Quality Assurance Project Plan: Effectiveness Monitoring of the South 356th Street Retrofit and Expansion Project, Federal Way, WA

June 2015 - Draft

King County

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Quality Assurance Project Plan: Effectiveness Monitoring of the South 356th Street Retrofit and Expansion Project, Federal Way, WA

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I certify under penalty of law, that this document and all attachments were prepared under my direction and supervision in accordance with a system designed to assure that qualified personnel properly gathered and evaluated the information submitted. Based on my inquiry of the person or persons who managed the system or those persons directly responsible for gathering information, the information submitted is, to the best of my knowledge and belief, true, accurate, and complete. I am aware that there are significant penalties for submitting false information, including the possibility of fine and imprisonment for willful violations.

Citation

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Distribution List

The following individuals will receive a copy of the project QAPP and any revisions or addenda.

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1.0 BACKGROUND

Bioretention facilities are increasingly being incorporated in stormwater management designs with the expectation that they not only help moderate flow but also reduce pollutant loadings to receiving waters. Recent studies in Western Washington, however, have demonstrated that uncertainties remain regarding the effectiveness of bioretention facilities, and especially their ability to consistently reduce concentrations of pollutants in stormwater runoff. As projects are planned and built, there is a critical need to evaluate their effectiveness to insure stormwater management goals are being met.

A recent retrofit and expansion of a regional stormwater detention facility (RDF) in Federal Way, WA, known as the "South 356th Street Project", provides an excellent opportunity to assess the performance of new bioretention facilities and compare their performance with another stormwater BMP, a wet pond complex. The recent retrofit included the construction of two bioretention facilities that will receive previously untreated stormwater from a 22.6-acre basin with more than 80% impervious surface. The addition of a new wet pond will expand the capacity of the RDF by providing additional flow control and treatment for a portion of the discharge from the existing wet pond. The system was engineered so that flow meters and autosamplers could be deployed at both the inlet and the outlet of each bioretention facility and at the inlet and the outlet of the entire, expanded wet pond complex.

This study will evaluate the effectiveness of each bioretention facility and the wet pond complex in altering flow dynamics, water quality and toxicity of stormwater. In addition, this study will monitor the water quality of the receiving waters, the North Fork of West Hylebos Creek (WRIA 10, tributary number 0013). The results of this effort will provide critical information regarding the effectiveness of BMPs (both alone and in combination) in commercial basins for removing a variety of pollutants and helping protect receiving waters.

1.1 Study area history and results of pre-retrofit studies

Historically, the North Fork of West Hylebos Creek (NFW Hylebos Creek) was part of a complex wetland and stream network that provided excellent spawning and rearing habitat for a variety of salmon species, as well as resident cutthroat trout. Over time, with increasing watershed development, water quality deteriorated and salmon populations declined. In 1997, to help control stormwater flows that were impacting the creek, the City of Federal Way (the City) built the South 356th Street Regional Detention Facility (RDF). Initial monitoring indicated the RDF was effective for reducing turbidity in stormwater, but other water quality concerns remained. The City found that although the RDF provided

some flow control and water quality improvements, the temperature of water leaving the RDF was often higher at the outlet than at the inlet. Macroinvertebrate communities in NFW Hylebos Creek also indicated further flow control and pollutant reduction were needed.

In 2011, the City applied for a Stormwater Retrofit and Low Impact Development grant from the Washington Department of Ecology (Ecology). In the grant, the City included monitoring data that demonstrated that although the original RDF was effective in improving some water quality measures, further improvements were needed to protect downstream aquatic habitats. A brief summary of the findings are listed below:

- Turbidity data were collected during 44 storm events at the inlet and outlet of the RDF between 2001 and 2005. On average a 59% reduction in turbidity between the inlet and the outlet (average at inlet = 120 NTU; average at outlet = 49 NTU) was observed; however, turbidity concentrations in the outlet frequently exceeded water quality criteria (WQC).).
- Temperatures in NFW Hylebos Creek between 2002 and 2008 did not exceed the WQC of 17.5°C but came close; the highest 7-Day Average Daily (DAD) Max was 17.38°C). Monitoring data from the outlet and in NFW Hylebos Creek indicated the warm water flowing from the RDF during storm events was increasing downstream creek temperatures by as much as 5°C.
- Macroinvertebrate data had been collected annually, starting in 1999, at a site approximately 0.2 miles downstream of the RDF in NFW Hylebos Creek (at S. 359th Street). From 1999 to 2009, the site consistently scored “fair”, based on the Ecology’s Multi Metric Index (MMI). Because the RDF is essentially the headwaters of NFW Hylebos Creek, the City proposed that any improvements to water quality and flow control at the RDF would help improve the health of the creek.

In 2011, the City received the grant from Ecology to retrofit and expand the S. 356th Street RDF. As part of the project, the City continued to monitor temperature, turbidity and macroinvertebrates. The 2012 Quality Assurance Project Plan (QAPP) prepared by the City (Appendix A) described the monitoring plan. Relevant sampling and analysis methods used for the pre-retrofit water quality monitoring will be used for post-retrofit monitoring as well to insure continuity between the data.

The results of the recent pre-retrofit monitoring, collected from March 2012 through June 2014, were consistent with previous monitoring results (described above) (Federal Way, 2014), and are summarized briefly here:

- Continuous turbidity data were collected with two YSI 6920 Multi-parameter Sondes and YSI 6560 probes at the RDF inlet and outlet. Results were consistent with previous studies where grab samples were collected to measure turbidity during storm events. On average, turbidity

between the inlet and outlet was reduced by 36%, 48% and 75%, respectively in 2012, 2013, and 2014. Despite this, values from the outlet indicated stormwater discharges from the RDF would exceed turbidity criteria for NFW Hylebos Creek several dozen times a year.

- Water temperature was measured over the same time period at the RDF inlet and outlet, and at a third site in NFWHC at S. 359th Street. Data were collected at all three sites with Onset® Instruments TidBit temperature loggers (and with YSI 6920 Sondes at the inlet and outlet). The YSI temperature data were used when there were gaps in the TidBit data records due to instrument maintenance and/or unexpected power failures. As with the turbidity data, the temperature results were consistent with earlier monitoring data. During the spring and summer seasons, water discharge from the RDF was relatively warm, and it appeared to be affecting downstream temperature. Although water temperatures in NFW Hylebos Creek did not exceed the temperature WQC (17.5°C), temperatures at the RDF outlet routinely exceeded 17.5°C in July and August.
- During 2010-2014, the City continued to collect benthic macroinvertebrates at the original sampling site (south of S. 359th St.) and added a second upstream location (north of S. 359th St.). The results indicated the sites were similar; the MMI scores at the two sites were within 4 points of each other and were classified as “fair” or “good” depending on the year.

The City plans to continue to monitor turbidity, temperature and macroinvertebrates, following the protocols used previously. The continuity of these datasets will allow for valuable pre- and post-retrofit comparisons. For example, comparison of the percent reduction in turbidity levels between the inlet and outlet during storm events prior to (2012-2104) and after the retrofit (2015 on) will allow the City to evaluate the effectiveness of the retrofit and expansion to reduce turbidity.

1.2 Description of RDF retrofit and expansion

The goals of the retrofit and expansion of the S. 356th Street RDF were to increase capacity and provide additional stormwater treatment. By 2011, the extent of impervious surface across the basins draining to the original RDF exceeded 70% (Figure 1), and the 21-acre feet (af) capacity of the original RDF was inadequate. The new wet pond will increase capacity by 5 af, and it is anticipated that the greater capacity will also result in improved water quality treatment. Some of the discharge from the existing (“old”) wet pond will flow into the new wet pond (Figure 2), thereby increasing the residence time and likely increasing sediment retention. Two new bioretention facilities will treat stormwater from adjacent sub-basins that had previously by-passed the RDF and flowed directly to NFW Hylebos Creek (Figure 1, portions of Basins15 and17; Figure 3). Originally there was an additional goal of reducing the temperature of water leaving the RDF by constructing the new pond with a deep, subsurface outlet. However; this goal was not met as the groundwater level at the site was too high to allow for the deep outlet.

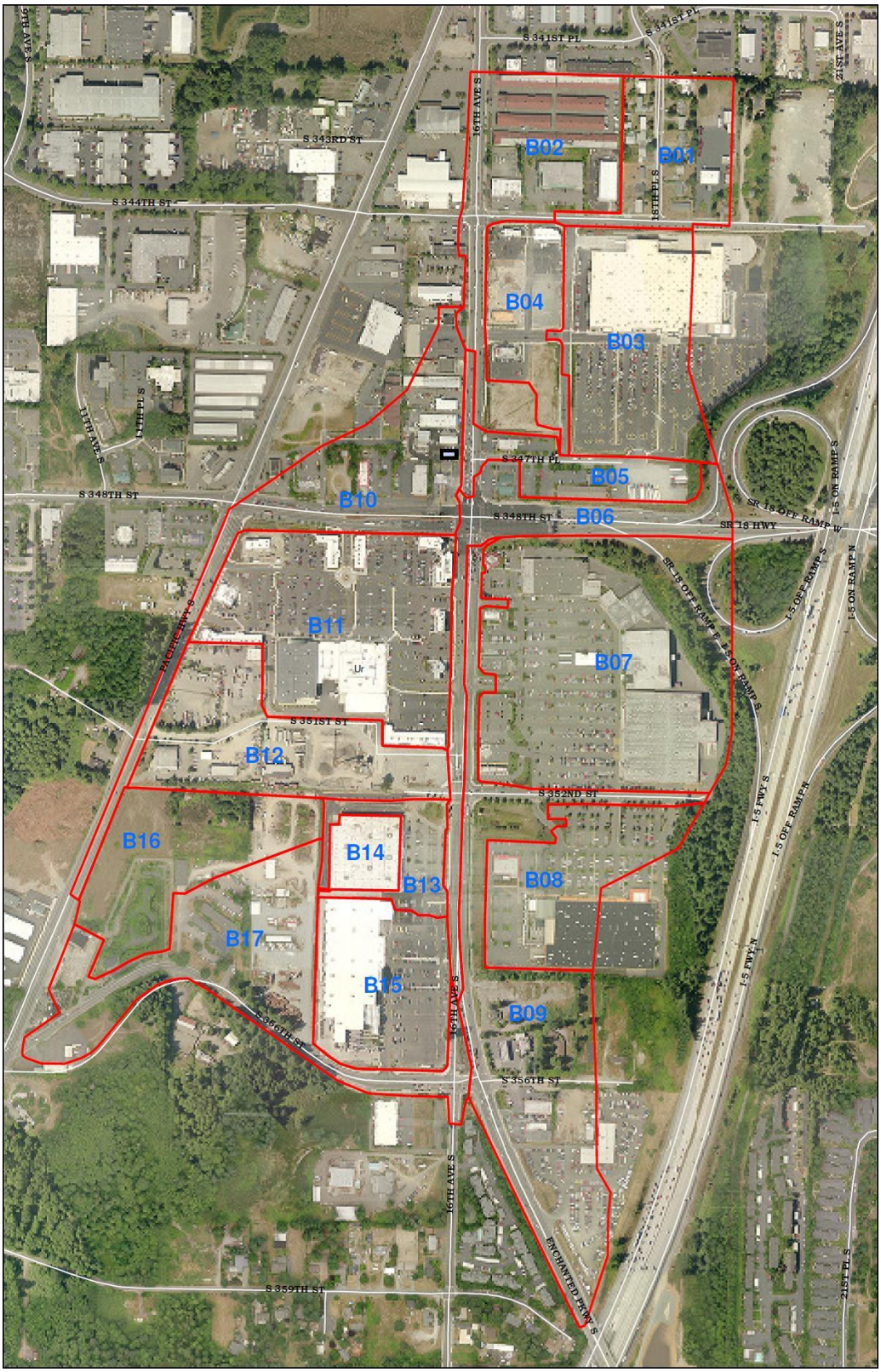

Figure 1. Stormwater basins that drain to S. 356th Street RDF in Federal Way, WA. The old wet pond is shown in Basin (B)16.

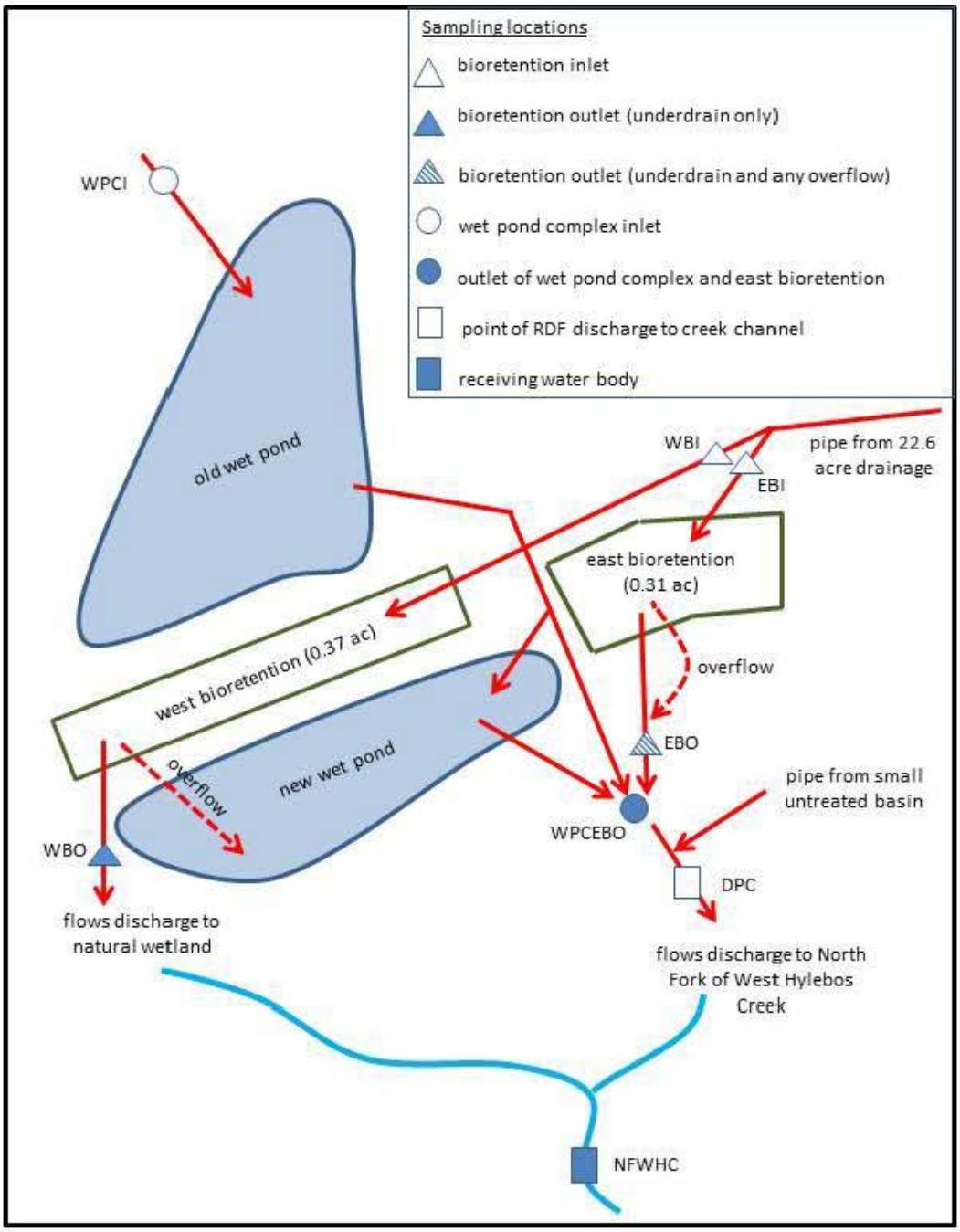
Sampling locations
bioretention inlet
bioretention outlet (underdrain only)
bioretention outlet (underdrain and any overflow)
wet pond complex inlet
outlet of wet pond complex and east bioretention
point of RDF discharge to creek channel
receiving water body
WPCI
old wet pond
WBI
EBI
pipe from 22.6 acre drainage
east bioretention (0.31 ac)
overflow
west bioretention (0.37 ac)
EBO
overflow
new wet pond
pipe from small untreated basin
WPCEBO
WBO
DPC
flows discharge to natural wetland
flows discharge to North Fork of West Hylebos Creek
NFWHC

Figure 2. Schematic of flow paths (not to scale). Sampling locations include the North Fork of West Hylebos Creek (NFWHC), the east and west bioretention inlets (EBI, WBI), the east and west bioretention outlets (EBO, WBO), and the wet pond complex inlet and outlet (WPCI, WPCEBO). Note the WPCEBO includes flows from the east bioretention facility as well as the wet pond complex.

The new wet pond was built according to specifications in Ecology's 2012 Stormwater Management Manual for Western Washington (SWMMWW; Ecology 2012). The new wet pond was not lined; however, during the 2014/2015 wet season shallow standing water (~1 ft deep) in at least half of the pond was observed. The presence of standing water was likely due to the low infiltration rate of the native soil. A marsh seed mix was combined with biotic soil amendment (BSA) and applied to the pond bottom in summer 2014; however, due to insufficient irrigation, the seedlings failed to establish. Native swale seed mix and BSA was applied on the slopes of the wet pond in summer 2014, but this vegetation also failed to establish. Seed mixes will be applied again in fall 2015 and the area will be irrigated; until the plants have become established, the new wet pond will remain offline.

The new pond was sized to maximize flow getting into the new pond without flooding it. A hydraulic model (XP-Storm) was used to size the new pond. When connected, the new wet pond will receive low-to-moderate discharges flowing from the old wet pond. The conveyance pipe discharging into the new pond is small and deep, and thus the majority of high flows from the old pond will by-pass the new pond. Both the new and old wet ponds are representative of a "wet pond BMP", with little or no infiltration, and benefits will largely be due to flow attenuation for low to intermediate flows. The combined old and new wet ponds will be referred to as the "wet pond complex" hereafter, and their collective effectiveness will be evaluated by monitoring the upstream inlet of the original old wet pond (where pre-retrofit monitoring was done) and the outlet that contains the discharges from the wet pond complex and the associated overflow discharge.

The bioretention facilities were constructed according to the Draft 2012 Low Impact Development Technical Guidance Manual for Puget Sound (Ecology, 2012). The east and west bioretention facilities are similar except for differences in some of the plant types and the west bioretention underdrain does not extend over the whole bioretention facility (Table 1). In addition, overflow from the east bioretention facility drains into an overflow pipe and then into the same pipe that the underdrain flows into (Figure 2). In contrast, the overflow from the west bioretention facility flows into the new wet pond (Figure 2). The outlet of the west bioretention facility drains to a natural wetland (Figure 2).

When the bioretention facilities were tested in February and March 2015, it became apparent that the east bioretention facility was not draining as planned. Until this problem is corrected, flow that would have entered the east bioretention facility will be diverted to the west bioretention facility. Flow measurement and water quality sampling at this facility will be initiated once it is fully operational. Will Appleton of the City anticipates that necessary repairs to the east bioretention facility will be completed by fall 2015.

Both bioretention facilities were originally built using Smart Drain™ underdrains, which are designed to facilitate draining without clogging (www.smartdrain.com). In the west bioretention facility, a network of Smart Drain™ material was included in the west end, and as of June 2015, this bioretention facility appears to be draining well and the underdrain appears to be functioning properly. In the east bioretention facility, Smart Drain™ was used throughout the facility. Because the facility is not draining as planned, initial repairs will include replacing half of the Smart Drain™ network with a traditional underdrain (personal communication with Fei Tang, June 2015).

Due to space limitations at the site, the bioretention systems were slightly undersized. Instead of treating 91% of the stormwater in this basin (Ecology's target), the expanded S. 356th Street RDF Project will treat approximately 89% of the stormwater (Fei Tang, personal communication).

Table 1. Physical description of east and west bioretention facilities at the S. 356th Street RDF.

Bioretention Facility	Size (acre)	Storage Capacity (acre-feet)	Max Depth (feet)	Soil	Vegetation Types	Extent of Underdrain
East	0.31	0.25 ac-ft before overflow, 0.69 ac-ft max.	1 ft before overflow, 2.5 ft max.	30 in of BSM[1], topped with 3 in of coarse compost[2]	Pacific crabapple, black gum, redtwig dogwood, salmonberry, dwarf arctic willow, black twinberry,	Underdrain installed throughout; material used included 8 in wide Smart Drain™ belts and PVC pipes[4]

					daggerleaf rush	
West	0.37	0.28 ac-ft before overflow, 0.6 ac-ft max.	1 ft before overflow, 2 ft max.	In eastern half: 30 in of BSM[1], topped with 3 in of coarse compost[2]; In western half: 33 in of top soil Type A BSM, topped with native swale seed mix and soil amendment A BSA[3]	In eastern half: Pacific crabapple, Pacific wax myrtle, dwarf arctic willow, salmonberry, Douglas spirea, redtwig dogwood, black gum; In the western half: native swale grasses	Underdrain installed in west half only; material used included 8 inch wide Smart Drain™ belts and PVC pipes

[1] All specifications in section 8-02.3(4)A for Bioretention Soil Media (BSM) quality and application were met.

[2] All specifications in Section 9-14.4(8) Special Provisions for compost were met.

[3] All specifications in Section 8-02.3(6) Special Provisions for BSA were met.

[4] Current as of June 2015, but improvements will include replacing half of the Smart Drain™ with a traditional underdrain made entirely of PVC pipes.

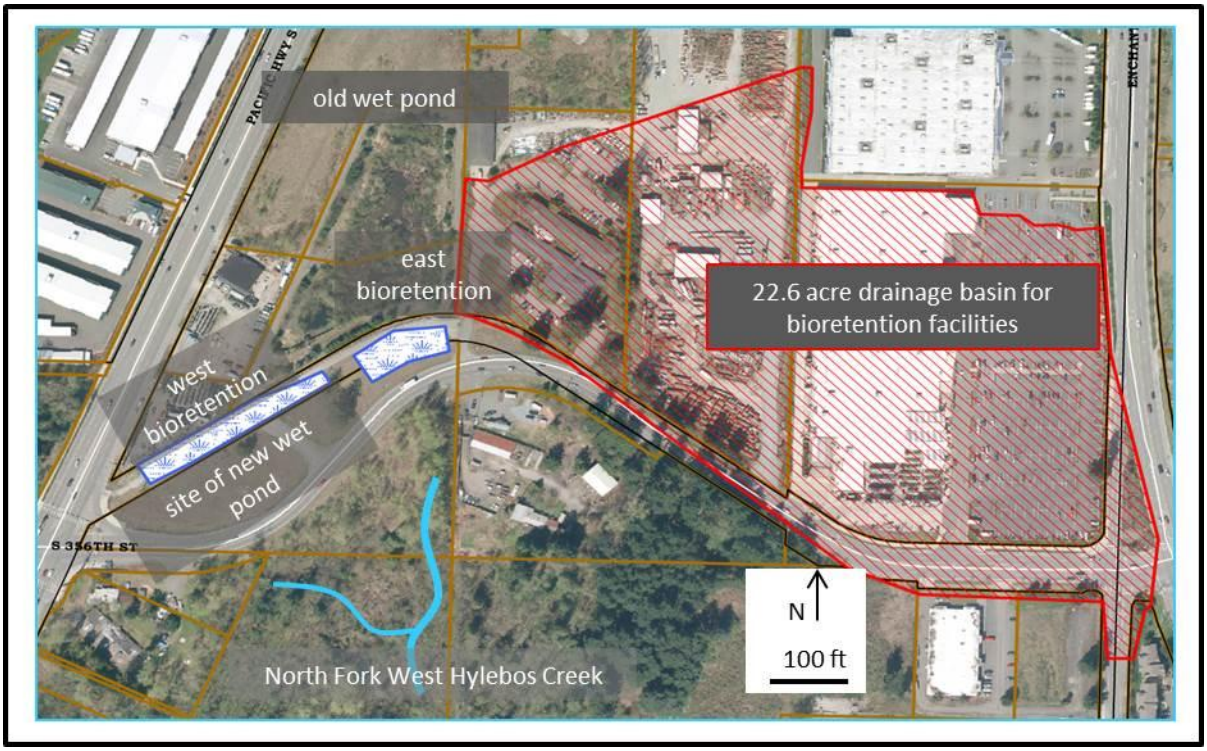

Figure 3. Aerial photo of drainage basin for bioretention facilities.

1.3 Parameters of concern

In addition to collecting temperature and turbidity measurements, the concentration and loading of additional contaminants typically associated with stormwater runoff from highly developed basins will be quantified (Table 2). Concentration data will be compared to available WQC. Per WAC 173-201A-200, the Aquatic Life Use for NFW Hylebos Creek is classified as (1)(a)(iii), "Salmonid spawning, rearing and migration".

Table 2. Water quality parameters to be measured in flow-weighted composite samples collected from all sampling locations, and the applicable WQC.

Group	Parameter	Water Quality Criteria for Creek
Metals	copper, dissolved and total	Depends on hardness, see WAC 173-201A-240
	lead, dissolved and total	Depends on hardness, see WAC 173-201A-240
	cadmium, dissolved and total	Depends on hardness, see WAC 173-201A-240
	zinc, dissolved and total	Depends on hardness, see WAC 173-201A-240
	hardness	NA

Nutrients	ammonia-N	Depends on pH, see WAC 173-201A-240
	nitratre+nitrite	NA
	total nitrogen	NA
	orthophosphate-Phosphorus	NA
	total phosphorus	NA
Conventionals (all in lab, except pH in the field)	total suspended solids	NA
	conductivity	NA
	turbidity	Shall not exceed 10 NTU over background, which is estimated to be 1.0 NTU for this creek
	total organic carbon	NA
	dissolved organic carbon	NA
	alkalinity	NA
	pH	Within 6.5 to 8.5 with a human-caused variation within the above range of less than 0.5 units.
Other Contaminants	polycyclic aromatic hydrocarbons	NA
	polychlorinated biphenyls	24-hr average not to exceed 2.0 (acute) or 0.014 (chronic) µg/L
	fecal coliform[1]	Fecal coliform organism levels must not exceed a geometric mean value of 100 colonies/100 mL, with not more than 10% of all samples (or any single sample when less than ten sample points exist) obtained for calculating the geometric mean value exceeding 200 colonies/100 mL.
Toxicity	*Daphnia pulex* acute toxicity	NA
	Ceriodaphnia dubia chronic toxicity	NA

[1] Grab samples will be collected to measure fecal coliform bacteria.

NA = none applicable

2.0 PROJECT DESCRIPTION

2.1 Study Goals

The study will evaluate the effectiveness of stormwater treatment facilities that were built as part of the retrofit of the South 356th Street RDF in the City. The overall goal is to evaluate two bioretention facilities, a wet pond complex that contains a new wet pond (constructed in 2013-2014), and the system as a whole, for their ability to improve the water quality of stormwater runoff and reduce peak flows. Specific goals are as follows:

Goal 1: Evaluate the relative effectiveness of individual bioretention facilities and a retrofitted wet pond complex to attenuate stormwater flows and reduce turbidity, nutrients, bacteria, metals, select organic contaminants and toxicity in stormwater runoff.

Goal 2: Evaluate the effectiveness of the entire, expanded RDF, to attenuate stormwater flows and improve water quality.

Goal 3: Determine if the expansion and retrofit of the RDF have improved the effectiveness of the RDF, using pre- and post-retrofit turbidity and temperature data.

Goal 4: Determine if there are improvements in the macroinvertebrate community and water temperatures in the receiving waters that are correlated with the RDF retrofit and expansion.

Goal 5: Contribute regionally-relevant and valuable data related to stormwater management in Western Washington.

The results of this project will address current regional questions and concerns regarding the effectiveness of stormwater treatment, as well as answer site-specific questions about the effectiveness of this RDF to control flow and reduce pollutant loading to NFW Hylebos Creek. Throughout the region, cities and counties are increasingly incorporating bioretention facilities into retrofit designs, and there is a critical need to evaluate their effectiveness to control flow and reduce some of the more toxic and/or persistent contaminants commonly found in stormwater draining from highly-developed basins.

2.2 Study objectives

To address the goals of the study, the following objectives will be accomplished:

To meet Goal 1:

- Collect continuous flow measurements at seven sampling stations (the inlets and outlets of the bioretention facilities and the wet pond complex, and in NFW Hylebos Creek), during the wet seasons between March 2015 and June 2017.
- Collect continuous water level data in the bioretention facilities to estimate frequency and duration of overflows.
- Quantify the relative effectiveness of individual bioretention facilities and a retrofitted wet pond complex to attenuate stormwater flows.
- Collect flow-weighted water samples from the seven sampling stations during 20 storm events over three years (2015-2017). Samples will be analyzed for metals, nutrients, some conventional parameters, and polycyclic hydrocarbons (PAHs). Polychlorinated biphenyl (PCB) congeners and bacteria will also be measured in samples from 10 of these storm events.
- Conduct toxicity tests on a subset of samples collected during 10 storm events from the seven sampling stations
- Quantify the relative effectiveness of individual bioretention facilities and a retrofitted wet pond complex to reduce pollutants in stormwater runoff.

To meet Goal 2:

- Use flow data to estimate pollutant loadings in the inlets and outlets of the RDF to determine the effectiveness of the entire RDF for moderating flow and reducing pollutant loadings.

To meet Goal 3:

- Compare pre-retrofit and post-retrofit turbidity and temperature data from the wet pond complex inlet and outlet to determine if there have been changes in these parameters due to the retrofit and expansion of the RDF.

To meet Goal 4:

- Analyze trends in water temperature and the macroinvertebrate community in NFW Hylebos Creek to identify improvements in receiving water quality that may be correlated with the retrofit and expansion of the RDF. Macroinvertebrate communities will be assessed using two similar metrics: Ecology's MMI and the Puget Sound Lowlands Benthic Index of Biotic Integrity (B-IBI).

To meet Goal 5:

- Collect high quality and relevant data.
- Analyze data with appropriate and robust statistical analyses.
- Distribute results of the study to regional audiences in a timely manner.

2.3 Sampling approach

The study was designed to collect field data to meet the study objectives stated in Section 2.2. These objectives require collection of continuous flow and water chemistry data in the receiving waters, at paired stations (inlet/outlet) for each functioning RDF component and for the whole RDF. Sample collection at the paired inlet/outlet stations for toxicity testing is also necessary. Because chemistry samples are intended to represent stormwater conditions over a storm hydrograph, not just one point in time, composite samples obtained with Isco® autosamplers will be collected. The chemistry samples will be composited based on flow (i.e. flow-weighted) thereby standardizing across this variable. Measurement of continuous flow will enable characterization of system hydrology and chemical specific loading calculations.

The effectiveness of each RDF component (bioretention facilities and the wet pond complex) will be evaluated by comparing flow and the percent difference in concentrations between the inlet and outlet for specific storms and averaged over multiple storms. Over the three year study period, continuous flow data will be collected and 20 storms will be targeted for sample collection. Estimated pollutant loadings from each inlet and outlet will be calculated for each sampling period as well, so that the net effect of each facility on loading during storm events can be compared. Loading comparisons will be made between individual inlets and outlets for the parameters measured for individual storms as well as across storms. The cumulative in- and outflow during storms will be compared to evaluate overall RDF effectiveness. These calculations are based on the assumption that flow and chemical composition of the influent and effluent can be adequately characterized, and the calculations make no assumptions about the fate and quality of the water that infiltrated (i.e. was “lost” from a facility).

2.3.1 Flow measurement

Continuous flow will be measured at the inlets and outlets of each bioretention facility, and at the inlet and outlet of the wet pond complex. Flow will also be measured in NFW Hylebos Creek, where it flows through a culvert under S. 359th Street. Flow meters will be installed inside the inlet or outlet pipes (or culvert for the creek station). To estimate the frequency and duration of overflows at the bioretention facilities, a water level data logger will be placed in each bioretention facility.

2.3.2 Water quality sampling

2.3.2.1 Continuous measurements of temperature and turbidity

City staff will continue to collect continuous turbidity and water temperature data at the same stations that were surveyed prior to the retrofit (for turbidity and temperature: the inlet of the wetland pond complex and the RDF outlet that discharges to NFW Hylebos Creek; temperature is also measured in NFW Hylebos Creek at S. 359th St). King County will use data loggers to continuously record water temperatures when water is present in the bioretention facilities.

2.3.2.2 Stormwater sampling

Flow-weighted composite water samples will be collected during 20 storms using Isco® autosamplers at the inlets and outlets of each bioretention facility, and at the inlet and outlet of the wet pond complex. Flow-weighted composite water samples will also be collected in NFW Hylebos Creek at the culvert under S. 359th Street. Each sample will be analyzed for conventional parameters, nutrients, total and dissolved metals, and PAHs. PCB congeners will be analyzed in a subset of samples collected from 10 storms. Grab samples will also be collected during 10 storms for bacteria analysis. A statistical comparison of influent and effluent results will determine treatment effectiveness.

2.3.2.3 Toxicity sampling

Toxicity testing will also be conducted using flow-weighted composite samples collected from 10 storms. *Daphnia pulex* will be used for acute toxicity tests and *Ceriodaphnia dubia* will be used for chronic toxicity tests. A statistical comparison of the toxicity test results for influent and effluent stormwater will be used to evaluate treatment effectiveness. If toxicity is not detected in any of the tests from samples collected over the first three storms, the option of conducting a more sensitive toxicity test will be explored (such as those used by McIntyre et al. 2015).

2.3.3 Benthic macroinvertebrate sampling

The City has collected aquatic benthic macroinvertebrates on an annual basis in NFW Hylebos Creek since 1999, and will continue to collect samples over the course of the study period (2015 -2017).

2.4 Sampling considerations and constraints

2.4.1 Delayed operation of the new wet pond and the east bioretention facility

Construction of the bioretention facilities and the new pond was completed in the summer of 2014; however, both facilities remained offline until recently. The inlet gates to the bioretention facilities were opened in February 2015 to begin to monitor flow through the facilities. As mentioned above, the east bioretention facility did not drain as planned and the facility will need to be repaired prior to initiation of sampling (anticipated fall 2015). While the east bioretention facility is offline, the west bioretention facility will receive all of the flow that will otherwise be divided between the two bioretention facilities when they are both online.

In addition, the new wet pond will also likely remain offline until mid-winter2015, because vegetation planted in summer 2014 failed to establish. The area will be replanted in fall 2015 and the gate allowing

water to flow from the old wet pond into the new wet pond will be opened once vegetation has established.

2.4.2 Determination of storm sampling methods

Flow monitoring was initiated in April 2015 in an effort to begin characterizing flow through the west bioretention facility. Flow monitoring equipment will be installed at the remaining locations in June or July 2015. Initials flow data will be used to establish sampling criteria and determine the appropriate autosampler sample collection intervals.

The objective is to collect samples from the inlets and outlets of all locations during each storm event, with the timing and intervals of each sample collection determined by the expected flow through the facility. To determine the timing and sample interval, continuous flow will be measured at all stations for a time period sufficient to capture at least three distinct storms. Hydrographs will be reviewed to address 1) the rain volume that will result in increased flows to the facilities, 2) the rain volume that results in effluent discharge from the individual facilities, and 3) the sampling timeframe necessary for each station to capture a representative amount of flow.

Initially, this assessment may be complicated by the delay in operation of the east bioretention facility, and the fact that the west bioretention facility will be receiving greater flow than expected until the east facility is online. Initial hydrographs from the west bioretention inlet and outlet will be inspected carefully and used to determine sampling intervals for storm events occurring before the east bioretention facility is online. Once both facilities are operational, new hydrographs will be evaluated to determine detention times and appropriate sampling intervals.

Ideally, the detention time in the bioretention facilities will be short and will, therefore, allow for a paired sampling approach. If the initial flow measurements indicate the detention times are long the sampling method will be changed to a protocol that is similar to the Technology Assessment Protocol – Ecology (TAPE) detailed in the *Guidance for Evaluating Emerging Stormwater Treatment Technologies* (Ecology 2011). In a modified TAPE sampling approach, inlet and outlet samples are not necessarily paired and a greater number of storms are targeted.

2.4.3 Preventing vandalism

Sampling equipment will be installed and left in place once the study begins. To protect equipment from possible vandalism, it will be secured onsite in locked sheds which will be anchored to stationary objects

(e.g., metal bird cages, lampposts, or concrete pads). Most of the sampling stations are located within a fenced and locked gate.

3.0 ORGANIZATION AND SCHEDULE

3.1 Project team

The project team consists of two groups from King County's Water and Land Resources Division (WLR Division) and partners from the City. Team members listed below with an asterisk by their name will be in regular contact to coordinate the sampling and analysis effort, and ensure adherence with the plan described in this QAPP.

King County WLR Division, Science Section Personnel:

This group is responsible for project planning, communicating between involved parties, collecting water depth data and synthesizing and communicating results.

- Kate Macneale– Project Manager*
- Jenée Colton – Technical Assistance
- Carly Greyell – Technical Assistance
- Richard Jack – Technical Assistance, PCB Data Management
- Deborah Lester – Toxicology and Contaminant Assessment (TCA) Supervisor

King County WLR Division, King County Environmental Lab (KCEL):

With the exception of water level measurements, KCEL staff are responsible for all field work. They are also responsible for conducting toxicity testing and chemical analysis of all parameters with the exception of PCBs which will be analyzed by a contract lab, Pacific Rim Laboratories. The KCEL will ship PCB samples to Pacific Rim Laboratories, provide laboratory data management and data review.

- Fritz Grothkopp – Laboratory Project Manager (LPM)*
- Colin Elliott – Quality Assurance Officer

<u>Analytical Group</u>

- Diane McElhany – Metals and Organics Laboratory Supervisor
- Brian Prosch – Conventionals Laboratory Supervisor
- Eric Thompson – Microbiology Laboratory Supervisor
- Fran Sweeney – Aquatic Toxicology Supervisor

Field Science Unit

- Ben Budka – Field Services Unit Supervisor*
- Jeff Droker – Lead Field Technician

City of Federal Way, Public Works Department

This group is responsible for collection of continuous temperature and turbidity data at the stations specified in section 5.0, providing site-specific technical expertise, and reviewing plans and draft documents.

- Dan Smith - Surface Water Quality Program Coordinator*
- Fei Tang – Surface Water Project Engineer

RSMP Representatives

This group is responsible for providing coordination between the Stormwater Working Group and the rest of the project team, as well as technical oversight.

- Brandi Lubliner , Ecology – RSMP Coordinator
- Will Appleton, City of Federal Way – RSMP Technical Liason

Table 3. Team members and contact information

Organization	Name	Contact Information

King County	Kate Macneale	206-477-4769; kate.macneale@kingcounty.gov
King County	Jenée Colton	206-477-4075; jenee.colton@kingcounty.gov
King County	Carly Greyell	206-477-4703; carly.greyell@kingcounty.gov
King County	Richard Jack	206-477-4715; richard.jack@kingcounty.gov
King County	Deborah Lester	206-477-4752; deborah.lester@kingcounty.gov
King County	Fritz Grothkopp	206-477-7114; fritz.grothkopp@kingcounty.gov
King County	Colin Elliott	206-477-7113; colin.elliott@kingcounty.gov
King County	Diane McElhany	206-477-7175; diane.mcelhany@kingcounty.gov
King County	Brian Prosch	206-477-7125; brian.prosch@kingcounty.gov
King County	Eric Thompson	206-477-7165; eric.thompson@kingcounty.gov
King County	Fran Sweeney	206-477-7117; francis.sweeney@kingcounty.gov
King County	Ben Budka	206-477-7142; ben.budka@kingcounty.gov
King County	Jeff Droker	206-477-7145; jeff.droker@kingcounty.gov
Federal Way	Dan Smith	253-835-2756; daniel.smith@cityoffederalway.com
Federal Way	Fei Tang	253-835-2751; fei.tang@cityoffederalway.com
Ecology	Brandi Lubliner	360-407-7140; brandi.lubliner@ecy.wa.gov
Federal Way	Will Appleton	253-835-2711; william.appleton@cityoffederalway.com
Pacific Rim Laboratories	David Hope	1-604-532-8711; david@pacificrimlaboratories.com

3.2 Project schedule

The project schedule and the corresponding due dates for deliverables are listed in Table 4.

Table 4. Schedule of activities and deliverable due dates for S. 356th Street RDF monitoring.

Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Deliverable Due Date
TASK 2.0 – Field Sampling, Data Collection and Analysis				
Continuous flow monitoring at inlets and outlets, and in NFWHC	April 2015	June 2017	Documenting Progress Reports	Semi-annually
Continuous temperature and turbidity monitoring at wet pond complex inlet and at RDF discharge point to creek	July 2015	June 2017	Documenting Progress Reports	Semi-annually
Continuous water depth and temperature monitoring in bioretention facilities	July 2015	June 2017	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Storm Sampling (target: 10 storm events)	Oct. 2015	June 2016	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Analysis at KCEL and Pacific Rim Laboratories, and toxicity tests at KCEL	Oct. 2015	Sept. 2016	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Storm Sampling (target: 10 storm events)	Oct. 2016	June 2017	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Analysis at KCEL and Pacific Rim Laboratories, and toxicity tests at KCEL	Oct. 2016	Sept. 2017	Documenting Progress Reports	Semi-annually
Annual macroinvertebrate sampling in creek, sample processing and data analysis	August 2015	March 2018	Documenting Progress Reports	Semi-annually
TASK 3.0 – Final Report				
Data Analysis	July 2017	March 2018	Documenting Progress Reports	Semi-annually
Draft Writing	July 2017	April 2018	Documenting Progress Reports	Semi-annually
Internal Review	April 2018	May 2018	Documenting Progress Reports	Semi-annually
External Review	May 2018	June 2018	Draft Report	June 2018
Finalizing Report	July 2018	Dec. 2018	Final Report	Dec. 2018
TASK 4.0 – Dissemination of Findings				
Submit creek data to EIM	Sept. 2018	Dec. 2018	Data submitted	Dec. 2018
Presentations (2 total)	Sept. 2016	Dec. 2018	Copies of	Dec. 2018

Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Deliverable Due Date
			presentations	
Website Development	July 2015	Dec. 2018	Post QAPP; Post Final Report	Dec. 2015; Dec. 2018
TASK 5.0 – Project Management				
Project Management	Jan. 2015	Dec. 2018	Documenting Progress Reports	Semi-annually
TASK 6.0 – Optional modified TAPE Protocol for Long-Term Detention BMP Monitoring				
Decide whether to implement TAPE Protocol	Sept. 2015	Dec. 2015	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Storm Sampling (4-6 additional storm events)	Jan 2016	June 2016	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Analysis at KCEL	Jan 2016	Sept. 2016	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Storm Sampling (4-6 additional storm events)	Oct. 2016	June 2017	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Analysis at KCEL	Oct. 2016	Sept. 2017	Documenting Progress Reports	Semi-annually

BMP – best management practice

TAPE – Technology Assessment Protocol – Ecology

Shaded cells are part of optional task requiring Ecology pre-approval before initiation. This optional task may not be completed.

3.2.1 Limitations imposed on the schedule

The project is subject to the timing of suitable storms and, therefore, the schedule is subject to change. If the target number of storm events is not reached by the end of each wet season, additional storms will be sampled the following year to achieve the same targeted total storm samples. Personnel affected by this change of schedule (Table 3) will be notified as soon as any changes are known.

4.0 QUALITY OBJECTIVES

The data quality objectives (DQOs) for this effort are to collect data of known and sufficient quality to meet study goals. The data quality issues of precision, bias, sensitivity and accuracy are described in the following sections. Detailed descriptions and specific limits for quality assurance/quality control (QA/QC) samples are discussed in Sections 8 and 9.

The DQOs discussed below cover new analytes and measurements to be collected for this project. The DQOs for measurements that City staff have previously collected (i.e., continuous monitoring of temperature and turbidity, and the macroinvertebrate collection and sample analysis) will be the same as those included and approved in their QAPP (Appendix A).

4.1 Precision

Precision is the agreement of a set of results among themselves and is a measure of the ability to reproduce a result. For this project, evaluation of precision will be based on field replicates, laboratory duplicates or triplicates and matrix spike duplicates. Differences between results for these QA/QC samples must be within the criteria presented in Sections 8 and 9 to meet measurement quality objectives (MQOs).

4.2 Bias

Bias is a measure of the difference, due to a systematic factor, between an analytical result and the true value of an analyte or a measurement. Bias will be evaluated by analyzing field blanks, method blanks, spike blanks, matrix spikes, certified reference materials, laboratory control samples and/or surrogates, along with ongoing recovery sample control charts. Results for these QA/QC samples must be within the criteria presented in Sections 8 and 9 to meet MQOs.

4.3 Sensitivity

Sensitivity is a measure of the capability of analytical methods to meet the study goal. The analytical method detection limits (MDLs) presented in Sections 8 and 9 are sensitive enough to detect conventional parameters, total and dissolved metals, low level PAHs and PCB congeners at concentrations sufficient to increase the understanding of the effect of stormwater treatment on concentrations of these parameters being discharged to NFW Hylebos Creek from the RDF.

4.4 Accuracy

Accuracy is an estimate of the difference between the true value and the measured value. The accuracy of a result is affected by both systematic and random errors. Accuracy of the results will be analyzed

using field blanks, method blanks, matrix spikes, certified reference materials and/or laboratory control samples, along with ongoing recovery sample control charts. Results for these QA/QC samples must be within the criteria presented in Sections 8 and 9 to meet MQOs. Additionally, the isotopic dilution method chosen for this study is the most rigorous method for PCB congener analysis. This method uses isotopically-labeled congeners to track the recovery performance of the range of congener homologs. Thus, each congener concentration is theoretically adjusted for the extraction efficiency and analytical performance of that specific sample.

5.0 SAMPLING DESIGN

5.1 Sampling stations

The sampling stations are described below and shown on Figure 2.

East Bioretention Facility Inlet (EBI) and the West Bioretention Facility Inlet (WBI)

These inlets receive the same stormwater runoff from heavily developed basins (Figure 3). Runoff from the basins flows through a single pipe and empties into a small catch basin. Two pipes drain the catch basin: one carries water to the east bioretention facility and one carries water to the west bioretention facility. The pipes were designed to deliver approximately the same amount of water to each bioretention facility but this will be confirmed with flow monitoring.

Flows are expected to be flashy and water samples are expected to have relatively high concentrations of pollutants typically found in urban stormwater (e.g., metals, PAHs). A field replicate will be collected during 10 of the 20 storms over the study period (at least 3 of those replicates will be collected from EBI, at least 3 will be collected from WBI, and the remaining 4 will be collected from one or the other).

East Bioretention Facility Outlet (EBO)

This sampling pipe contains flow from the east bioretention facility that reached the underdrain and any water that entered the overflow stand pipe.

West Bioretention Facility Outlet (WBO)

This outlet only includes effluent that has passed through to the underdrain in the west bioretention facility. Any overflow from the west bioretention facility flows into the new wet pond.

Wet Pond Complex Inlet (WPCI)

This inlet receives runoff from heavily urbanized basins (Figure 1). The City has been collecting temperature and turbidity data here and those measurements will continue through June 2017 at a minimum. Continuous flow data and water quality samples will also be collected here.

Combined Wet Pond Complex and East Bioretention Outlet (WPCEBO)

Flow from the old wet pond, the new wet pond, and the east bioretention facility (overflow and underdrain) empty into a catch basin. The pipe leaving that catch basin will be sampled, and referred to as the WPCEBO. To estimate the separate contribution of the wet pond complex (the combined old and

new wet pond), the flow and loading from the east bioretention facility will be subtracted from the flows and loading measured at the WPCEBO. To estimate the entire outflow of the retrofitted and expanded RDF, the flow and loading from the WPCEBO will be combined with similar measurements at the WBO.

RDF Discharge Point to Creek (DPC)

Water flowing from the RDF through the WPCEBO and a small amount of untreated runoff from a basin to the east of the RDF combine before being discharged to NFW Hylebos Creek. The City has monitored temperature and turbidity at this site, and to maintain continuity of those data sets, they will continue to collect these data at this site. No additional parameters will be measured here.

North Fork West Hylebos Creek (NFWHC)

The RDF is the headwaters of NFW Hylebos Creek. Approximately 0.2 miles downstream of the RDF, NFW Hylebos Creek flows under S. 359th Street through a culvert. The City has collected, and will continue to collect, continuous water temperature data at this station. Additional water quality and flow parameters will also be sampled by King County (Table 5) at this location.

Benthic macroinvertebrate samples will be collected by the City from two sites on NFW Hylebos Creek. Both sites can be accessed from S. 359th Street (approximately 0.2 miles south of the RDF). One sampling site is ~50 m upstream of the culvert at S. 359th Street, and the other site is ~50 m downstream of the culvert. Sampling will occur once per summer per site using the same methods previously used in 2015, 2016, and 2017 (see Appendix A – Federal Way QAPP).

East and West Bioretention facilities

Data loggers that continuously record water level and temperature will be placed near the overflow points in both the east and west bioretention facilities. In the east bioretention facility, the data logger will be placed near the overflow stand pipe. In the west bioretention facility, the data logger will be placed near the rock weir that serves as an overflow point into the new wet pond. These data will be used to determine the frequency and duration of overflows, and water temperature (when water is present).

5.2 Sampling frequency by parameter and site

Table 5 summarizes the parameters of interest and the frequency with which they will be analyzed at each sampling station. Table 6 presents personnel and laboratory responsibilities for sample (or data) collection and analysis.

Table 5. Type of data or samples collected at each station and the number of storms targeted between 2015 and 2017.

Data/Samples Collected	EBI	EBO	WBI	WBO	WPCI	WPCEBO	DPC	NFWHC	Field Rep	Bioretention Facilities
Continuous flow	X	X	X	X	X	X		X		
Continuous temperature					X		X	X		X
Continuous turbidity					X		X			
Continuous water level										X
Metals (FWC)	20	20	20	20	20	20		20	10	
Nutrients (FWC)	20	20	20	20	20	20		20	10	
Conventional Parameters: alkalinity, conductivity, DOC, TOC, TSS and turbidity (FWC); pH (field)	20	20	20	20	20	20		20	10	
PAHs (FWC)	20	20	20	20	20	20		20	10	
PCBs (FWC)	10	10	10	10	10	10		10		
Fecal coliforms (G)	10	10	10	10	10	10		10		
Toxicity (FWC)*	10	10	10	10	10	10		10		
Macroinvertebrates**								3		

FWC = flow weighted composite samples

G = grab samples

* The SOW states toxicity tests will be done with samples from all 7 sampling stations for 2-4 storms each wet season. The number and type of tests may be refined depending on results from the first three tests.

**Macroinvertebrate samples are collected in late summer each year.

Table 6. Personnel or laboratory responsibilities.

Data/Samples Collected	Personnel or Lab Responsible for Equipment Installation and Sample Collection	Personnel or Lab Responsible for Data Recording or Sample Analysis	Personnel Responsible for Data Analysis

Continuous flow	Jeff Droker, KCEL FSU	Jeff Droker, KCEL FSU	Kate Macneale, KC
Continuous temperature at WPCI, DPC and NFWHC	Dan Smith, Federal Way	Dan Smith, Federal Way	Dan Smith, Federal Way
Continuous turbidity	Dan Smith, Federal Way	Dan Smith, Federal Way	Dan Smith, Federal Way
Water level and temperature in bioretention facilities	Kate Macneale, KC	Kate Macneale, KC	Kate Macneale, KC
Metals	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
Nutrients	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
Conventional Parameters	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
PAHs	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
PCBs	Jeff Droker, KCEL FSU	Pacific Rim	Richard Jack, KC
Fecal coliform	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
Toxicity	Jeff Droker, KCEL FSU	KCEL	Kate Macneale, KC
Macroinvertebrates	Dan Smith, Federal Way	Rhithron Associates	Dan Smith, Federal Way

5.3 Continuous field measurements and macroinvertebrate sampling

The City will collect continuous temperature and turbidity data, in addition to macroinvertebrate data at the sites indicated in Table 5. The sampling design previously used by the City will continue to be followed and is included in Appendix A.

King County will use data loggers to continuously record water level and temperature in the two bioretention facilities. However, data recorded during periods with no flow or standing water will not be analyzed.

5.4 Qualifying storm event sampling criteria

One challenging aspect of stormwater sampling is storm variability. Developing storm criteria increases the chances that sampling equipment is only deployed when stormwater flows can provide sufficient sample volume. The criteria presented below have been adapted from the TAPE *Guidance for Evaluating Emerging Stormwater Treatment Technologies* (Ecology 2011). These criteria may be modified as necessary based on initial flow monitoring in the RDF.

Storm Event Guidelines:

- Forecasted rainfall: at least 0.15 inch, no fixed maximum
- Rainfall duration: at least one hour, no fixed maximum
- Antecedent dry period: at least 6 hours with less than 0.04 inches of rain
- Flow requirements: Effluent must be flowing from outlet locations

5.5 Parameters for stormwater sampling

The parameters that will be analyzed in stormwater samples are listed in Table 2. For PCBs, all 209 congeners will be analyzed; a complete list of congeners is included in section 7.3.

PAHs to be analyzed include:

1-Methylnaphthalene

2-Methylnaphthalene

Acenaphthene

Acenaphthylene

Anthracene

Benzo(a)anthracene

Benzo(a)pyrene

Benzo(b,j,k)fluoranthene

Benzo(g.h.i)perylene

Chrysene

Dibenzo(a,h)anthracene

Fluoranthene

Fluorene

Indeno(1,2,3-Cd)pyrene

Naphthalene

Phenanthrene

Pyrene

5.6 Representativeness

Representativeness expresses the degree to which sample data accurately and precisely represent a characteristic of a population, parameter variations at the sampling point, or an environmental condition. Samples are to be collected in a manner to minimize potential contamination and other types of chemical or physical degradation. This can be achieved by following guidelines for sampler decontamination, sample acceptability criteria, sample processing, observing proper hold-times, preservation, storage and preparation of samples, as described in Sections 6.0 and 7.0. In order to reduce the risk of cross-contamination between sampling stations, sampler and sample splitting tubing will be pre-cleaned and either new or dedicated to a particular sampler. In order to best characterize conditions in the RDF, storm sampling criteria are intended to be as inclusive as possible (see Section 5.4) while insuring that there will be sufficient sample volumes for analysis. The twenty storms that meet these criteria and are sampled should be representative of storms that affect Federal Way and the RDF. However, because of the criteria that there be sufficient effluent from the facilities for adequate sample volumes, the study may not be representative of small storms. The samples are intended to generate data of sufficient quality to evaluate effectiveness of the individual bioretention facilities and the wet pond complex, as well as the overall retrofitted and expanded RDF.

5.7 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared with another. Comparability is addressed through use of standard techniques to collect and analyze representative samples, along with standardized data verification and reporting procedures described below in this QAPP. Changes or updates to analytical methods and sampling techniques midway into the project must be tested, validated, and shown to be equivalent to existing methods. This validation must be approved by the project manager and QA officers before being implemented.

The only previous datasets available for comparison to this study are the temperature, turbidity, and macroinvertebrate datasets that were collected by the City (temperature and turbidity from March 2012 through June 2014, and macroinvertebrates since 1999). City staff will collect, manage and analyze new

temperature, turbidity and macroinvertebrate data using the same methods used previously, which should minimize problems with comparability of the datasets.

5.8 Completeness

Completeness is defined as the total number of samples analyzed for which acceptable analytical data are generated, compared to the total number of samples submitted for analysis. Sampling according to storm criteria, along with adherence to standardized sampling and testing protocols outlined in this QAPP, will aid in providing a complete set of data for this project. The goal for completeness is a total of 20 samples collected at each sampling station over the three-year sampling period. The target number of storms is based on limits of time and resources and not on a statistical power analysis. The samples from each event should produce greater than 90% acceptable chemical and biological data under the QC conditions described in Section 8 of this QAPP. However, all dissolved metals and orthophosphate phosphorus analyses will be "H" flagged because samples will be filtered in the lab, exceeding the requirement for filtration within 15-minutes of sample collection (see Section 6.3).

Storms are unpredictable, and until the hydrodynamics of the facilities are better understood, it is unclear how difficult it will be to meet the target number of storms and the target sample volumes for each station during each storm. While preliminary flow monitoring data and implementation of storm criteria increase the chances of collecting adequate sample volume, it is still possible that sampling will result in insufficient volume to perform all analyses. Therefore, samples from each station pair (inlet and outlet) will be analyzed when there is sufficient volume in each sample to analyze the metals, nutrients, PAHs and conventional parameters (4.3 L see decision tree Figure 4). 10.2 liters of sample volume per sample are necessary to meet the goal of analyzing PCBs and evaluating toxicity in samples from 10 storms.

If it is necessary to shift the sampling design to a modified TAPE protocol, the need for pairing samples may be relaxed. In that case, all samples with at least 4.3L will be analyzed for metals, nutrients, PAHs and conventional parameters as long as storm event criteria were met.

If completeness goals are not achieved, the project team will determine if the DQOs can still be met, or if collection of additional samples is necessary.

6.0 SAMPLING AND MONITORING PROCEDURES

6.1 Macroinvertebrate monitoring and continuous measurement of field parameters

The City will collect continuous temperature and turbidity measurements and macroinvertebrate data at the sites indicated in Table 5. The sampling and monitoring procedures are included in Appendix A.

King County will collect continuous water level measurements and temperature data in the bioretention facilities with Onset HOBO U20L-04 data loggers. One data logger will be placed in each facility. Each data logger will be securely attached to a stake or other stationary object to ensure it will not shift in height over the deployment period. Each data logger will be placed as close as possible to the overflow point in each bioretention facility (i.e., the stand pipe in the east bioretention facility and by the rock weir in the west facility) while also ensuring it will not be physically influenced by the effluent flow. The relative elevation of the data logger and overflow point will be measured with a level to determine the water levels that would result in an overflow condition. The data loggers are sealed and require little maintenance; however, to provide additional protection they will be placed in perforated PVC housing prior to deployment. A third data logger will be positioned at the site to measure barometric pressure, which is necessary to calculate accurate water levels from the other two loggers. Data will be downloaded quarterly from the loggers.

6.2 Flow Measurement

Continuous flow data will be collected at each sampling station using either an air bubbler (level sensor-type flow meter; Isco® 730 Bubbler Flow Module) or an area velocity meter (Isco® 750 Area Velocity Flow Module) (Table 7). Continuous flow data collected during storm events will be analyzed prior to sampler deployment to determine residence time of water in the facility and gain a better understanding of how the various components of the RDF alter stormwater flow. Rainfall data from nearby King County rain gages and flow data will provide information necessary to program the autosamplers based on forecasted rainfall.

Equipment installation includes, but is not limited to:

- Installation of sampler tubing in stormwater pipe

- Installation of mounting rings for sampler tubing and flow meter probe
- Installation of a liquid level actuator or telemetry equipment
- Installation of other necessary sampler equipment into/onto sampler (bottles, flow meter)

Installation and monitoring procedures will follow SOP NPDES-CM-1000 (King County 2008; see section 2.1.4) and the guidelines in the instrument manuals (Teledyne 1995; Teledyne 1996). The bubbler will determine the level in each pipe, and the Isco® 6712 sampler will convert that level into flow rate. For locations with an area velocity meter (AVM), the AVM directly measures the average velocity of the flow stream in a pipe, and an integral pressure transducer measures the water depth to determine flow area. An Isco® 6712 sampler then calculates the flow rate by multiplying the cross section of the flow by the velocity.

During equipment installation, the flow meter will be programmed and tested. If there is no flow in the facility to allow for a test run at the time of installation, field staff will return when there is flow to check that the equipment is working properly.

Table 7. Type of flow meter used at each sampling station; a model 6712 Isco® Autosampler will be used at all locations.

Sampling Station	Station Code	Diameter of Pipe (in)	Slope of Pipe (%)	Flow Meter Model
East Bioretention Inlet	EBI	12	13.20	750 AVM
East Bioretention Outlet	EBO	18	18.39	730 Bubbler Flow Module
West Bioretention Inlet	WBI	18	1.20	750 AVM
West Bioretention Outlet	WBO	8	6.30	730 Bubbler Flow Module
Wet Pond Inlet	WPCI	48	0.81	750 AVM
Wet Pond and East Bioretention Outlet	WPCEBO	48	0.50	730 Bubbler Flow Module
North Fork West Hylebos Creek	NFWHC	60	TBD	730 Bubbler Flow Module
Field Replicate	WBI_FR or EBI_FR	18 or 12	1.20 or 13.2	750 AVM

6.3 Flow-weighted composite sample collection

Composite water samples will be collected using Isco® 6712 autosamplers (Table 7). Autosamplers will be equipped with 20-liter glass (or suitable fluorinated plastic) sample carboys. The carboys will be dedicated to specific sampling stations for the duration of the project. Autosamplers will be installed inside protective sheds at ground level. Autosamplers will be fitted with new and/or site-dedicated silicon tubing in the peristaltic pump for each sampling event. All tubing, new and site-dedicated, should be decontaminated prior to use for this project. Site-dedicated Teflon® tubing and stainless steel fittings shall be used for all other tubing.

The flow meters installed at each station will allow collection of a flow-weighted composite sample. After a pre-determined volume of water passes by the flow meter, a pulse trigger is sent to the autosampler to collect a pre-determined aliquot ranging in volume from 100-mL to 500-mL. The specific volume to be collected by the autosampler will be programmed based on anticipated flow conditions as predicted using previous flow and rainfall monitoring data.

Autosamplers will be programmed to collect flow-weighted samples for a period between 12 and 24 hours[1]. The end of the compositing period will be considered the start of the holding time period for all samples.

Autosamplers are not appropriate for collecting samples for bacteria analysis (e.g., decontamination and holding time issues). Thus, single grab samples will be collected for fecal coliform analysis using a dedicated sterile container. When possible, single grab samples will be collected at or near the beginning of the sampling period.

Sampling personnel will retrieve the samples as soon as possible after the sampling event ends. Once on site, field personnel will review flow data to confirm that stormwater runoff has subsided or that sampling occurred for a maximum of 24 hours. If the target volume has not been reached at less than 24 hours, and storm flow is still present, the sampling program will continue. Sampling will be complete once the target volume has been reached, stormwater runoff has ceased, or the sampler has sampled for 24 hours.

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[1] The target sampling duration may be modified after initial flow monitoring.

An aliquot of each sample will be removed and analyzed in the field for pH, and the remaining samples will then be placed on ice and transported to the KCEL. Upon arrival at the KCEL, samples will be split into the necessary aliquots and the appropriate containers. Samples requiring filtration will be processed as soon as possible with a 0.45 micron capsule filter. Orthophosphate phosphorus aliquots will be filtered as soon as possible using a 0.45 micron SFCA syringe filter. All parameters requiring filtration within 15 minutes of sample collection will be flagged with an "H" qualifier.

6.4 Toxicity Tests Sample Collection

For approximately 10 sampling events, 3.8 L of each composite sample will be used for toxicity analysis at all stations. The project manager and field team will communicate with the toxicity laboratory prior to sample collection to ensure test organisms are available for the toxicity tests.

6.5 Sampling Deployment

6.5.1 Monitoring Forecast

Although it is ideal to randomize sampling days, this is unrealistic for the personnel resources at FSU. Instead, the project manager and field team will plan sampling events around the weather forecast and available personnel. NOAA's forecast for Federal Way will be used to assess whether a storm will qualify for sampling (as defined in Section 5.4). If a storm qualifies, the forecast will be used to define the timing of sampling. The following website will be used:

http://forecast.weather.gov/MapClick.php?lat=47.32231907300047&lon=-122.31261885299972&site=all&smap=1#.VRMn6vPn-Uk

When a qualifying storm is forecast, field personnel will prepare for the event after a discussion with the project manager. For each sampled storm event, the forecast will be sent to the project manager before mobilization. The sampler will be programmed based on the predicted rainfall amount. Sampling Deployment Procedures

Once the decision is made to deploy, the field team will gather all materials for deployment, which may include decontaminated containers, batteries and ice, and proceed to the sampling sites. When handling sample bottles, field personnel will wear powder-free nitrile gloves for safe handling to prevent cross contamination of samples.

The field team will need to prepare autosamplers prior to the sampling event. This may include battery replacement, replacing or rinsing tubing, placement of sample bottles, and programming the sampler at each station using weather forecast information and previously collected flow data.

6.6 Sampling Considerations

Sampling and flow meter installation at the RDF will require entering confined spaces. This will be done by King County personnel who have the training and experience to safely enter these spaces. King County confined space entry requirements and safety protocols will be followed at all times. Field personnel are confined space entry certified through the Wastewater Treatment Division (WTD) Permit-Required Confined Space Entry Program. All guidelines and requirements for confined space entry can be found in the WTD Permit-Required Confined Space Entry Program Manual (King County 1998).

6.7 Additional Sampling Equipment

Sampling supplies include Ziploc® bags, cooler with ice, and nitrile gloves. Safety equipment includes hard hats, safety vests, safety shoes, safety glasses, and appropriate traffic control equipment. Documentation supplies include field notebook, sample labels, chain-of-custody (COC) forms, and a camera.

When visiting the sampling site, field personnel will record the following information on field forms that are maintained in a waterproof field notebook:

- Date and time of sample collection/visit
- Name(s) of sampling personnel
- Weather conditions
- Number and type of samples collected
- Instrument calibration procedures
- Sequence of events (order of sites sampled)
- Time of flow data download
- Log of photographs taken[2]
- Comments on the working condition of the sampling equipment
- Deviations from sampling procedures
- Unusual conditions (e.g., water color or turbidity, presence of oil sheen, odors, and land disturbances)
- Signature of field staff project manager

[2] At a minimum, photos must document the autosampler and flow meter setup at one inlet and one outlet during sampling. Any deviations from the QAPP or unusual conditions must also be photographed.

6.8 Sample Handling Procedures

6.8.1 Qualifying Samples – Post-Sampling

Actual weather events will not always match the forecasted weather; therefore, after sample collection but prior to sample analysis, it must be determined that the storm events met the criteria described in section 5.4. Specifically, there must have been sufficient rain to result in sufficient effluent flow from the bioretention facilities. Initial hydrographs and rain gage data will be analyzed to determine the volume of rain that is predicted to result in sufficient effluent flow to meet sampling requirements. However, it is anticipated that a minimum of 0.15 in of rain over a 24 hour period, including the sampling period, will be sufficient.

In addition, samples at individual stations must meet post-sampling criteria. After sample collection, the project manager and field personnel will work together to analyze flow and rainfall data to evaluate hydrograph conditions during the sampled storm event. Samples will have met post-sampling criteria if they were collected over the same time period in which:

- 50% or more of the volume from a particular storm flowed

<u>OR</u>

- the hydrograph peaked.

If it is determined that the storm meets the acceptance criteria, the sample volume of the paired samples will be evaluated to determine if target volumes are adequate (10.2 L per station per event). If the target sample volume is not met, sample analysis will be prioritized following the decision tree in Figure 4.

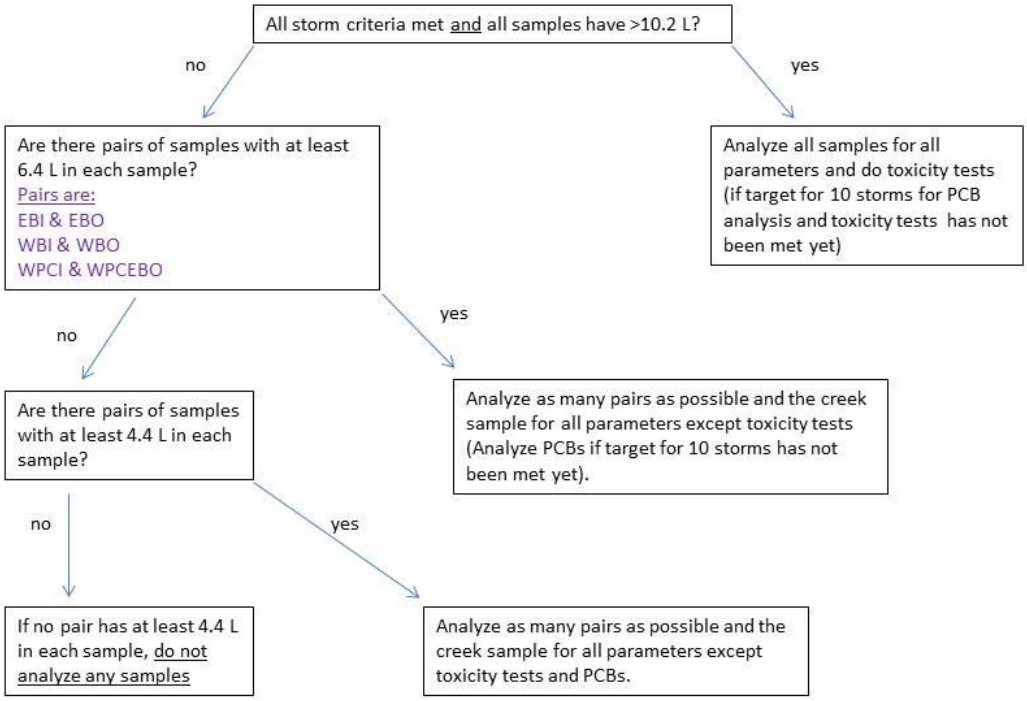

Figure 4. Decision tree to determine which samples and parameters to analyze if target volumes are not met .

To comply with sample holding times, the decision to analyze samples must be made within 24 hours of collection.

6.8.2 Sample Delivery and Storage

After sampling is completed, all samples will be stored on ice and transported back to the KCEL where each sample will be filtered if necessary and subsequently split into individual laboratory containers. This will be done by continuously agitating the sample in the carboy while transferring sample aliquots to the appropriate laboratory containers using a Teflon® siphon tube. All tubing must be new or site dedicated. Each sample container will be filled to the appropriate volume. This procedure will ensure a representative sample from the carboy in each laboratory sample container.

Containers for PCB congener analysis will be delivered to Pacific Rim Laboratories within one to three months of sample collection. Samples will be held at the KCEL at 4°C in darkness until shipping. Samples will be maintained on ice and/or ice packs during the delivery process. Samples will either be driven to Pacific Rim Laboratories or shipped via overnight express delivery service.

Table 8 shows sample handling and storage requirements for all parameters, in order of priority. If a sample has insufficient volume for all analyses, the order of priority from this list will be followed.

Table 8. Sample Volume, Container, Preservation, Storage, and Hold Time Requirements

Analyte(s)	Container	Storage Prior to Preservation	Preservation Holding Time	Preservation Technique	Analysis Holding Time
Alkalinity (ALK)	500-mL CWM HPDE (collect with COND & TURB)	Cool to ≤6° C	NA	Cool to ≤6° C	14 days
Conductivity (COND)	500-mL CWM HPDE (collect with ALK & TURB)	Cool to ≤6° C	NA	Cool to ≤6° C	28 days
Turbidity (TURB)	500-mL CWM HDPE (collect with ALK & COND)	Cool to ≤6° C	NA	Cool to ≤6° C	2 days
Total Organic Carbon	125-mL amber glass	Cool to ≤6° C	1 day	Add H_3PO_4 to pH < 2, Cool to ≤6° C	28 days
Dissolved Organic Carbon	125-mL AWM HDPE	Cool to ≤6° C	1 day	Filter, H_3PO_4 to pH <2, Cool to ≤6° C	28 days
Total Suspended Solids	1-L CWM HDPE	Cool to ≤6° C	NA	Cool to ≤6° C	7 days
Ammonia-N (NH_3)	60-mL CWM HDPE (collect together with nitrate + nitrite and ORTHOP)	Cool to ≤6° C	1 day	Filter and freeze at -20° C	14 days
Nitrate + Nitrite	60-mL CWM HDPE (collect	Cool to ≤6° C	1 day	Filter and freeze	14 days

	together with NH_3 and ORTHOP)			at -20° C	
Orthophosphate Phosphorus (ORTHOP)	60-mL CWM HDPE (collect together with NH_3 and nitrate + nitrite)	NA	15 minutes	Field filter and freeze at -20° C	14 days
Total Nitrogen	250-mL CWM HDPE	Cool to ≤6° C	2 days[a]	Freeze at -20° C	28 days
Total Phosphorus	Same container as Total Nitrogen	Cool to ≤6° C	2 days[a]	Freeze at -20° C	28 days
Total Metals and Hardness	Acid washed 500-mL HDPE	transport on ice	Add acid ≤24 hours before digestion	Ultra-pure HNO_3 to pH <2	180 days
Dissolved Metals	Acid washed 500-mL HDPE or PS filter unit	transport on ice	15 minutes for field filtration, add acid ≤24 hours before analysis	Ultra-pure HNO_3 to pH <2	180 days
Fecal Coliform	Sterile 500-mL HDPE	Cool to ≤10° C	ASAP	Cool to ≤10° C[b]	24 hours
Polycyclic Aromatic Hydrocarbons	1-L ANM glass	NA	NA	Cool to ≤6° C in the dark [c]	7/40 days[d]
PCB Congeners	2, 1-L amber glass	Cool to ≤4° C	NA	Cool to ≤4° C in the dark	1 year
Toxicity Tests	1 gallon (3.79 L) plastic cubitainer	Cool to 0 to 6° C	NA	Cool to 0 to 6° C, must not freeze, no headspace	36 hours [e]

[a] Samples and filtrates may be stored at ≤6° C if digested within 2 days of collection, otherwise they must be frozen. The holding time for digestates is 28 days.

[b] Samples that contain chlorine must be treated with sodium thiosulfate or other appropriate treatment within 15 minutes of collection.

[c] Add a reducing agent (sodium thiosulfate) only if an oxidant, such as chlorine, is detected in the sample. Only add sufficient reducing agent to remove detected oxidant.

[d] Seven days from sampling to extraction, 40 days from extraction to analysis.

[e] Toxicity holding is 36 hrs to initiate testing. Daily renewals for the 7-day chronic tests will be made using same the initial sample. All efforts will be made to initiate testing within 36 hrs, experience with previous storm water projects has shown that some latitude in holding time may be necessary to obtain test

organisms at the method required age (< 24 hrs and within an 8 hr age range) and in sufficient numbers to initiate testing. The project manager will be informed of any delays in initiating tests.

6.8.3 Chain of Custody

Chain of custody (COC) will commence at the time that each autosampler is deployed or when collection of grab samples is initiated. Autosamplers will be secured to ensure no tampering can occur. Thus, all samples will be under direct possession and control of King County field personnel. For COC purposes, closed/latched storm drains, autosamplers, and field vehicles will be considered "controlled areas". All sample information will be recorded on a COC form (Appendix B). The COC form will be completed in the field and accompany all samples during transport and delivery to the KCEL. The date and time of sample delivery will be recorded and the COC form will be signed off in the appropriate sections at this time. Once completed, original COC forms will be archived in the project file.

Samples delivered to the contract laboratory, Pacific Rim Laboratories, will be accompanied by a properly-completed KCEL COC form and custody seals will be placed on the shipping cooler. Pacific Rim Laboratories will provide a copy of the completed COC form as part of their analytical data package.

6.8.4 Sample Documentation

Sampling information and sample metadata will be documented using the methods described below:

- Field sheets generated by King County's Laboratory Information Management System (LIMS) will be used at all stations and will include the following information:
    1. Sample ID number
    2. Locator/station name
    3. Date and time of sample collection (start and end times of the compositing period)
    4. Initials of all sampling personnel
- LIMS-generated container labels will identify each container with a unique sample number, station and site names, collect date, analyses required, and preservation method.
- Field Observation Forms: after each sampling event, a field observation form will be completed and uploaded to LIMS. These forms will document weather conditions, observations, and any types of field instruments used to analyze samples in the field.
- The field sheet will contain records of collection times, general weather, and the names of field crew.
- COC documentation will consist of KCEL's standard COC form, which is used to track release and receipt of each sample from collection to arrival at the lab.

6.9 Decontamination Procedures

Once samples are collected, all re-usable equipment should be decontaminated. Autosampler containers and their associated Teflon® tubing shall be cleaned with: (1) alconox or other suitable laboratory detergent; (2) a sulfuric acid rinse; and (3) a deionized water (ASTM I or II) rinse.

All stainless steel fittings and connectors are to be cleaned in the same manner except they are not subject to the acid rinse step. Composite autosampler bottles and autosampler tubing will be cleaned prior to each sampling event according to laboratory SOPS (KCEL SOP #234 and KCEL SOP #223) for collection of samples for low-level analysis using autosamplers. Proofed clean PCB sampling containers will be supplied by Pacific Rim Laboratories. Proper personal protective equipment (new powder-free gloves for each site) should be worn during sampling activities and during decontamination processes.

6.10 Collection of QA/QC Samples

Table 9 summarizes required QA/QC samples for this project.

Table 9. QA/QC Samples Required for Each Sampling Method

QA/QC Sample Type	Number of QA/QC Samples	Collection Procedure
Equipment Blank	One for autosampler setup **(1 total)**	Run ASTM Type I or II de-ionized water through autosampler equipment after decontamination and collect samples in the appropriate container with preservative for a full analysis of all parameters collected during a sampled storm event. Place immediately on ice.
Field Replicate	At least 3 at the EBI and at least 3 at the WBI, and 4 others at either site **(10 total)**	Collect replicate samples concurrently with primary field samples, following identical methods.

6.11 Periodic Preventative Maintenance

Periodic preventative maintenance of equipment will occur as needed between storm events to ensure equipment is operating properly. Signs of vandalism, rusting equipment, equipment failure or other maintenance issues will be documented in field notebooks or on field data forms. Any significant changes in site conditions that will affect sampling will be documented in the final report under Deviations from the QAPP.

7.0 MEASUREMENT PROCEDURES

7.1 Field measurements

The procedures that the City will follow to measure continuous temperature and turbidity, and collect macroinvertebrates are described in the 2012 Federal Way QAPP in Appendix A.

An EXO YSI Sonde will be used to measure pH in each sample at the time of collection (KCEL SOP #202v3).

The water level, temperature, and barometric pressure data recorded by the HOBO U20L-04 water level loggers will be downloaded quarterly. Data from the loggers, in combination with station flow data and local rainfall data (see section 9.4), will be used to determine when the loggers in the bioretention facilities were submerged. Data collected when loggers were submerged will be analyzed, and the remaining data will be discarded.

Table 10 presents the manufacturer's specifications for accuracy and resolution for pH, water level, temperature and barometric pressure (Appendix C).

Table 10. Accuracy and resolution of the field pH meter and the HOBO U20L-04 water level loggers.

Parameter	Accuracy	Resolution
pH	±0.2 standard units	0.01 standard units
Water level	Typical error: ±0.1%FS, 0.4 cm water; Maximum error: ±0.2%FS, 0.8 cm water	0.14 cm water
Temperature	±0.44°C from 0° to 50°C	0.10°C
Raw pressure	±0.3%FS, 0.43 kPa maximum error	<0.014 kPa

7.2 KCEL Analytical Methods and Detection Limits

Analytical methods are presented in this section, along with analyte-specific detection limit goals. For conventional parameters, nutrients, metals, and PAHs, the terms MDL and RDL used in the following

subsections refer to method detection limit and reporting detection limit, respectively. The KCEL reports both the LIMS reporting detection limit (LIMS RDL) and the LIMS method detection limit (LIMS MDL) for each sample and parameter, where applicable.

A practical quantitation limit (PQL) is generally defined as the minimum concentration of a chemical constituent that can be reliably quantified while the MDL is defined as the minimum concentration of a chemical constituent that can be detected. The LIMS RDL is analogous to the PQL for all analyses. It is verified either by including it on the calibration curve or by running a low level standard near the PQL value during the analytical run.

Actual LIMS MDLs and RDLs may differ from the target detection limit goals as a result of necessary analytical dilutions or a reduction of extracted sample amounts based on available sample volumes. When sample extracts are diluted because the concentrations for one or more target analytes exceeded the upper end of the calibration curve or parameter-specific interferences, MDLs and RDLs from the original, undiluted extract will be reported for parameters other than the target analytes that required dilution. Every effort will be made to meet the MDL/RDL goals listed in the QAPP; however, there may be times when the MDL/RDL values rise because the sample must be run at a greater dilution. This may be due to the concentration of some target analytes exceeding the calibration range, interfering target or non-target compounds, or run QC not passing (e.g., internal standard failures).

Table 11 presents methods and detection limits for parameters analyzed at KCEL.

Table 11. Method and Detection Limits for Parameters Analyzed at the KCEL or in the field

Parameter	Analytical Method	Method Detection Limit	Reporting Detection Limit
Conductivity	SM2510-B	1 umhos/cm	5 umhos/cm
Alkalinity	SM2320-B	1 mg CaCO3/L	5 mg CaCO3/L
Turbidity	SM2130-B	0.2 NTU	0.5 NTU
Dissolved organic carbon	SM5310-B	0.5 mg/L	1 mg/L
Total organic carbon	SM5310-B	0.5 mg/L	1 mg/L
Total suspended solids	SM2540D	0.5 mg/L	1.0 mg/L
Orthophosphate Phosphorus	SM4500-P-F	0.0005 mg/L	0.002 mg/L
Total phosphorus	SM4500-P-B, F	0.005 mg/L	0.01 mg/L
Total nitrogen	SM4500-N-C	0.05 mg/L	0.1 mg/L

Parameter	Analytical Method	Method Detection Limit	Reporting Detection Limit
Nitrate-nitrite Nitrogen	SM4500-NO3-F	0.01 mg/L	0.04 mg/L
Ammonia Nitrogen	Kerouel & Aminot 1997	0.002 mg/L	0.01 mg/L
Fecal coliform	SM9222D	1 cfu/100mL	1 min., 1E6 max cfu/100mL
Hardness as $CaCO_3$	EPA 200.8/ SM2640B.ED19	0.331 mg $CaCO_3$/L	0.331 mg $CaCO_3$/L
Total cadmium	EPA 200.8	0.05 µg/L	0.25 µg/L
Dissolved cadmium	EPA 200.8	0.05 µg/L	0.25 µg/L
Total copper	EPA 200.8	0.4 µg/L	2.0 µg/L
Dissolved copper	EPA 200.8	0.4 µg/L	2.0 µg/L
Total lead	EPA 200.8	0.1 µg/L	0.5 µg/L
Dissolved lead	EPA 200.8	0.1 µg/L	0.5 µg/L
Total zinc	EPA 200.8	2.5 µg/L	2.5 µg/L
Dissolved zinc	EPA 200.8	0.5 µg/L	2.5 µg/L
PAHs	SW846-8270D-SIM	TABLE 15	TABLE 15

7.3 PCB Congener Analytical Methods and Detection Limits

PCB congeners will be analyzed following the EPA Method 1668 Revision C (EPA 2010a), which is a high-resolution gas chromatography/high-resolution mass spectroscopy (HRGC/HRMS) method using an isotope dilution internal standard quantification. For this method, the MDL and RDL terms are less applicable because limits of quantitation are derived from calibration capabilities and ubiquitous but typically low level equipment and laboratory blank contamination. Additional reporting limit terms used particularly for PCB congener analyses are sample specific detection limits and lowest method calibration limits. The sample specific detection limit (SDL) is determined by converting the area equivalent to 2.5 times the estimated chromatographic noise height to a concentration. For each sample analysis run, SDLs are determined individually for every congener and account for any effect of matrix on the detection system and recovery achieved through the analytical work-up. Lowest method calibration limits (LMCL) are based on calibration points from standard solutions. They are prorated by sample size and are supported by statistically-derived method reporting limit (MRL) values.

The PCB congener data will be reported to LMCLs and flagged down to the SDL value. In many cases the SDL may be below the LMCL. Method 1668C defines a Minimum Level (ML) value for each congener. The ML value is used to evaluate levels in the method blank. The ML is based on the LMCL and any laboratory performing the method should be able to achieve the least that level. Pacific Rim Laboratories uses an additional calibration point that is lower than the calibration points specified in the method; as such they are able to quantify congeners below the ML specified in the method.

Pacific Rim Laboratories will perform this analysis according to their SOP LAB02. A one-liter sample will be extracted followed by standard method clean-up, which includes an acid wash followed by Acid Silica and Alumina column chromatography. Analysis is performed with an SGE HT-8 column. Method 1668C requires that is a sample contains more than 1% total solids, the solids and liquid will be extracted and analyzed separately.

Table 12 lists the 209 PCB congeners and their respective target SDL and LMCL values. The reporting limits for individual samples may differ from those in Table 12 since they are determined by signal-to-noise ratios and changes to final volumes. Typical sample detection limits are shown. Note that several of the congeners co-elute and a single SDL or LMCL value is provided for the congeners in aggregate.

Table 12. Detection Limits for PCB Congeners. The LMCL based on Low Cal (RDL) (pg/L) is 10 for each congener or set of congeners.

PCB(s)	MDL (pg/L)	PCB(s)	MDL (pg/L)	PCB(s)	MDL (pg/L)
PCB-001	2.0	PCB-068	0.8	PCB-143	0.7
PCB-002	2.1	PCB-070	1.0	PCB-144	1.1
PCB-003	2.5	PCB-071	0.7	PCB-145	0.9
PCB-004	2.5	PCB-073	0.9	PCB-146	0.6
PCB-005/008	1.7	PCB-074	0.9	PCB-147	1.3
PCB-006	1.7	PCB-076	0.9	PCB-150	0.8
PCB-007	1.7	PCB-077	0.8	PCB-151	1.1
PCB-009	1.7	PCB-078	0.9	PCB-152	0.8
PCB-010	1.7	PCB-079	0.9	PCB-153	0.6

PCB(s)	MDL (pg/L)
PCB-011	1.8
PCB-012/013	1.8
PCB-014	1.6
PCB-015	2.0
PCB-016	1.7
PCB-017	1.8
PCB-018	1.5
PCB-019	2.0
PCB-020/033	1.0
PCB-021	1.2
PCB-022	1.1
PCB-023	0.8
PCB-024	1.4
PCB-025	0.9
PCB-026	0.7
PCB-027	0.9
PCB-028	0.9
PCB-029	0.7
PCB-030	1.2
PCB-031	0.7
PCB-032	1.5

PCB(s)	MDL (pg/L)
PCB-081	1.0
PCB-082	1.3
PCB-083/109	1.0
PCB-084	1.0
PCB-085	1.1
PCB-086/117	1.0
PCB-087/115	1.0
PCB-088	1.0
PCB-089	1.0
PCB-090	1.1
PCB-091/121	0.9
PCB-092	1.2
PCB-093/098/102	1.0
PCB-094	1.1
PCB-095	1.0
PCB-096	0.7
PCB-097/116	1.0
PCB-099	0.9
PCB-100	0.9
PCB-101	1.0
PCB-103	0.8

PCB(s)	MDL (pg/L)
PCB-154	1.0
PCB-155	3.8
PCB-156	0.4
PCB-157	0.4
PCB-158	0.5
PCB-159	0.5
PCB-163/164	0.6
PCB-165	0.6
PCB-166	0.5
PCB-167	0.4
PCB-168	0.6
PCB-169	0.4
PCB-170	0.7
PCB-171	0.7
PCB-172	0.7
PCB-173	0.9
PCB-174	0.8
PCB-175	0.8
PCB-176	0.6
PCB-177	0.7
PCB-178	0.8

PCB(s)	MDL (pg/L)
PCB-034	1.0
PCB-035	1.1
PCB-036	1.0
PCB-037	1.4
PCB-038	1.2
PCB-039	1.1
PCB-040/057	1.1
PCB-041	1.5
PCB-042	1.3
PCB-043/049	1.2
PCB-044	1.5
PCB-045	1.2
PCB-046	1.4
PCB-047/048	1.3
PCB-050	1.1
PCB-051	1.1
PCB-052/069	1.0
PCB-053	1.1
PCB-054	1.2
PCB-055/080	0.9
PCB-056	0.9

PCB(s)	MDL (pg/L)
PCB-104	2.7
PCB-105/127	0.5
PCB-106	0.6
PCB-107/108	0.6
PCB-110	0.8
PCB-111	0.8
PCB-112/119	0.8
PCB-113	0.8
PCB-114	0.5
PCB-118	0.5
PCB-120	0.8
PCB-122	0.6
PCB-123	0.6
PCB-124	0.5
PCB-125	0.8
PCB-126	0.4
PCB-128/162	0.6
PCB-129	0.7
PCB-130	0.8
PCB-131	0.8
PCB-132/161	0.6

PCB(s)	MDL (pg/L)
PCB-179	0.5
PCB-180	0.7
PCB-181	0.8
PCB-182/187	0.8
PCB-183	0.7
PCB-184	0.5
PCB-185	0.8
PCB-186	0.6
PCB-188	1.2
PCB-189	0.3
PCB-190	0.4
PCB-191	0.5
PCB-192	0.6
PCB-193	0.5
PCB-194	0.5
PCB-195	0.5
PCB-196	0.7
PCB-197	0.6
PCB-198	0.6
PCB-199	0.9
PCB-200	0.6

PCB(s)	MDL (pg/L)
PCB-058	0.9
PCB-059	0.9
PCB-060	1.0
PCB-061	1.0
PCB-062	1.0
PCB-063	0.8
PCB-064/072	0.9
PCB-065/075	0.8
PCB-066	0.8
PCB-067	0.9

PCB(s)	MDL (pg/L)
PCB-133	0.7
PCB-134	0.9
PCB-135	1.3
PCB-136/148	1.0
PCB-137	0.7
PCB-138/160	0.6
PCB-139/149	1.2
PCB-140	0.6
PCB-141	0.7
PCB-142	0.7

PCB(s)	MDL (pg/L)
PCB-201	0.6
PCB-202	0.9
PCB-203	0.7
PCB-204	0.6
PCB-205	0.3
PCB-206	0.8
PCB-207	0.8
PCB-208	0.9
PCB-209	0.6

7.4 Toxicity Testing Procedures

Two sets of toxicity tests will be conducted. A 7-day chronic test with *Ceriodaphnia dubia* will be conducted according to KCEL SOP #408v3 and EPA Method 1002.0. A 48-hour acute test with *Daphnia pulex* will be conducted according to KCEL SOP #412v2 and EPA Test Method 2021.0. For the acute test, each sample concentration including the control is tested in four replicates, each test chamber consisting of a 30-mL beaker containing 25 mL of control or treatment and five daphnid neonates. Additional water quality chambers are set up at each sample concentration and the control for pH and dissolved oxygen measurements at 24 and 48 hours. Testing will consist of control and each inlet and outlet sample tested at 100% sample concentration. Replicates are positioned randomly in a 9” x 13” glass tray according to random placement bench sheet generated by Comprehensive Environmental Toxicity Information System™ (CETIS) toxicity software and placed in the laboratory notebook.

For the chronic test, each sample, including the control, is tested in ten replicates. Each test chamber contains 15 mL of test solution or control (dilution) water and one *C. dubia* neonate. Individual broods are blocked across treatments, and each replicate contains a neonate from a different brood.

Treatments are positioned randomly on the acrylic test board according to random placement bench sheet generated by CETIS and recorded in the laboratory notebook. Six additional blank reps are placed at the center and four outer corners of the test board for temperature measurements. Testing will consist of control and each inlet and outlet sample tested at 100% sample concentration.

8.0 QUALITY CONTROL

This section describes the applicable field and laboratory QC required for this project. In general, QC measures include 1) ensuring that field and laboratory personnel are well trained and exhibit attention to detail, and 2) making certain that equipment calibrations are well documented and performed carefully and consistently following manufacturer's instructions.

8.1 Field Measurements

The QC required for the measurements collected by the City are described in the Federal Way 2012 QAPP (Appendix A).

The QC requirements for the pH, water level and temperature measurements collected by King County are described here. For pH, the difference between duplicate (or replicate) measurements tested once per sampling events will be ±0.2 standard units. For the water level and temperature data loggers, experience in handling and deployment will be obtained through reading the operations manual, testing the loggers, and gaining familiarity with the loggers prior to deployment. King County staff will follow all operating instructions carefully to launch, deploy, download data, and process water level and temperature data. Loggers will be properly maintained per instructions. Improper handling and storage can lead to damage of the logger and loss of data. Problems with logger function are best avoided by following the operating instructions. Technical staff at the manufacturer (Onset Computer Corporation) will be consulted for troubleshooting assistance should problems arise with the loggers.

Good field practices and scheduled QC checks will be followed and include:

- Field teams maintain a permanent instrument log book recording observations, calibrations, maintenance and repairs.
- All manually recorded field measurement data will be collected on field forms, with the recorded data captured electronically.
- Complete records will be maintained for each sampling station.
- The procedures in this project are routinely reviewed and modified as necessary.

8.2 Flow Meter and Autosampler Operation

KCEL field staff will install, maintain and calibrate flow monitoring equipment according to the equipment manuals (Teledyne 1995 and 1996). KCEL field staff will set up, program, and maintain the Isco® Autosamplers according to the equipment manual (Teledyne 2013). The following steps will also be taken as part of the QC process:

- Following initial set-up, field calibration checks will involve re-measuring water levels in the pipes at each station when flows are present (for at least 1 storm per year).
- Field staff will download flow data (every 30 days) and ensure flow meters are working properly.
- All data will be reviewed, rated for accuracy, and approved before being submitted as a final product.
- Data management will follow procedures outlined in Section 9.0.

8.3 Laboratory measurements

Samples collected as field replicates and equipment blanks are described in Section 6.10. Details regarding the frequency and control limits of required QC samples are provided in Tables 13 through 15. A general description of the required laboratory QC samples is listed below.

- Analysis of method blanks is used to evaluate the levels of contamination that might be associated with the processing and analysis of samples in the laboratory and introduce bias into the sample result. Method blank results for all target analytes (other than PCB congeners) should be “less than the MDL”.
- A laboratory duplicate is a second aliquot of a sample, processed concurrently and in an identical manner with the original sample. The laboratory duplicate is processed through the entire analytical procedure along with the original sample in the same quality control batch. Laboratory duplicate results are used to assess the precision of the analytical method and the relative percent difference (RPD) between the results should be within method-specified or performance-based quality control limits. In the case of PAHs a matrix spike duplicate may be used in lieu of a laboratory duplicate due to the large number of non-detects frequently encountered in these analyses.
- A laboratory control sample is a sample of known analyte concentration(s) that is prepared in the lab from a separate source of analyte(s) relative to the calibration standards. Since the laboratory control sample analysis should follow the entire analytical process, it should be stored and prepared following the same procedures as a field sample. Analysis of a laboratory control sample is used as an indicator of method accuracy and long-term analytical precision.
- A spike blank is a spiked aliquot of clean reference matrix used for the method blank. The spiked aliquot is processed through the entire analytical procedure. Analysis of the spike blank is used as an indicator of method accuracy. It may be conducted in lieu of a laboratory control sample. A spike blank duplicate should be analyzed whenever there is insufficient sample volume to include a sample duplicate or matrix spike duplicate in the batch.
- A matrix spike is a sample aliquot fortified with a known concentration of a target analyte(s). The spiked sample is processed through the entire analytical procedure. Analysis of the matrix spike is used as an indicator of sample matrix effect on the recovery of target analyte(s).

- A matrix spike duplicate is a second sample aliquot fortified with a known concentration of a target analyte(s). The spiked sample is processed through the entire analytical procedure. Analysis of the matrix spike duplicate is used as an additional indicator of sample matrix effect on the recovery of target analyte(s) as well as an indicator of method precision.
- A surrogate is a known concentration of non-target analyte which is added to each sample (both analytical and QC samples) prior to extraction and analysis for all trace organic analyses. Surrogate recovery is used as a sample-specific indication of method or matrix bias for target analytes. The surrogate is selected to behave in a similar manner to the target analytes.
- The ongoing precision and recovery (OPR) samples must show acceptable recoveries, according to the respective methods for data to be reported without qualification.

8.3.1 Conventional Parameters and Nutrients

Laboratory QC samples and associated control limits for conventional parameters and nutrient analyses are summarized below. These QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples.

Table 13. Conventional and Nutrient QC Samples and Control Limits

Parameters	Method Blank	Lab Duplicate (%RPD)	Spike Blank (% Recovery)	Matrix Spike (% Recovery)	Lab Control Sample (% Recovery)
Conductivity	NA	10%	NA	NA	90-110%
Alkalinity	NA	10%	NA	NA	85-115%
Turbidity	NA	25%	NA	NA	90-110%
Total suspended solids	<MDL	25%	NA	NA	80-120%
Total organic carbon	<MDL	20%	80-120%	75-125%	85-115%
Dissolved organic carbon	<MDL	20%	80-120%	75-125%	85-115%
Ortho-phosphate	<MDL	20%	80-120%	75-125%	85-115%
Total Phosphorus	<MDL	20%	80-120%	75-125%	85-115%
Total Nitrogen	<MDL	20%	80-120%	75-125%	85-115%
Ammonia	<MDL	20%	80-120%	75-125%	85-115%
Nitrate+nitrite	<MDL	20%	80-120%	75-125%	85-115%

8.3.2 Microbiology

Laboratory QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples. If batches are less than 20 in number and received throughout the working day, then QC samples are run on samples received over a 4 hour period. Each QC batch will include a negative and positive control sample, a laboratory duplicate, and a before and after membrane filtration blank.

A negative control sample is media streaked with a non-target organism and analyzed through the complete procedure. The negative control is expected to show no detectable target organisms thereby evaluating the specificity of the method.

A positive control is a QC sample prepared or obtained by the lab which is known or expected to yield a positive response. A positive control can be either a sample of contaminated water, such as Lake Union Ship Canal Water, or media streaked with the target organism, which is analyzed through the complete procedure.

A before membrane filtration blank is an aliquot of sterile diluent added to challenge the testing apparatus and conditions prior to membrane filtration of samples. The before filtration blank is analyzed to evaluate the sterility of the materials, equipment and work area at the beginning of sample analysis.

An after membrane filtration blank is an aliquot of sterile diluent added to challenge the testing apparatus and conditions after membrane filtration of samples. The after filtration blank is analyzed to evaluate cross-contamination during sample analysis.

8.3.3 Metals

Laboratory QC samples required for trace metals analyses and associated control limits are summarized below. These QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples.

Table 14. Metals QC Samples and Control Limits

Parameters	Method	Lab Duplicate	Matrix Spike	Lab Control

	Blank	(%RPD)	(% Recovery)	Sample (% Recovery)
Total metals, dissolved metals and hardness	<MDL	20%	75-125%	85-115%

8.3.4 Polycyclic Aromatic Hydrocarbons

Laboratory QC samples and associated control limits for PAH analyses are summarized below. Control limits are empirically derived and may change annually; therefore, control limits reported with data may or may not match the limits below. Unless otherwise noted, these QC samples will be analyzed at a frequency of one per analytical batch of 20 or fewer samples.

Table 15. Individual PAH Matrix Spike Limits

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
1-Methylnaphthalene	41	94	40
2-Methylnaphthalene	41	94	40
Acenaphthene	45	101	40
Acenaphthylene	45	98	40
Anthracene	49	103	40
Benzo(a)anthracene	62	112	40
Benzo(a)pyrene	66	108	40
Benzo(b,j,k)fluoranthene	48	118	40
Benzo(g,h,i)perylene	59	109	40
Chrysene	52	110	40
Dibenzo(a,h)anthracene	60	107	40
Fluoranthene	48	131	40
Fluorene	34	128	40

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
Indeno(1,2,3-cd)Pyrene	60	109	40
Naphthalene	43	77	40
Phenanthrene	59	93	40
Pyrene	47	123	40

If there is insufficient sample volume for a matrix spike duplicate, a spike blank duplicate will be prepared.

Table 16. Individual PAH Spike Blank Recovery Limits

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
1-Methylnaphthalene	46	97	40
2-Methylnaphthalene	46	97	40
Acenaphthene	50	100	40
Acenaphthylene	51	107	40
Anthracene	50	116	40
Benzo(a)anthracene	55	122	40
Benzo(a)pyrene	59	125	40
Benzo(b,j,k)fluoranthene	52	120	40
Benzo(g,h,i)perylene	59	116	40
Chrysene	48	127	40
Dibenzo(a,h)anthracene	57	122	40
Fluoranthene	54	131	40
Fluorene	54	117	40
Indeno(1,2,3-cd)Pyrene	59	120	40

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
Naphthalene	39	94	40
Phenanthrene	55	104	40
Pyrene	52	123	40

Table 17. Laboratory QC Limits for PAH Surrogate Recoveries

Parameter	Lower QC Limit (%)	Upper QC Limit (%)
2-Fluorobiphenyl	31	101
d14-Terphenyl	51	130

8.3.5 PCB Congeners

This PCB congener method provides reliable analyte identification and very low detection limits. An extensive suite of labelled surrogate standards (Table 15) is added before samples are extracted. Data are "recovery-corrected" for losses in extraction and clean-up, and analytes are quantified against their labeled analogues.

Table 18. Labeled Surrogates and Recovery Standards Used for EPA Method 1668C PCB Congener Analysis

^{13}C-labeled PCB Congener Surrogate Standards				
1	37	123	155	202
3	54	118	167	205
4	81	114	156	208
15	77	105	157	206
19	104	126	169	209
			189	
^{13}C-labeled Cleanup Standards				
28	111	178		
^{13}C-labeled Internal (Recovery) Standards				

9	52	101	138	194

QA/QC samples include method blank, OPR sample, and surrogate spikes. Method blanks and OPR, which are the same as spike blanks, are each included with each batch of samples. Surrogate spikes are labeled compounds that are included with each sample. The sample results are corrected for the recoveries associated with these surrogate spikes as part of the isotope dilution method. In addition, a laboratory duplicate will be conducted with each batch of samples. Note that a matrix spike and matrix spike duplicate are not required, nor meaningful under Method 1668C. Method 1668C has specific requirements for method blanks that must be met before sample data can be reported (see Section 9.5.2 of Method 1668C). The OPR samples must show acceptable recoveries, according to Method 1668C, to analyze the samples and report the data. A summary of the quality control samples are shown in Table 19.

Table 19. PCBs QA/QC Frequency and Acceptance Criteria

	Method Blank	Lab Duplicate (RPD)	OPR (% Recovery)	Surrogate Spikes
Frequency	**1 per batch**	**1 per batch**	**1 per batch**	**Each sample**
PCB Congeners	<LMCL[a]	RPD <50%	laboratory QC limits [b]	laboratory QC limits [b]

batch = 20 samples or less prepared as a set
[a] EPA Method 1668C blank criteria (see Table 2 of the published method) is to be below the Minimum Levels: 2, 10, 50 pg/congener depending on the congener with the sum of all congeners below 300 pg/sample. Higher levels are acceptable when sample concentrations exceed 10x the blank levels.
[b] EPA Method 1668C OPR recovery criteria 60-135% for select congeners (see Table 6 of the published method) will be used as quality control limits.

8.4 Corrective Action for QC Problems

Corrective action for field measurements and laboratory analysis will follow those described in each SOP. Examples of corrective action include:

- Re-analyzing the samples
- Re-extracting the samples
- Re-preparing of the calibration verification standard for laboratory analyses
- Re-calibrating or replacing field equipment
- Qualifying results as described in Section 9.3

8.5 Toxicity Tests

8.5.1 *Daphnia pulex* Acute Toxicity Test

The criterion for test acceptance is 90% or greater survival in control animals Specific test conditions per EPA Test Method 2021.0 include:

1. Test type: Static non-renewal,

2. Test duration: 48 Hr

3. Temperature: 20°C ±1°C;

4. Light quality: Ambient laboratory illumination

5. Light intensity: 10-20 µE/m2/s (50-100 ft-c)

6. Photoperiod: 16 h light, 8 h darkness

7. Test chamber size: 30 mL

8. Test solution volume: 25 mL

10. Age of test organisms: Less than 24-h old

11. No. organisms per replicate: 5

12. No. replicate chambers per concentration: 4

13. No. organisms per concentration: 20

14. Feeding regime: Feed YCT and *Selenastrum* while holding prior to the test

17. Dilution water: Uncontaminated well water

18. Test concentrations: 100% and a control

20. Endpoint: Mortality

23. Test acceptability criterion: 90% or greater survival in controls

8.5.2 *Ceriodaphnia dubia* Chronic Toxicity Test

The criterion for test acceptance is 80 % or greater control survival and average of 15 or more young per surviving female in the control. Specific test conditions per EPA Method 1002.0 include:

1. Test type: Static renewal (required)

2. Temperature (EC): 25 ± 1EC

3. Light quality: Ambient laboratory illumination (recommended)

4. Light intensity: 10-20 µE/m2/s, or 50-100 ft-c (ambient laboratory levels)

5. Photoperiod: 16 h light, 8 h dark

6. Test chamber size: 30 mL

7. Test solution volume: 15 mL

8. Renewal of test solutions: Daily

9. Age of test organisms: Less than 24 h; and all released within a 8-h period

10. No. neonates per test chamber: 1 Assigned using blocking by known parentage

11. No. replicate test chambers per concentration: 10

12. No. neonates per test concentration: 10

13. Feeding regime: Feed 0.1 mL each of YCT and algal suspension daily

14. Aeration: None (recommended)

15. Dilution water: Uncontaminated source of natural water,

16. Test concentrations: 100% and a control

17. Test duration: Until 60% or more of surviving control females have three broods (maximum test duration 8 days)

18. Endpoints: Survival and reproduction

19. Test acceptability criteria: 80% survival, average of 15 or more young per surviving female in the control.

20. Reference Toxicant Testing: Monthly, control limits mean IC25±2SD.

8.6 Flow Data

Water level at both locations will be hand measured at least five times throughout the project and compared with the readings from the flow meter. The meter will be recalibrated as necessary, and the RPD between the recorded water levels should be within 10% or the generated flow data will be qualified according to Section 9.2.2. Results will be documented in the field sheets.

8.7 Audits

Audits can help verify data quality by ensuring the QAPP is implemented correctly, and data quality is acceptable. To verify samples are collected according to the methods described in the QAPP, the project manager will conduct a field audit by supervising at least one sampling event for this project. Documentation will include field notes and pictures taken by the project manager. The project manager will also conduct an analytical audit by a preliminary data review; comparing analytical results, including detection limits, to the QAPP-specified goals. If review of chemistry data suggests sampling or method revisions are required, outside of those allowed in the cited methods and SOPs, an addendum to this QAPP will be prepared.

9.0 DATA MANAGEMENT, VERIFICATION, AND REPORTING

This section explains the standard practices for managing, verifying and reporting data collected or analyzed as part of this study.

9.1 Data Storage

Data will not be distributed outside each lab unit or to clients until it has met the full definition of final data. "Final Data" is defined as approved data posted to the historical database (EDS) or is otherwise in its final reportable and stored format (if not a LIMS parameter). This implies the data has been appropriately peer reviewed, properly qualified and is in its final format in terms of units and significant figures.

King County will retain records of all monitoring information that the County collects, including all calibration and maintenance records and all original recordings for continuous monitoring instrumentation, copies of all reports generated for this study, and records of all data used in this study, for a period of at least five years.

Federal Way will retain records of all monitoring information that the City collects, including all calibration and maintenance records and all original recordings for continuous monitoring instrumentation, copies of all reports that include data collected as part of this study, and records of all data used in this study, for a period of at least five years. The County and the City will provide copies of relevant data, reports and records as needed or requested.

9.2 Data Verification and Validation

9.2.1 Analytical Data

Data reported by the KCEL, including field measurements, must pass a review process before final results are available to the client. A "Peer Review" process is when a second analyst or individual proficient at the method reviews the data set. The reviewer will complete a data review checklist which will document the completeness of the data package and if any QC failures exist. In addition to the peer review, the data will be reviewed by the technical coordinator (TC) within each lab unit or the LPM for adherence to project goals. Results of these reviews will be documented in data review checklists, DAFs, and the QA narrative.

Once data review is complete and all data quality issues have been resolved, the data in LIMS will be moved to the LIMS historical database. Signatures or initials of the reviewer(s) indicate formal approval of hardcopy data typically on the review checklist. A copy of this approved checklist should be stored with the final hardcopy laboratory data package.

For data generated by KCEL, a QA narrative will be generated by the LPM and will summarize all QA/QC results for analytical data generated by the KCEL. This narrative will also include Field Observation Forms generated by field personnel describing sample collection conditions and anomalies. An EPA Level 2A data validation will be conducted by the project manager in accordance to the National Functional Guidelines (EPA 2010b and EPA 2014).

All necessary data needed for independent review of PCB congener data will be provided by Pacific Rim Laboratories. A subcontracted data validator will review the PCB congener data following EPA Level III guidelines (EPA 1995). Both data validation sets will be based on QA/QC samples and included in the final report as an appendix.

Qualifiers will be applied to analytical data during the data quality review process, and are presented in Table 20 (KCEL) and Table 21 (Pacific Rim Laboratory).

Table 20. KCEL and EIM Equivalent Data Qualifiers

KCEL Qualifier	Description	EIM Qualifier
General		
H	Indicates that an analysis holding time criterion was not met.	J
SH	Indicates that a sample handling criterion was not met. The sample may have been compromised during the sampling procedure or may not comply with storage conditions or preservation requirements.	J
R	Indicates that the data are judged unusable by the data reviewer. The qualifier is applied based on the professional judgment of the data reviewer rather than any specific set of QC parameters and is applied when the reviewer feels that the data may not or will not provide any useful information to the data user.	Reported as an observation

KCEL Qualifier	Description	EIM Qualifier
<MDL	Applied when a target analyte is not detected or detected at a concentration less than the associated method detection limit (MDL). The MDL is the lowest concentration at which a sample result will be reported.	U
<RDL	Applied when a target analyte is detected at a concentration greater than or equal to the associated MDL but less than the associated reporting detection limit (RDL). RDL is defined as the lowest concentration at which an analyte can reliably be quantified.	JT
RDL	Applied when a target analyte is detected at a concentration that, in the raw data is equal to the RDL.	No qualifier added
TA	Applied to a sample result when additional narrative information is available in the text field. The additional information may help to qualify the sample result but is not necessarily covered by any other qualifier.	C

Chemistry		
B, B2 or B3	Applied to a sample result when an analyte was detected at a concentration greater than the MDL in the associated method blank. The qualifier is applied when the sample concentration is >MDL but less than five or ten times the blank concentration. The qualifier indicates that the analyte concentration in the sample may be significantly influenced by laboratory contamination.	B, B2 = UJ B3 = JL
E	Applied to a sample result that was measured at a concentration greater than the calibration range of the method. It is applied when the detected analyte concentration exceeds the upper instrument calibration limit and further dilution is not feasible. The reported value is an estimated analyte concentration.	E
J	Applied to a sample result that is considered an estimated value.	J for lab data; EST for field measurements
JG	Applied to a sample result that is considered an estimated value with a low bias. This will typically be applied when QC results indicate the recovery of the analyte is below the expected limits of the method.	JG
JL	Applied to a sample result that is considered an estimated value with a high bias. This will typically be applied when QC results indicate the recovery of the analyte is above the expected limits of the method.	JL

Microbiology		
FAIL	The result of the positive or negative control failed (applied to QC results only)	No qualifier added
PASS	The result of the positive or negative control passed (applied to QC results only)	No qualifier added
C	Value is an estimate, based on presence of confluent growth	J
TNTC	Too Numerous To Count: Used when the number of target colonies exceeds the countable range and no reliable estimate is available.	Reported as an observation

Table 21. Pacific Rim Laboratory Data Qualifiers

Qualifier	Description	EIM Qualifier
U	Indicates the compound was not detected at the concentration listed.	U
J	Indicates the sample concentration is less than the lowest point on the calibration curve.	J
N	Indicates the compound was not detected due to incorrect ion ratio. The concentration is reported as the estimated maximum possible concentration (EMPC)	U, with description in Comment Field
B	Indicates the compound was detected in the associated method blank.	Depends on data validation (UJ, JL, or Null)
B1	Indicates the sample concentration is less than five times the concentration found in the method blank.	UJ

Additionally, equipment blank and field replicate results will be presented in the final report. If these results indicate a problem with precision or accuracy, data qualifiers may be applied based on the National Functional Guidelines (EPA 2010b and EPA 2014) and best professional judgment.

9.2.2 Flow Data

Flow measurement devices and methods will be consistent with accepted scientific practices and will be selected and used to ensure the accuracy and reliability of measurements of the volume of monitored discharges. The devices will be installed, calibrated, and maintained to ensure that the accuracy of the

measurement is consistent with the accepted industry standard for that type of device. The device will be recalibrated in conformance with manufacturer's recommendations or at a minimum frequency of at least one calibration per month during the wet season (or within a month of any data collection) for the duration of the project. Calibration records will be maintained for a minimum of three years beyond the final report.

Flow data collected in association with this monitoring program will be reviewed for quality assurance purposes. These data will be examined for gaps, anomalies, or inconsistencies between the water level and precipitation data. In the event that quality assurance issues are identified on the basis of these reviews, a site visit will be performed immediately to troubleshoot the problem and to implement corrective actions if possible.

During verification of the water level readings, if the relative percent difference (RPD) between the water level measurements is greater than 10%, all flow data generated since the previous calibration will be "J" flagged and considered estimated. If the difference is such that the generated flow data is deemed unusable, the project team will "R" flag and reject the data. If flow data is rejected over a sampling period, the project team may decide not to analyze samples collected by autosamplers.

9.2.3 Rain Gauge Data

Rainfall record data are available on the King County Hydrological Information Center (HIC) website (http://green2.kingcounty.gov/hydrology/). Rainfall from two gages (24v, 41v) near the study site will be used to evaluate storm intensity and duration when evaluating whether samples had been met the post-sampling storm criteria (Section 6.8.1).

Rainfall is measured by a tipping bucket rain gauge recording rainfall in 0.01 inch increments. The time of each 0.01 inch tip is recorded by a data logger and transmitted to the King County hydrologic database hourly. The database generates a report of seven days of 24 hour rainfall totals for all reporting rain gauges. Designated staff examine the report daily to verify gauge function and data reasonableness. Routine site visits are made to clean and maintain the equipment and test the calibration of the rain gauge according to manufacturer's specifications. Periods of missing record are filled with data from a nearby gauge and flagged "E". Data for periods when the gauge is more than 10% out of calibration may be adjusted. Data logger time is checked daily by the telemetry program and adjusted if off by more than five seconds.

Rainfall data that are entered into the hydrologic database are initially flagged "P" for provisional. Final QA/QC is performed at least annually. Field notes are checked to verify rain gauge calibration. Daily rainfall totals are compared to three or four nearby sites by charting cumulative totals and visually looking for anomalies. Tabular daily totals are examined and 15-minute totals for the comparison sites

are put in columns in a spreadsheet. A visual check is performed to search for periods where a funnel may be plugged or otherwise malfunctioning, indicated by rainfall records being too regularly spaced or exhibiting unnatural intensity compared to nearby sites. These QC procedures are used whenever the ongoing examination of the daily reports indicates a problem with a gauge. Rainfall data that has passed final QC is flagged "L" for Locked, meaning it cannot be overwritten without special administrator permission.

9.3 Data Reduction, Review, and Reporting

All lab and field measurements will follow the procedures outlined in the KCEL's SOPs and QA Manual or in the Federal Way QAPP (Appendix A). Laboratory personnel will be responsible for internal quality control verification, proper data transfer, and reporting data to the project manager via LIMS.

The final report will include:

- A summary of parameter concentrations at the inlet and outlet at each station and at the station on the NFWHC.
- A summary of flow measured during sampled storm events at each station.
- A summary of chemical loadings calculated for each station.
- A discussion of treatment effectiveness of each bioretention facility and the wet pond complex based on the analysis of change in concentrations and loadings between inlets to outlets.
- A discussion of the overall effectiveness of the RDF based on the comparison of pre-retrofit and post-retrofit turbidity data from the wet pond complex inlet and the discharge point to NFWHC.
- A section discussing QA/QC for the data.
- An appendix including all raw analytical data with laboratory qualifiers (described in Section 9.2)
- An appendix including bench sheets for toxicity tests.
- A toxicity data analytical report
- CETIS export files for the toxicity tests
- Final data will be entered into the EIM system by the close of the project
- Ecology and the City representatives will provide a technical review of the final report.

10.0 DATA QUALITY ASSESSMENT AND DATA ANALYSIS

After data verification and validation, the project manager will conduct a data quality assessment to ensure the data satisfies the MQOs and is of sufficient quality to meet study goals. The following list outlines the steps in this process, as described in the Data Quality Assessment Guidelines (EPA 2006):

1. Review the project's objectives and sampling design

The first step in this process is to verify whether the execution of the sampling design satisfies the project objectives. Deviations from the QAPP and site condition anomalies will be considered as part of this step.

2. Conduct a preliminary data review

By reviewing the QA reports and data validation memos, the project manager can assess whether the goals of precision, bias, sensitivity, accuracy, representativeness, comparability and completeness have been achieved, as defined in Sections 4 and 5 of this QAPP. The project manager will then explore the data by generating summary statistics and basic graphs. Any observed anomalies will be investigated. The LIMS MDL value (sample-specific) will be used as a surrogate for any non-detect results. In general, this results in a high bias, which will be addressed as appropriate in the final report.

3. Select the statistical method

Comparisons of concentrations and calculated loadings in samples from the inlets and outlets of the bioretention facilities and the wet pond complex will utilize standard parametric tests (e.g., t-tests) or non-parametric tests (e.g., Wilcoxon signed rank tests) as appropriate given the distribution of the data. Concentrations or loadings from multiple facilities may be compared using ANOVAs (e.g., comparing % reductions in nitrogen across the two bioretention facilities and the wet pond complex) or regression analyses (e.g., rainfall amount vs. % reductions in nitrogen by facility). The project manager may decide not to include statistical analysis for parameters with low frequency of detection, due to increased uncertainty.

4. Verify the assumptions of the statistical method

The distribution of the datasets will determine whether parametric or non-parametric statistical tests will be implemented. The number of samples proposed for this project is not based on a power analysis, but instead on the maximum number of samples that can

feasibly be collected by field personnel. If variability is high within the dataset, it may result in low statistical power, meaning lower probability of detecting differences between the populations (e.g., inlet vs. outlet sample results).

5. Draw conclusions from the data

In this step, the statistical tests will be conducted and the uncertainty of the results will also be assessed. In the final report, visual representations of the data may include scatter plots, box plots or bar charts with error bars representing standard deviations or confidence intervals. The report will also include descriptions and detailed interpretations of the statistical results. Suggested amendments to the sampling design for future use will also be discussed.

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APPENDIX A: CITY OF FEDERAL WAY, 2012, QUALITY ASSURANCE PROJECT PLAN

APPENDIX B: CHAIN OF CUSTODY (COC) FORM

APPENDIX C: HOBO® U20L WATER LEVEL LOGGER (U20L-0X) MANUAL