the north lateral SD line. Additional grab sampling locations were not identified. In place of the grab samples, six parking lot surface solids samples were collected to address potential data gaps associated with filtered solids collection at MH434.

Tidal inflow was a frequent problem at MH434. All samples collected at MH434 consisted of tidal water co-mingled with stormwater. Filtered suspended solids results may not be representative of the sampled event. Surface solids samples were collected near Drain 283A and Drain 436A, two samples were collected from an area south of Drain 435B, and two samples were collected from an area south of Drain 434A (Figure 4). The surface solids samples represent material in the parking lot that is adjacent to the SD channel drains and could therefore enter the SD system and be transported to Slip 4.

2.1 Flow Measurements

All stormwater flow measurements were collected using Teledyne Isco (Isco; Lincoln, NE) equipment leased from Whitney Equipment, Bothell, WA. Clearcreek Contractors performed all confined space entry necessary for the Isco installation at each of these locations.

Sampling equipment at MH108 and LS431 was installed as part of the preliminary stormwater sampling (SAIC 2010a). Continuous flow measurements at LS431 were collected using an Isco 6712 stormwater sampler equipped with a Model 750 area velocity flow module. AC power from the east side of the lift station was available to power the Isco unit. Due to the short cycling time of the lift station pumps, the flow sampler was programmed to collect data every 1 minute.

Continuous flow measurements at MH108 were collected using an Isco Model 4250 flow meter run off a 12-volt marine battery. The battery was replaced on a biweekly basis for the duration of the sampling period. The flow meter was programmed to collect data every 15 minutes.

Continuous flow measurements at MH226, MH356, MH369, CB423, and MH434 were collected using Isco Model 2150 flow meters. Each unit was powered by two internal 6-volt lantern batteries. MH356 and MH434 were set to collect data at 1-minute intervals. The unit at MH369 was briefly set to 1-minute intervals, but was switched to 15-minute intervals when the sensor was moved (Section 3.1.3). MH226 and CB423 were set to collect data at 15-minute intervals.

2.2 Sample Collection

Expanded stormwater sample collection efforts began in February and ended in July 2010. Storm event-based whole water and filtered suspended solids were collected at up to 13 sample locations during a given storm event (Table 1). Base flow samples were collected at LS431 and MH108 (whole water and filtered suspended solids) and at CB173 (filtered suspended solids) (Table 2).

A total of six storm events were sampled. Whole water and filtered suspended solids were collected during Events 6 through 10. Event 9b involved filtered suspended solids sampling at

MH434 and CB423 due to previous sampling difficulties at these locations. LS431 was also sampled during Event 9b to provide a constant location between events. Base flow samples were collected during three time periods. During the first base flow event, whole water was collected at LS431 and whole water and filtered solids were collected at MH108. Filtered solids were missed at LS431 due to sampling error. Filtered solids were collected at LS431 during a second base flow event, (Base Flow Event 1b in Table 2). A third base flow event was sampled at the completion of expanded stormwater sampling to obtain a whole water and filtered solids sample at both locations during the same time frame.

Sample equipment for each location was stored in a polypropylene garden shed for protection. When not in operation, the sheds were moved to a nearby storage location to prevent interference with Boeing operations. During sampling, vehicles were parked in front of the flight line sample units to provide a buffer in the event of jet blasts.

The start and end time for each sampling event are based on the times listed on the totalizer log sheets (Appendix A). These times are listed separately for each location, and may vary slightly between locations depending on when each sample unit was activated.

2.2.1 Filtered Suspended Solids Samples

The collection of filtered suspended solids at the expanded stormwater sampling locations was performed in a manner consistent with preliminary filtered suspended solids sample collection methods, as outlined in the preliminary stormwater sampling SAP/QAPP (SAIC 2009a). Events and locations where filtered suspended solids were collected are listed in Table 1.

Prior to each sampling event, clean, pre-weighed filters were installed in each filter housing and the beginning totalizer reading was recorded on the totalizer field form (Appendix A). A 50-gallon per minute (gpm) pump was positioned in the SD beneath the manhole cover. A float switch on the pump was set to trigger sampling when SD water depth exceeded a pre-determined depth. Once triggered, water was pumped up through the intake line and split into parallel filter housings. Each filter housing contained a 20-inch long, 4-inch diameter filter bag. All filter bags were constructed of 5 micron (μm) polypropylene felt. The outflow from each filter housing was piped into a totalizer to measure flow. Outflow from both totalizers was combined and piped back into the SD. When possible, discharge pipes were installed downstream of the effluent pump, avoiding the potential for re-circulation of water. After sampling, the final totalizer readings were recorded, filter housings were drained, and filters were removed. Residual water was gently squeezed from the filter bags. Filter samples were placed in clean, labeled, Ziploc bags and stored on ice for delivery to the analytical laboratory.

Exceptions to this method are described below:

MH133D, MH138, MH178, and CB423. Field observations made during Event 8 indicated that stormwater was not deep enough to trigger continual float switch activation at these locations. The periodic activation of the float switch and pump allowed for excess air to enter the system, causing air lock and preventing further sampling.

Prior to Event 9, pre-washed silica sand was triple bagged inside polypropylene sand bags and placed slightly downstream of the effluent pump to increase the water depth. All sand bags were tightly secured. During subsequent events, stormwater flows successfully triggered the float switches and activated sample equipment at all locations except MH178, which required the installation of a second sandbag after Event 9.

CB165. The float switch was inconsistently activated during Event 8 due to the small vault volume and low flow of stormwater. The pump was plugged into an automated timer and set to 15-minute intervals to prevent the pump from overheating. Prior to Event 9, the discharge pipe was removed from the system and stormwater was allowed to continuously re-circulate during sampling.

CB173. No additional modifications were made to this location. It is important to note that the SD leaving this structure was engineered to be inverted. During a storm, discharge water from the filtration system would flow backwards into the CB173 vault. An unknown quantity of stormwater was likely re-circulated though the sample unit during sampling.

MH434. Stormwater flow during Event 8 inconsistently activated the float switch due to low flows. During Event 9, a high tide obscured the stormwater flow. Prior to Event 9b, a weir was constructed to allow the stormwater to accumulate to a depth that could be sampled. The weir consisted of a 0.15-meter (6-inch) tall piece of wood cut to fit the width of the drain. Ten sandbags were secured and positioned to hold the weir in place.

Several days after Event 9b, field personal noticed the weir had been dislodged and several sandbags had moved. It is believed a combination of high velocity flow from the lift station and a high tide blocking the flow to Slip 4 resulted in water being diverted toward MH434. Sample results collected at this location may not be representative of actual stormwater runoff from the parking lot. They are likely a mix of parking lot runoff, tidal water from Slip 4, and stormwater discharged from the lift station.

2.2.2 Whole Water Samples

Whole water samples were collected using Isco 6712 stormwater sampling units at MH108 and LS431. The inlet for the Isco samplers and the flow sensors were mounted adjacent to each other on stainless steel scissors brackets. As outlined in the preliminary stormwater sampling SAP (SAIC 2009a), the flow sensor and Isco inlet were installed upstream of the filtered solids effluent pump at MH108. However, the large vault-like drain configuration at the lift station prevented upstream installation of the bracket at LS431. Instead, the flow sensor and inlet were installed about 1.5 meters (5 feet) downstream of the effluent pump. The output from the filtered solids sampler was designed to discharge an additional 0.6 meter (2 feet) farther downstream.

Flow-weighted sampling programs were selected for each Isco unit prior to a sampling event. Flow weighting consists of collecting equal volume aliquots at predetermined volume intervals. The aliquot volume was constant at 500 milliliters (mL) for all sampled events. The volume interval was calculated using forecasted rainfall totals and the relationship between rainfall and stormwater flow established from previous rain events.

All samples were collected in 5-gallon glass carboys. During sampling, the carboy and collected water were stored on ice in the base of the Isco unit. After sampling, the carboy was delivered to the analytical laboratory, where the sample was split for analysis. The laboratory was responsible for decontamination of the carboy as specified in the SAP/QAPP Addendum (SAIC 2010b). Additional information regarding whole water sample events is listed in Table 1.

2.2.3 Base Flow Samples

The methods described above for filtered suspended solids and whole water sampling were also used to collect base flow samples from MH108 and LS431. During dry periods, the lift station pumps are active for less than an hour per day. Base flow sampling spanned a multiple-day dry period in order to collect enough solids at the lift station. At the lift station, the Isco sampler was set to collect an aliquot every lift station pump cycle. At MH108, the Isco was set to collect an aliquot every 4 hours. The filtered solids pump at MH108 was set on a timer at a rate of one-half hour on, one-half hour off to avoid damage to the pump. A base flow sample was collected at CB173 during the second base flow event. The pump ran for one day without a timer. A timer was installed on the second day for the remainder of sampling. Table 2 lists the dates of the base flow samples.

2.2.4 Particle Size Fractionation Samples

Three composite samples were collected for analysis of PCBs, metals, and PAHs by grain size fraction. Each sample was split into four size categories: <63 µm, 63 to 250 µm, 250 to 500 µm, and >500 µm. A large filtration system consisting of four parallel filter bags was constructed in order to obtain enough material for analysis. The system was installed in the lift station vault to avoid the intermittent flow at the downstream side of the lift station.

The sampler was only activated during periods of continuous precipitation in an effort to collect solids from stormwater rather than base flow. Precipitation events for these samples did not follow the event-based criteria of the regular storm events (Section 3.1.4). Each sample consisted of four filters from three events.

Filters for the first sample were collected between March 26 and March 30, 2010. The second sample was collected between April 27 and May 5. The third sample was a composite of two different time periods. The first set of filters was collected April 3, the second on April 9, and the third on May 20.

2.2.5 Parking Lot Surface Solids Samples

Filtered solids collected from the MH434 SD are not representative of stormwater runoff. To better evaluate the parking lot as a potential source of contaminated sediment to Slip 4, six surface solids samples were collected on July 13, 2010 (Figure 4).

The channel drains in the parking lot were sampled for surface material. Because drains D434A and D435B are long, samples were collected from the north and south ends of both of these structures. Additional samples were collected from channel drains D283A and D436A located southeast of Building 3-370. Composite samples were obtained from each of these areas to create a representative sample of sufficient size for analysis. These composite samples were collected from empty parking spaces within several lateral feet of each structure. A separate push broom was used at each location. Surface sweepings included surface material such as fragments of pavement, vehicle debris, soil, gravel, other fine particulate debris, and organic matter from each area. Cigarette butts were removed from the sample. Areas of liquid oily material or sheen were avoided when collecting surface solids.

Material collected for each sample was combined and homogenized in a clean stainless-steel bowl using a clean stainless-steel spoon. The material was placed into appropriately sized sample jars, labeled, and stored on ice. Material greater than 6 millimeters (1/4 inch) was removed by the sampler prior to filling the sample jars.

2.3 Chemical Analysis

All chemical and physical analytical procedures were performed by subcontracted laboratories in accordance with Ecology guidelines as outlined in the SAP/QAPP Addendum (SAIC 2010b).

2.3.1 Filtered Suspended Solids Samples

After collection, all filters were delivered to Analytical Resources, Inc. (ARI), of Tukwila, WA, for processing and analysis. Table 3 lists the filtered suspended solids samples selected for analysis. Filtered solids from the "A" filter of the parallel filter setup were first scraped to obtain material for analysis of metals and grain size. Approximately 10 grams of material were needed for metals analysis, and approximately 20 grams for grain size. If insufficient sample material was obtained, mercury was analyzed first, followed by other metals, then grain size. The remainder of the filter bag was dried to determine the dry weight of material captured during filtration. The dry filter bag was extracted and analyzed for PCB Aroclors.

The "B" filters from Events 6, 7, 8, and 10 were analyzed for PAHs. Due to the volatility of PAHs, the filter was not dried prior to extraction. The "B" filters from Events 9, 9b, Base Flow Event 1, and Base Flow Event 2 were dried and weighed by ARI and sent to Axys Analytical Services, Ltd (Axys) of Sidney, BC, for analysis of dioxin/furan congeners by Method E1613. Dioxin/furan extracts from Event 9 and 9b were combined for CB423 to ensure enough material for analysis.

Analytical methods are listed in the chemistry summary (Tables 4 through 7).

2.3.2 Whole Water Samples

The carboys containing whole water samples were delivered to ARI for splitting and analysis. Samples from LS431 and MH108 were analyzed from Storm Events 6, 7, 8, 9, and 10 and Base Flow Events 1 and 2 for conventional parameters (hardness, pH, alkalinity, anions, total organic carbon [TOC], dissolved organic carbon [DOC], total suspended solids [TSS]), volatile organic compounds (VOC), semi-volatile organic compounds (SVOC), SVOC by Selective Ion Monitoring (SIM), low level PCBs, and total and dissolved metals.

Due to instrument problems at ARI, analysis of metals for Event 6 and Base Flow Event 1 were sub-contracted to Fremont Analytical, Seattle, WA. All analytical methods are listed in the chemistry summary in Tables 8 and 9.

2.3.3 Particle Size Fractionation Samples

After sampling a precipitation event, filters were delivered to ARI. ARI scraped and composited solids from each filter. Solids were archived until a sufficient volume was collected. Total mass for each sample ranged from 2,500 to 4,300 grams. ARI passed the composited sample through appropriately-sized sieves for separation into particle size fractions. During processing, filters and other equipment were rinsed with stormwater collected from the filter housings at the lift station vault.

Samples were alternatively analyzed for PCBs, metals, and PAHs. Analytical methods are listed in Table 10.

2.3.4 Surface Solids Samples

Six surface solids samples were delivered to ARI for analysis. All samples were analyzed for TOC, grain size, SIM SVOC, PCB Aroclors, and metals. Analytical methods are listed in Table 11.

3.0 Flow Measurement Results

This section presents a summary of flow measurements collected from the NBF lateral SD lines. Measured values for flow are compared to the total area in each of the lateral SD line drainage areas.

3.1 Flow Measurements and Precipitation

Flow data logged by the Isco equipment was managed using the Isco program Flowlink (Version 5.10.206). All data incorporated into Flowlink are stored in a Microsoft Access database. Local precipitation and tide height data were added to the Access database to aid interpretation of the storm hydrographs.

3.1.1 Precipitation

Precipitation data from the Seattle Boeing Field-King County International Airport rain gauge (identified as "KBFI") was used to represent rainfall at NBF-GTSP (Figure 1). Trace amounts of precipitation are reported as "T", and were replaced with 0.0254 millimeter (mm) (0.001 inch) when added to the Access database. Precipitation data from March through July 2010 were added to the database. There were no gaps or other obvious recording issues during this time period.

3.1.2 Tide

Validated tidal data from the Seattle tide station (Station ID 9447130) were used to determine tidal inflow at MH434 and LS431. Tide data between October 1, 2009, and June 30, 2010, were downloaded from the National Oceanic and Atmospheric Administration (NOAA) website (http://coops.nos.noaa.gov/data_menu.shtml?stn=9447130%20Seattle,%20Puget%20Sound,%20WA,%20WA&type=Tide%20Data). All data were added to the Access database in units of meters above mean lower low water (MLLW).

The heights of the sensors at MH434 and LS431 were determined by comparing the level measurements made by the Isco flow sensors with the NOAA tide height. The sensor at MH434 sits at 3.32 meters MLLW (10.9 feet). The sensor at LS431 sits at 3.84 meters MLLW (12.6 feet). Figures showing total flow, tidal height, and rainfall for each event at LS431 and MH434 are presented in Appendix B. The tide was above the level of the sensor at LS431 during Events 5, 7, and 8. The tide was above the level of the sensor at MH434 during Events 8, 9, 9B, and 10.

3.1.3 Stormwater Flow Records

This section summarizes the flow measurements collected from mid-February through early July, 2010. A regression between volume of stormwater (liters) and precipitation amount (mm) for all recorded rain events was created for each location. The intercept of each regression was set to zero to prevent negative flow volumes at low precipitation amounts. The slope of each regression is a constant representing runoff from each of the lateral line drainage areas.

LS431. Flow through the lift station is described in the preliminary stormwater sampling data report (SAIC 2010a). Briefly, stormwater runoff from NBF drains to the lift station where it collects in an underground storage vault. Up to four pumps are activated to lift the water above sea level for discharge to Slip 4. Errors with the flow sensor's level measurements resulted in flows from the lift station being underreported. The original flow was modified by adding a 0.2-

meter (8-inch) correction factor to the level data. Volume versus precipitation regressions for both the original (Figure 5, graph A) and modified flow (Figure 5, graph B) were calculated to show the range of possible values. As in the preliminary data report, the modified flows are used in the report text and figures to describe conditions at the lift station.

Lift station flow remained between 0.8 and 0.95 m^3/s (12,700 to 15,000 gpm) through March. Beginning in early April, flows became more variable between pump cycles. Discussions with the county revealed that the individual pumps rotate activation. The variable flow is either due to calibration issues with the flow sensor or that the lift station pumps need servicing.

Base flow through LS431 decreased over the duration of expanded stormwater sampling. In mid-February, base flow was approximately 2,300,000 liters (590,000 gal) per day, equating to an average of five pump cycles. Base flow had decreased to just over four pump cycles per day in early March. By late June, the pumps were only activated three times per day.

Figure 5, graphs A and B, show the volume versus precipitation relationships between the original and modified flows at LS431. The slope of the original regression is 213,880 liters of stormwater per millimeter of precipitation. The slope of the modified relationship is over three times higher at 722,689 L/mm rain ($r^2 = 0.923$).

There were three periods where measurements at the lift station were not recorded. The first spanned February 5 through February 19. The second spanned March 12 through March 17. The third spanned May 20 through June 1.

MH356. The portion of the south lateral SD line between the lift station and MH353 is part of the storage capacity of the lift station. The water level in this area is dictated by the cycling of the lift station. As a result, the flow profile at MH356 is similar to that of LS431 (see Appendix B).

During base flow conditions, one lift station pump is activated when the water level at MH356 reaches 0.9 meter (3 feet). Over the course of the 8- to 10-minute pump cycle, the water level drops to 0.35 meter (1.1 feet). After the lift station pump shuts off, the water level rapidly increases to about 0.6 meter (2 feet). The velocity and flow are negative during this period of rapid level rise. This implies that water is flowing backward over the sensor from elsewhere in the water storage area behind the lift station. The water level continues to rise to 0.9 meter. Velocity is too slow to measure during this period of slow level rise.

The same general pattern is observed during precipitation events. However, the large amount of water coming through the south lateral SD line during storm events prevents much of the backward flow of water over the sensor. Given the complexities of the sensor location, it is difficult to determine if there is any base flow input from the south lateral SD line.

Figure 5, graph C shows the relationship between volume and precipitation at MH356. The slope of the regression is 152,279 L/mm rain ($r^2 = 0.912$). Flow at MH356 is 21 percent of the modified flow at LS431.

There were gaps in data collection at MH356 between April 21 and May 4, and between June 2 and June 10.

MH369. The flow sensor at MH369 was installed in a 1.52-meter (5-foot) diameter SD that serves as part of the lift station's storage overflow in the south-central lateral line. During base flow, water level at MH369 varied with the activation of the lift station. The lift station pump was activated when the water level reached 0.78 meter (2.6 feet). The level dropped to 0.44 meter (1.5 feet) after the pump turned off. There was no negative flow of water over the sensor comparable to that observed at MH356.

During base flow, velocity readings were approximately 0.06 m/s (0.2 ft/s) when the lift station was activated. During storm flow, the water near the sensor was agitated due to input from an elevated SD line and from an upstream bend in the south-central SD line. As a result, velocity readings during storm flow were variable and frequently negative. Total flows could not be measured during storm events.

When the flow sensor was installed, it was mistakenly believed the only input to MH369 were two 0.3-meter (1-foot) surface drains located 1.2 meters (4 feet) beneath the surface. On May 7, the flow sensor was moved from the 1.52-meter drain to the only one of these drains with stormwater flow. The intent was to measure at least a portion of flow entering MH369.

The volume versus precipitation relationship at this location has a slope of 11,045 L/mm rain (r^2 = 0.899). This slope is only 1.5 percent of the modified LS431 flow. This is much smaller than the expected amount of runoff from this area. Flow from the small drain at MH369 was not representative of total flow in the south-central SD line. Close inspection of the CAD files showed that the larger and deeper line where the sensor was originally installed was the correct location for flow through the south-central SD line. This location was not suitable for flow measurements due to the conditions noted above.

None of the flow data from MH369 is considered usable.

MH226. There were no major issues with data collection at MH226. Flow data spanning the entire time period were successfully collected. Maximum level readings were 0.21 meter (0.7 feet) and velocity reached a maximum of 1 m/s (3 ft/s). Between precipitation events, level and velocity were slow to reach zero, although the impact this had on flow was negligible.

The volume versus precipitation relationship is shown in Figure 5, graph D. The slope is 63,569 L/mm rain (r^2 = 0.964).

MH108. The most persistent issue encountered at MH108 during the preliminary stormwater sampling was errors in the velocity measurements while sampling (SAIC 2010a). Velocity readings would increase as the first flush of stormwater hit the sensor, and then remain elevated after the stormwater flow was reduced. This issue was present for Events 1 through 5.

The problem was less severe, but not solved, for the expanded stormwater sampling. Flow data from Events 6 and 10 were impacted the most. As a precaution, flow from these two events has been calculated from the volume versus precipitation regression. Event 7 did not seem to be impacted by this problem. Events 8 and 9 had some issues with velocity, but the velocity profile was still a good match with the storm hydrograph. Flow from Events 7 through 9 is usable as measured.

With the exception of the velocity measurement problems during sampling events, there were no issues at MH108. All measurements were successfully collected through the end of June. Maximum water levels at MH108 were close to 0.5 meter (1.5 feet), and maximum velocities approached 0.9 m/s (2.95 ft/s). The slope of the relationship between volume and precipitation was 111,562 L/mm rain (r^2 = 0.940) (Figure 5, graph E).

CB423. There were no major issues with data collection at CB423. Data spanning the entire time period was successfully measured. Maximum level readings were 0.09 meter (0.3 feet) and velocity reached a maximum of 0.55 m/s (1.8 ft/s). As with MH226, level and velocity were slow to reach zero between precipitation events.

Figure 5, graph F shows the volume and precipitation regression for CB423. The slope is 8,335 L/mm rain ($r^2 = 0.919$). CB423 drains the area around Building 3-380 and is the smallest area draining to the lift station. It represents about 1.2 percent of the total modified flow from the lift station.

MH434. Flow data from storm events was not successfully measured at MH434. Tides entered MH434 with a frequency that made it difficult to isolate flows associated with precipitation events. There were a few instances where there was precipitation and no tide. During these times, level readings from the flow sensor did not exceed 0.04 meter (1.5 inches). By comparison, tidal depths ranged up to 0.5 meter (1.5 feet).

3.1.4 Event Summaries

The same precipitation criteria were applied to Storm Events 6 through 10 as for the preliminary stormwater sampling (SAIC 2010a). The goal of each storm event was to meet criteria established by Ecology's Environmental Assessment Program's (EAP) standard operating procedures (SOPs) for stormwater monitoring (Ecology 2009). All sample event figures are presented in Appendix B.

A qualifying storm event was defined as follows:

- At least 3.8 mm (0.15 inch) of rainfall;
- Event duration of at least 5 hours;
- No more than 1 mm (0.04 inch) of rainfall during the preceding 24 hours;
- Sampling duration that includes at least 75% of the storm event hydrograph, or at least 75% of the first 24 hours of the storm if the storm lasted more than 24 hours;
- Collection of at least 10 sample aliquots, with a minimum volume of 200 mL.

All sampled events had at least 3.8 mm of precipitation and lasted for at least 5 hours. For Events 7 and 9, 4.6 mm (0.11 inch) and 2.8 mm (0.11 inch) fell in the preceding 24 hours, respectively. Less than 1 mm fell before all other events. Determination of storm hydrographs was difficult for many of the events due to the inconsistent nature of spring rainfall. For Event 8, the entire storm hydrograph was sampled. A period of at least 20 hours was sampled for all other events. Nine aliquots were sampled at LS431 for Event 10. A sufficient number of aliquots were collected for all other events.

The only criteria for the base flow sampling were to avoid precipitation and make sure enough aliquots were collected to be representative of the sampling period. At least 10 aliquots were collected for each of the base flow events. During the first base flow sampling event, a trace amount of precipitation fell during the last hour of sampling. During the second full base flow event, a trace amount of precipitation fell midway through sampling.

4.0 Chemistry Results

This section presents and summarizes analytical results for the expanded stormwater sampling effort. Results from the preliminary stormwater sampling are included in the discussion as relevant. The particle size fractionation results and parking lot surface solids samples are summarized separately. Chemical data validation results are summarized in Section 5.0.

4.1 Filtered Suspended Solids Sampling

Filtered suspended solids sampling results from LS431 and MH108 are summarized in Tables 4 and 5, respectively. Results from the additional locations on the north lateral SD line are presented in Table 6. Results from sampling of additional SD lateral lines are presented in Table 7. Included in each table are the mass of solids from each filter bag, the flow through each totalizer, and if available, the total volume of stormwater at each location. Laboratory data summaries are available in Appendix C.

4.1.1 Physical Parameters

Two measures of filtered solids mass are included in the tables. “Total extracted solids” represents the dried mass of the sample filter (after wet weight splits were removed for grain size and metals) minus the pre-weighed mass of the filter. In other words, total extracted solids are the mass of material extracted for PCB Aroclor and dioxin/furan congener analysis. “Estimated total solids” represents the total extracted solids mass plus an assumed dry weight of the grain size and metals splits.

The calculated TSS is the estimated total solids mass divided by flow through the totalizer. However, the filtration system design likely resulted in inflated totalizer flows relative to collected solids. One problem was the variable velocity of water through the filtration system over the course of an event. As solids were collected on the filter, the flow through the filter became restricted. The decrease in flow decreased the line velocity and may have resulted in the settling of some of the larger suspended solids prior to reaching the filter.

A second problem was related to the seal between the filter bag and the top of the filter housing. A felt gasket on top of the filter bag formed a seal between the filter bag and the filter housing during sampling. As the filter bag collected solids, the pressure on the bag increased. It is possible that the pressure became high enough during sampling to separate the seal and bypass the filter. This would allow water to flow through the totalizer without contributing solids to the filter. TSS as measured by the filtration system should be used with reservations. Filtered solids and whole water TSS measurements are compared in Section 4.2.

Because neither of these issues occurred until a sufficient amount of solids had accumulated on the filter, the physical and chemical data analyzed from the collected solids are believed to be representative of stormwater suspended solids.

Grain size analysis was conducted when sufficient material could be scraped from the filter bag. Eight samples each were analyzed from the storm events at MH108 and LS431, plus the two base flow events. There was no consistent particle size distribution at LS431. Events 4, 7, and 8 had percent fines at 97.4 percent, 99.6 percent, and 99.3 percent, respectively. In contrast, percent fines in Events 1, 2, 6, and 9 ranged between 13.8 percent and 65.9 percent.

The particle size distribution at MH108 was more uniform across storm events. Percent fines for Events 1 through 6 and Events 8 and 9 ranged between 37.7 and 66.6 percent. Most of the coarse material for these events was in the sand fraction. Event 7 differed from the rest with 99.9 percent fines. The particle size distribution between silt and clay was similar between LS431 and MH108 for Event 7. Both were near 66 percent silt and 33 percent clay.

Percent fines for base flow events were expected to be high. Fines for Base Flow Event 1 (March 20, 2010) at LS431 was 92.4 percent, and 99.9 percent at MH108 (February 23, 2010). Percent fines for Base Flow Event 2 at LS431 were 99.9 percent. Fines for Base Flow Event 2 at MH108 were 57.9 percent, with 26.2 percent of the particle size distribution consisting of coarse sand.

Grain size was measured in two other locations representing NBF drainages. Two samples were analyzed from MH434, containing 97.5 and 99 percent fines. Both events were tidally influenced, suggesting river water as the source of the fines. One sample was analyzed from CB423. It contained 81.7 percent fines and 17.2 percent sand. There was visible sand at the bottom of the catch basin at this location.

Seven grain size samples from four locations were collected from the north lateral SD line locations. Percent fines ranged between 73.6 and 100 percent for all samples.

4.1.2 Chemical Analysis

Metals

Metals results were compared to the Washington State Sediment Management Standards (SMS) numeric Sediment Quality Standards (SQS) and Cleanup Screening Levels (CSL) criteria (Washington Administrative Code [WAC] 173-204). PCBs and PAHs were compared to the lowest apparent effects threshold (LAET) and the second LAET (2LAET) (PTI 1988). The LAET and 2LAET are functionally equivalent to the SMS/CSL values, but are not organic carbon normalized. Collection of TOC data from the filters was not possible due to interference from the organic polypropylene filter bag.

Metals were analyzed in all of the filtered suspended solids samples collected as part of the expanded stormwater sampling effort. Silver and arsenic were frequently not detected. Of the detected concentrations of silver, only one exceeded the SQS/CSL. During Event 9 at CB165, silver concentrations were 160 milligrams per kilogram (mg/kg). Arsenic was detected in about half of the filtered solids samples. Undetected samples frequently exceeded the SQS and CSL criteria due to elevated reporting limits. Detected arsenic concentrations exceeded the criteria at MH369, MH226, MH133D, and MH138 (Tables 4 through 7).

Chromium and lead had one exceedance each. Chromium exceeded the CSL at MH133D during Event 10 with a concentration of 274 mg/kg. The only exceedance for lead occurred at MH108 during Event 4 of the preliminary stormwater sampling. Copper exceeded the SQS/CSL criteria in a total of six samples. Five of these exceedances were from locations in the north lateral SD line. The only other exceedance was Event 10 at MH226 in the north-central lateral line.

With the exception of one exceedance at LS431, all exceedances for mercury occurred in the north lateral line (Figure 6). MH133D, CB173, and CB165 had the highest average concentrations. Both CB165 and CB173 had individual measurements of mercury over 10 mg/kg (Figure 6, graph C). Average concentrations at MH152 and MH108 were also elevated at levels above 0.7 mg/kg. Unlike other locations in the north lateral SD line, concentrations at MH178 and MH138 were below the SQS. Stormwater at MH178 enters from off site at the north end of the drainage. MH138 is at the downstream end of a small drainage within the north SD line. Concentrations at LS431 averaged 0.4 ± 0.6 mg/kg. Combined concentrations at all remaining drainage lines averaged 0.23 ± 0.09 mg/kg.

Zinc and cadmium were detected at levels that exceed the SQS and CSL criteria at nearly all locations. The highest cadmium concentrations were 78 mg/kg and 102 mg/kg from Events 9 and 10 at MH133D, respectively. These were the only two samples collected at MH133D. Measured concentrations of cadmium at all other locations ranged between 3.0 and 31.2 mg/kg. Zinc exceeded the CSL in at least one sample at all locations except MH369 and MH178.

Base flow filtered solids samples were analyzed for metals at MH108, LS431, and CB173. At CB173, base flow concentrations were comparable to those found during storm events. Arsenic, cadmium, mercury, and zinc were detected in base flow at CB173 at concentrations above the SQS. At LS431 and MH108, base flow concentrations were lower than during storm events with two exceptions. The highest lead concentration at LS431 was measured during Base Flow Event 1. The second highest mercury concentration at MH108 (2.29 mg/kg) was also measured during Base Flow Event 1.

Many of the metals show a pattern where concentrations are lowest at LS431. This is true for cadmium, chromium, copper, lead, and zinc. It is not clear what could have resulted in higher concentrations in the individual lateral lines than in the combined output. Though not directly comparable, the concentrations of metals from samples collected for size fractionation from the lift station vault (Section 4.3) do appear to be higher than concentrations from the downstream side of the lift station.

PCBs

Total PCB concentrations were reported as micrograms (µg)/filter and converted to µg/kg by dividing by the mass of total extracted solids. Total PCBs were calculated as the sum of detected Aroclors 1221, 1232, 1242, 1016, 1248, 1254, and 1260. Total PCBs exceeded the LAET or 2LAET in all samples with the exception of Event 9 at MH178.

Average total PCB concentrations at LS431 over 11 events (plus Event 9b) were 1.3 ± 0.8 mg/kg, compared with 6.4 ± 5.9 mg/kg at MH108. MH108 had the highest average PCB concentration of the major lateral lines. Total PCBs exceeded the 2LAET in every sample collected at MH108. Average concentrations in the other three lateral SD lines were closer to 0.5 mg/kg (Figure 7b).

The base flow samples had some of the highest PCB concentrations measured in this study (Figure 7a and 7c). Base Flow Event 1 and 2 at MH108 had concentrations of 25 mg/kg and 22 mg/kg, respectively. One base flow sample was collected at CB173. The concentration in this sample was 43 mg/kg. There is some question as to whether this sample was representative of base flow or stormwater holdover. The structure CB173 is lower than the exiting SD. Boeing has observed no base flow entering the structure from upstream, but has indicated that base flow from downstream may be flowing into this location. Two base flow samples were also collected at LS431. Both samples fell within the range of concentrations measured during the storm events. These results indicate that base flow is responsible for higher PCB concentrations in the north lateral SD line, but that these higher concentrations do not have a significant impact at LS431, possibly due to dilution with cleaner base flow from other areas of the site.

There were also differences in the Aroclor distribution between storm event and base flow samples. Aroclors 1254 and 1260 were most commonly detected in the storm events. Aroclors 1242 and 1254 were detected in the base flow samples.

PCBs in the north lateral SD line were higher than in other locations. The locations with the highest concentrations were those on the main branch of the north lateral SD line. Concentrations at CB165 averaged 3.8 ± 3.2 mg/kg over the course of three events, while concentrations at CB173 averaged 14.2 ± 3.7 mg/kg. MH178 is located next to CB173. However, unlike CB173, much of the stormwater flow at MH178 comes from off site. Concentrations at MH178 were over an order of magnitude lower than those at CB173 (Table 7, Figure 7, graph C).

There is a small positive correlation ($r^2 = 0.666$) between MH108 and LS431 PCB concentrations, suggesting that elevated concentrations at LS431 are influenced by MH108. While there is no overall correlation between rainfall (stormwater volume) and concentration, the two events with the lowest rainfall at both MH108 and LS431 had the highest PCB concentrations.

PAHs

PAHs were measured in filters from Events 3, 6, 7, 8, and 10. Total high molecular weight PAHs (HPAHs) were calculated as the sum of the detected compounds fluoranthene, pyrene, benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, dibenz(a,h)anthracene, and benzo(g,h,i)perylene. Total low molecular weight PAHs (LPAHs) are the sum of detected compounds of naphthalene, acenaphthylene, acenapthene, fluorene, phenanthrene, and anthracene.

Phenanthrene frequently exceeded the LAET or 2LAET criteria. Other LPAHs were often not detected. Total LPAH concentrations were typically about one-tenth as high as total HPAH concentrations.

Total HPAH concentrations were variable between LS431 and MH108 (Figure 8, graph A). However, the average concentration of HPAH across the five events was similar at both locations, at 17.8 mg/kg for MH108 and 18.8 mg/kg for LS431. MH369 had the lowest concentrations found in the main lateral lines, while MH226 and MH356 had the highest (Figure 8, graph B).

Locations in the north lateral SD line were just as variable. HPAH ranged between 3.8 and 7.0 mg/kg at CB173 and CB165. The concentration from the lone sample collected from MH133D was 97.8 mg/kg.

Dioxins/Furans

Dioxin/furan congeners were analyzed from Events 2, 4, and 9, with select samples analyzed from Event 9b. The first base flow sample from MH108 was analyzed for dioxin/furan congeners. Filters from MH108, LS431, and CB173 were analyzed from the second base flow event.

Concentrations of each congener were normalized to the toxicity of 2,3,7,8-TCDD (tetrachlorodibenzodioxin) using toxic equivalency factors (TEFs) updated by the World Health Organization (WHO) in 2005 (Van den Berg et al. 2006). The toxic equivalent quotient (TEQ) is equal to the sum of the concentrations of individual congeners multiplied by their TEF. TEQ values are reported using 0 and ½ times the method detection limits for nondetected congeners.

TEQ concentrations at both LS431 and MH108 were much higher for Events 2 and 4 than for Event 9. At MH108, Event 2 and 4 concentrations were 144 and 157 picograms per gram (pg/g) TEQ, respectively. For Event 9, the concentration was 10.6 pg TEQ/g (ND=0). There was a similar decrease at LS431. Base flow concentrations at MH108 and LS431 were similar in magnitude to Event 9. At CB173, the Base Flow Event 2 concentration was 65 pg TEQ/g, compared with 18.5 pg TEQ/g for storm Event 9.

All locations were sampled as part of Event 9 or 9b. Of the lateral line locations, MH356 was most similar to the lift station with a concentration of 6.58 pg TEQ/g. MH369 and MH226 had concentrations of 17.2 and 44.6 pg TEQ/g (ND=0), respectively. As with the metals, it is not clear why the dioxin/furan concentration at LS431 is lower than those at the other lateral lines. MH434 in the parking lot drainage had a TEQ of 65.6 pg/g.

Samples from the north drain line during Event 9 ranged from 10.6 to 49.6 pg/g TEQ. There is no clear pattern to the concentrations (Tables 6 and 7).

4.2 Whole Water Sampling

Whole water sampling results from LS431 and MH108 are summarized in Tables 9 and 10, respectively. Concentrations are compared to the lower of the chronic marine water or freshwater criteria (WAC 173-201A-240). Contaminants lacking marine or freshwater criteria are compared to the human health water quality criteria for consumption of organisms (HHO) (USEPA 2006). Laboratory data summaries are presented in Appendix C.

4.2.1 Physical Parameters

Conventional parameters including pH, alkalinity, hardness, TSS, chloride, nitrate, sulfate, DOC, and TOC were measured in each of the whole water samples. The pH was consistently higher at LS431, although all events at both locations ranged between pH values of 6.7 and 7.7. Correspondingly, alkalinity was also higher at LS431. At both locations, alkalinity was highest during the two base flow samples. Chloride varied over the course of 10 events, particularly at LS431. There was no relationship between chloride and tidal influx into LS431 (Section 3.1.2).

TOC ranged between 6.5 and 21.2 mg/L and averaged 8.7 mg/L at LS431. TOC ranged between 4.3 and 31.8 mg/L and averaged 7.2 mg/L at MH108.

Figure 9 presents whole water TSS for all storm and base flow events at LS431 and MH108. Calculated TSS from the filtered solids are included for comparison. As stated, TSS data from the filtered solids collection are biased low due to excess water flow through the totalizer (Section 4.1.1). Given the problems with calculating TSS from the filtration system, whole water TSS are considered more representative of stormwater conditions. Sampling and analytical methods support this. The whole water samples analyzed for TSS were volume weighted over the course of a storm event and were sampled using a consistent pump flow and velocity. In the laboratory, a known volume of water was passed through a 0.45-micron filter.

The relationship between the whole water and filtered solids TSS at LS431 and MH108 can hopefully be extrapolated to the sampling locations in the other drainage basins to allow for better loading estimates.

Average TSS concentrations were 27.5 mg/L at LS431 and 24.2 mg/L at MH108. There was some variability around these averages. Concentrations ranged between 3.3 and 75.9 mg/L. There was a positive correlation between TSS at the two locations ($r^2 = 0.678$).

4.2.2 Chemical Analysis

Cadmium, copper, lead, and zinc were detected at concentrations above the marine water criteria (MWC). Copper had more exceedances than the other metals. Average total copper concentrations were 8.5 µg/L at LS431 and 15.7 µg/L at MH108 for all 10 storm events. Base flow concentrations were lower than for storm events, although total copper did exceed the MWC for Base Flow Event 2 at MH108. Dissolved copper concentrations were usually about one half that of total copper.

Total cadmium was detected above the MWC in Event 6 at MH108 and Base Flow Event 1 at both LS431 and MH108. Total lead exceeded the MWC in one storm event at LS431, and three at MH108. Both cadmium and lead were rarely detected in the dissolved phase. Total zinc was detected at the highest concentration in the whole water samples. There were two exceedances at LS431 and four at MH108. Base flow concentrations of zinc were four to seven times lower than those found in stormwater.

Mercury was analyzed in all samples but never detected. The reporting limits for mercury are higher than the freshwater criteria (FC) of 0.012 µg/L.

Total PCB concentrations for each event are presented in Figure 10. Total PCBs from filtered solids are included for comparison. PCBs were detected in all samples analyzed from MH108, with concentrations ranging from 0.016 to 0.15 µg/L for the stormwater events. Base flow concentrations were higher, at 0.22 µg/L and 0.27 µg/L for Base Flow Events 1 and 2, respectively.

Total PCB concentrations at LS431 were lower than MH108. PCBs were undetected in Events 1, 2, and 10. Event 4 was below the FC. All other events exceeded the criteria. Using the reporting limit in place of undetected values, the average PCB concentration at LS431 was 0.029 for stormwater events. The concentrations from the base flow samples were lower, at 0.014 and 0.016 µg/L. The conclusion drawn from the base flow samples for filtered solids is the same for whole water: base flow is responsible for higher concentrations in the north drain line, with little impact at the lift station.

There is no direct correlation between PCBs in filtered solids and in whole water at either location (Figure 10). If whole water PCBs are normalized to mg/kg using the TSS, there is a slight correlation at MH108 ($r^2 = 0.553$) for all 10 storm events. The same correlation is not present at LS431. TSS normalized whole water concentrations are similar in magnitude to total solids concentrations at both locations.

HPAHs were detected more frequently than LPAHs. Several HPAHs, including benzo(a)anthracene, chrysene, benzo(b)fluoranthene, benzo(k)fluoranthene, benzo(a)pyrene, indeno(1,2,3-cd)pyrene, and dibenz(a,h)anthracene, have a water quality criterion (HHO) of 0.018 µg/L. These compounds frequently exceeded the HHO at LS431. HPAH concentrations were typically higher at LS431. The HHO criterion was exceeded with about half this frequency at MH108 (Tables 9 and 10).

Average HPAH concentration was 2.1 µg/L at LS431 and 1.9 µg/L at MH108. Base flow concentrations were an order of magnitude lower. PAHs in stormwater are likely a result of surface runoff, rather than groundwater infiltration.

Additional SVOCs were analyzed but seldom detected. Bis(2-ethylhexyl)phthalate was detected at levels that exceeded the HHO criteria during Events 4 and 7 at MH108. Additional phthalates, including di-n-octyl phthalate, diethylphthalate, and di-n-butyl phthalate, were detected at both locations.

VOCs detected as part of the preliminary stormwater sampling were also present in Events 6 through 10. Methylene chloride, acetone, and 2-butanone were detected in most samples. Each of these VOCs was detected in at least one of the base flow samples at each location at concentrations comparable to the stormwater samples.

4.3 Particle Size Fractionation

Results of the particle size fractionation analysis are described in the Slip 4 Sediment Recontamination Modeling Report (SAIC 2010c). Briefly, the highest total PCB concentrations were found in the finest (<63 µm) and coarsest (>500 µm) fractions in all three samples. Concentrations in both of these fractions were similar, ranging from 0.77 to 1.4 mg/kg DW. The concentrations in the medium two size fractions were 20 to 50 percent of these values (Table 10).

The metals cadmium, chromium, copper, lead, mercury, and zinc were detected in all size fractions from Composite 1. The highest concentrations of metals were found in the fine fraction and the second highest concentrations in the coarsest fraction.

Both LPAHs and HPAHs were detected in all fractions analyzed. Again, the greatest concentrations were in the fine and coarse fractions. In Composite 4, the coarsest fraction (>500 µm) contained LPAHs and HPAHs an order of magnitude higher than other fractions.

The percentage of each grain size fraction in the total composites is unknown. As such, sample concentrations cannot be reconstructed. This prevents a direct comparison of filtered solids between the lift station vault and downstream side of the lift station.

4.4 Surface Solids Samples

Parking lot surface solids samples are summarized in Table 11. Grain size analysis was conducted on each of the six samples. Total fines ranged from 7.9 to 17.2 percent. Total sand was the dominant fraction in all samples, falling in the narrow range of 75.7 to 84.2 percent. The sweep samples consist of a much coarser grain size distribution than the TSS samples collected by the filter bags.

PCBs, metals, and PAHs were analyzed in each of the samples. Concentrations were similar across the six locations for all analytes. The results were compared to the LAET and 2LAET criteria on the assumption that a portion of these solids may end up in the SD system (Table 11).

Aroclors 1254 and 1260 were detected at all locations, and Aroclor 1248 was detected at four of the locations. Total PCB concentrations ranged between 0.20 and 0.34 mg/kg, with five of the locations exceeding the LAET.

Concentrations of most metals were lower than those found in the filtered suspended solids samples. Lead and chromium were exceptions. Concentrations of these two metals were toward the high end of the range of concentrations from the filtered solids. PAH concentrations were lower than in the filtered solids. Total HPAH ranged between 1.0 and 6.3 mg/kg DW. None of the PAH or metals concentrations exceeded the LAET.

5.0 Quality Assurance/Quality Control

A full Level IV data validation was performed by EcoChem, Inc. of Seattle, WA, on all analytical results, including all quality assurance/quality control (QA/QC) samples. All reported results are considered acceptable for use as qualified. The data validation report is presented in Appendix D.

Field QA/QC samples such as field replicates, whole water equipment rinseates (rinseates from the Isco samplers), and blank filter bag analyses were conducted as part of the preliminary stormwater sampling and were not repeated for the expanded stormwater sampling. During the preliminary stormwater sampling, an equipment rinseate was also collected from the filtration system; however, prior to the preliminary sampling the paint from the bottom of the sump pump was stripped using chemical strippers and abrasives. Some metals were detected in the rinseate blank. For the expanded sampling events, the paint from the bottom of the sump pump was not removed. To account for this difference, an additional equipment rinseate blank was collected during the expanded stormwater sampling to provide a quality control check on the potential for contamination from sampling equipment.

The equipment rinseate blank was collected by running de-ionized water through the filtration system, and was analyzed for SVOCs, PCBs, and dissolved metals. Bis(2-ethylhexyl)phthalate was detected at a concentration of 2.1 µg/L and copper was detected at a concentration of 1.4 mg/L. All of the associated stormwater samples that were less than the action level of 10x the rinseate blank concentration for bis(2-ethylhexyl)phthalate, a common laboratory contaminant, or 5x the rinseate blank concentration for copper, were re-qualified as non-detect during data validation.

6.0 Summary

Expanded stormwater sampling was a continuation of the preliminary sampling at NBF-GTSP. As part of this effort, the collection of filtered suspended solids and whole water samples continued at LS431 and MH108 for five additional storm events and two base flow events. Sampling of filtered suspended solids was added at selected locations in the north SD line and at the downstream end of the other lateral SD lines. Continuous flow measurements were collected at the lift station and at each of the SD lateral lines.

Sufficient flow measurements were collected from LS431, MH108, MH226, CB423, and MH356 to characterize the relationship between precipitation amount and the volume of stormwater runoff for each location. In addition, the presence of the flow meters in each lateral line helped to determine the extent of the storage capacity of the lift station. Both MH369 and MH356 were affected by the activation of the lift station pumps.

Concentrations of metals in filtered suspended solids were variable. Cadmium and zinc exceeded the LAET criteria at nearly all locations, while mercury concentrations were highest in the north lateral SD line. Concentrations of most metals in base flow were lower than the stormwater samples.

PCB concentrations for both filtered suspended solids and whole water were highest in the north lateral SD line. Base flow concentrations from the north SD line had higher concentrations than the storm events. However, base flow concentrations at LS431 were within the same range as the storm event samples, suggesting that the inflow of PCBs from the north lateral SD line was not enough to alter base flow concentrations at the lift station. The Aroclor distribution of PCBs varied between storm events and base flow. Aroclors 1254 and 1260 were most commonly detected in stormwater, while Aroclors 1242 and 1254 were most common in base flow.

Additional parameters were analyzed in the whole water samples. Phthalates were detected occasionally, but only bis(2-ethylhexyl)phthalate exceeded the HHO criteria. Methylene chloride, acetone, and 2-butanone continued to be detected in whole water samples. Base flow concentrations of these VOCs were similar to the storm event concentrations.

Filtered suspended solids samples from MH434 were not representative of parking lot runoff due to tidal intrusion. Six surface solids samples were collected to determine whether the parking lot is a potential source of contaminants to Slip 4. PCBs exceeded the LAET in five of the samples, but concentrations were lower than those in the lateral SD lines. No metals or PAHs exceeded the LAET criteria.

7.0 References

Ecology. 2009. Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring. Washington State Department of Ecology. Draft Version 1.0.

Landau. 2010. Revised Work Plan, Storm Drain System Catch Basin, Manhole, and Oil/Water Separator Sampling and Storm Drain System Cleaning, North Boeing Field, Seattle, Washington. Prepared for The Boeing Company by Landau Associates, Edmonds, WA. March 26, 2010.

PTI. 1988. Sediment Quality Values Refinement: 1988 Update and Evaluation of Puget Sound AET. Volume I. Final Report. Prepared for Tetra Tech, Inc., Bellevue, WA, and the U.S. Environmental Protection Agency, Region 10, Seattle, WA. Prepared by PTI Environmental Services, Bellevue, WA.

SAIC. 2009a. North Boeing Field/Georgetown Steam Plant Site Remedial Investigation/ Feasibility Study: Sampling and Analysis Plan and Quality Assurance Project Plan for Preliminary Stormwater and Filtered Suspended Solids Sampling. Prepared for Toxics Cleanup Program, Northwest Regional Office, Washington State Department of Ecology, by SAIC, Bothell, WA. August 2009.

SAIC. 2009b. North Boeing Field and Georgetown Steam Plant, Supplemental Report: Summary of Existing Information and Identification of Data Gaps. Prepared for Toxics Cleanup Program, Northwest Regional Office, Washington State Department of Ecology, by SAIC, Bothell, WA. August 2009.

SAIC. 2010a. North Boeing Field/Georgetown Steam Plant Site Remedial Investigation/ Feasibility Study: Preliminary Stormwater Sampling Interim Data Report. Prepared for Toxics Cleanup Program, Northwest Regional Office, Washington State Department of Ecology, by SAIC, Bothell, WA. May 2010.

SAIC. 2010b. North Boeing Field/Georgetown Steam Plant Site Remedial Investigation/ Feasibility Study: Work Plan and SAP/QAPP Addendum Expanded Stormwater Monitoring. Prepared for Toxics Cleanup Program, Northwest Regional Office, Washington State Department of Ecology, by SAIC, Bothell, WA. March 2010.

SAIC. 2010c. North Boeing Field/Georgetown Steam Plant Site Remedial Investigation/ Feasibility Study: Slip 4 Sediment Recontamination Modeling Report. Prepared for Toxics Cleanup Program, Northwest Regional Office, Washington State Department of Ecology, by SAIC, Bothell, WA. July 2010.

USEPA. 2006. National Recommended Water Quality Criteria. Prepared by United States Environmental Protection Agency, Office of Water, Office of Science and Technology. 2006.

Van den Berg, M., L.S. Bimbaum, M. Denison, M. De Vito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R. Peterson. 2006. The 2005 World Health Organization Re-Evaluation of Human and Mammalian Toxic Equivalency Factors for Dioxins and Dioxin-like Compounds. Prepared for the World Health Organization (WHO). ToxSci Advance Access published July 7, 2006. Published by Oxford University Press on behalf of the Society of Toxicology.