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

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King County

Department of Natural Resources and Parks
Water and Land Resources Division

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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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Department of
Natural Resources and Parks
Water and Land Resources Division

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Appendices

Appendix A: City of Federal Way 2012 Quality Assurance Project Plan

Appendix B: As Built Drawings of the Expanded and Retrofitted S. 356th Street Regional Detention Facility

Appendix C: Chain of Custody (COC) Form

Appendix D: HOB0 U20L Water Level Logger (U20L-0X) Manual

Distribution List

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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 (Ecology 2013, Herrera 2012, Herrera 2014). As stormwater retrofit projects are planned and built, there is a critical need to evaluate the effectiveness of the stormwater best management practices (BMPs) to insure treatment, flow reduction and receiving water protection goals are being met.

This study was designed to address data gaps identified by the Washington State Stormwater Work Group (SWG) in the effectiveness of stormwater treatment technologies used in the Puget Sound Region. The SWG represents several layers of government, economic stake holders, and researchers, and was formed under the leadership of the Puget Sound Partnership (PSP) and Washington State Department of Ecology (Ecology) in 2008 to develop a Stormwater Monitoring and Assessment Strategy for the Puget Sound Region. The Regional Stormwater Monitoring Program (RSMP), through which this and several other effectiveness studies are funded, was created out of this process.

The primary goal of this study is to assess the effectiveness of two new bioretention facilities that were built as part of an expansion and retrofit of a regional stormwater detention facility (RDF) in Federal Way, WA, known as the “South 356th Street Project” (Figure 1). The RDF was built originally in 1997, and included a combined detention and stormwater treatment wetland (CDSTW) that was designed to both attenuate flow and provide some water treatment. In 2013–2014, the RDF was expanded and retrofitted with the addition of two bioretention facilities and a new CDSTW. The two bioretention facilities were designed to treat previously untreated stormwater from a 22.6-acre basin with more than 80% impervious surface. The new CDSTW expanded the capacity of the RDF by providing additional flow control and treatment for a portion of the discharge from the old CDSTW. The RDF was engineered in a way that allows flow meters and autosamplers to be deployed at both the inlet and the outlet of each bioretention facility and at the inlet and the outlet of the entire retrofitted and expanded detention facility. In addition, there are some pre-retrofit monitoring data available that can be used to assess the impact of the project on the local receiving water body.

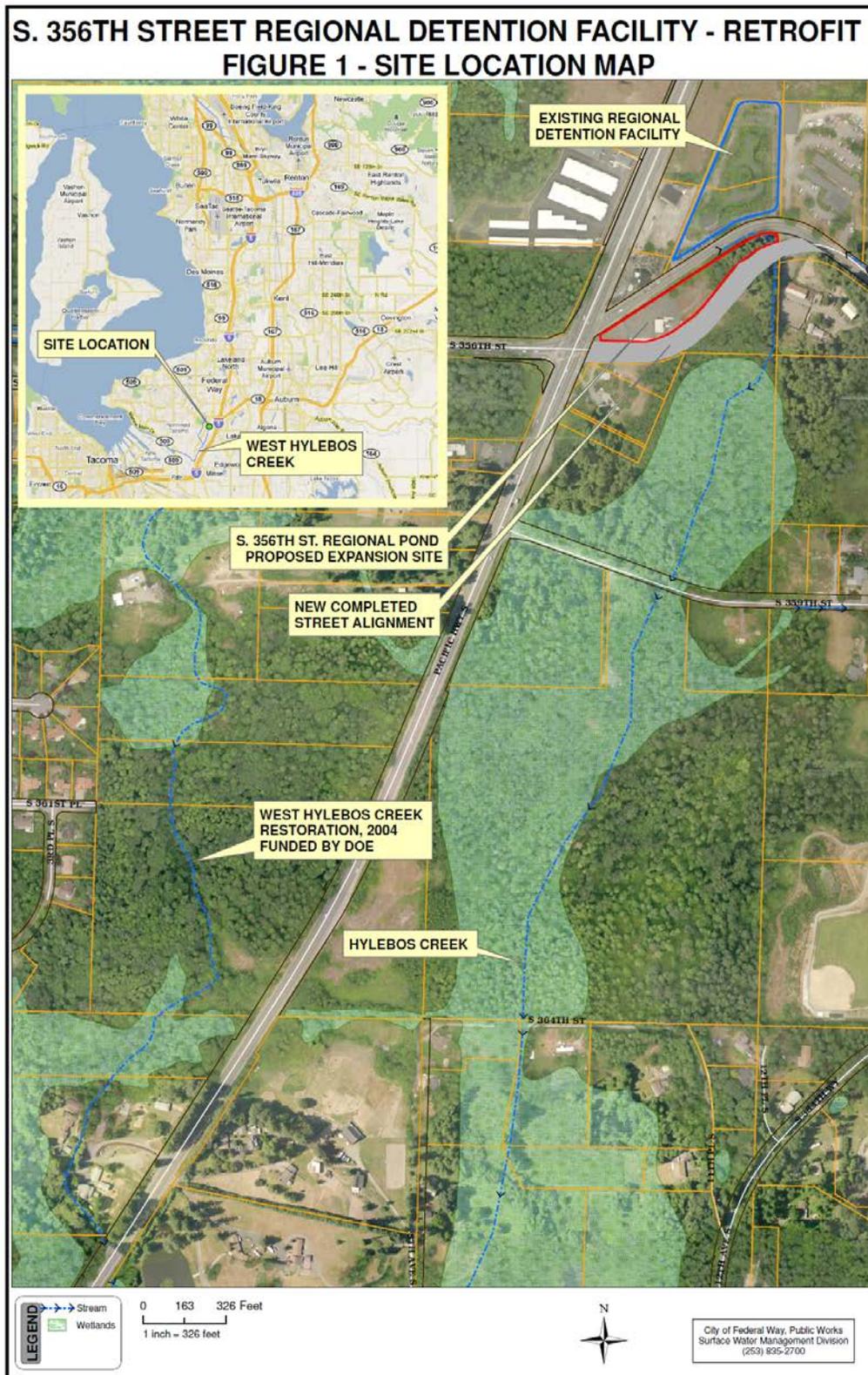


Figure 1. Site location map for South 356th Street Detention Facility, as shown prior to the expansion and retrofit. (Map created by Federal Way and originally included in a report for grant G1200017.)

This study will evaluate: (1) the effectiveness of each bioretention facility to improve stormwater quality, (2) the effectiveness of the expanded combined detention and stormwater treatment wetland complex to improve stormwater quality, and (3) the effectiveness of the entire retrofit (bioretention facilities and CDSTWs) to improve stormwater flow dynamics, water quality and toxicity to the receiving water (the North Fork of West Hylebos Creek, tributary number 0013; WRIA 10). 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 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) (Figure 1). 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 (Federal Way 2010). Degraded macroinvertebrate communities in NFW Hylebos Creek also indicated further flow control and pollutant reduction were needed (Federal Way 2010).

In 2010, the City applied for a Stormwater Retrofit and Low Impact Development grant from the Washington Department of Ecology (Ecology) (Federal Way 2010). In the grant application, the City included monitoring data that demonstrated that although the original RDF was partially effective in reducing turbidity, further improvements in turbidity, temperature, and flow control were needed to protect downstream aquatic habitats. A brief summary of the monitoring data used to justify the retrofit and expansion is 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 WA State instream water quality criteria.
- Temperatures in NFW Hylebos Creek between 2002 and 2008 did not exceed the state's criteria 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.

- The application noted that stormwater discharges from the RDF were not being adequately buffered and suggested the high flows limited juvenile fish passage and were causing the streambed and channel to be unstable. These conditions reduced the amount of suitable fish spawning and macroinvertebrate habitat, and improving flow attenuation was listed as a primary objective of the retrofit.
- 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.

By 2011, the extent of impervious surface across the basins draining to the original RDF exceeded 70% (Figure 2), and the 21-acre feet capacity of the original RDF was inadequate for flow control and treatment. To help address the problem, the City applied for and received a Stormwater Retrofit and LID Grant (G1200017) from Ecology to retrofit and expand the 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. Water quality and benthic macroinvertebrate 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 instream samples collected from March 2012 through June 2014 at the RDF and in the NFW Hylebos Creek, were consistent with previous monitoring results from 2002–2008 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 NFW Hylebos Creek 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.

King County will monitor turbidity, temperature and macroinvertebrates, following the protocols used previously by the City. 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 (2016 on) will allow King County to evaluate the effectiveness of the retrofit and expansion to reduce turbidity.

1.2 Description of RDF Retrofit and Expansion

Using the Ecology grant G1200017, the City of Federal Way expanded the S. 356th Street RDF to increase capacity and provide additional stormwater treatment. The City incorporated stormwater BMPs and followed design guidelines as much as possible when designing the retrofit and expansion. However, like many facilities in highly developed watersheds, the limited available space and the design of the existing RDF imposed constraints on the new design and construction. The resulting facility was designed to work at this site, and the components of this facility (the CDSTWs and the bioretention facilities) do not necessarily represent other facilities with the same components. The CDSTWs and the bioretention facilities meet some of the specifications outlined in Ecology’s and King County’s manuals (Ecology 2012, King County 2009) (Tables 1 and 2), but not all of the design recommendations were incorporated. As a result, the findings from this study should reflect but not necessarily help predict the effectiveness of these types of stormwater BMPs in other facilities.

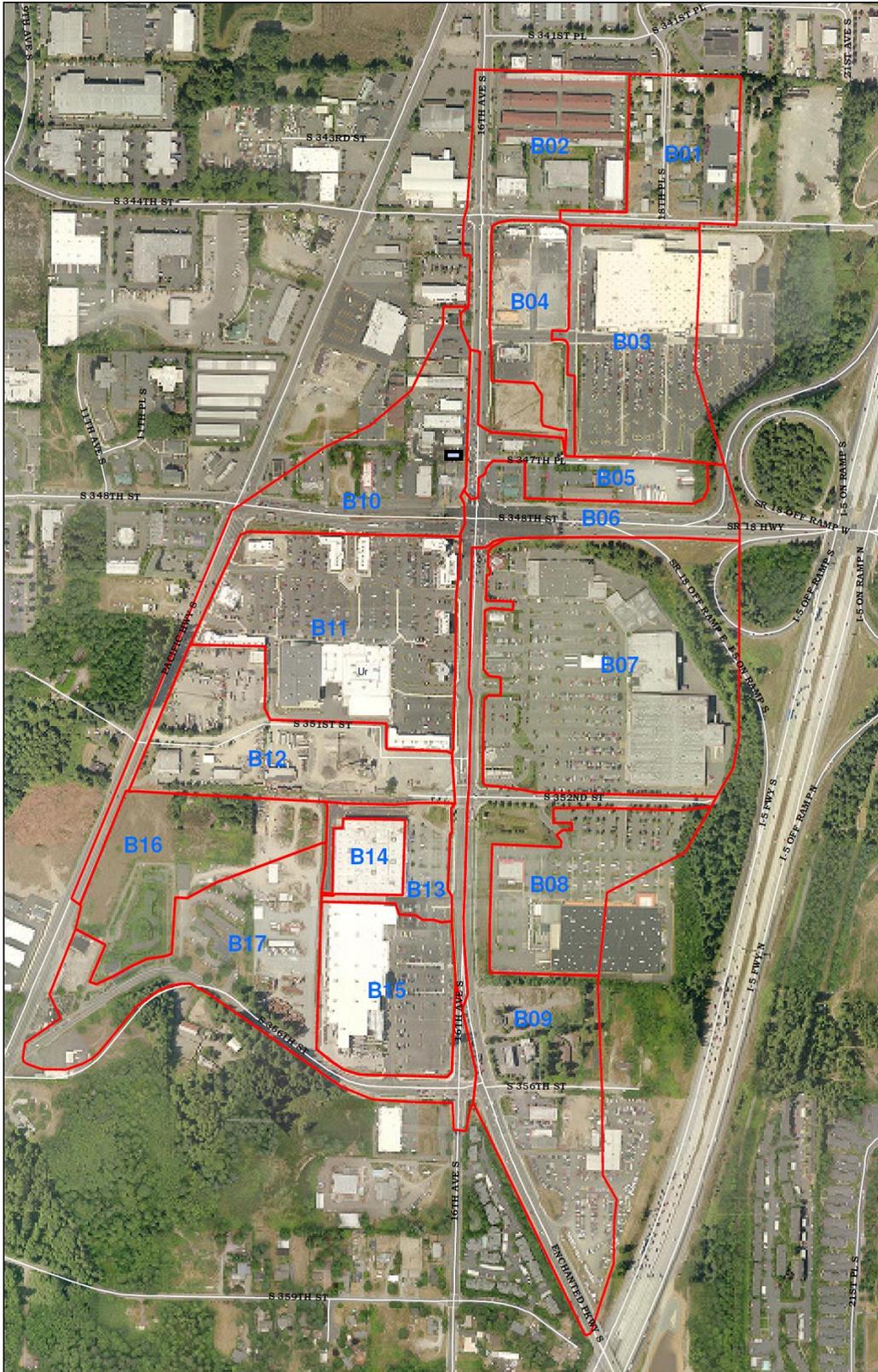


Figure 2. Stormwater basins that drain to S. 356th Street RDF in Federal Way, WA. The old CDSTW is shown in Basin (B)16.

1.2.1 Site Layout

The majority of the stormwater runoff delivered to the retrofitted and expanded S. 356th Street RDF comes via two primary pipelines, one from the north and one from the east.

The northern pipe drains approximately 189 acres of highly developed commercial, industrial, and residential areas within the city of Federal Way. Stormwater from this line is delivered to the northwest corner of the original combined detention and stormwater treatment wetland (“old CDSTW”) which is undersized given the growth in Federal Way. The new CDSTW (Figures 3 and 4, Appendix B) was designed to provide additional detention and treatment to a portion of the discharge from the old CDSTW (Table 1). It is unclear exactly how much flow enters and is treated by this new, in-series CDSTW, but it is designed to receive much of the discharge from the old CDSTW when flows from the old CDSTW are low to moderate. Therefore, stormwater entering the RDF from the north will be treated by the old and possibly the new CDSTW. Discharges from both CDSTWs eventually become mixed prior to discharging to the NFW Hylebos Creek. There are two additional pipes that drain stormwater into the old CDSTW (labeled “minor input pipes” in Figure 3). Although it is expected that these two pipes contribute <10% of the total input to the RDF (based on the area of the assumed basins), the exact volumes are unknown.

The eastern pipe delivers previously untreated stormwater runoff to two bioretention facilities. Prior to the RDF expansion, runoff from a 22.6 acre area to the east bypassed the RDF and discharged directly to NFW Hylebos Creek (Figure 2, portions of Basins 15 and 17; Figure 5). Those flows are now directed to two bioretention facilities that were designed to improve water quality through filtration (Figure 5, Table 2). The bioretention facilities are underdrained and filtered water is eventually discharged to the creek (from the east bioretention facility) or surrounding natural wetlands (from the west bioretention facility). If high flows are anticipated (forecast of >1.5 inches of rain /24 hrs), flows may be diverted from the bioretention facilities to a bypass pipe that drains to a catch basin that then discharges directly to the creek (Figure 3). In addition, overland flow from the area immediately around the bypass pipe (~8000 ft²) may also flow into that catch basin (note this does not include runoff from the roadway).

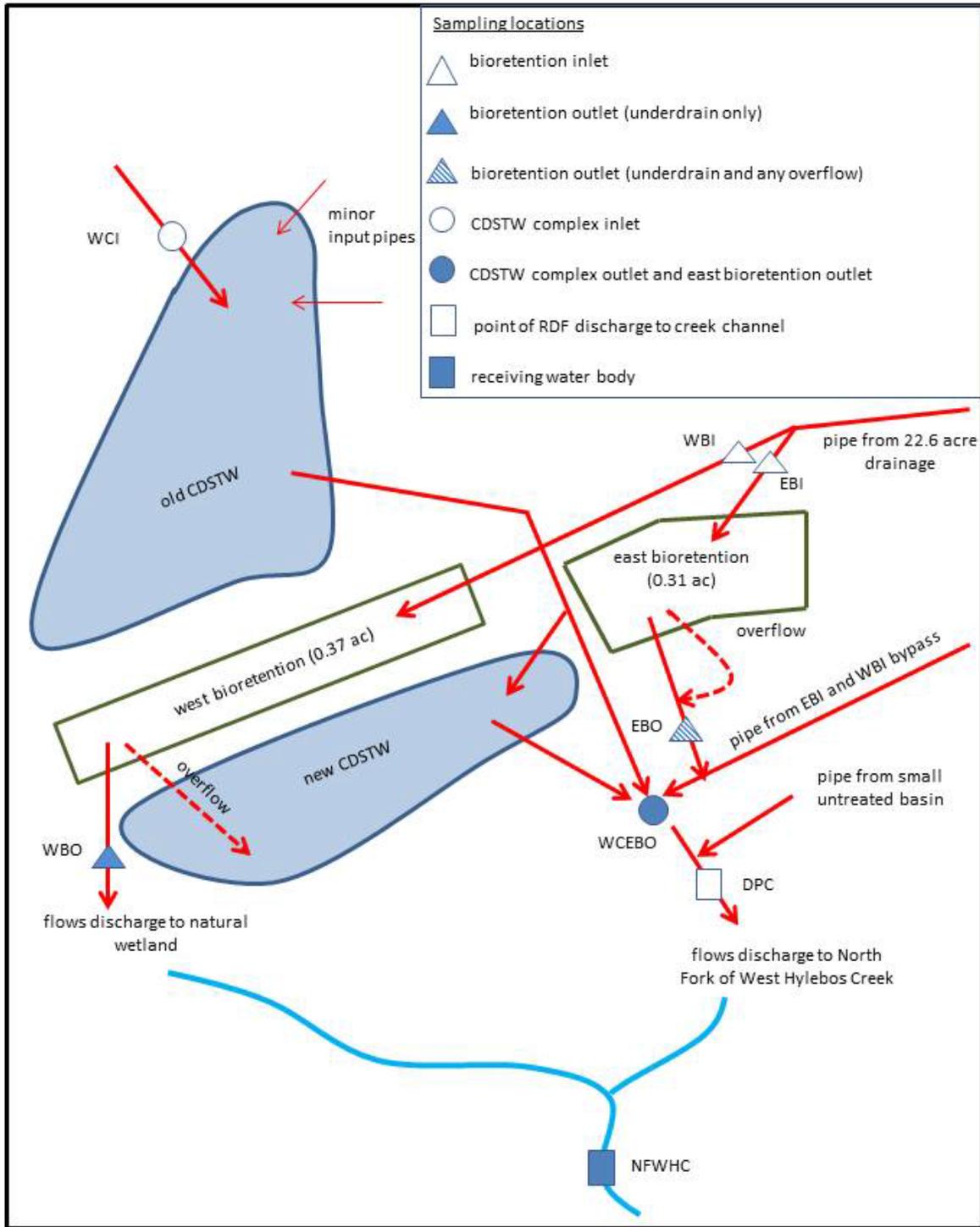


Figure 3. Schematic of flow paths (not to scale). Sampling locations include the North Fork of West Hylebos Creek (NFWHC), the east and west bioretention inlets (EBI, WBI), the east and west bioretention outlets (EBO, WBO), and the wetland complex inlet and outlet (WCI, WCEBO). Note the WCEBO includes flows from the east bioretention facility, flows from the old CDSTW, flows from the new CDSTW, and any untreated flows that enter from the EB and WB bypass.



Figure 4. Photo of S. 356th Street Project, taken in late spring 2015.

1.2.2 Retrofitted BMP Design and Descriptions

1.2.2.1 Combined Detention and Stormwater Treatment Wetlands in Series

The City of Federal Way designed both the old and new CDSTWs to attenuate flows and provide treatment of stormwater. Although neither wetland was designed to meet all of the specifications of the combined detention and stormwater treatment wetlands, they meet many of the current specifications for this kind of BMP (Table 1). The “as built” drawings of the old and new CDSTWs are included in Appendix B.

The new CDSTW increases the capacity of the entire RDF by approximately 5 acre-feet, and it is anticipated that the greater capacity will also result in improved water quality treatment. The new CDSTW is in fact in-series with the old CDSTW. The old CDSTW provides effective pretreatment for the stormwater entering the new CDSTW, therefore the required “first cell” per the Ecology design manual is eliminated for the new CDSTW. The design of the new CDSTW was constrained by the limited space available and the existing BMPs, but it was designed to meet as many specifications as possible that are described in Ecology’s Stormwater Management Manual for Western Washington (SWMMWW; Fei Tang consulted WSU (2012) which was later incorporated into the amended 2012 Ecology SWMMWW) and King County’s Surface Water Design Manual (2009) (Table 1). The new CDSTW is not lined and due to the impermeable native soils, it has low infiltration rates. This results in standing water throughout the wet season. After several failed attempts, the slopes of the new CDSTW were successfully seeded with a marsh seed mix in fall 2015 and the area was irrigated to promote establishment. The grasses are now established but it is not yet clear if and how much irrigation will be needed to maintain the grasses during the subsequent summer months.

Table 1. Properties of the old and new combined detention and stormwater treatment wetlands (CDSTW) at the S. 356th RDF.

Properties	Old CDSTW (built 1997)	New CDSTW (built 2013–2014)
Applicable design manual codes	Most similar to Ecology T10.40 (2012 SMMWW, amended in 2014) and King County 6.4.4 (2009 and 2016 [Draft] Surface Water Design Manuals)	Most similar to Ecology T10.40 (2012 SMMWW, amended in 2014) and King County 6.4.4 (2009 and 2016 [Draft] Surface Water Design Manuals)
Surface area at weir overflow	2.5 acre	1.07 acre
Active storage	21 acre–feet	3.8 acre-feet
Dead storage	approximately 1 to 2 acre-feet	1.05 acre-feet
Average depth	7.8 feet	6 feet
Max depth	Does not exceed 8 feet	Does not exceed 8 feet
Infiltration expected?	No; lined	No; not lined but minimal infiltration expected because of highly impermeable native soils
Designed for detention	Yes, live storage is above the seasonal high groundwater level	Yes, live storage is above the seasonal high groundwater level

Properties	Old CDSTW (built 1997)	New CDSTW (built 2013–2014)
Designed for sediment storage	Sedimentation forebay that is >1 foot deep	No, but because this is in series with old CDSTW, sediment loads are expected to be small
Wetland plants	Diverse community of native plants currently present	Native grass seed planted; other plants have become established and may be removed as needed (e.g., cattails)
Ratio of flow path length to width	At least 3:1	At least 3:1
Outlet control structure	Present, with grate	Present, with back slope
Additional features	<ul style="list-style-type: none"> • Oil/water separator • Low-flow channel • Outlet micropool • Low islands to support diverse community of native vegetation 	<ul style="list-style-type: none"> • Small separator berm helps direct inflow away from outlet and avoid short circuiting
Deviations from current codes	<ul style="list-style-type: none"> • There is no distinct second cell • Inlets are not submerged • Undersized 	<ul style="list-style-type: none"> • Small separator berm was not designed to promote plug flow or help create a distinct second cell • No area designed specifically for sediment storage • Inlet is not submerged but is designed to minimize resuspension of settled sediments • Undersized

Inputs to the new CDSTW are exclusively from the old CDSTW, and a hydraulic model (XP-Storm) was used to size new wetland. Outflows from the old CDSTW enter a catch basin via a large (48”) pipe. From the catch basin, water flows either to the new CDSTW via a deep and relatively small (18”) pipe or away from the new CDSTW and towards the creek via another large (48”) pipe (Figure 3). The catch basin and pipes were designed to direct low-to-moderate flows to the small pipe and thus to the new CDSTW. In contrast, under high flow conditions, the catch basin is designed to direct most of the water away from new CDSTW to minimize the chance of flooding the new CDSTW and the adjacent streets.

The new CDSTW will provide added flow control and treatment, especially during small and medium storm events, but we will not measure this directly. Because of the challenge of measuring flow in these systems, we are limited to measuring the CDSTWs as a complex rather than as individual units. We will measure flow into the old CDSTW to represent the majority of the flows entering the complex, but the best option for measuring outflow efficiently is at WCEBO (Figure 3), where the flow consists of discharge from the old CDSTW that bypasses the new CDSTW, discharge from the new CDSTW, discharge (and overflow) from the east bioretention facility, and any water that bypasses the bioretention facilities (Figure 3). Thus, the effectiveness of the CDSTW complex will be evaluated by monitoring the net improvements in flow and water quality as stormwater passes through

the entire RDF, and calculating how much of that improvement may have been due to the east bioretention and how much from the CDSTW complex.

1.2.2.2 Bioretention Facilities

The bioretention facilities were constructed according to the Draft 2012 Low Impact Development Technical Guidance Manual for Puget Sound (WSU, 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 2). 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 3). In contrast, the overflow from the west bioretention facility flows into the new CDSTW (Figure 3). The outlet of the west bioretention facility drains to a natural wetland (Figure 3).

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 used in combination with PVC collector pipes in the western half of the facility. The PVC pipes are not perforated except where the Smart Drain material is joined to them. The eastern half of the west bioretention facility is not underdrained, and there is typically standing water in this half during the wet season.

In contrast, the entire east bioretention facility is underdrained. Originally, the entire underdrain network was constructed using Smart Drain™ strips that connected with PVC collector pipes (just as in the west half of the west bioretention facility). However, initial observations indicated the facility was not draining and in the summer of 2015, the Smart Drain™ underdrain in the western half of the facility was replaced with a traditional perforated pipe underdrain. The facility is now draining and no further changes are anticipated.

Due to space limitations at the site, the bioretention facilities were undersized. Ecology recommends 91% of the stormwater is treated for flow control in this basin (using WWHM), however because a WWHM model was not built for the expanded S. 356th Street RDF Project, the level of flow control treatment is currently unknown. A single event model (XP Storm) was run on an expanded time scale and estimated that approximately 89% of stormwater would be treated (Fei Tang, personal communication).

Table 2. Physical description of east and west bioretention facilities at the S. 356th Street RDF.

Properties	West Bioretention Facility	East Bioretention Facility
Size (acre)	0.37	0.31
Storage Capacity (acre-feet)	0.28 before overflow, 0.6 max.	0.25 before overflow, 0.69 max.
Max Depth (feet)	1 before overflow, 2 max.	1 before overflow, 2.5 max.
Soil	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	30 in of BSM ¹ , topped with 3 in of coarse compost ²

Properties	West Bioretention Facility	East Bioretention Facility
	soil amendment A BSA ³	
Vegetation Types	In eastern half: Pacific crabapple, Pacific wax myrtle, dwarf arctic willow, salmonberry, Douglas spirea, redbud dogwood, black gum; In the western half: native swale grasses	Pacific crabapple, black gum, redbud dogwood, salmonberry, dwarf arctic willow, black twinberry, daggerleaf rush
Extent of Underdrain	Underdrain installed in west half only; material used included 8 inch wide Smart Drain™ belts that connect to PVC pipes	Underdrain installed throughout; west half is made of standard PVC underdrain; east half is made of 8-in wide Smart Drain™ belts that connect to PVC pipes

¹ All specifications in section 8-02.3(4)A for Bioretention Soil Media (BSM) quality and application (WSDOT, 2010) were met.

² All specifications in Section 9-14.4(8) Special Provisions for compost (WSDOT, 2010) were met.

³ All specifications in Section 8-02.3(6) Special Provisions for BSA (WSDOT, 2010) were met.

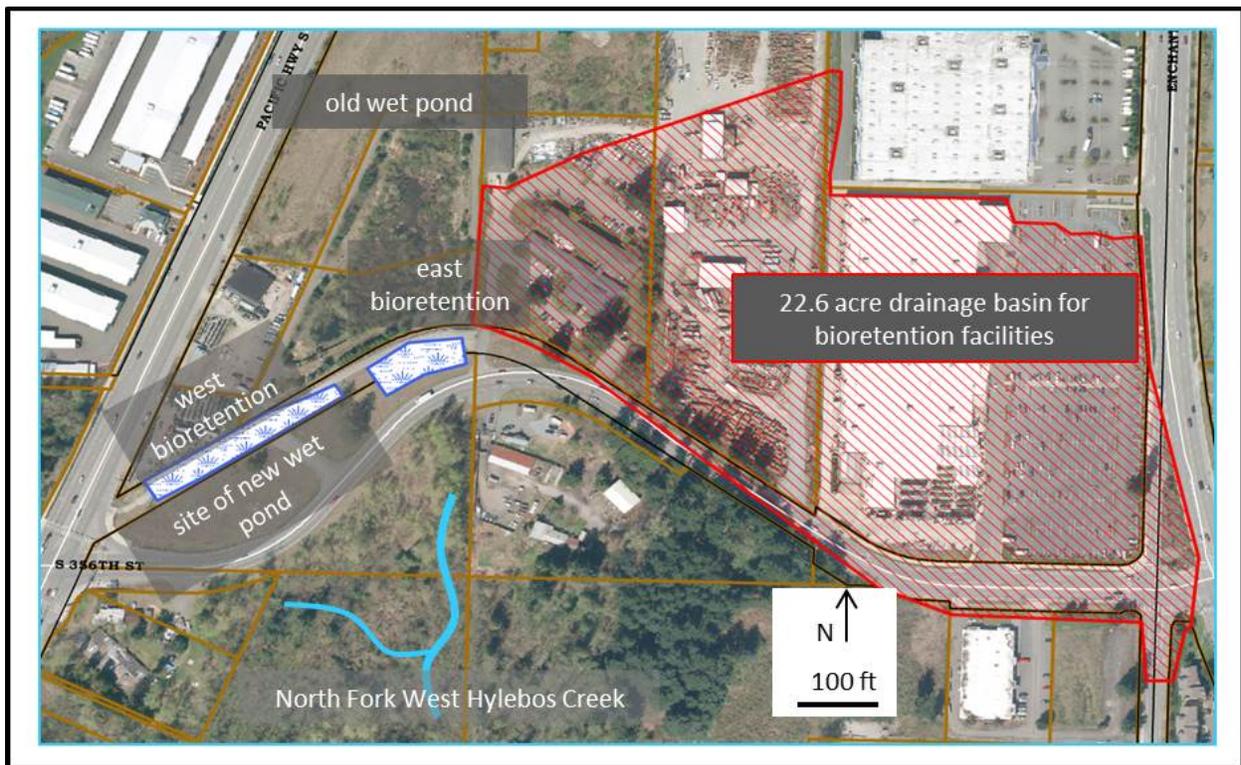


Figure 5. Aerial photo of drainage basin for bioretention facilities.

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 3). Concentration data will be compared to available criteria. 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 3. Water quality parameters to be measured in flow-weighted composite samples collected from all sampling locations, and the applicable WA State criteria.

Group	Parameter	Water Quality Criteria for NFW Hylebos 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
	nitrate+nitrite	NA
	total nitrogen	NA
	orthophosphate-Phosphorus	NA
	total phosphorus	NA
Conventionals	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 including: 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	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	<i>Daphnia pulex</i> acute toxicity	NA
	<i>Ceriodaphnia dubia</i> 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 CDSTW complex that contains an old and new CDSTWs (constructed in 1997 and 2013–2014, respectively), 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 CDSTW 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: Present these site-specific effectiveness data in a context that is useful to others in the region. This will include presenting lessons learned when incorporating bioretention facilities in retrofits for 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 CDSTW complex, and in NFW Hylebos Creek), during the wet seasons between January 2016 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 CDSTW complex to attenuate stormwater flows.
- Collect flow-weighted water samples from the seven sampling stations during 20 storm events over two years (2016–2017), or 2 wet seasons. 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 a subset 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 CDSTW complex to reduce pollutant concentrations and loads in stormwater runoff. Note that the effectiveness of the CDSTW complex will be estimated by subtracting the estimated loadings from the east bioretention facility from the estimated loadings measured at the RDF outlet. It will not be possible to directly estimate the effectiveness of the CDSTW complex, and it will not be possible to identify how the new CDSTW is performing compared to the old CDSTW.

To meet Goal 2:

- Use flow and water quality 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. The effectiveness in reducing pollutant loadings will be calculated by summing the estimated loadings to the entire RDF (old CDSTW and the bioretention facilities), and then subtracting the sum of the estimated loadings in the outflows (from the bioretentions and the CDSTW complex).

To meet Goal 3:

Compare pre-retrofit and post-retrofit turbidity and temperature data from the RDF 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 in NFW Hylebos Creek to identify improvements in receiving water quality that may be correlated with the retrofit and expansion of the RDF. Focus analysis on times when RDF outflow temperatures are higher than RDF inflow temperatures (as seen in pre-retrofit monitoring), and determine the effect on stream temperatures.

- Collect and report macroinvertebrate community data in NFW Hylebos Creek. Macroinvertebrate community data will be reported using two similar metrics: Ecology's MMI and the Puget Sound Lowlands Benthic Index of Biotic Integrity (B-IBI). Although the recovery of sensitive macroinvertebrate communities will not likely occur within the timeframe of this study, these data will be valuable for future trends analyses and evaluation of how improvements in receiving water quality that may be correlated with the retrofit and expansion of the RDF.

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.
- Create and distribute presentations, web site updates, and informational pamphlets describing results of the study.

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 CDSTW 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 two sampling seasons, continuous flow data will be collected and storms will be targeted for sample collection. The target is to sample each location during 20 storms. 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 (when applicable data are available and comparisons are appropriate). 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. We also assume there are minimal if any inflows from unmeasured sources (including groundwater and any pipes not being monitored), and the only unmeasured outflows include water that evaporates or infiltrates and is not collected in the underdrains. We may calculate the volume of precipitation that falls directly on the

RDF to help account for flow volumes, but we will not analyze any rain samples for water quality parameters.

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 CDSTW 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

King County staff will collect continuous turbidity and water temperature data at the same stations that the City had surveyed prior to the retrofit (for turbidity and temperature: the inlet of the old CDSTW 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 storms using Isco® autosamplers at the inlets and outlets of each bioretention facility, and at the inlet and outlet of the CDSTW complex. Flow-weighted composite water samples will be also collected in NFW Hylebos Creek at the culvert under S. 359th Street. The goal is to collect 20 samples at each location, with as many of those during the same storms as possible. 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 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 three consecutive storms, the toxicity testing will end.

2.3.3 Benthic Macroinvertebrate Sampling

Aquatic benthic macroinvertebrates samples will be collected in NFW Hylebos Creek in the summers of 2016 and 2017. Results will be compared to results from samples collected annually from 1999 through 2015.

2.4 Sampling Considerations and Constraints

2.4.1 Determination of Storm Sampling Methods

The objective is to collect flow-weighted samples that will allow for the best measure of effectiveness of the bioretention facilities and the RDF as a whole. This would ideally include paired samples, in which the same plug of water is sampled as it flows into and out of a given facility. The collections would also ideally be timed, or paced, so that similar plugs of water are sampled at all of the locations during the same storm. This would be advantageous because we plan to estimate the effectiveness of the CDSTWs from data collected from other locations rather than measuring it directly, and having samples from all locations for the same storm would help control for variability introduced when comparing data from different storms.

Preliminary analyses of flow data collected in late 2015 and early 2016 suggest that the ideal sampling conditions will be rare, and it will be challenging to meet the storm and sample criteria (see Sections 5.4 and 6.8) for all locations during each storm. Because of this and the greater regional interest in measuring the effectiveness of the bioretention facilities, sampling the bioretention facilities will be the top priority (EBI/EBO and WBI/WBO), and sampling other locations will be a lower priority.

For both bioretention facilities, preliminary flow data indicate there is influent and effluent following moderate storms (>0.25 and <1.0 inches/24 hrs). These data indicate that the detention times for the bioretention facilities during following moderate storms are sufficiently short to justify a paired sampling approach. For larger storms or storms that last more than a day (> 1.25 in/24 hrs or > 2 inches/48 hrs), the east bioretention facility fills and drains within a day but the west bioretention facility fills and can take more than 72 hours to drain. If continued flow measurements indicate these facilities typically require more than a day to drain after inflows have ceased, the detention times may be too long to justify a paired sampling approach. If this is the case, 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.

2.4.2 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 are

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

Analytical Group

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

Field Science Unit

- Ben Budka – Field Science Unit Supervisor*
- Jeff Droker – Lead Field Technician*
- Houston Flores – Field Technician*

City of Federal Way, Public Works Department

The City is responsible for providing site-specific technical expertise and reviewing plans and draft documents.

- Fei Tang – Surface Water Project Engineer*
- Theresa Thurlow, City of Federal Way (also RSMP Technical Liaison)

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
- Theresa Thurlow, City of Federal Way – RSMP Technical Liaison

Table 4. 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
King County	Houston Flores	206-477-5192; houston.flores@kingcounty.gov
Federal Way	Fei Tang	253-835-2751; fei.tang@cityoffederalway.com
Ecology	Brandi Lubliner	360-407-7140; brandi.lubliner@ecy.wa.gov
Federal Way	Theresa Thurlow	253-835-2750; theresa.thurlow@cityoffederalway.com
Pacific Rim Laboratories	David Hope	604-532-8711; david@pacificrimlaboratories.com

3.2 Project Schedule

The project schedule and the corresponding due dates for deliverables are listed in Table 5.

Table 5. 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	Locations phased in starting April 2015; all locations monitored as of January 2016	June 2017	Documenting Progress Reports	Semi-annually
Continuous temperature and turbidity monitoring at CDSTW complex inlet and at RDF discharge point to creek	February 2016	June 2017	Documenting Progress Reports	Semi-annually
Continuous water depth and temperature monitoring in bioretention facilities	September 2015	June 2017	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Storm Sampling (target: 10 storm events)	February 2016	June 2016	Documenting Progress Reports	Semi-annually
2015-2016 Wet Season Analysis at KCEL and Pacific Rim Laboratories, and toxicity tests at KCEL	February 2016	Sept. 2016	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Storm Sampling (target: 10 storm events)	February 2016	June 2017	Documenting Progress Reports	Semi-annually
2016-2017 Wet Season Analysis at KCEL and Pacific Rim Laboratories, and toxicity tests at KCEL	February 2016	Sept. 2017	Documenting Progress Reports	Semi-annually
Annual macroinvertebrate sampling in creek (late summer 2016 and 2017), sample processing and data analysis	August 2016	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

Activity	Anticipated Date of Initiation	Anticipated Date of Completion	Deliverable	Deliverable Due Date
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 presentations	Dec. 2018
Website Development	March 2016	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	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 4) 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 3.

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

These inlets receive the same stormwater runoff from heavily developed basins (Figure 2). Runoff from the basins flows through an open ditch along S. 356th Street and then 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.

Preliminary flow measurements at EBI and WBI indicate there is likely some infiltration of flows in the ditch before reaching the catch basin (and EBI and WBI). For most isolated, small storms (<0.2 inches/day), no inflows reached the EBI and WBI catch basin. For larger storms (>0.2 inches/day), inflow reached the catch basin but there may have been some infiltration and settling due to the ditch. Therefore, although the 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), the water quality and flow dynamics may not be representative of stormwater runoff that is exclusively piped.

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 outlet sample is taken from a pipe that contains effluent 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 sample will contain only effluent from the west bioretention underdrain. Any overflow from the west bioretention facility flows into the new CDSTW.

CDSTW Complex Inlet (WCI)

The inlet sample will be collected at the head of the old CDSTW, prior to the oil/water separator (Figure 3). The City collected temperature and turbidity data at this location previously and KCEL will continue collecting those measurements through June 2017 at a minimum. Continuous flow data and water quality samples will also be collected here.

Two other pipes discharge to the old CDSTW; one is a 6" pipe that is connected to a catch basin east of the maintenance road and one is an 8" pipe that is connected to a catch basin at the northeast corner of the site. The exact size of the basins draining to these pipes is

unknown, but Fei Tang suspects that they contribute less than 10% of the total flow to the old CDSTW. Preliminary observations indicate there is little to no flow discharging from these two pipes, but King County staff will continue to visually check to determine how frequently and under what conditions they discharge. If flows are observed, King County will measure turbidity to determine if these could be an important source that may require more intense monitoring.

Combined CDSTW Complex and East Bioretention Outlet (WCEBO)

Flow from the old CDSTW, the new CDSTW, 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 WCEBO. To estimate the separate contribution of the CDSTW complex (the combined old and new CDSTW), the flow and loading from the east bioretention facility will be subtracted from the flows and loading measured at the WCEBO. To estimate the entire outflow of the retrofitted and expanded RDF, the flow and loading from the WCEBO will be combined with similar measurements at the WBO.

When large storms (≥ 1.5 inches/24 hrs) are forecasted, flows may be diverted away from the bioretention facilities and towards this catch basin through the EB and WB bypass pipe (Figure 3). When this occurs, water quality samples will not be collected from WCEBO. When flows are not diverted but there is steady rain (> 1.0 inch/24 hrs), there may be local overland flow into this bypass pipe and into the catch basin from the ~ 8000 ft² area just upslope of the catch basin. King County staff will visually assess flows in this pipe when they are sampling, but the presence of some overland flow will not prevent water quality sampling at WCEBO.

RDF Discharge Point to Creek (DPC)

Water flowing from the RDF through the WCEBO 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, King County 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 collected continuous water temperature data at this station as part of the monitoring associated with the retrofit and expansion of the RDF. King County will continue to collect continuous water temperature here as well as additional water quality and flow parameters (Table 5).

Benthic macroinvertebrate samples will be collected by King County 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. Both sites will be sampled to maintain the data sets that have been established based on these sites and to provide

greater power for future trends analysis. Sampling will occur once per site and once per summer in 2016 and 2017 using the same methods previously used by the City (see Appendix A).

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 attached to one of the upright cleanout pipes. In the west bioretention facility, the data logger will be placed on a stake near the rock weir that serves as an overflow point into the new CDSTW. 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 6 summarizes the parameters of interest and the frequency with which they will be analyzed at each sampling station. Table 7 presents personnel and laboratory responsibilities for sample (or data) collection and analysis.

Table 6. Type of data or samples collected at each station and the number of storms targeted between 2016 and 2017.

Data/Samples Collected	EBI	EBO	WBI	WBO	WCI	WCEBO	DPC	NFWHC	Field Rep	Bio-retention 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, pH and turbidity	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**								2		

FWC = flow weighted composite samples

G = grab samples

* The scope of work with Ecology (RSMP) 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 7. 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 at all seven locations	Jeff Droker and Houston Flores, KCEL FSU	Jeff Droker and Houston Flores, KCEL FSU	Kate Macneale, KC
Continuous temperature at WCI, DPC and NFWHC	Jeff Droker and Houston Flores, KCEL FSU	Jeff Droker and Houston Flores, KCEL FSU	Kate Macneale, KC
Continuous turbidity at WCI and DPC	Jeff Droker and Houston Flores, KCEL FSU	Jeff Droker and Houston Flores, KCEL FSU	Kate Macneale, KC
Water level and temperature in bioretention facilities	Kate Macneale, KC	Kate Macneale, KC	Kate Macneale, KC
Metals	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
Nutrients	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
Conventional Parameters	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
PAHs	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
PCBs	Jeff Droker and Houston Flores, KCEL FSU	Pacific Rim	Richard Jack, KC
Fecal coliform	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
Toxicity	Jeff Droker and Houston Flores, KCEL FSU	KCEL	Kate Macneale, KC
Macroinvertebrates	Kate Macneale, KC	Rhithron Associates	Kate Macneale, KC

5.3 Continuous Field Measurements and Macroinvertebrate Sampling

Due to staffing changes at the City, King County 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 inches in 24 hours, no fixed maximum. However, if forecast is for >1.5 inches in 24 hours, check with Fei Tang to ensure flows will not be diverted from bioretention facilities.
- 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: Influent must be flowing into the east and west bioretention facilities and 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 3. For PCBs, all 209 congeners will be analyzed; a complete list of congeners is included in Section 7.3.

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 storms that meet these criteria and are sampled should be representative of storms that affect Federal Way and the RDF. However, adequate sample volume is important, thus 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 CDSTW 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). King County 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 two-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 the preliminary flow data suggest the hydrodynamics of the facilities are complex. Consequently, it is possible that there will be insufficient volume to perform all analyses at all locations per sampling event. 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 6). 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

King County will collect continuous temperature and turbidity measurements and macroinvertebrate data at the sites indicated in Table 6. 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 HOB0 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., an upright cleanout pipe in the east bioretention facility and on a stake 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. 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 8. 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	730 Bubbler Flow Module
East Bioretention Outlet	EBO	12	0.21	750 AVM
West Bioretention Inlet	WBI	18	1.20	730 Bubbler Flow Module
West Bioretention Outlet	WBO	8	6.30	750 AVM
CDSTW Inlet	WCI	48	0.81	750 AVM
CDSTW and East Bioretention Outlet	WCEBO	48	0.50	730 Bubbler Flow Module
North Fork West Hylebos Creek	NFWHC	60	6.0	750 AVM
Field Replicate	WBI_FR or EBI_FR	18 or 12	1.20 or 13.2	730 Bubbler Flow Module

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 silicon tubing in the peristaltic pump at the beginning of the season. Tubing will remain site-dedicated 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 hours¹. The start of the holding time period for all samples commences when the sample is split at the laboratory.

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.

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

¹ The target sampling duration may be modified after additional flow monitoring.

around the weather forecast and available personnel. NOAA's forecast for Federal Way and the University of Washington's forecast for Sea-Tac will be used to assess whether a storm will qualify for sampling (as defined in Section 5.4). If a storm qualifies, the forecasts will be used to define the timing of sampling. The following websites will be used:

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

http://www.atmos.washington.edu/mm5rt/rt/meteograms_d3.cgi?current_gfs

When a qualifying storm is forecast, field personnel will prepare for the event. If there are uncertainties or questions about the forecast, the field team and the project manager will discuss how to proceed. 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. The sampler will be programmed based on the predicted rainfall amount.

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 taken²
- 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 one of the field staff leads (Jeff Droker or Houston Flores)

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

OR

- 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 6.

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.

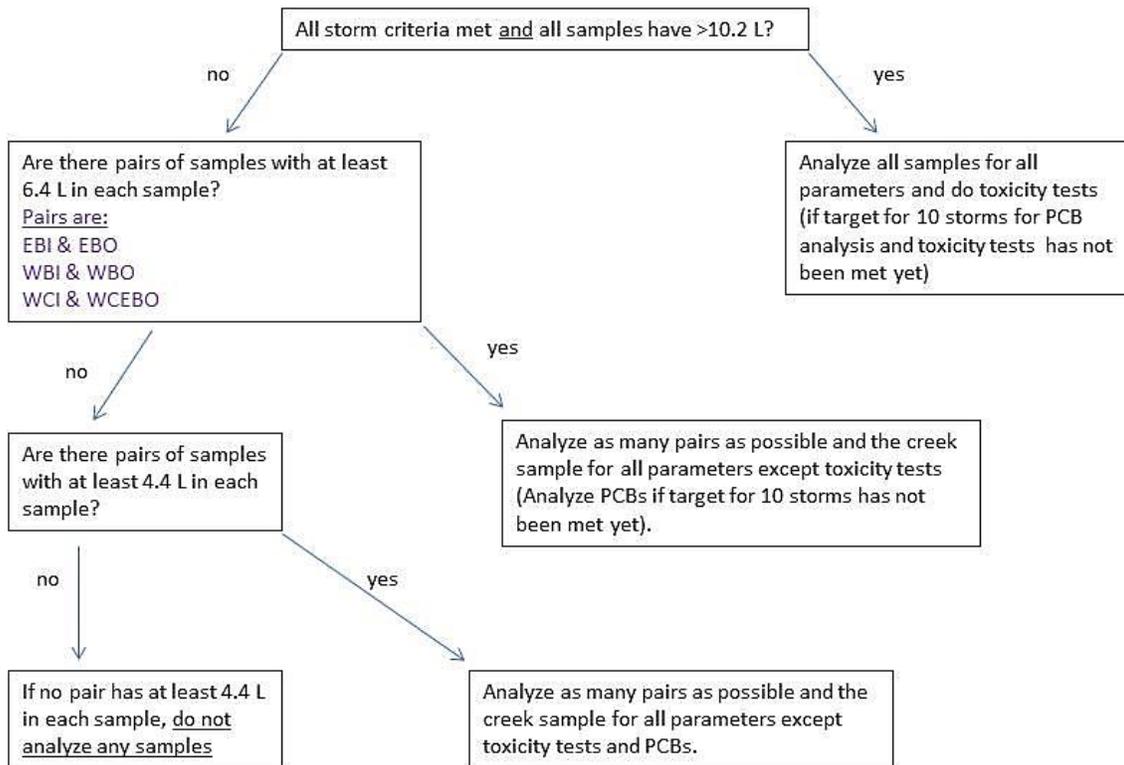


Figure 6. Decision tree to determine which samples and parameters to analyze if target volumes are not met .

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 9 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 9. 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 $\leq 6^{\circ}$ C	NA	Cool to $\leq 6^{\circ}$ C	14 days
pH	500-mL CWM HPDE (collect with COND & TURB)	Cool to $\leq 6^{\circ}$ C	15 minutes	Cool to $\leq 6^{\circ}$ C	15 minutes
Conductivity (COND)	500-mL CWM HPDE (collect with ALK & TURB)	Cool to $\leq 6^{\circ}$ C	NA	Cool to $\leq 6^{\circ}$ C	28 days
Turbidity (TURB)	500-mL CWM HDPE (collect with ALK & COND)	Cool to $\leq 6^{\circ}$ C	NA	Cool to $\leq 6^{\circ}$ C	2 days
Total Organic Carbon	125-mL amber glass	Cool to $\leq 6^{\circ}$ C	1 day	Add H_3PO_4 to pH < 2, Cool to $\leq 6^{\circ}$ C	28 days
Dissolved Organic Carbon	125-mL AWM HDPE	Cool to $\leq 6^{\circ}$ C	1 day	Filter, H_3PO_4 to pH < 2, Cool to $\leq 6^{\circ}$ C	28 days
Total Suspended Solids	1-L CWM HDPE	Cool to $\leq 6^{\circ}$ C	NA	Cool to $\leq 6^{\circ}$ C	7 days
Ammonia-N (NH_3)	60-mL CWM HDPE (collect together with nitrate + nitrite and ORTHOP)	Cool to $\leq 6^{\circ}$ C	1 day	Filter and freeze at -20° C	14 days
Nitrate + Nitrite	60-mL CWM HDPE (collect together with NH_3 and ORTHOP)	Cool to $\leq 6^{\circ}$ C	1 day	Filter and freeze at -20° C	14 days
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 $\leq 6^{\circ}$ C	2 days ^a	Freeze at -20° C	28 days
Total Phosphorus	Same container as	Cool to $\leq 6^{\circ}$ C	2 days ^a	Freeze at -20° C	28 days

Analyte(s)	Container	Storage Prior to Preservation	Preservation Holding Time	Preservation Technique	Analysis Holding Time
	Total Nitrogen				
Total Metals and Hardness	Acid washed 500-mL HDPE	transport on ice	Add acid at least 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 at least 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	24 hours
Polycyclic Aromatic Hydrocarbons	1-L ANM glass	NA	NA	Cool to ≤6° C in the dark ^b	7/40 days ^c
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 ^d

^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 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.

^c Seven days from sampling to extraction, 40 days from extraction to analysis.

^d 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 C). 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. Antecedent dry period (in days) before the start of the collection period for each location
 5. 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 reusable 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 10 summarizes required QA/QC samples for this project.

Table 10. 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 King County will follow to measure continuous temperature and turbidity, and collect macroinvertebrates are described in the 2012 Federal Way QAPP in Appendix A.

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 11 presents the manufacturer’s specifications for accuracy and resolution for water level, temperature and barometric pressure (Appendix D).

Table 11. Accuracy and resolution of the HOBO U20L-04 water level loggers.

Parameter	Accuracy	Resolution
Water level	Typical error: $\pm 0.1\%$ FS, 0.4 cm water; Maximum error: $\pm 0.2\%$ FS, 0.8 cm water	0.14 cm water
Temperature	$\pm 0.44^\circ\text{C}$ from 0° to 50°C	0.10°C
Raw pressure	$\pm 0.3\%$ 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 12 presents methods and detection limits for parameters analyzed at KCEL.

Table 12. Method and detection limits for parameters analyzed at the KCEL

Parameter	Analytical Method	Method Detection Limit	Reporting Detection Limit
Conductivity	SM2510-B	1 umhos/cm	5 umhos/cm
Alkalinity	SM2320-B	1 mg CaCO ₃ /L	5 mg CaCO ₃ /L
Turbidity	SM2130-B	0.2 NTU	0.5 NTU
pH	SM4500-H-B	N/A	N/A
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
Nitrate-nitrite Nitrogen	SM4500-NO ₃ -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	0.01 to 0.02 µg/L	0.05 to 0.1 µg/L

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 if a sample contains more than 1% total solids, the solids and liquid will be extracted and analyzed separately.

Table 13 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 13 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 13. 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-011	1.8	PCB-081	1.0	PCB-154	1.0
PCB-012/013	1.8	PCB-082	1.3	PCB-155	3.8
PCB-014	1.6	PCB-083/109	1.0	PCB-156	0.4
PCB-015	2.0	PCB-084	1.0	PCB-157	0.4
PCB-016	1.7	PCB-085	1.1	PCB-158	0.5
PCB-017	1.8	PCB-086/117	1.0	PCB-159	0.5
PCB-018	1.5	PCB-087/115	1.0	PCB-163/164	0.6
PCB-019	2.0	PCB-088	1.0	PCB-165	0.6
PCB-020/033	1.0	PCB-089	1.0	PCB-166	0.5
PCB-021	1.2	PCB-090	1.1	PCB-167	0.4
PCB-022	1.1	PCB-091/121	0.9	PCB-168	0.6
PCB-023	0.8	PCB-092	1.2	PCB-169	0.4
PCB-024	1.4	PCB-093/098/102	1.0	PCB-170	0.7
PCB-025	0.9	PCB-094	1.1	PCB-171	0.7
PCB-026	0.7	PCB-095	1.0	PCB-172	0.7
PCB-027	0.9	PCB-096	0.7	PCB-173	0.9
PCB-028	0.9	PCB-097/116	1.0	PCB-174	0.8
PCB-029	0.7	PCB-099	0.9	PCB-175	0.8
PCB-030	1.2	PCB-100	0.9	PCB-176	0.6
PCB-031	0.7	PCB-101	1.0	PCB-177	0.7
PCB-032	1.5	PCB-103	0.8	PCB-178	0.8
PCB-034	1.0	PCB-104	2.7	PCB-179	0.5

PCB(s)	MDL (pg/L)	PCB(s)	MDL (pg/L)	PCB(s)	MDL (pg/L)
PCB-035	1.1	PCB-105/127	0.5	PCB-180	0.7
PCB-036	1.0	PCB-106	0.6	PCB-181	0.8
PCB-037	1.4	PCB-107/108	0.6	PCB-182/187	0.8
PCB-038	1.2	PCB-110	0.8	PCB-183	0.7
PCB-039	1.1	PCB-111	0.8	PCB-184	0.5
PCB-040/057	1.1	PCB-112/119	0.8	PCB-185	0.8
PCB-041	1.5	PCB-113	0.8	PCB-186	0.6
PCB-042	1.3	PCB-114	0.5	PCB-188	1.2
PCB-043/049	1.2	PCB-118	0.5	PCB-189	0.3
PCB-044	1.5	PCB-120	0.8	PCB-190	0.4
PCB-045	1.2	PCB-122	0.6	PCB-191	0.5
PCB-046	1.4	PCB-123	0.6	PCB-192	0.6
PCB-047/048	1.3	PCB-124	0.5	PCB-193	0.5
PCB-050	1.1	PCB-125	0.8	PCB-194	0.5
PCB-051	1.1	PCB-126	0.4	PCB-195	0.5
PCB-052/069	1.0	PCB-128/162	0.6	PCB-196	0.7
PCB-053	1.1	PCB-129	0.7	PCB-197	0.6
PCB-054	1.2	PCB-130	0.8	PCB-198	0.6
PCB-055/080	0.9	PCB-131	0.8	PCB-199	0.9
PCB-056	0.9	PCB-132/161	0.6	PCB-200	0.6
PCB-058	0.9	PCB-133	0.7	PCB-201	0.6
PCB-059	0.9	PCB-134	0.9	PCB-202	0.9
PCB-060	1.0	PCB-135	1.3	PCB-203	0.7
PCB-061	1.0	PCB-136/148	1.0	PCB-204	0.6
PCB-062	1.0	PCB-137	0.7	PCB-205	0.3
PCB-063	0.8	PCB-138/160	0.6	PCB-206	0.8
PCB-064/072	0.9	PCB-139/149	1.2	PCB-207	0.8
PCB-065/075	0.8	PCB-140	0.6	PCB-208	0.9
PCB-066	0.8	PCB-141	0.7	PCB-209	0.6
PCB-067	0.9	PCB-142	0.7		

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 field measurements that had previously been collected by the City, and will now be collected by King County, are described in the Federal Way 2012 QAPP (Appendix A).

The QC requirements for the water level and temperature measurements collected by King County are described here. 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 remeasuring water levels in the pipes at each station when flows are present (for at least one 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 14. 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%
pH	NA	+/- 0.2 pH units ^a	NA	NA	+/- 0.2 pH units ^a
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%

^a Absolute difference rather than RPD

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 15. Metals QC samples and control limits

Parameters	Method Blank	Lab Duplicate (%RPD)	Matrix Spike (% Recovery)	Lab Control 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 16. Individual PAH matrix spike limits

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
1-Methylnaphthalene	41	94	40
2-Methylnaphthalene	41	94	40

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
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
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 17. 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

Analyte	Lower QC Limit (%)	Upper QC Limit (%)	%RPD
Indeno(1,2,3-cd)Pyrene	59	120	40
Naphthalene	39	94	40
Phenanthrene	55	104	40
Pyrene	52	123	40

Table 18. 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 labeled surrogate standards (Table 19) 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 19. 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 20.

Table 20. 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:

- Reanalyzing the samples
- Re-extracting the samples
- Repreparing of the calibration verification standard for laboratory analyses
- Recalibrating 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:

- Test type: Static non-renewal,
- Test duration: 48 Hr
- Temperature: 20°C ±1°C;
- Light quality: Ambient laboratory illumination
- Light intensity: 10-20 µE/m²/s (50-100 ft-c)
- Photoperiod: 16 h light, 8 h darkness
- Test chamber size: 30 mL
- Test solution volume: 25 mL

- Age of test organisms: Less than 24-h old
- Number of organisms per replicate: 5
- Number of chambers per concentration: 4
- Number per concentration: 20
- Feeding regime: Feed YCT and *Selenastrum* while holding prior to the test
- Dilution water: Uncontaminated well water
- Test concentrations: 100% and a control
- Endpoint: Mortality
- 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:

- Test type: Static renewal (required)
- Temperature (EC): 25 ± 1EC
- Light quality: Ambient laboratory illumination (recommended)
- Light intensity: 10–20 µE/m²/s, or 50–100 ft-c (ambient laboratory levels)
- Photoperiod: 16 h light, 8 h dark
- Test chamber size: 30 mL
- Test solution volume: 15 mL
- Renewal of test solutions: Daily
- Age of test organisms: Less than 24 h; and all released within a 8-h period
- Number of neonates per test chamber: 1 Assigned using blocking by known parentage
- Number of replicate test chambers per concentration: 10
- Number of neonates per test concentration: 10
- Feeding regime: Feed 0.1 mL each of YCT and algal suspension daily
- Aeration: None (recommended)
- Dilution water: Uncontaminated source of natural water,
- Test concentrations: 100% and a control
- Test duration: Until 60% or more of surviving control females have three broods (maximum test duration 8 days)
- Endpoints: Survival and reproduction

- Test acceptability criteria: 80% survival, average of 15 or more young per surviving female in the control.
- Reference Toxicant Testing: Monthly, control limits mean $IC_{25} \pm 2SD$.

8.6 Flow Data

Water levels at each sampling location will be hand measured at least three times throughout the project and compared with the readings from the meters. The meters 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.

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 21 (KCEL) and Table 22 (Pacific Rim Laboratory).

Table 21. 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
<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.	No qualifier added
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

KCEL Qualifier	Description	EIM Qualifier
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 22. 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)

Qualifier	Description	EIM Qualifier
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 (Monday–Friday) 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 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 CDSTW 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 CDSTW 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 receiving water data will be entered into the EIM system by the close of the project
- Final BMP data will be entered into the National BMP Database 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 CDSTW complex will utilize standard parametric tests (e.g., t-tests) or non-parametric tests (e.g., Wilcoxon signed rank tests, permutation tests) as appropriate given the distribution of the data. Concentrations or loadings from multiple facilities may be compared using ANOVAs or permutation tests (e.g., comparing % reductions in nitrogen across the two bioretention facilities and the CDSTW complex) or regression analyses (e.g., rainfall amount vs. % reductions in nitrogen by facility). For parameters with non-detect values, the project manager substitute non-detects with the MDL (as mentioned above) and $\frac{1}{2}$ the MDL, and will compare the statistical analyses and conclusions to determine how sensitive they are to the non-detects. 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. The regional applicability of the major report findings to other similar BMPs will be discussed. Lessons learned and other 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

The relevant parts of the Federal Way 2012 QAPP for this project include the continuous turbidity and temperature measurements.

Quality Assurance Project Plan

Water Quality Monitoring Study
South 356th Street

Regional Detention Facility Retrofit Project
Federal Way, Washington

GRANT #G1200017

A Project Funded by a Department of Ecology
Stormwater Retrofit and LID Grant FY2011

March 2012



Public Works Department
Surface Water Management Division
33325 8th Avenue South
Federal Way, WA 98003

Publication Information

Pursuant to the FY2011 Stormwater Retrofit and LID Competitive Grant Program Funding Agreement (Grant Number G1200017) between the State of Washington Department of Ecology and the City of Federal Way, Task 6 Monitoring, the City must have an approved Quality Assurance Project Plan (QAPP). The plan describes the objectives of the study and the procedures to be followed to achieve those objectives.

Data for this project will be available on Ecology's Environmental Information Management (EIM) website at www.ecy.wa.gov/eim/index.htm.

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Quality Assurance Project Plan

Water Quality Monitoring Study South 356th Street Regional Detention Facility Retrofit Project Federal Way, Washington

March 2012

Approved by:

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APPENDICES

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Appendix C – Water Quality Data Worksheets (Calibration, Recordkeeping)
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1.0 ABSTRACT

Water quality monitoring (temperature, turbidity, benthic macroinvertebrate sampling, and flow) conducted by the City of Federal Way suggests that stormwater discharging from the South 356th Street Regional Detention Facility (RDF) is impacting downstream receiving waters in the North Fork of the Hylebos Creek (see Section 2.2). As a result, a retrofit project involving RDF expansion to improve water quality and to moderate flows discharged to downstream wetlands (which form the headwaters of the North Fork of West Hylebos Creek) has been designed.

The South 356th Street RDF retrofit project will enlarge the capacity of the RDF (currently 4 acre-feet). The improvements will allow for the storage of stormwater for bio-retention, spill containment, and better flow control. Additionally, stormwater discharging to the North Fork West Hylebos Creek is expected to be cooler and less turbid. The entire retrofit construction project (including the water quality monitoring effort), is funded by the Surface Water Management division and a Department of Ecology Stormwater Retrofit and LID Grant (FY 2011) #G1200017.

This water quality study will involve stormwater and surface water quality monitoring associated with the retrofit of the South 356th Street RDF in Federal Way, Washington. Results of the study will be compared to available water quality guidelines and background levels, and will provide a means to evaluate the effectiveness of the RDF retrofit project in buffering flows and reducing targeted stormwater pollutants.

2.0 INTRODUCTION

2.1 Background

Up until the mid-1990's, stormwater runoff in the South 356th St. RDF retrofit project drainage basin was captured in a small detention pond north of the project site. But due to frequent and severe flooding events in the basin, the South 356th Street Regional Detention Facility (RDF) was constructed in 1997 to provide over ten-times the stormwater capacity of the original pond.

All stormwater tributary to the South 356th St. RDF originates from 223-acres of highly developed commercial, industrial and retail land use areas within the City of Federal Way (See Figure 1). The 21 acre-foot capacity facility (located just north of South 356th Street between State Route 161 and Highway 99) was designed to provide additional storage and modulated flow (to reduce downstream flooding). It also affords pollutant removal capabilities with an oil/water separator at the inlet and sedimentation bays located in the interior of the pond.

The South 356th Street RDF is located at the headwaters of the North Fork of West Hylebos Creek (WRIA 10, tributary number 0013), a watercourse that provides spawning and rearing habitat for Chum, Coho and Chinook salmon as well as to resident cutthroat trout. Numerous habitat restoration projects and conservation property purchases have been carried out along this watercourse to improve and preserve salmonid spawning and rearing habitat.

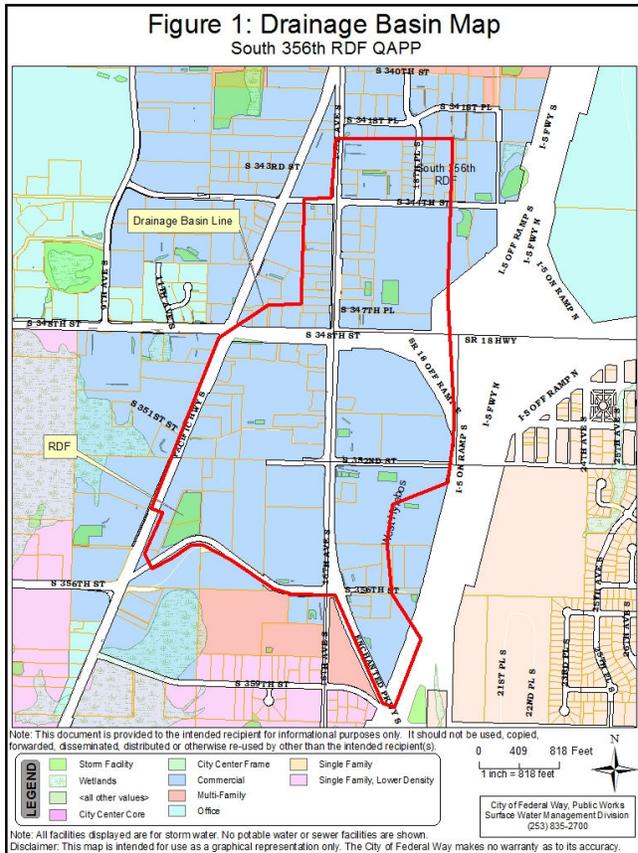
The City of Federal Way operates under a Western Washington Municipal Phase II NPDES Stormwater Permit, which was issued January 17, 2007 and became effective February 16, 2007. The permit expires February 15, 2012.

2.2 Historical Data Review

The North Fork of the West Hylebos Creek is not listed per Washington State's Water Quality Assessment (representing the Integrated Report for Sections 303(d) and 305(b) of the Clean Water Act). However, historical monitoring data suggests that stormwater may be impacting receiving waters. The following outlines three specific water quality problems recently studied by the City of Federal Way: temperature, turbidity, and impacts to macroinvertebrate communities. These data help to provide baseline conditions and may be used to gauge the effectiveness of the completed South 356th Street RDF retrofit project.

2.2.1 *Historical Temperature Monitoring*

From 2002 to the present, Surface Water Management (SWM) conducted temperature monitoring at both the existing South 356th Street RDF outlet and downstream in the North Fork of the West Hylebos Creek. The cumulative temperature data suggests that stormwater discharging from the RDF during the summer months is warming downstream receiving waters. While summertime discharges from the regional detention facility have not contributed to exceedances of Washington State freshwater designated uses and criteria standards, the temperature increases are of a magnitude sufficient to be of concern for downstream aquatic organisms, including juvenile salmon and trout.



Thermistor sensors (reliable, accurate, relatively inexpensive and durable instruments that require little maintenance) were used to measure regional detention facility stormwater discharge and downstream water temperature. A continuous temperature monitoring protocol was established that utilized optical TidbiT StowAway Loggers[®] and YSI[®] 6-series multi-parameter sondes. The monitoring instruments in this study area were positioned at two in-situ sites: 1) South 356th Street RDF outlet; and, 2) North Fork West Hylebos Creek stream at South 359th Street (approximately 0.2 miles downstream). Instruments were placed in the main flow-path to avoid measurement bias from the warmer stream edges and from thermal stratification.

All temperature thermistors were programmed to record measurements at 30-minute sample intervals. The TidbiT thermistors used for in-stream temperatures have a range of -4 to 37 degrees C; and an accuracy of ±0.2 degrees C. The YSI water quality sondes (Model 600XL or 6920) thermistors have a range of -5 to 45 degrees C; and an accuracy of ±0.15 degrees C.

Quality control procedures were used to generate consistent, representative, and comparable temperature data. These procedures included equipment calibration with known standards and implementation of personnel training (attention to detail; careful documentation; follow manufacturer's instructions; and adhering to the required process steps).

Data management involved a close examination for outliers, aberrations, abnormalities, and deviations. The following procedures were followed to generate a reliable master temperature database:

1. The data were scanned for gaps and dates are noted.
2. To assist with this exercise, annual data were graphed for each site to visually determine if any obvious irregularities exist.
3. The site activity logs were examined to confirm periods of unreliable and/or suspicious data.
4. Best professional judgment was used to remove abnormal data points. These included: data logged during download events; data recorded during periods when the thermistor was out of the water; and when other circumstances affected the accuracy of the data.
5. When available, corresponding sonde temperature data were used to fill in missing TidBiT data.
6. Flow metering data were analyzed to help eliminate temperature data collected during periods of no flow. As a general rule, if flow was absent at the site for five or more consecutive days, then the temperature data for that corresponding period of time were removed and noted as “no flow”.

Water temperature was measured by the 7-day average of the daily maximum temperatures (7-DADMax). The 7-DADMax for any individual day was calculated by averaging that day’s daily maximum temperature with the daily maximum temperatures of the three days prior to, and the three days after that date.

Per WAC 173-201A-200, the Aquatic Life Use for the North Fork of West Hylebos Creek at South 359th Street is classified as (1)(a)(iii), “Salmonid spawning, rearing and migration”, with a 7-DADMax temperature standard specified as 17.5 °C (63.5 °F).

The following data summary provides further detail concerning historical temperature monitoring focused on 16 individual stormwater discharges (associated with rain events) from the S. 356th Street RDF. These data document downstream temperature impacts to the North Fork of the West Hylebos.

Table 1. Temperature, South 356th Stormwater Pond Outlet and North Fork West Hylebos Creek at South 359th Street, 2002-2008

Date	Approximate Downstream Temperature Increase (°C)	Highest 7-DADMax Measurement at South 359th Street During Event (°C)
June 28, 2002	4	14.11
July 7, 2002	4	14.13
October 7, 2003	2	12.57
October 17, 2003	2	12.25
October 20, 2003	5	14.98
August 22, 2004	5	17.38
September 11, 2004	5	15.72
June 17, 2005	4	13.46
July 6, 2005	5	13.60
May 24-25, 2006	3	13.36
June 2-4, 2006	4	15.04
June 29, 2007	4	14.39
July 19-21, 2007	4	16.77
August 19-21, 2007	4	16.17
August 24, 2008	3	16.08
August 27, 2008	1	15.67

2.2.2 Historical Turbidity Monitoring

From 2001 to 2005, stormwater at both the inlet and outlet to the S. 356th RDF were measured for turbidity. Grab samples were collected during this period and submitted for analysis to Test America (formerly Severn-Trent Laboratories) by EPA Method 180.1, or analyzed in-house using a Hach 2100P Turbidimeter.

The following table summarizes historical turbidity monitoring findings:

Table 2. Turbidity, South 356th RDF, 2001-2005

Total number of samples	44
Average turbidity at RDF inlet	120 NTU
Average turbidity at RDF outlet	49 NTU
Number of samples exceeding 50 NTU / Average turbidity	16 / 111 NTU
Highest recorded value	350 NTU

Staff continues to work on eliminating upstream turbidity sources. Through the Western Washington Stormwater permit program, the City has implemented extensive educational efforts and enforcement actions targeting turbid discharges. In 2006, a large unpaved commercial property within the watershed was redeveloped, eliminating a significant source of turbid stormwater. Several more sources are currently implementing best management practices and undergoing corrective actions to eliminate prohibited turbid discharges to the City's stormwater system and the South 356th Street RDF:

- Corliss Resources, 35053 Enchanted Pkwy S., (covered by a Department of Ecology General Sand & Gravel Stormwater Permit,#WAG 50-3255).
- United Rentals, 35100 Pacific Hwy S.
- Donald B. Murphy Contractors, 1220 S. 356th St.
- South 351st Street (a graveled private driveway).

2.2.3 Historical Benthic Macroinvertebrate Monitoring (B-IBI)

Benthic macroinvertebrates are particularly well suited for bio-monitoring; they are diverse and abundant, sensitive to human disturbance, and are excellent indicators of a stream's condition. Macroinvertebrates are also key components of the aquatic food web, often long-lived, and not migratory. Traditional chemical and physical stream measurements often do not provide sufficient information to detect or resolve all surface water problems; however, measurement of the diversity and quantity of microorganisms living in a waterway can help to determine the overall health of an aquatic system.

As a supplement to water quality measurements, biological monitoring of benthic macroinvertebrate populations have been conducted for more than ten years in the North Fork West Hylebos Creek, at S. 359th Street in order to better assess the impacts of the highly developed portion of the watershed on the downstream environment. The multi-metric benthic index of biotic integrity (B-IBI) is used to summarize invertebrate data. It is composed of ten metrics representing multiple biological aspects that are consistent and predictable in their response to human disturbances affecting stream health (Fore et al., 1996 and Karr and Chu, 1999). The ten metric scores are added together to produce a total B-IBI score that is rated qualitatively as excellent, good, fair, poor or very poor.

The following summarizes B-IBI scores recorded at North Fork Hylebos Creek at South 359th Street, between 1999 and 2011:

Table 3. B-IBI Scores, North Fork West Hylebos Creek 2001-2011, and Scoring Criteria

Year	B-IBI Score	Scoring Criteria
1999	14	Very Poor
2000	14	Very Poor
2001	20	Poor
2002	18	Poor
2003	20	Poor
2004	27	Poor
2005	24	Poor
2006	26	Poor
2007	24	Poor
2008	18	Poor
2009	20	Poor
2010	30	Fair
2011	26	Poor

As with many urban streams, the subject drainage system has been degraded. This is supported by the macroinvertebrate data presented above which show metric B-IBI scores consistently in the range of “very poor” to “fair”, indicating overall depressed diversity. Improvements to water quality and flow are expected to improve the downstream aquatic environment.

2.2.4 Historical Flow Monitoring

Flow monitoring and data logging equipment have been installed at the South 356th RDF outlet since 2001 (Isco 4250 Flow Meter and area-velocity sensor mounted in the RDF 60-inch diameter concrete stormwater outlet pipe). Historical flows have been calculated from measured water surface levels, the size and shape of the channel, and the water velocity. Archived data is available upon request.

3.0 PROJECT DESCRIPTION AND GOAL

3.1 Retrofit Project Description

This project will expand and retrofit the existing South 356th Street RDF. The following lists three general goals planned for the proposed South 356th Street Regional Detention Facility (RDF) Retrofit project:

1. Improve water quality
2. Improve flow control
3. Incorporate improved spill containment

The project goals will be achieved through the construction/ incorporation of the following elements:

- A wet pond that will be sized to capture and infiltrate the majority of summer warm stormwater runoff;
- A detention pond that will provide additional detention capacity to address downstream erosion/streambed migration;
- Bio-retention areas;
- Removal of impervious roadway surface, use of pervious pavement and extensive native plantings.
- Retrofitting the existing RDF to provide an additional level of spill containment.

These improvements are necessary to address the following stormwater induced problems downstream of the facility:

- Thermal pollution of receiving waters during summer time discharges from the RDF;
- Stream channel erosion downstream of the wetland that is restricting fish passage;
- Excessive migration of streambed materials; and,
- The potential for contamination of downstream resources due to spill events within the heavily developed upper watershed.

3.2 Retrofit Project Goals

The following lists the expected goals of the South 356th Street RDF Retrofit Project:

1. Expansion of the RDF will increase the detention capacity of the facility and will reduce downstream erosion and streambed migration. The added detention will bring the facility more into line with current flow control requirements (based on the 2009 King County Surface water Design Manual), allowing future repairs to the downstream channel to remain functional and continue to facilitate the movement of fish between the defined channel and the wetland complex. Added streambed stabilization resulting from reduced peak flows will expand the viable spawning habitat for salmonids and improve habitat for benthic invertebrates.
2. The expanded RDF will incorporate a wet pond to capture and infiltrate the summer warm stormwater runoff, thereby reducing the temperature of summertime discharges to downstream wetland complex. The outlet structure will also be designed to accommodate long-term hydraulic and water quality monitoring equipment.
3. The proposed project will offer a greater degree of protection to the downstream wetland/stream complex. Emergency bypass and gates will be added to the existing RDF to capture contaminated flow resulting from large spill events that may occur during storm events and contain it in the existing RDF.
4. The bio-retention area will treat flows that currently bypass the RDF.
5. RDF expansion will help to reduce discharge turbidity levels by increasing residence time within the facility. A decrease in the discharge turbidity will benefit both spawning beds and benthic invertebrate habitat.
6. The RDF retrofit project will provide an increase in stormwater infiltration through the construction of a bio-retention area, removal of impervious surfaces and the installation of native

plantings. Increased infiltration will help to reduce surface water flows into the wetland, provide additional water quality benefits and will contribute to groundwater availability up-gradient of the wetland.

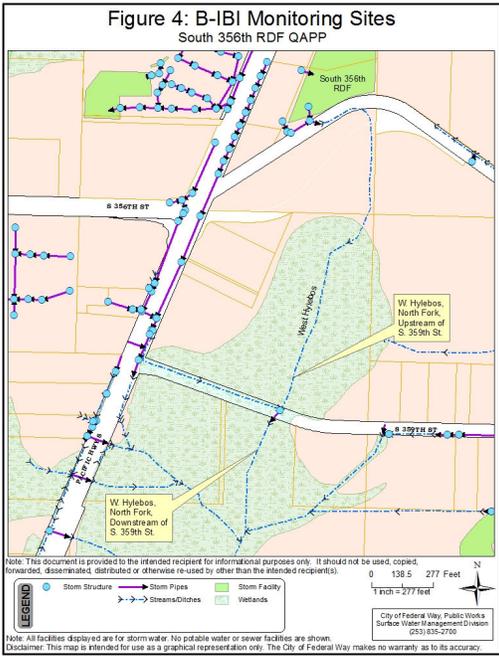
3.3 Water Quality Monitoring Project Objectives

Per the grant agreement, the South 356th Street Regional Detention Facility Stormwater Retrofit Water Quality Monitoring effort will continue through all phases of the project until expiration (December 31, 2014), as well as for a period of four years following the completion of the project. The effort will include the following stormwater and surface water quality monitoring elements:

1. Stormwater quality monitoring at the RDF inlet for temperature and turbidity (see Figure 2).
2. Stormwater quality monitoring at the RDF outlet for temperature and turbidity (see Figure 2).
3. Surface water quality monitoring in the North Fork of the West Hylebos Creek at South 359th Street for temperature (see Figure 3).
4. Surface water quality monitoring both the upstream and downstream North Fork of the West Hylebos Creek at South 359th Street for benthic macro invertebrates (B-IBI) (see Figure 4).
5. Stormwater flow monitoring at the RDF outlet (see Figure5).

The purpose of this project is to continue to gather water quality data in order to assess the effectiveness of the 356th Street Regional Detention Facility Stormwater Retrofit and LID Grant project. These chemical, physical and biological parameters and methods were chosen to support, in part, long term watershed water quality improvements and salmon restoration efforts. This QAPP will provide minimum standards and guidelines that all participants will utilize. The major goal is to generate consistent, representative, and comparable field data that the City of Federal Way can utilize to evaluate the effectiveness of the RDF retrofit project on improving surface water quality in North Fork of the West Hylebos Creek over the long term.

The best approach to ensure that data are most representative is to ensure that field and laboratory personnel are well trained and exhibit a professional's attention to detail; that equipment calibrations are well documented and performed carefully and consistently following manufacturer's instructions; and that protocol development has followed the process steps outlined in this QAPP.



This QAPP utilizes the following protocols and guidance documents:

Water Quality and Flow Monitoring:

1. Surface Water Management (SWM) YSI 6-Series Sonde Field SOPs (Appendix A)
2. Isco Flow Meter Instruction Manuals (Model 4250), 2011
3. Environmental Monitoring Systems Manual for 6-Series Sondes, YSI, Inc., 2011.
4. YSI 6-Series Manual Supplement, YSI, Inc., 2011.
5. YSI 6-Series Field and Calibration Tip Sheets, YSI, Inc., 2010
6. YSI 650 Operating Manual, 2011
7. YSI 581 Rapid Transfer Device Manual, 2011
8. *Guidelines and Standard Procedures for Continuous Water Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting*, United States Geological Survey (USGS), 2000.
9. *Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams Conducted in a Total Maximum Daily Load (TMDL) Project for Stream Temperature*, Washington State Department of Ecology, EAP, 2009.
10. Surface Water Management (SWM) Temperature Logger SOPs (Appendix B)
11. TidbiT v2 and HOBO Waterproof Shuttle Users Manuals, Onset Corporation, 2011

Note: YSI documents can be accessed through their Document Library at:
<http://www.ySI.com/resource-library.php>

B-IBI Monitoring:

1. *Measuring the Biological Integrity of Puget Sound Lowland Streams*, Fore, 1999.
2. *Assessing Invertebrate Responses to Human Activities: Evaluating Alternative Approaches*, Fore, et al., 1996
3. *Assessing and Restoring the Health of Urban Streams in the Puget Sound Basin*, Karr and Chu, 2002.
4. *Washington State Department of Ecology, EAP, Standard Operating Procedures and Minimum Requirements for the Collection of Freshwater Benthic Macroinvertebrate Data in Wadeable Streams*, Version 1.0, 2011.
5. *Washington State Department of Ecology, Multi-Metric Index Development for Biological Monitoring in Washington State Streams*, 2003.

3.4 Project Management and Oversight

This project will be managed by the City of Federal Way, Surface Water Management division. The project team will meet periodically to communicate progress, problems, and plan future activities. All products, including this QAPP, will be reviewed by the project team assigned to this grant. The QAPP may be revised as needed to address changing monitoring situations.

4.0 ORGANIZATION AND SCHEDULE

4.1 Staff List and Rolls

Project Lead *Dan Smith, Surface Water Quality Program Coordinator*
(253) 835-2756
Responsible for managing the project, preparing the QA Project Plan, coordinating and completing sampling activities, analyzing project data and EIM data migration, and preparing the draft and final data reports. Serves as the principal public contact for the technical water quality and monitoring aspects of the study.

Project Assistant *Jarred Larson, Water Quality Technician*
(253) 835-2793
Responsible for assisting with sampling activities, analyzing project data, data reporting/management, EIM data migration, and QA/QC.

4.2 Major Activities and Timelines

The major timelines of the field data collection, data management, QA/QC, EIM data entry, preparation of draft report, completion of final report include:

Table 4. Major QAPP Timelines

Task	Schedule	Responsibility
Preparation and submittal of draft QAPP	September 2011	Water Quality Coordinator
Preparation of updated draft QAPP	February 2012	Water Quality Coordinator
Field data collection	January 2011 – December 2014	Water Quality Coordinator; Water Quality Technician
Data processing, analysis, and preparation of data report	January 2011 – December 2014	Water Quality Coordinator; Water Quality Technician
QA/QC implementation	January 2011 – December 2014	Water Quality Coordinator; Water Quality Technician
Begin entering data into EIM	October 2014	Water Quality Coordinator; Water Quality Technician
Prepare and submit draft final report	November 2014	Water Quality Coordinator
Prepare and submit final report	December 2014	Water Quality Coordinator

4.3 Grant Budget and Funding

Table 5. Grant Water Quality Monitoring Project Budget

Task	Total Project Cost	Total Eligible Cost
1 - Monitoring	\$54,296	\$54,296

5.0 DATA QUALITY OBJECTIVES

High quality data is critical to accurately assess the condition of stormwater and surface water. The following lists the types of environmental data to be collected in this study:

Table 6. QAPP Environmental Data Types

Data Type	Units
Water Quality Parameters	
Turbidity	NTU
Temperature	°C
Biological Parameters	
B-IBI	Number of individuals of each taxon
Physical Parameters	
Flow	CFS

The specific data quality objectives, as discussed below, include accuracy and precision, bias, representativeness, comparability, completeness, and sensitivity.

5.1 Accuracy and Precision

Accuracy is the measure of the difference between an analytical result and the true value, usually expressed as percent. The accuracy of a result is affected by both systematic errors (bias) and random errors (imprecision).

Precision is the degree of agreement between replicate analyses of a sample under identical conditions and is a measure of the random error associated with the analysis, usually expressed as Relative Percent Difference (RPD) or Relative Standard Deviation (RSD).

All field water quality instruments are calibrated regularly using standard solutions such that their accuracy may be quantified. Flow monitoring also undergoes periodic calibration. This protocol involves the implementation of appropriate field and laboratory Standard Operating Procedures (SOPs) and QA/QC procedures.

Data quality objectives also emphasize accuracy and precision of benthic macroinvertebrate identification at the family level of taxonomy, which will be supported by following appropriate field and laboratory Standard Operating Procedures (SOPs) and QA/QC procedures used by the benthic laboratory.

5.2 Bias

Bias is the systematic or persistent distortion of a measurement process that causes errors in one direction (Zar 1999). The primary technique for avoiding bias in the course sampling will be the frequent, planned calibration of field water quality instruments. In-situ calibration checks will also occur. Any failures during calibration will result in the repair or replacement of the water quality equipment.

5.3 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.

For in-situ monitoring, the sonde or temperature logger is placed at a location where the water is well-mixed and most representative of the ambient conditions.

Benthic data collection follows standard protocols in focusing on the most biologically productive habitat types (e.g., riffles). These habitats are sampled in proportion to their occurrence within the sample site. For example, field staff collect samples from appropriate habitat locations within the study reach, that represent a total of three square meters. Samples are then combined into one composite sample most representative of the entire stream segment. Representativeness refers to a qualitative determination of whether B-IBI samples are collected in a manner that appropriately reflect stream conditions (Barbour, et al, 1999).

B-IBI sampling methods and techniques, sample preservation, and sample handling are interactive factors that directly affect achievement of representativeness of benthic macroinvertebrate sampling. Standard operating procedures (sampling techniques, collection, preservation, handling, and processing) will be implemented to maintain standards of representativeness.

5.4 Comparability

Comparability is a qualitative parameter expressing the confidence with which one data set can be compared to another. This goal is achieved through using standardized techniques to collect and analyze representative samples, along with standardized data validation and reporting procedures.

Comparability of data for this QAPP is supported by the use of rigorous, well-established methods applied by field and laboratory crews with proper training. Field training emphasizes the importance of consistent application of standard sample collection and handling methods. Strict adherence to all standards and protocols is emphasized throughout sampling and lab work. Any deviations are noted in project records.

5.5 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 collected. To reach completeness objectives, every effort is made to avoid sample or data loss. Sampling at stations with known position coordinates in favorable conditions and at the appropriate time points, along with adherence to standardized sampling

and testing protocols, will aid in providing a complete data set for this project. The goal for completeness is 100%.

Benthic sample loss is minimized by using sturdy sample storage containers and adequate labeling. Sample contamination can occur when containers are improperly sealed or stored. Loss of benthic material or desiccation diminishes the integrity of the sample. If the validity of the information from the sample is in question, the sample is excluded from analysis.

5.6 Sensitivity

Sensitivity is related to the ability of a measurement to detect environmental conditions of interest. Detection limits for field water quality measurements are determined by the instrument detection limits. Biological monitoring protocols specify that specific taxonomic levels are used (i.e., family level identification of benthos). The QAPP measurement performance criteria are listed below:

Table 7. QAPP Measurement Performance Criteria

Data Quality Indicator	Techniques	Measurement Performance Criteria
Precision	Direct measurements using calibrated sonde, probe, or sensor	Strict adherence to all SOPs
	Biological monitoring	Strict adherence to all SOPs
Bias	Instrument calibration (lab and field checks)	Follow manufacturer recommendations
Accuracy	Direct measurements using calibrated sonde, probe or sensor	(See Section 6.1)
	Biological monitoring	95% accuracy in benthic taxonomy
Representativeness	Qualitative determination whether data are collected in such a manner that appropriately reflect stormwater or surface water conditions	Strict adherence to all SOPs
Comparability	Use of consistent and well-maintained instrumentation, adherence to QA protocols, standardized data collection and analytical procedures	Strict adherence to all SOPs
	Collection of biological samples	Strict adherence to all SOPs
Completeness	Comparisons of the number of valid samples collected or analyzed with the number targeted to meet project objectives	Benthic sorting efficiency \geq 90%
		Benthic data 95% complete
Sensitivity	Noting the minimum units that can be measured	See specific detection limits as per manufacturer
	Use of appropriate levels of identification for biological samples	Benthic identification to genus/species

6.0 FIELD SAMPLING DESIGN

The field sampling effort is designed to collect data needed to assess the effectiveness of the RDF Retrofit Project. The overall design of the field data collection effort includes water quality monitoring (turbidity, and temperature) B-IBI monitoring, and flow monitoring as described in the table below:

Table 8. Field Sampling Design Outline

Parameter	Type	Equipment	RDF Inlet	RDF Outlet	North Fork West Hylebos Creek, Upstream of S. 359 th St.	North Fork West Hylebos Creek, Downstream of S. 359 th St.
Temperature	Continuous	YSI 6920/TidBIT v2 Logger	X	X	X	
Turbidity	Continuous	YSI 6920	X	X		
B-IBI*	Annual	N/A			X	X
Flow	Continuous	Isco 4250, A-V probe		X		

*Per Ecology B-IBI SOPs, 2011

6.1 Water Quality Monitoring

The objective of the South 356th Street RDF Retrofit Project Water Quality Monitoring QAPP is to provide for the accurate measurement, management and interpretation of water quality information. It is important to note that the RDF Retrofit Project QAPP is partially based upon a previous water quality monitoring program developed by SWM for a 2004 Department of Ecology Centennial Grant QAPP (West Hylebos Creek Restoration, Department of Ecology Grant # G0300233). As such, the lessons learned from the 2004 Centennial Grant QAPP (including improvements and modifications) have been incorporated into the South 356th Street RDF Retrofit Project Water Quality Monitoring QAPP.

6.1.1 YSI 6920 Multi-parameter Sonde Location

Two water quality monitoring stations will be established for this project (see Figure 2). Below is a description of each location:

Water Quality Monitoring Site Number 1 South 356th RDF Inlet

This site is located at the South 356th RDF inlet (north side). One YSI 6920 water quality sonde will be installed in-situ inside the inlet structure. The site was chosen because of its security, accessibility, and representation of uniform stormwater flow conditions at the facility inlet. To prevent damage, the sonde will be protected within a PVC stilling well installed in the inlet structure. The placement of the sonde will meet the minimum depth requirements for all instrument probes.

Water Quality Monitoring Site Number 2 South 356th RDF Outlet

This site is located south of South 356th Street in a stormwater structure just upstream from the headwaters of the North Fork of the West Hylebos Creek. One YSI 6920 water quality sonde will be installed in this structure which represents all stormwater discharging from the RDF. The site was chosen because of its security, accessibility, and representation of uniform stormwater flow conditions out of the facility. To prevent damage, the sonde will be protected within a PVC stilling well installed in the inlet structure. The placement of the sonde will meet the minimum depth requirements for all instrument probes.

6.1.2 Onset TidbiT v2 Temperature Logger Location

Thermistor sensors (optical TidbiT v2 Loggers[®]) will also be used to measure water temperature (See Appendix B for SWM Temperature Logger SOPs). Thermistors are reliable, accurate, and durable instruments that require little maintenance and are relatively inexpensive.

Three project logger locations have been selected because of their security and ease of access (see Figures 2 and 3):

- South 356th RDF Inlet
- South 356th RDF Outlet
- North Fork of the West Hylebos Creek at S. 359th Street (downstream of RDF).

6.1.3 Water Quality Instrument Principals of Operation

A detailed description of the sonde and sensor types to be used for continuous measurement of temperature and turbidity, including their measurement methods and accuracy, are found in the following sections.

6.1.3.1 YSI 6920 Sonde

Yellow Springs Instruments (YSI) model 6920 sonde will be used to assess variations in the stormwater both upstream and downstream of the project site. The sonde will be positioned in-situ at the measuring point in the storm drainage structure. The water-quality monitoring/recording is self-contained, and requires no external power. Power is supplied by conventional batteries located in a sealed compartment, and sensor data are stored within the sonde on nonvolatile, flash-memory, recording devices. The data will be manually downloaded during regular site visits approximately every 30 days and logged onto a YSI 650 MDS. All data is then uploaded to a PC.

6.1.3.2 YSI Temperature Probe (6560)

YSI temperature is measured with a thermistor, which is a semiconductor with resistance that changes with temperature. Thermistors are reliable, accurate, and durable sensors that require little maintenance and are relatively inexpensive. The YSI thermistors will measure temperature to plus or minus (\pm) 0.15 degree Celsius ($^{\circ}$ C). The range is -5 to $+45$ $^{\circ}$ C. The resolution is 0.01 $^{\circ}$ C.

6.1.3.3 Onset TidbiT v2 Temperature Logger

The Onset TidbiT v2 temperature logger utilizes a 12-bit resolution and a precision sensor. The logger will measure temperature from -20 to 70 degree Celsius (°C). The resolution is 0.02 °C. The accuracy is 0.2°C over 0° to 50°C

6.1.3.4 YSI Turbidity Probe (6136)

The turbidity sensor operates by directing a light beam from a light-emitting diode into the water sample and measuring the light that scatters off the suspended particles present in the water in nephelometric turbidity units (NTU). The YSI turbidity probe will measure within ± 5% of reading or 2 NTU, whichever is greater. The range is 0 to 1000 NTU. The resolution is 0.1 NTU.

6.2 B-IBI Monitoring

Traditional measurements of chemical and physical components for streams may not provide sufficient information to detect or resolve all surface water problems. As such, biological evaluations of surface waters may provide a broader indication of ecosystem degradation. Benthic macroinvertebrates are particularly well suited for these types of evaluations because they are diverse, abundant, sensitive to human disturbance, and are excellent indicators of stream condition. More importantly, they are key components of the aquatic food web, often long-lived, and not migratory or artificially stocked.

In order to determine the success in improving biological conditions in the North Fork of the West Hylebos Creek, two downstream monitoring sites will be monitored annually: 1) upstream of South 359th Street, and 2) downstream of South 359th Street (Figure 4). In addition, other sites historically sampled in the West Hylebos Creek basin will also continue to undergo annual biological monitoring and may be used to determine the overall health of the drainage basin.

6.3 Flow Monitoring

One flow monitoring station will be established for this project: RDF outlet, south of South 356th Street within a 48 inch pipe just upstream from the headwaters of the North Fork of the West Hylebos Creek. The site was chosen because of its security, accessibility, and representation of uniform stormwater flow discharging from the facility (Figure 5).

Flow monitoring and data logging equipment will be installed at this site (Isco 4250 Flow Meter and area-velocity sensor). The a-v sensor will be mounted within the 48 inch diameter concrete stormwater pipe in a section with consistently laminar flow. Data logging equipment and battery will be secured within a fiberglass “dog house” mounted on top of an adjacent concrete structure. Flow will be calculated from measured level, the size and shape of the channel, and the velocity of the flow stream.

7.0 MEASUREMENT PROCEDURES

The objectives of the measurement procedures will be met through a combination of field work, laboratory calibrations, field calibration checks, laboratory analysis, and in-office evaluations.

7.1 Water Quality Measurement Procedures

The general operational goal for each water quality monitoring station will include the following: 1) proper maintenance of equipment; 2) inspection and recording of sensor or logger readings; 3) cleaning, calibration and trouble-shooting of sensors or loggers and recording equipment, and; 4) the accurate recording of station activity. Field instrument specifications are provided in Table 9.

Table 9. Field Instrument Specifications

Parameter	Instrument	Method	Range	Accuracy	Resolution
Temperature	YSI 6920 sonde/6560 probe	Thermistor	-5 to +45°C	(±) 0.15°C	0.01°C
Temperature	Onset TidBiT V2 logger	Thermistor	-20 to +70°C	(±) 0.2°C	0.02°C
Turbidity	YSI 6920 sonde/6560 probe	Sensor	0-1000 NTU	(±) 5% or 2 NTU	0.1 NTU
Flow	Isco 4250 logger with A-V sensor	Area-Velocity	0.4 to 250 CFS	See Table 8	
B-IBI	N/A	Ecology B-IBI SOPs, 2011	N/A	N/A	N/A

7.1.1 YSI Sonde Maintenance

The maintenance frequency of each YSI 6920 sonde will be governed by the fouling rate of the individual sonde sensors (influenced by hydrologic conditions and the environment). Based upon experience and the availability of field staff, initial maintenance intervals will be established approximately once every 30 days. Field observations performed during maintenance activities will be recorded (see Section 9.0). These observations may include:

1. Inspection of site for signs of physical disruption
2. Inspection of sensors for fouling, corrosion, accumulation of sediment, or damage
3. Battery or power check; battery replacement
4. Time check

7.1.2 YSI Sonde Data Retrieval

Data recorded by the 6920 sonde will be retrieved in the field approximately once every 30 days using a YSI 650 MDS (Multiparameter Display System) data logging device. The data recorded by the MDS

will then be uploaded to a PC. Field calibration checks (see Section 8.1.2) will also utilize the MDS. Sonde data retrieval will adhere to the procedures outlined in Surface Water Management (SWM) YSI 6-Series Sonde Field SOPs (Appendix A).

7.1.3 YSI Sonde Cleaning, Reconditioning and Calibration

A calibration drift occurs during the period between calibration events, and is determined by the difference between readings of a cleaned sensor in standards or buffers and a calibrated sensor. Drift is generally a result of fouling (chemical precipitates, stains, siltation, or aquatic growth). Calibration checks using known standards will be performed once every 30-days on monitoring sensors to determine if they are operating outside of the acceptable calibration criteria.

Cleaning, reconditioning, laboratory calibration and troubleshooting of the YSI 6920 sondes will adhere to the procedures outlined in the following references: *YSI Environmental Monitoring Systems Manual for 6-Series Sondes*; the *YSI 6-Series Manual Supplement*; and the *YSI 6-Series Field and Calibration Tip Sheets*.

YSI Eco Watch DCP™ software using modem communications between the sonde and PC is used to perform all setup, calibration and instrument adjustment operations. Eco Watch will alert the operator with messages concerning calibration errors, sonde communication and sensor performance. All calibration activities and diagnostics will be recorded on various worksheets (Appendix C).

7.1.4 Onset TidbiT v2 Temperature Logger Procedures

Temperature monitoring will use the Surface Water Management (SWM) Temperature Logger SOPs, (Appendix B). These methods closely follow the guidance *Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams Conducted in a Total Maximum Daily Load (TMDL) Project for Stream Temperature*, Washington State Department of Ecology, EAP, 2009

7.2 B-IBI Field Monitoring and Laboratory Procedures

The following describes the B-IBI field monitoring and laboratory procedures associated with the RDF retrofit project.

7.2.1 Benthic Macroinvertebrate Field Sampling Procedures

The environmental characteristics of in-stream and riparian areas of the stream have a substantial influence on the structure and function of benthic macroinvertebrate communities. Environmental characterization biological assessment surveys will be performed in order to: 1) understand the natural physical and chemical constraints imposed on macroinvertebrate communities, and 2) detect physical and chemical changes within sensitive stream areas and adjacent riparian zones.

Since 1998, SWM has been performing B-IBI monitoring at approximately a dozen stream sites in Federal Way. During the last twelve years, a high level of proficiency has been achieved in implementing B-IBI field sampling techniques. All field sampling methods designed for the S. 356th RDF Retrofit Water Quality Monitoring Project will be consistent with the B-IBI protocols and guidance documents listed in Section 3.3, including: *Washington State Department of Ecology, EAP, Standard Operating Procedures and Minimum Requirements for the Collection of Freshwater Benthic*

Macroinvertebrate Data in Wadable Streams, Version 1.0, 2011; and *Washington Department of Ecology, Multi-Metric Index Development for Biological Monitoring in Washington State Streams*, 2003.

7.2.2 Benthic Macroinvertebrate Laboratory Procedures

Biological metrics measure different aspects of stream biology including taxonomic richness, tolerance and intolerance, habit, reproductive strategy, feeding ecology and population structure. The B-IBI qualified laboratory will follow a standard set of sample processing procedures.

The benthic index of biotic integrity (B-IBI), is composed of ten biological metrics for a given population of stream invertebrates' response to human disturbance. The scoring criteria used to integrate into the B-IBI will be consistent with the guidance, *Measuring the Biological Integrity of Puget Sound Lowland Streams*, Fore, 1999.

7.3 Flow Measurements

The principals of operations and field procedures/methods for flow monitoring are described in this section.

7.3.1 Flow Measurement Principals of Operation

Isco 4250 Area Velocity Flow Meter

The Isco 4250 Area Velocity Flow Meter uses a probe with two different sensor systems submerged in an open channel flow stream (known as an area-velocity sensor). The A-V sensor consists of a pressure transducer (measures level) and a pair of ultrasonic transducers (measures velocity).

When measuring flow rate, the 4250 flow meter calculates flow rate from a combination of the following parameters: level, stream velocity and channel cross-sectional area. This method can measure submerged, full pipe, surcharged, and reverse flows.

The flow meter contains micro-processor controlled circuitry to calculate level and flow rates from the output produced by the area-velocity sensor. It can also store user programming instructions, operate the display panel and drive the internal plotter. An alphanumeric liquid crystal display (LCD) shows current total flow, level, and flow rate information. Technical specifications for the 4250 are located in Table 9.

Data stored by the flow meter is transferred monthly via an Isco 581 Rapid Transfer Device, a collection unit designed to collect data and upload files to a PC hard drive. Data is managed by Flowlink® software, an industry-standard Microsoft Access database. The Flowlink workspace displays all of the sites and data, graphs and tables in the database.

Installation and maintenance of the A-V sensor and flow meter programming will follow the Isco 4250 Instruction Manual. Flow monitoring records will be documented per Data Management procedures outlined in Section 9.0.

Table 10. Isco 4250 Technical Specifications

Level Measurement Specifications	
Measurement Range	Standard Sensor: 0.1 to 10.0 ft.
Maximum Level	Standard Sensor: 20.0 ft.
Measurement Accuracy	Standard Sensor: (at 25 ^o C) Level change of 0.1 to 5.0 ft (±) 0.01 ft Level change of 0.1 to 7.0 ft (±) 0.03 ft
Temperature Error	Standard Sensor: to 0.4 feet (±) 0.005 foot per degree F 4.0 to 20.0 feet (±) 0.007 feet per degree F
Velocity Measurement	
Minimum Depth	2, 3, 4 inches (selected during programming)
Range	-5 to +20 feet per second
Accuracy	-5 to +5 feet per second (±) 0.1 foot per second 5 to 20 feet per second: (±) 2% of reading
Resolution	(±) 0.024 feet per second
Flow Rate Measurement	
Range	(±) 0.4 cfs to 250 cfs
Accuracy*	(Level change: 0.1 to 5.0 ft) – (V: 0.5 to 5.0 ft/s) – (Q: 0.0003 cfs) (Level change: 0.1 to 7.0 ft) – (V: 5.0 to 20.0 ft/s) – (Q: 0.0055 cfs)
Resolution	N/A

* Derived from d, v, and 48" diameter pipe

8.0 QUALITY ASSURANCE AND CONTROL

Quality assurance and control procedures will be implemented to ensure that the water quality data generated meet the highest standard. This will be achieved through the following:

- Ensuring that field and laboratory personnel are well trained and exhibit a professional’s attention to detail;
- Making certain that equipment calibrations are well documented and performed carefully and consistently following manufacturer’s instructions; and,
- Certifying that protocol development has followed the process steps outlined in this QAPP.

8.1 Water Quality Monitoring Quality Assurance and Control

Automated water-quality sondes (Yellow Springs Instruments, model 6920) and TidbiT temperature loggers will be used to assess variations in the stormwater and surface water associated with the South 356th Street RDF Retrofit Project. Because this sampling system does not involve wet chemistry analyses, quality assurance and control procedures will not involve field blanks, trip blanks, duplicates, or sample spikes.

The water quality monitoring maintenance, cleaning and calibration procedures described below will constitute the quality assurance and control protocols for the YSI 6920 sondes and TidbiT temperature loggers. These procedures will ensure that the data collected is as representative of the natural environment as possible. Adherence to these standard operation procedures will:

1. Eliminate bias (defined as the degree of the difference between the measured value and the true value due to systematic error)
2. Increase precision (defined as the measure of the variability in the results of replicate measurements due to random error).
3. Provide good representation (defined as the degree to which data appropriately describe the conditions that the program seeks to evaluate). This element is addressed through the proper selection of sampling locations.

8.1.1 YSI Sonde Field SOPs

Experience in equipment handling, calibration, and use/field deployment of the sondes will be obtained through a combination of apprenticeship, vendor workshop training, and through testing of and gaining familiarity with the equipment prior to deployment in the field.

Becoming familiar with the manufacturer's equipment operation and maintenance manual is also extremely important. Supervisory and field personnel will be experienced in the use of water quality sensors, and will be familiar with the manufacturer's operating references listed in Section 3.3.

Improper handling and storage of the multi-parameter sonde and sensors can lead to equipment damage or premature sensor failure. Problems with probe or sensor function, their failure or damage, is best avoided by following the manufacturer's instructions carefully. YSI staff will be consulted for additional assistance in troubleshooting should problems arise with equipment

The field SOPs include implementing good field practices and scheduled quality control checks. This requires that:

1. Field measurements are made only with calibrated instruments.
2. Field teams maintain a permanent instrument log book recording calibrations, observations, maintenance and repairs.
3. All manually recorded field measurement data will be collected on field forms, with the recorded data captured electronically.
4. Complete records are maintained for each uniquely identified sampling station.
5. The procedures in this water quality program are routinely reviewed and modified as necessary.

Troubleshooting problems may be categorized into three general areas: 1) calibration error messages, 2) sonde communication, and 3) sensor performance. Sensor performance problems that cannot be identified or fixed will require that the instrument be sent back to the manufacturer for appropriate service.

8.1.2 YSI Sonde Field Checks

Each YSI water quality monitoring location will undergo periodic quality control field checks to monitor inaccurate readings due to fouling or drift occurring during the deployment period. Field calibration checks will begin on a monthly schedule, and then will be increased in frequency if troubleshooting does not identify the cause of noted drift. Additionally, SWM operates a total of two other YSI 6920 sondes that may be used for field checks on a rotating schedule. Procedures to be followed are detailed in the *Surface Water Management (SWM) YSI 6-Series Sonde Field SOPs* (Appendix A).

Below is a brief outline of the field check procedure that will be implemented:

1. One reference sonde (calibration sonde) will be pulled from the field and will be fully calibrated in the laboratory.
2. This reference sonde will then be re-deployed side-by-side with the in-situ subject sonde (field sonde).
3. After a period for temperature stabilization, measurement for each of the five parameters will be recorded.
4. By multiplying sonde measurement sensitivity values by two (2), a determination may be made as to whether the field sonde is producing quality measurements within specified tolerance limits (see Table 11).
5. Readings obtained which are outside of acceptable values will require troubleshooting to identify the cause of the difficulty. Symptoms and causes are described in the manufacturer’s operating references listed in Section 3.3.

Field check calibration events are recorded on recorded on the Sonde Calibration Check the Field Check Data Summary Log (*Surface Water Management YSI 6-Series Sonde Field SOPs*, Appendix A). Below are the acceptable tolerance limits for the measured parameters.

Table 11. YSI 6920 Field Check Measurement Limits

Measured Parameter	Acceptable Tolerance Limits
Temperature	± 0.3 °C
Turbidity	±5% of reading, or 4 NTU, whichever is greater

Data drift or failure of the instrument to hold calibration will require corrective measures. These measures may include performing more frequent sonde cleaning, reconditioning, and calibration. Sensor performance problems that cannot be identified or fixed will require that the instrument be sent back to the manufacturer for appropriate service.

8.1.3 YSI Sonde Laboratory Calibration

Calibration of instruments is required to ensure that the equipment is operating correctly and operating at the proper sensitivity. In general, calibration is accomplished by measuring instrument response to standards in known concentrations. Requirements for YSI sonde calibration for use in routine water quality analyses are briefly described below. SOPs for all sonde laboratory calibration procedures are described in the manufacturer's operating references listed in Section 3.3.

All YSI instruments (YSI 6920) involved in the collection of physical water quality data are lab calibrated monthly. All instruments are maintained in accordance with manufacturers' specifications. Standards and reagents involved in the calibration of instrumentation are handled, prepared and stored in accordance with standard laboratory practices. If any apparent problems become apparent during laboratory calibration, the instrument is removed from use and the malfunction is diagnosed and remedied.

Sonde performance information is managed by EcoWatch software. Cleaning, reconditioning and calibration of the YSI 6920 sondes will be performed approximately once every 30 days.

8.1.4 Onset TidbiT v2 SOPs and Calibration

Quality assurance and control for temperature monitoring will use the *Surface Water Management (SWM) Temperature Logger SOPs*, (Appendix B). These methods closely follow the guidance *Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams Conducted in a Total Maximum Daily Load (TMDL) Project for Stream Temperature*, Washington State Department of Ecology, EAP, 2009.

For TidbiT v2 temperature logger operation, all supervisory and field personnel will be experienced in the use of the instruments, and will be familiar with the manufacturer's instructions. Experience in equipment handling, calibration, and use/field deployment of the temperature loggers will be obtained through a combination of apprenticeship, vendor workshop training, and through testing of and gaining some familiarity with the equipment at the office/lab prior to entering the field.

Becoming familiar with the operation and maintenance of the temperature loggers is critical. Improper handling and storage of the loggers lead to equipment damage or premature failure. Problems with logger function, their failure or damage, is best avoided by following SOPs carefully. Onset staff will be consulted for additional assistance in troubleshooting should problems arise with the equipment.

Optic TidbiT v2 themistors are small battery-powered loggers that are manually downloaded to an optic HOBO Waterproof Shuttle during regular site visits. In brief, the *Surface Water Management (SWM) Temperature Logger SOPs* include:

1. Site selection and deployment options
2. Data download/upload procedures
3. Quality control/quality assurance: accuracy check ice bath and side-by-side field check
4. Documentation and data management

8.2 B-IBI Quality Assurance and Control

8.2.1 B-IBI Field Quality Assurance and Control

Adherence to the field sampling methods established by *Washington State Department of Ecology, EAP, Standard Operating Procedures and Minimum Requirements for the Collection of Freshwater Benthic Macroinvertebrate Data in Wadable Streams*, Version 1.0, 2011; and *Washington State Department of Ecology, Multi-Metric Index Development for Biological Monitoring in Washington State Streams*, 2003 will ensure that:

1. Consistent and repeatable results are obtained, based upon the representativeness of the benthic community conditions, as determined by the sampling protocol.
2. Completeness is 95% achievable. Completeness is defined as the proportion of usable data gathered. Sample loss is minimized with sturdy sample storage vessels and adequate labeling of each vessel. Sample contamination occurs when containers are improperly sealed or stored. Loss of benthic material or desiccation diminishes the integrity of the sample. If the validity of the sample is in question, the sample is excluded from analysis. The goal for completeness of the benthic macroinvertebrate data sets is 95% of the total samples collected. Completeness is defined as the total number of samples we are confident in using for further data analysis following field collection.
3. Comparability of data sets is primarily achieved through adherence to commonly accepted protocols (field sampling, analytical methods and objectives). Comparability describes the confidence in comparing one data set to another.

8.2.2 B-IBI Laboratory Quality Assurance and Control

The following describes the QA/QC procedures as provided by Federal Way's contracted laboratory from 1998 to the present (Rhithron Biological Associates):

B-IBI Laboratory Quality Control

B-IBI laboratory sample processing procedures for bio assessment studies will be employed. Samples will typically be cycled through five general steps: a) receiving, b) sorting, c) taxonomy, d) data entry, and e) reporting. Each step will be monitored through Quality System (QA) evaluations.

The lab will employ several internal Quality Systems procedures designed to rigorously evaluate and improve the performance of all staff and the efficiency of the standard laboratory procedures. These procedures will begin as soon as the samples are received and will continue throughout each step.

B-IBI Lab Sample Receiving

Upon arrival at the laboratory, the condition of the samples will be immediately evaluated. They are checked for leakage and breakage and "topped-off" with preservative, if necessary. An inventory will be compiled and compared with the chain of custody forms or field inventory and any discrepancies will be reported as soon as possible.

At this time the laboratory procedures that will be used for each sample are confirmed. This includes sub-sampling ranges and procedures, taxonomic resolution, and reporting options.

B-IBI Lab Sample Sorting

Caton subsampling devices will be used, divided into 30 grids, each approximately 5 cm by 6 cm, for all sample handling. To obtain subsamples of a specified minimum of organisms (500), samples will be poured out into the device, grids will be randomly chosen, and the substrate materials will be lifted out into petri dishes. Using 10x-30x magnification under dissecting microscopes, technicians will remove all organisms from the contents of each grid until the specified number of organisms is collected. Quality Systems procedures described below will be carried out for each sample. Sorted substrate and unsorted remainders for all samples will be retained and stored until completion of the project.

Most bioassessment projects include a standardized subsampling protocol. The defensibility of bioassessment depends on carefully executing these protocols in a precise and repeatable way; therefore, Rhithron routinely evaluates subsampling efficiency.

B-IBI Sample Sorting Efficiency Quality Systems (QA)

Sorting efficiency checks describe the ability of the sorters to remove organisms from the detritus in a sample. Generally, it involves an independent observer to re-examine some portion of the sorted detritus and to count the number of organisms that were missed in the first sorting of a sample. When a technician sorts a sample, there are three components: the unsorted portion of the sample, the organisms, and sorted detritus. Some portion of the sorted detritus is again sorted by another technician using a dissecting scope to determine how many organisms the first technician missed. The results are usually reported as a “percent efficiency.” For example, if 10 organisms were missed in 500-organism subsampling protocol, the sample was sorted with 98% efficiency.

Rhithron’s standard Quality System for evaluating the level of sorting efficiency is to check 100% of the samples from each project. For this procedure, 20% of the sorted detritus from each sample is randomly selected for resorting and examination by a second technician. The portion of the sample is examined under a dissecting microscope at 10-30x magnification and all organisms, if any, are removed. The sample fails the check if the total number of organisms indicates that >10% of invertebrates were missed in the first sort. For example, in a 300 organism subsample protocol, if >6 (300 x 20% x 10%) individuals are found in the routine check then the sample has failed the sorting efficiency check. In the event of a failure, the entire sample is resorted, the failure rectified, and totals adjusted. Thus all samples must have >90% sorting before they are identified.

This procedure guarantees quality sorting and provides immediate training and feedback to the technical staff. In many ways it is more rigorous than many program-specific sorting requirements: Whereas, other programs usually only check a sub-set of the total number of samples, Rhithron requires that 100% of the samples are checked and corrected. Rhithron’s standard sorting efficiency checks do not preclude the use of program-specific quality assurance procedures. In fact, when combined with other procedures, Rhithron is able to provide a uniquely high standard of data quality because our efficiency may be evaluated several ways. For example, the U.S. EPA’s Environmental Monitoring and Assessment Program (EMAP) requires complete (100% of the sorted detritus) sorting efficiency checks for 10% of the total number of samples. Rhithron can implement this level of validation in addition to their routine evaluation to provide a very rigorous assurance of data quality.

Complete Sorting Efficiency (SE) may be evaluated as:

$$SE = \frac{n_1}{n_2} \times 100$$

Where: n_1 is the total number of specimens in the first sort, and n_2 is the total number of specimens in the first and second sorts combined.

B-IBI Taxonomic Resolution and Validation

Taxonomy is the science of correctly assigning names to organisms. Rhithron's biologists can provide determinations of invertebrate groups to specified resolution levels.

Occasionally, two people may assign different names to the same organism, causing unwanted variation in the data. This may happen for several reasons: different levels of taxonomic experience, specimen condition, specimen maturity, use of different references, or different kinds of equipment. Several Quality Systems procedures are in place that assures that specimens are identified with uniform taxonomic effort. For example, all samples will be examined by two taxonomists.

Taxonomic similarity integrates taxonomic composition and abundance into a single statistic. For this evaluation, Rhithron may utilize Bray-Curtis Similarity ((BCS) or other similarity statistics) to describe the taxonomic and numerical precision for samples as a single numerical value when t is the taxa richness resulting from identifications j and k :

$$BCS = \left(\frac{2W}{A + B} \right) \times 100$$

Where : $W = \sum_{i=1}^t \left[\min (X_{ij}, X_{ik}) \right]$

$$A = \sum_{i=1}^t X_{ij}$$
$$B = \sum_{i=1}^t X_{ik}$$

Perform of this check is routinely done on 15% of the samples analyzed in the laboratory, usually having a percent agreement exceeding 95%.

B-IBI Laboratory Reference Library

A library of current taxonomic literature is maintained. The staff frequently updates the library with new reference materials on the taxonomy and ecology of aquatic organisms. This enables the laboratory staff to use the most current conventions of taxonomic science for all projects. However, for long-term studies, consistency of taxonomic effort is essential. Therefore a host of historic references that allow us to provide consistent taxonomic effort for programs with specific taxonomic protocols is maintained. For example, the Washington State environmental agencies specifically list the appropriate taxonomic references to maintain uniformity among the data collected for their Bioassessment programs. These references are available in house and are employed regularly.

B-IBI Laboratory Personnel Training

Taxonomic personnel have strong backgrounds in the taxonomy and ecology of aquatic invertebrates. Skills are continually developed by participating in regional workshops and scientific meetings. Rhithron participates in the Northwestern Bioassessment Workgroup, taxonomic workshops, and other professional meetings to help develop and maintain standards for taxonomic effort. As a result of active development of standards, Rhithron is often asked to provide training for sampling, taxonomy, or monitoring for water-monitoring organizations.

B-IBI Laboratory Internal Taxonomic Consistency

Rhithron's Quality System for taxonomic determinations requires that 100% of samples are checked for taxonomic consistency. The taxonomists come from diverse backgrounds and bring with them different perspectives, experiences, and taxonomic specializations. After a sample has been identified, a second taxonomist examines the sample and verifies the determinations made by the first. All discrepancies are addressed; if consensus on a particular determination cannot be reached, external verification is sought. This helps to ensure consistency among taxonomists and to ensure that all benefit from one another's knowledge and experience. Such exchanges provide a meaningful and constructive internal taxonomy evaluation.

In addition to exchanging specimens among the professional staff, a comprehensive reference collection is maintained. This allows taxonomists to compare difficult or unusual specimens with similar taxa collected from earlier studies. This helps with long-term consistency and, since this collection is validated externally, ensures taxonomic accuracy.

B-IBI Laboratory External Taxonomic Consistency

Occasionally, specimens that are unusually difficult to identify are encountered. These are often rare taxa that some of the taxonomists have not previously encountered. For these events Rhithron maintain professional contacts with specialist systematists. These are biologists, usually working for universities or large museums that specialize in classifying certain groups of organisms. These biologists write the dichotomous keys that taxonomists use, and they should easily recognize unusual species or species that are new to science. Rhithron will send specimens or digital images to these systematists and receive identifications for problem organisms. Furthermore, these same specialists will validate the in-house reference collection.

In addition to our contacts with professional systematists, Rhithron has established a sample exchange program with the Western Bioassessment Center (a.k.a. the Buglab) at Utah State University. A subset of all samples that come into our lab is sent to Buglab, and they independently identify and enumerate all specimens in those samples. Rhithron then discusses any discrepancies. Similarly, Buglab sends our laboratory a subset of samples, which are independently identified and enumerated. This cross validation provides valuable feedback to ensure that the samples are routinely and independently verified.

Benthic Macroinvertebrate Rechecking/Cross Checking

Rhithron's Quality System for accuracy of data entry requires that data are proofed upon entry into the taxonomic database and errors are corrected. Twenty percent of the samples are randomly selected for rechecking and crosschecking with laboratory bench sheets. When errors are discovered, they are corrected, and then an additional 20% are selected for validation. This process is repeated until no errors are found in the data entered. A suite of templates is used to calculate a wide variety of metrics used by bioassessment programs around the country. These are checked for accuracy and proper cross-tabulation

before the results are used in analyses. The results presented in reports are compared with the results in the spreadsheets to eliminate transcription error.

8.3 Flow Monitoring Quality Assurance and Control

Field technicians will maintain and calibrate flow monitoring equipment according to the *Isco 4250 Flow Meter Instruction Manual* in order to provide high quality data. The following is a brief outline of flow monitoring QA/QC procedures:

- Following initial set-up, field calibration checks will involve re-measuring the level in the stormwater pipe when flows are present (twice per year, spring and fall).
- Field staff will periodically download data (every 30 days) and ensure proper working conditions of the field equipment.
- All data will be reviewed, rated for accuracy, and approved before being submitted as a final product.
- Flow Monitoring Data Management will follow procedures outlined in Section 9.0.

9.0 DATA MANAGEMENT PROCEDURES

Data management procedures will address the path from acquisition in the field, to laboratory, to final use and archiving. Adherence to the *Surface Water Management (SWM) YSI 6-Series Sonde Field SOPs* will reduce errors in results by reducing mistakes in recording results, calculations, and transcription.

9.1 Data Recordkeeping

Generated information includes flow monitoring data, water quality data, water quality station maintenance, instrument calibration, and benthic macroinvertebrate data. Important project information will be recorded on various worksheets and logs (Appendix C). Data generated for this project will be submitted to the Department of Ecology consistent with the Washington State Department of Ecology's Environmental Information Management (EIM) System project.

The following outlines each QAPP data management task:

9.1.1 Water Quality Data Management

YSI 6920 Sondes

Continuous water quality data for temperature, specific conductivity, dissolved oxygen, pH, and turbidity are measured every 30 minutes and logged into the YSI 6920 internal memory. Data from the sondes will be retrieved in the field approximately every 30 days using a YSI 650 MDS data logger.

Data is managed by Flowlink® software, an industry-standard Microsoft Access database that displays all of the sites and data, graphs and tables in the database. Data will be exported to Excel spreadsheets for further management, study, archiving and reporting to Ecology.

TidbiT v2 Loggers

Continuous temperature are measured every 30 minutes and logged into the Onset TidbiT v2 Temperature Logger internal memory. Data from the loggers will be retrieved in the field approximately every 30 days using a HOBO Waterproof Optical Shuttle. Field data is uploaded to a PC hard drive from the shuttle. Uploaded data is managed by HOBOWare Pro ® software. Data will be exported to Excel spreadsheets for further management, study, archiving and reporting to Ecology.

9.1.2 Water Quality Equipment Field Maintenance

Field maintenance activities (data retrieval, sensor/logger inspection, battery voltage, battery replacement, dessicant condition, time check, general observations) will be recorded on a Water Quality Station Field Log or Temperature Logger Station Field Log. On-going water quality station activities (data retrieval, battery replacement, dessicant replacement, program changes, instrument maintenance) will be recorded on the Water Quality Station Activity Log.

9.1.3 Water Quality Equipment Cleaning, Reconditioning and Calibration

Cleaning, reconditioning, and laboratory calibration of the YSI 6920 sondes will be performed approximately once every 30 days. Sonde performance information (i.e., battery voltage, pH millivolts, dissolved oxygen charge value) is managed by EcoWatch software and recorded by hand on the Sonde Calibration Worksheet and Sonde Calibration Log.

9.1.4 Water Quality Equipment Corrective Actions

Documentation concerning corrective actions affecting sample collection, equipment/sample handling, equipment failures, data management, lab and field calibration issues, and or data analysis, will be recorded on the Water Quality Station Activity Log.

9.1.5 Benthic Macroinvertebrate Data Management

Field observations, selected water quality measurements, and environmental variables will be recorded on a Benthic Macroinvertebrate Site Description Form. Information to be recorded include: air temperature; water temperature; substrate composition; and sample riffle depth, length and width.

Rhithron Biological Associates will produce laboratory reports in an Excel spreadsheet that includes the following information for each site: individual B-IBI metrics (taxa richness, clinger richness, % tolerant, % predator, % dominance); site B-IBI scores; and sorting quality assurance results.

9.1.6 Flow Data Management

Procedures for the set-up, calibration, and operation of flow monitoring equipment will be documented on the Flow Programming and Chronology Worksheets will be used to record a “hard copy” of program steps completed for the set-up of the 4250 Isco Flow Data Logger.

Flow data will be retrieved in the field approximately once every 30 days via an Isco 581 Rapid Transfer Device, then uploaded to the PC hard drive. Data is managed by Flowlink® software, an industry-standard Microsoft Access database that displays all of the sites and data, graphs and tables in the database. Data will be exported to Excel spreadsheets for further management, study, archiving and reporting.

10.0 AUDITS AND REPORTS

The following processes have been developed to ensure that the QAPP is implemented correctly, that the quality of the data is acceptable, and that corrective actions are implemented in a timely manner.

10.1 Audits

In order to assure that the proper measurement procedures are taking place and to determine if procedural changes are needed, two forms of audits will be conducted: field audits and reporting audits.

10.1.1 Field Audits

Once per year the Project Lead will accompany water quality field staff in order to monitor and audit all field activities including calibrations, maintenance, and sonde/logger deployment methods. The Project Lead will focus on ensuring that all SOPs are followed, calibrations are conducted in compliance with manufacturer specifications when applicable, and this QAPP is followed. The Project Lead will ensure that modifications to SOPs are implemented if observations indicate that any deviations from QAPP are noted. The Project Lead will be responsible for ensuring that each corrective action is implemented. A subsequent audit may be required to ensure that the change has been successfully implemented.

10.1.2 Reporting Audits

It is the responsibility of SWM to ensure that all of the reporting requirements of the Department of Ecology Stormwater Retrofit and LID Grant are met. The Project Lead audit reports and data management records as appropriate, to ensure that the necessary data are present, legible, correct, and verifiable. Any deviations from requirements will be rectified and corrected.

10.2 Reports

Reporting will be conducted in a variety of ways, which depend primarily on the frequency of monitoring.

10.2.2 Annual Reports

Per the Grant Agreement, the monitoring results will be integrated into an Annual Summary for Ecology's review. A final report will be submitted to the Project Manager that discusses the baseline conditions and an analysis of post-construction monitoring data.

10.0 DATA VERIFICATION AND VALIDATION

SWM staff will review all data generated for the project to verify that the methods and protocols specified in the QA Project Plan were followed; that all instrument calibrations, quality control checks, and intermediate calculations were performed appropriately; and that the final reported data are consistent, correct, and complete, with no omissions or errors. Based on these assessments, the data will be accepted, accepted with appropriate qualifications, or rejected.

After the field data have been reviewed and verified by the project manager, they will be transitioned (where appropriate) to EIM for access. The EIM data will be independently reviewed for errors by another SWM staff person before closing out the EIM project and setting the data validation flag to "completed." If any errors are discovered during the initial data review, a full independent review will be undertaken.

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Appendix A
SWM YSI 6-Series Sonde Field SOPs

APPENDIX A

Surface Water Management (SWM) YSI 6-Series Sonde Field SOPs

1.0 *Field Calibration Check 6920 to 6920*

The following procedure instructs the user how to complete a side-by-side data collection for a newly calibrated YSI 6920 multi-parameter sonde (calibration sonde) next to a second field-deployed YSI 6920 multi-parameter sonde (field sonde). The user will be setting up each 6920 to sample at 5-second intervals for quality control analysis. This procedure is done at the end of the field deployment period (after approximately 30 days).

Field Calibration Check Steps

1. Retrieve the field 6920 sonde from the sampling location (i.e. 356th Inlet) and connect to YSI 650 MDS data logger
2. Select **Sonde Menu > Run > Unattended Sample**
3. Select **Stop Logging**
4. Select **Yes**
5. Adjust Sample Interval of sample to 00:00:05 seconds
6. Enter filename for field calibration period i.e. 356IN F (F denotes field sonde).
7. Select **Start Logging**
8. Select **Yes**
9. Press **ESC** to back up to 650 main menu
10. Replace the field sonde to the sampling location
11. Ensure that the lab calibrated sonde has fresh AA batteries
12. Repeat Steps 1 through 11 for the lab-calibrated sonde used for the field calibration check
13. After deployment of both sondes (field and calibration), allow a 20 minute burn in period
14. Allow a minimum of an additional 10 minute sampling period to collect data for QC analysis
15. Retrieve both sondes after the sampling period
16. For both sondes, repeat Steps 1 through 5
17. Press **ESC** to back up to the sonde Menu
18. Select **File**
19. Select **Upload** and select files to upload
20. Select **Proceed**
21. Select **Comma & “ “ delimited text**
22. Press **ESC** to back up to 650 main menu
23. Select **File > Directory** to insure that each calibration data file has been successfully uploaded
24. Press **ESC** to back up to main menu
25. Return field sonde to the lab for laboratory calibration.

When the field sonde has been lab calibrated and ready for redeployment in the field, the following procedure is used:

1. Connect the field sonde to 650 MDS
2. Select **Sonde Menu > Run > Unattended Sample**
3. Adjust Sample Interval to **00:30:00** minutes
4. Enter the appropriate filename for the new sampling period (i.e. 356IN).
5. Select **Start Logging**
6. Select **Yes**
7. Press **ESC** to back out to 650 MDS menu
8. Disconnect and redeploy the field sonde at the assigned field sampling site.

Side-by-Side – Newly Calibrated YSI 6920 with Field-Deployed 6920

TO START Calibration:

1. Step 1 is to stop the 6920 currently sampling in the field from logging:
650 MAIN MENU> SONDE MENU>RUN>UNATTENDED SAMPLE>STOP
LOGGING>YES
2. Set up the 6920 in the field for side by side by resetting sample interval and renaming file:
650 MAIN MENU>SONDE MENU>RUN>UNATTENDED SAMPLE>
>INTERVAL= 00:00:05
>FILE= (enter file name, i.e., 356INF)
* "F" denotes field.
>START LOGGING>YES
* Press Esc until sonde disconnects and place in water for sampling.
3. Set up the newly lab calibrated 6920 sonde for side by side with the field 6920 sonde by resetting the sample interval and renaming the file like above:
650 MAIN MENU>SONDE MENU>RUN>UNATTENDED SAMPLE>
>INTERVAL= 00:00:05
>FILE= (enter file name, i.e., 356INC)
* "C" denotes field.
>START LOGGING>YES
* Press Esc until sonde disconnects and place in water next to the field for sampling.
* Allow to collect data for approximately 30 minutes

TO STOP Calibration Sonde:

1. Connect 650 to Calibration sonde and stop logging:
650 MAIN MENU> SONDE MENU>RUN>UNATTENDED SAMPLE>STOP
LOGGING>YES
2. Upload that calibration file:
650 MAIN MENU> SONDE MENU>FILE>UPLOAD>(Select correct file name)
>PROCEED>COMMA DELIMITED
* Disconnect by pushing Esc repeatedly

TO STOP Field Sonde:

1. Connect 650 to Field sonde and stop logging:
650 MAIN MENU> SONDE MENU>RUN>UNATTENDED SAMPLE>STOP
LOGGING>YES
2. Upload that calibration file:
650 MAIN MENU> SONDE MENU>FILE>UPLOAD>(Select correct file name)
>PROCEED>COMMA DELIMITED
* Disconnect by pushing Esc repeatedly
3. Upload all data that the field sonde had been collecting while deployed for the last month:
650 MAIN MENU> SONDE MENU>FILE>UPLOAD>(Select correct file name):
> PROCEED>COMMA DELIMITED
* Disconnect by pushing Esc repeatedly
*Check to be sure the files are now on the 650:
650 MAIN MENU>FILE>VIEW FILES (account for each file uploaded)

2.0 Returning 6920 to Field for Normal Sampling

1. Replace all AA batteries in the field sonde
2. Replace calibration cup with screened cup
3. Check to be sure all files have been previously uploaded from the sonde to the 650 and are no longer needed on the sonde
4. Delete all files on the sonde:
650 MAIN MENU>SONDE MENU>FILE>DELETE ALL FILES>DELETE
5. Reset the sampling interval to 30 minutes and name the file:
650 MAIN MENU>SONDE MENU>RUN>UNATTENDED
SAMPLE>INTERVAL= 00:30:00
>FILE= (enter file name, i.e., 356IN)
>START LOGGING>YES
*ESC to disconnect and redeploy the field sonde at the assigned field sampling site.

3.0 Data Management

3.1 6920 PC Upload to Field for Normal Sampling

The following procedure instructs the user how to upload and manipulate the 6920 sonde data using EcoWatch software to an Excel spreadsheet for data archive and QC analysis.

To Upload to PC from 650

Connect 650 with white cable (655174) to grey USB cable. Plug into PC USB.
Open EcoWatch program. Comm > sonde > COM4

On 650, Main menu > File > Upload to PC
Highlight text file > enter (begins initializing)
Both 650 and PC will show status of upload (bytes sent). Will beep when finished
A text file is created in C:Ecowin/data

To Access/Convert Data on PC

Open EcoWatch
File > Import [choose text file as file type] > Highlight desired file > OK
Convert ASCII file to PC6000 file format? > Yes > OK > OK
Click “view” > Table
Click on upper left box in table (this action will highlight the whole table)
Click edit > copy
Paste the data into an Excel spreadsheet. Transfer the data into the on-going water quality database for the individual site. Ensure that the column headers for the parameters sampled align correctly.

Delete files (BE CAREFUL):

Delete all files from the sondes (field and calibration) when they are successfully uploaded to PC and confirmed.
Delete all files from the 650 when they are successfully uploaded to the PC and confirmed.
Delete all redundant files from the PC (C:Ecowin) when all of the data has been successfully transferred to the ongoing data base maintained on the K drive

3.2 Field Calibration Data File Management

Initial files are kept at this location:

K:/SWM/Water Quality/WQ Stations/Field WQ Data/Calibration Downloads

A second copy are kept here for further manipulation and calibration check calculations:

K:/SWM/Water Quality/WQ Stations/Calibration

3.3 Sonde Data Management

Sonde data files are kept here, and second copies for the YSI 650 folder to be imported into Flowlink:

K:/SWM/Water Quality/WQ Stations/Field WQ Data

3.4 TidbiT Data Management

TidbiT data files are exported to this folder:

K:/SWM/Water Quality/Temperature/Tidbit Data

Appendix B
SWM Temperature Logger SOPs

APPENDIX B

Surface Water Management (SWM) Temperature Logger SOPs

1.0 Purpose and Scope

These standard operating procedures (SOPs) covers the monitoring of stormwater and stream temperature. The purpose of water quality temperature monitoring is to characterize thermal conditions in a stream in order to determine if the water body meets surface water temperature criteria, and to protect beneficial uses. Parameters that influence surface water temperature and are affected by human activity include:

- Riparian Vegetation (shade)
- Channel morphology (shape, hydraulic geometry)
- Hydrology
- Temperature (point source and non-point source)

2.0 Applicability

These SWM Temperature Logger Standard Operating Procedures will be followed during the installation and maintenance of continuous temperature monitoring stations. The protocols contained in this document reflect in part those outlined in the Timber, Fish, and Wildlife (TFW) Monitoring Program's Method Manual for the Stream Temperature Survey, June 1999; and the WA Department of Ecology Standard Operating Procedures for Continuous Temperature Monitoring of Fresh Water Rivers and Streams, Version 2.3, September 2009.

3.0 Personnel Qualifications/Responsibilities

No certification or license is required to conduct surface water monitoring. Persons involved in the field data collection and analysis must have experience and training in the natural, environmental or physical sciences.

4.0 Equipment, Reagents, and Supplies

All equipment installation events should include a toolbox with all the hand tools you will need including (but not limited to): pipe wrenches, pliers (multiple types), wire cutters, screwdrivers, hammer, nails, rebar pounder, 8lb steel mallet, socket wrench and socket set, and duct tape. Additional items for anchoring Onset temperature loggers include: fencing wire, rebar, plastic zip ties, steel enforced plastic cable ties, eyebolts, stainless steel braided cable, or whatever your unique installation situation requires.

Specialized field equipment for each type of field set-up includes:

- Continuously recording thermistors 5.3.1.1 Onset Hobo[®] Water Temp Pro v2 (#U22-001), -20°C to +50°C, +/- 0.2C
- PC communication cables or optic shuttles specific for each instrument type

5.0 Summary of Procedure

5.1 Site Selection Criteria for In-stream Temperature Loggers

1. Temperature loggers should be installed only in well mixed zones. The outside of stream bends or the low-flow channels in a riffle are good choices.
2. Use a reference thermometer to check the stream temperature at several points around the potential temperature logger site to make sure the site is truly representative of the well-mixed stream temperature at that location.
3. Temperature loggers should be installed at a location and depth where they won't become exposed if stream stage drops. It is often best to install the temperature data loggers at about one-half of the water depth. Periodically check the loggers throughout the study and move them farther down into the water column if necessary as flows drop to base-flow levels during the summer and fall.
4. If at all possible, do not install temperature loggers where they must lie directly on the stream bottom since they may be thermally affected by groundwater inflow. However, for shallow depths (<0.5 ft), you may have no choice but to install the thermistor on or near the stream bed. Likewise, avoid installing loggers in back water eddies or pools that may stratify during low flow conditions.
5. As the stream stage drops during the summer it may be necessary to move the in-stream logger to keep it in the active stream channel.
6. Vandalism can be a problem, so avoid suspect locations if possible or find creative ways to camouflage the logger.
7. If necessary, make sure the thermistors are fastened and anchored in the stream sturdy enough to withstand high stream velocities.

5.2 In-stream Temperature Logger Deployment Options

1. It is important to always shade in-stream loggers to reduce any bias from direct solar radiation.
2. Rebar (2-3' long by ½" or ¾" diameter) may be used as an anchor to attach a logger in-stream.
3. Smooth fencing wire (10 or 8 gage whichever is easier for you to work with but is still durable) is the best option for securing loggers and shade devices to the anchor in stream flows of 50cfs or greater. For stream flows less than 50 cfs, plastic zip ties or steel enforced plastic cable ties may be a viable option to secure the in-stream logger.
4. Stable large woody debris or roots extending into the stream can be used as an anchor for zip tying or wiring a logger into an area of swift flow. Exposed large roots that extend into the primary stream flow can often be found.
5. Protect the logger using a TidbiT v2 plastic boot covering.

5.3 Documentation and General Considerations

1. Proper documentation of temperature logger installation sites and conditions is important for relocating instruments and makes for more efficient use of field time during periodic survey checks and end of season instrument removal. Proper documentation also helps prevent equipment and data loss. A monitoring site can look very different during the spring installation compared to the fall removal if there is any kind of riparian vegetation.
2. To ensure that the periodic reference measurements can be accurately attributed to the appropriate thermistor record, **ALWAYS** record the **date and time** that each field measurement is made.
3. PC s that connect to the network should be synchronized to the official US time. All temperature loggers should be set to record data at 30 minute intervals on the hour and half hour (i.e. 5:00, 5:30, 6:00, 6:30, etc). If you need to replace a lost or malfunctioning thermistor, be sure to set them to record data at 30 minute intervals with a delayed launch for the nearest hour or half hour.
4. Temperature instruments can be damaged or lost due to vandalism, flooding, animals, or anchors becoming unfastened. Monitoring sites should be visited once per month (or more frequently if necessary) to make reference measurements, download station and/or temperature data, and to make sure the data loggers are still present and in working order. Damaged or missing data loggers must be replaced immediately with another calibrated data logger.
5. Always use loggers that have been properly checked for meeting accuracy requirements as described in the data quality requirements of the QAPP.

5.4 Installation of In-stream Temperature Loggers

1. Arrive at a station prescribed in the Quality Assurance Project Plan (QAPP).
2. Determine the area for the installation attempt based on the site selection criteria in the QAPP. Chose a well-mixed (in regards to temperature) part of the stream.
3. Where there is not a secure structure available to protect the logger, choose a length of rebar appropriate for driving it deep enough into the streambed to stay in place but that also leaves enough rebar in the stream to attach the logger at about one-half of the total stream depth. Additional installation options are outlined in Section 5.0.
4. Write the serial number of the in-stream logger, stream name/location, field crew name, date and time in the appropriate space on the field form.

6.0 Records Management

Field forms for the installation of continuous monitoring stations and for regular site visits can be found at the end of this document. Completed field forms should be kept in a project notebook for entry into the project database and long-term record keeping.

7.0 Quality Control and Quality Assurance Section

1. The Onset Tidbit v2 must be checked both pre- and post-study to document instrument bias and performance at representative temperatures. A NIST certified reference thermometer must be used for the check. At the completion of the monitoring, the raw data will be assigned a measurement accuracy value based on the pre- and post-study calibration results.
2. If the average temperature difference for a temperature logger, compared against the NIST certified thermometer, is equal to or less than the manufacturer stated accuracy of the instrument the instrument can be used without further qualification. If the average temperature difference is greater than the stated accuracy, then a second check should be performed to ensure there wasn't a problem with the calibration method.
3. If the second result is still greater than the manufacturer accuracy, and if this is the pre-study check, then the logger should not be used. If the second result is greater than the manufacturer accuracy, and if this is the post-study check, then the stated accuracy for the data should be the mean difference of the pre- and post-study calibration values from the NIST thermometer. If the logger is off by a degree or more, a decision should be made whether or not to include the data set from the faulty logger.

7.1 Temperature Logger Accuracy Check Procedure

1. Prepare two insulated coolers for water baths at least 12 hours before the temperature loggers are calibrated and conduct this test in a room where the air temperature can be held constant for the duration of the test. One bath should be at ambient temperature (typically around 16 degrees Celsius) and the other should contain ice and water for a cool bath.
2. Program the temperature loggers using a delayed launch so they all begin at the same time and use a 1 minute sample interval to measure temperatures. Keep temperature loggers at room temperature until the baths are ready. Use a cord or long rubber band to string the loggers together.
3. Soak the loggers in the ambient bath first for 20 minutes before beginning comparison temperature measurements using the NIST calibrated thermometer.
4. Stir the bath constantly to maintain homogeneous water temperature. After the soak time has lapsed, record the bath temperature using the NIST thermometer every 2 minutes beginning at the time the loggers record their temperature measurements. Record the time and temperature of the NIST measurement. Keep stirring. An example data logger calibration form can be found in Appendix A.
5. Record 10 comparison readings in the ambient bath.
6. Transfer all loggers to the cool water bath and soak for 20 minutes. Keep the bath stirred to ensure a well-mixed (non-stratified) water bath. You may want to remove most of the ice at the beginning of the soak.
7. After the soak time has lapsed repeat steps 4 and 5.

8. This procedure should also be used to check the accuracy of the field meter for measuring temperature.
9. Variation for field sampling of in-stream temperatures and potential thermal stratification will be addressed using a field check of stream temperature at all monitoring sites upon deployment, during regular site visits, and during instrument retrieval at the end of the study period. Air temperature data and in-stream temperature data for each site will be compared to determine if the in-stream temperature was exposed to the air due to stream stage falling below the installed depth of the stream temperature.

7.2 Side by Side Data Analysis

To help ascertain whether temperature data recorded by both the optic TidBiT logger and YSI thermistors are recording accurately at locations where they are both deployed (i.e. 356th outlet), a quality control test may be conducted by performing a side-by-side temperature QC test involves the following steps:

1. A side-by-side QC test is performed for each year of operation. The annual data for each monitoring site will be examined to locate a total of 100 identical days where data were recorded on each instrument. This data set will represent over 4,800 readings (at 30 minute increments).
2. Each data set is averaged.
3. A tolerance limit range is established by adding the sensitivity value of the optic TidBiT (± 0.20 degrees C) and the sensitivity value of the YSI thermistor (± 0.15 degrees C). The average value of the 100 recordings for each instrument will be compared to the tolerance limit range calculated (± 0.35 degrees C, the sum of the sensitivity values for both instruments).
4. The side-by-side QC test confirms whether the field-deployed temperature instruments are producing quality measurements within specified tolerance limits; and whether the YSI thermistor data may be substituted to fill optic TidBiT logger gaps where necessary to ensure an uninterrupted span of continuous readings

Appendix C
Water Quality Data Worksheets
(Calibration, Recordkeeping)

SONDE CALIBRATION WORK SHEET

Sonde Location: _____

Sonde Serial Number: _____

Date of Calibration: _____

Operator: _____

Manufacturer: _____

Sonde Type: _____

Optical DO? Yes No

DO membrane changed? Yes No N/A *Note: Should wait 6 to 8 hours before final DO calibration, and run sensor for 10 minutes in Discrete Run to accelerate burn-in.*

DO probe o-rings changed? Yes No N/A

Optical DO Wiper changed? Yes No N/A Wiper parks $\approx 180^\circ$ from optics? Yes No N/A *(Note: Change wiper if probe will not park correctly)*

Turbidity Wiper changed? Yes No N/A Wiper parks $\approx 180^\circ$ from optics? Yes No N/A *(Note: Change wiper if probe will not park correctly)*

6920 battery voltage: _____

DIAGNOSTIC CALIBRATION TEST (after DO membrane installation)

		<u>Record Values</u>	
		<u>Pre Cal</u>	<u>Post Cal</u>
Conductivity cell constant _____	Range: 4.5 to 5.5		
pH MV Buffer 7 _____	Range: (-)50 to 50 MV	Sp. Cond (uS/cm) 1000	_____
pH MV Buffer 4 _____	Range: +177 from 7 Buffer MV	pH 7 7.0	_____
<i>Note: Span between pH 4 and 7, millivolt numbers should be ≈ 165 to 180 MV</i>	MV Span _____	pH 4 4.0	_____
DO charge _____	Range: 25 to 75	Turbidity 0/123	_____
		Turbidity Finger Test	_____ NTU
DO gain _____	Range: 0.7 to 1.5	DO mg/L	_____
Barometric Pressure _____	Date _____	DO %	_____
_____ inches x 25.4 = _____ mm		DO Temp	_____

Optical DO Probe _____ (If yes, do not perform the following DO Sensor Output Test)

DISSOLVED OXYGEN SENSOR OUTPUT TEST (before DO calibration / probe in saturated air)

The following tests will confirm the proper operation of your DO sensor. The DO charge and gain must meet spec before proceeding.

PC – Stop discrete and unattended sampling. Confirm that auto-sleep RS-232 is enabled (found in Advanced Menu under Setup). Wait 60 seconds. Start discrete sampling at 4 seconds. Watch the DO % output, it must display a positive number and decrease with each 4-second sample, eventually stabilizing to the calibration value in approximately 40 to 60 seconds. **Note:** You can disregard the first two samples since they can be affected by the electronics warm-up. The **ACCEPT/REJECT** criteria is as follows:

The DO output in % must start at a positive number and decrease during the warm up. Readings: _____
 _____ Should the output display a negative number or start at a low number and climb up to the cal point, the probe is rejected and must not be deployed.

Date _____ (10 min) DO Burn-In Start _____ DO Burn-In End _____ (5 min) DO Pre-Cal Start _____ DO Pre-Cal End _____

RS-232 Enabled _____ RS-232 Disabled _____ Return Settings to Field Parameters _____

DO Output Test: _____ ACCEPT _____ REJECT

Notes:

SONDE CALIBRATION CHECK WORKSHEET

Date: _____ Start Sampling: _____

End Sampling: _____ Duration (min): _____

FIELD SONDE	
Location:	_____
Model:	_____
Serial Number:	_____
Date Last Calibrated:	_____
Days Between Cal:	_____
Sample Interval (sec):	_____

CALIBRATION SONDE	
Location:	_____
Model:	_____
Serial Number:	_____
Date Last Calibrated:	_____
Days Between Cal:	_____
Sample Interval (sec):	_____

Burn-in, stabilization period (min):

* Number of data points averaged:

Field Calibration Check Data

Parameter	Field Sonde Reading (Ave*)	Calibration Sonde Reading (Ave*)	Acceptable Tolerance Limits	Tolerance Limit Range Used	Pass/Fail
Dissolved Oxygen (mg/L)			± 4% of calibration sonde reading, or 0.4 mg/l (whichever is greater)		
pH (standard units)			±0.4 standard units		
Temperature (degrees Celsius)			± 0.3 degrees Celsius		
Specific Conductivity (uS/cm)			± 1.0 % of calibration sonde reading (uS/cm), + 2uS/cm		
Turbidity (NTU)			±5% of calibration sonde reading, or 4 NTU, whichever is greater		

Notes:

YSI 6920 FIELD CHECK DATA SUMMARY LOG

	Field Sonde
Date	
Cal. Sonde	
DO	PASS/FAIL
pH	PASS/FAIL
Temp	PASS
Spec Cond	PASS/FAIL
Turb	PASS
Problem	
Corrective Actions	
Data Drift Correction?	yes/No (probe type)

Appendix D
B-IBI Recordkeeping Form

Benthic Macroinvertebrate Sampling Form K:\SWM\water quality\Macro Data\macro field form
City of Federal Way

Date:

Site ID:

Riffle Location:

Include description of sample site and distances from nearby landmarks if possible

Weather: Sunny Cloudy P. Cloudy Light Rain Heavy Rain Other:

Air Temp: (C)

Water Temp: (C)

Substrate Composition:

% Boulders

% Cobble

% Gravel

% Sand/Silt

% Clay

% Other

Riffle Depth: (in)

Riffle Length: (ft)

Riffle Width: (ft)

Canopy Cover Estimate: %

Riffle Map:

UPSTREAM

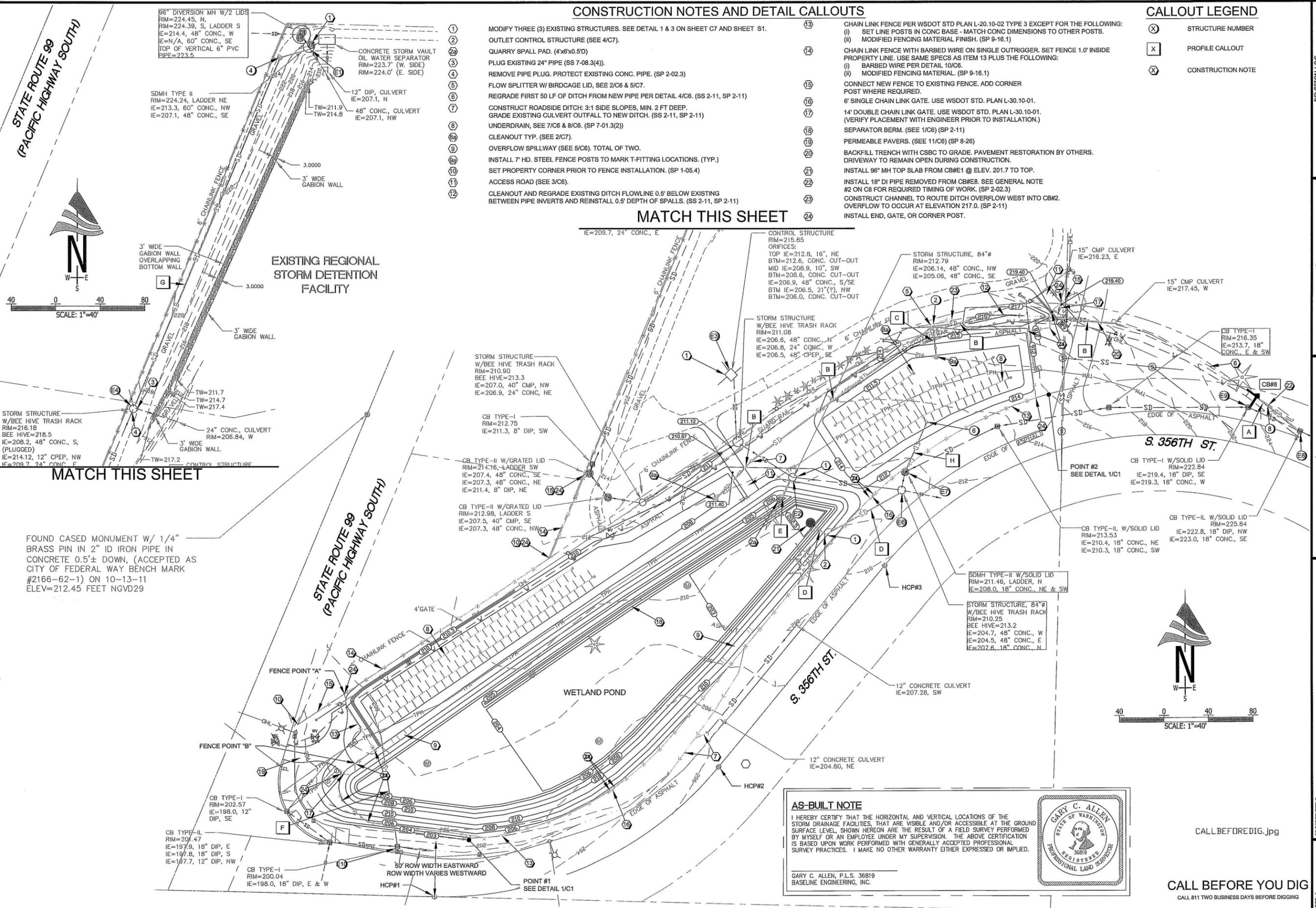
DOWNSTREAM

NOTES:

APPENDIX B: AS BUILT DRAWINGS FOR THE EXPANDED AND RETORFITTED **S.** 356TH STREET REGIONAL DETENTION FACILITY

The “as built” drawings include specifications for the components of the regional detention facility that were new or modified during the 2013-2014 expansion and retrofit. As built drawings for the original regional detention facility are available from the City of Federal Way.

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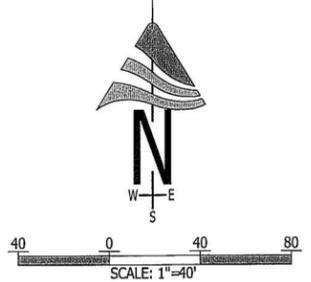
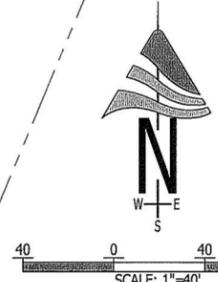


CONSTRUCTION NOTES AND DETAIL CALLOUTS

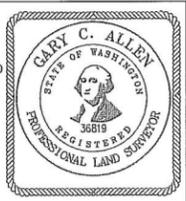
CALLOUT LEGEND

- ① MODIFY THREE (3) EXISTING STRUCTURES. SEE DETAIL 1 & 3 ON SHEET C7 AND SHEET S1.
- ② OUTLET CONTROL STRUCTURE (SEE 4/C7).
- ③ QUARRY SPALL PAD. (4'x6'x0.5')
- ④ PLUG EXISTING 24" PIPE (SS 7-08.3(4)).
- ⑤ REMOVE PIPE PLUG. PROTECT EXISTING CONC. PIPE. (SP 2-02.3)
- ⑥ FLOW SPLITTER W/ BIRDCAGE LID, SEE 2/C6 & 5/C7.
- ⑦ REGRADE FIRST 50 LF OF DITCH FROM NEW PIPE PER DETAIL 4/C6. (SS 2-11, SP 2-11)
- ⑧ CONSTRUCT ROADSIDE DITCH: 3:1 SIDE SLOPES, MIN. 2 FT DEEP. GRADE EXISTING CULVERT OUTFALL TO NEW DITCH. (SS 2-11, SP 2-11)
- ⑨ UNDERDRAIN, SEE 7/C6 & 8/C6. (SP 7-01.3(2))
- ⑩ CLEANOUT TYP. (SEE 2/C7).
- ⑪ OVERFLOW SPILLWAY (SEE 5/C6). TOTAL OF TWO.
- ⑫ INSTALL 7" HD. STEEL FENCE POSTS TO MARK T-FITTING LOCATIONS. (TYP.)
- ⑬ SET PROPERTY CORNER PRIOR TO FENCE INSTALLATION. (SP 1-05.4)
- ⑭ ACCESS ROAD (SEE 3/C6).
- ⑮ CLEANOUT AND REGRADE EXISTING DITCH FLOWLINE 0.5' BELOW EXISTING BETWEEN PIPE INVERTS AND REINSTALL 0.5' DEPTH OF SPALLS. (SS 2-11, SP 2-11)
- ⑯ CHAIN LINK FENCE PER WSDOT STD PLAN L-20.10-02 TYPE 3 EXCEPT FOR THE FOLLOWING:
 - (i) SET LINE POSTS IN CONC BASE - MATCH CONC DIMENSIONS TO OTHER POSTS.
 - (ii) MODIFIED FENCING MATERIAL FINISH. (SP 9-16.1)
- ⑰ CHAIN LINK FENCE WITH BARBED WIRE ON SINGLE OUTRIGGER. SET FENCE 1.0' INSIDE PROPERTY LINE. USE SAME SPECS AS ITEM 13 PLUS THE FOLLOWING:
 - (i) BARBED WIRE PER DETAIL 10/C6.
 - (ii) MODIFIED FENCING MATERIAL. (SP 9-16.1)
- ⑱ CONNECT NEW FENCE TO EXISTING FENCE. ADD CORNER POST WHERE REQUIRED.
- ⑲ 6' SINGLE CHAIN LINK GATE. USE WSDOT STD. PLAN L-30.10-01.
- ⑳ 14' DOUBLE CHAIN LINK GATE. USE WSDOT STD. PLAN L-30.10-01. (VERIFY PLACEMENT WITH ENGINEER PRIOR TO INSTALLATION.)
- ㉑ SEPARATOR BERM. (SEE 1/C6) (SP 2-11)
- ㉒ PERMEABLE PAVERS. (SEE 11/C6) (SP 8-26)
- ㉓ BACKFILL TRENCH WITH CSBC TO GRADE. PAVEMENT RESTORATION BY OTHERS. DRIVEWAY TO REMAIN OPEN DURING CONSTRUCTION.
- ㉔ INSTALL 96" MH TOP SLAB FROM CB#E1 @ ELEV. 201.7 TO TOP.
- ㉕ INSTALL 18" DI PIPE REMOVED FROM CB#E8. SEE GENERAL NOTE #2 ON C8 FOR REQUIRED TIMING OF WORK. (SP 2-02.3)
- ㉖ CONSTRUCT CHANNEL TO ROUTE DITCH OVERFLOW WEST INTO CB#2. OVERFLOW TO OCCUR AT ELEVATION 217.0. (SP 2-11)
- ㉗ INSTALL END, GATE, OR CORNER POST.

MATCH THIS SHEET



AS-BUILT NOTE
 I HEREBY CERTIFY THAT THE HORIZONTAL AND VERTICAL LOCATIONS OF THE STORM DRAINAGE FACILITIES, THAT ARE VISIBLE AND/OR ACCESSIBLE AT THE GROUND SURFACE LEVEL, SHOWN HEREON ARE THE RESULT OF A FIELD SURVEY PERFORMED BY MYSELF OR AN EMPLOYEE UNDER MY SUPERVISION. THE ABOVE CERTIFICATION IS BASED UPON WORK PERFORMED WITH GENERALLY ACCEPTED PROFESSIONAL SURVEY PRACTICES. I MAKE NO OTHER WARRANTY EITHER EXPRESSED OR IMPLIED.



CALL BEFORE YOU DIG.jpg

CALL BEFORE YOU DIG
CALL 811 TWO BUSINESS DAYS BEFORE DIGGING

REVISION LOG	
#	DATE

CITY OF Federal Way
 PHONE: (253) 835-7000
 FAX: (253) 835-2709
 www.CityOfFederalWay.com
 33325 8TH AVE. SOUTH
 FEDERAL WAY, WA 98003

Will's Seal.JPG

Fei's Seal.JPG

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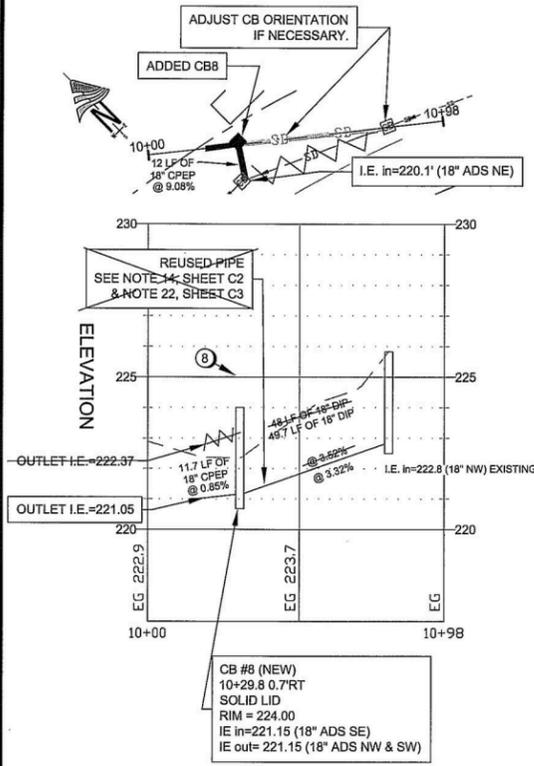
SHEET NAME: **GRADING AND DRAINAGE PLAN**

PROJECT ENGINEER: FEEI YANG
 DRAWN BY: PPH
 DATE PROJECT BEGAN: 8/2010
 EMAIL: FEI.TANG@CITYOFFEDERALWAY.COM
 PHONE #: 253-835-2751
 DRAINAGE BASIN: WEST HYLBROS

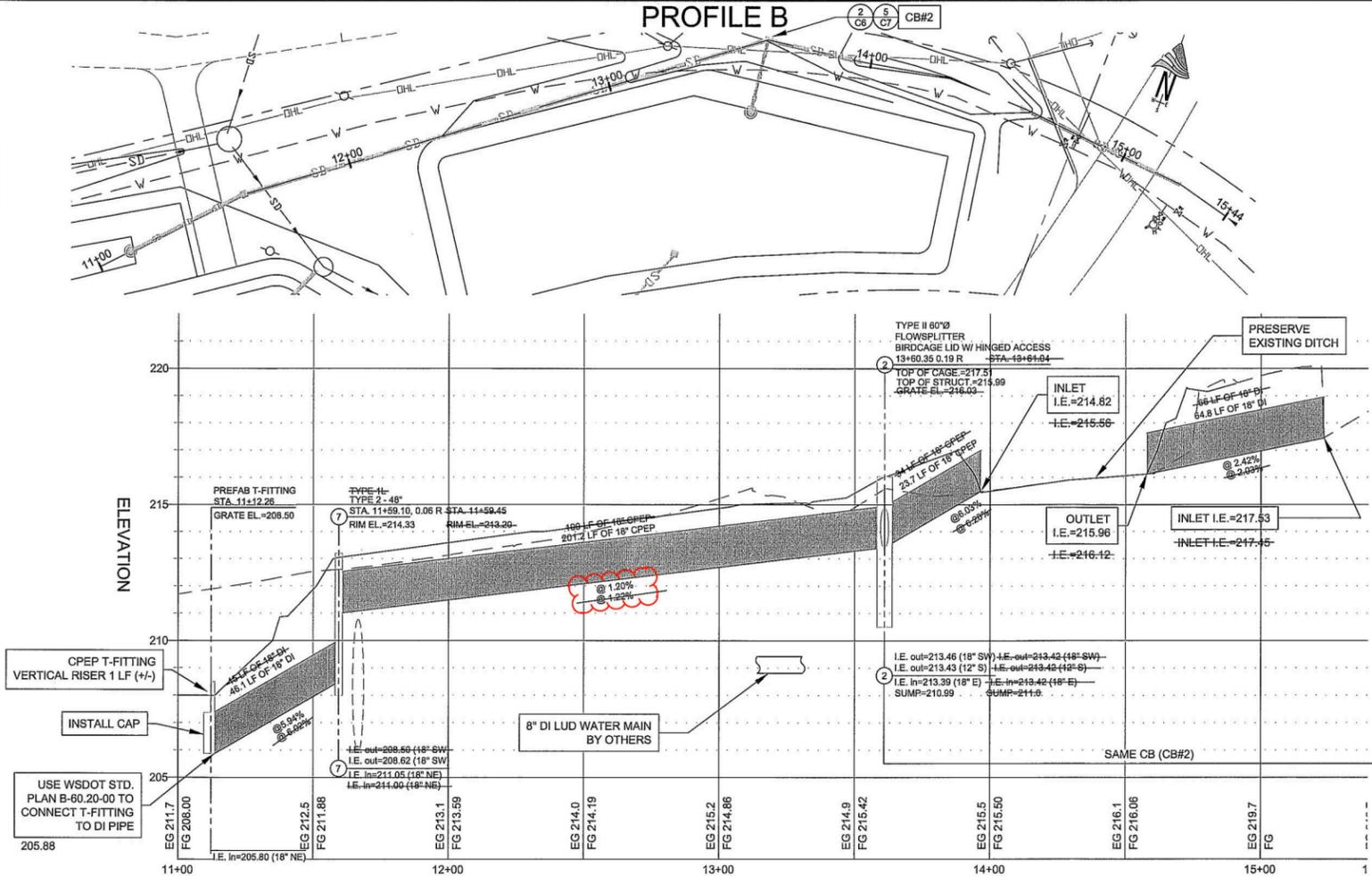
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SHEET **4** OF **14**

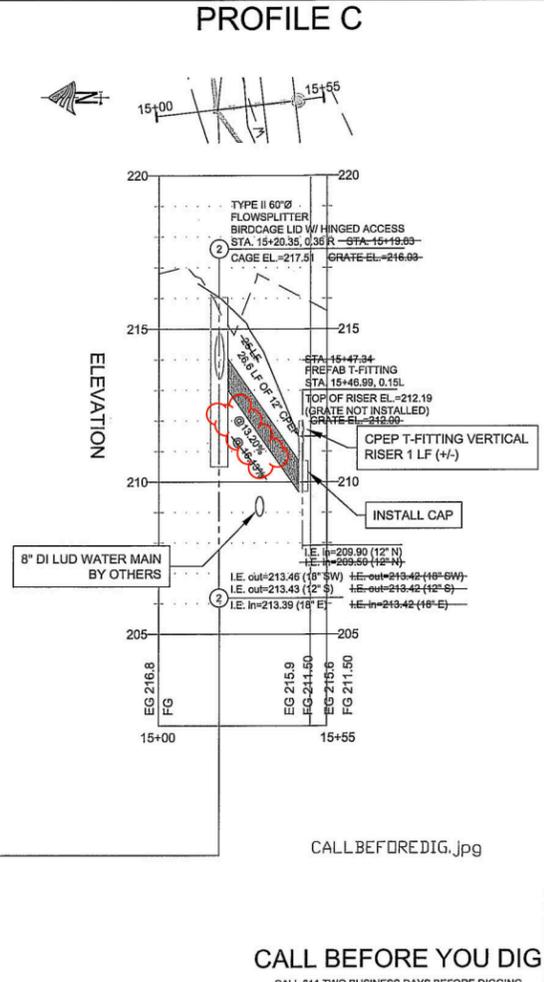
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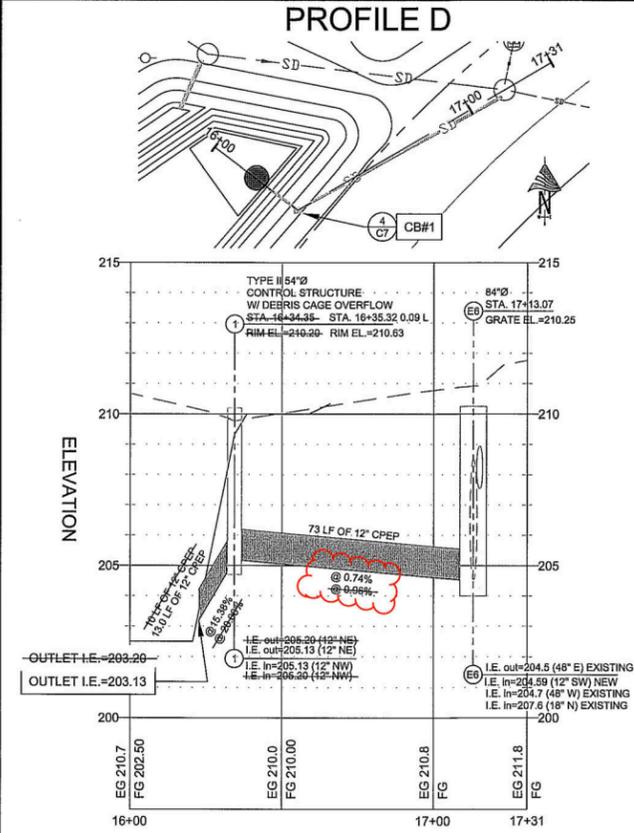
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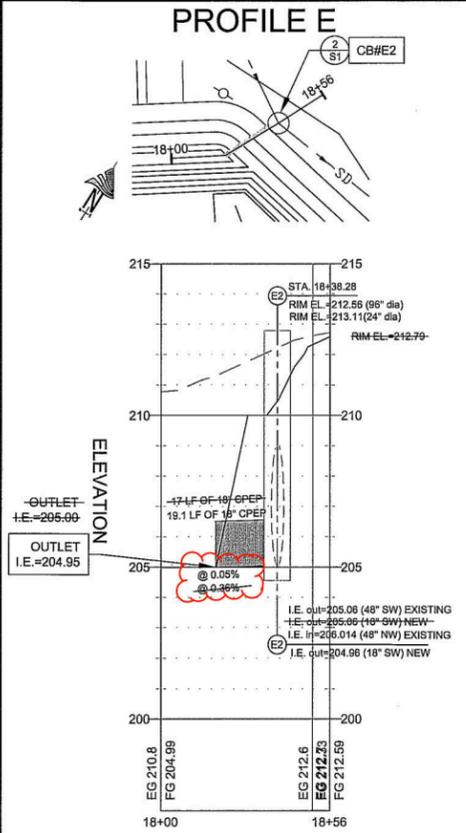
PROFILE C



PROFILE D

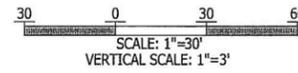


PROFILE E



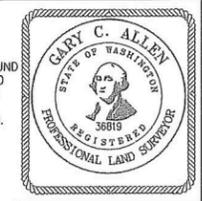
GENERAL PROFILE NOTES

- STANDARD CB SUMP DEPTH = 2' BELOW LOWEST OUTLET INVERT UNLESS OTHERWISE NOTED.
- ALL CBS TO HAVE SOLID LOCKING LIDS UNLESS OTHERWISE NOTED.



AS-BUILT NOTE

I HEREBY CERTIFY THAT THE HORIZONTAL AND VERTICAL LOCATIONS OF THE STORM DRAINAGE FACILITIES, THAT ARE VISIBLE AND/OR ACCESSIBLE AT THE GROUND SURFACE LEVEL, SHOWN HEREON ARE THE RESULT OF A FIELD SURVEY PERFORMED BY MYSELF OR AN EMPLOYEE UNDER MY SUPERVISION. THE ABOVE CERTIFICATION IS BASED UPON WORK PERFORMED WITH GENERALLY ACCEPTED PROFESSIONAL SURVEY PRACTICES. I MAKE NO OTHER WARRANTY EITHER EXPRESSED OR IMPLIED.



GARY C. ALLEN, P.L.S. 36819
BASELINE ENGINEERING, INC.

REVISION LOG	
#	DATE

CITY OF Federal Way
 PHONE: (253) 835-7000
 33325 8TH AVE. SOUTH
 FEDERAL WAY, WA 98003
 FAX: (253) 835-2709
 www.CityOfFederalWay.com

Will'sSeal.JPG

CALL BEFORE YOU DIG
 CALL 811 TWO BUSINESS DAYS BEFORE DIGGING

Fei'sSeal.JPG

PROJECT TITLE: S. 356TH ST. REGIONAL STORMWATER FACILITY RETROFIT

SHEET NAME: STORM DRAINAGE PLAN AND PROFILE [1]

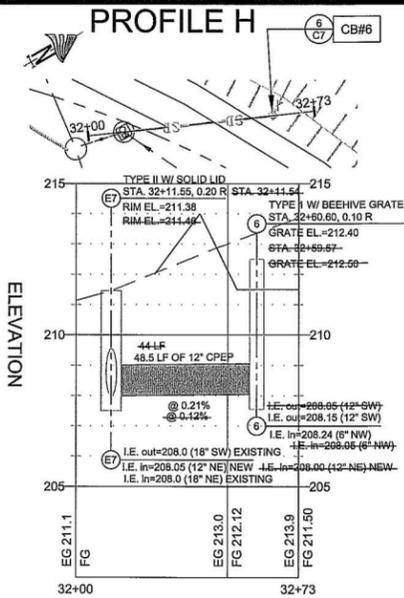
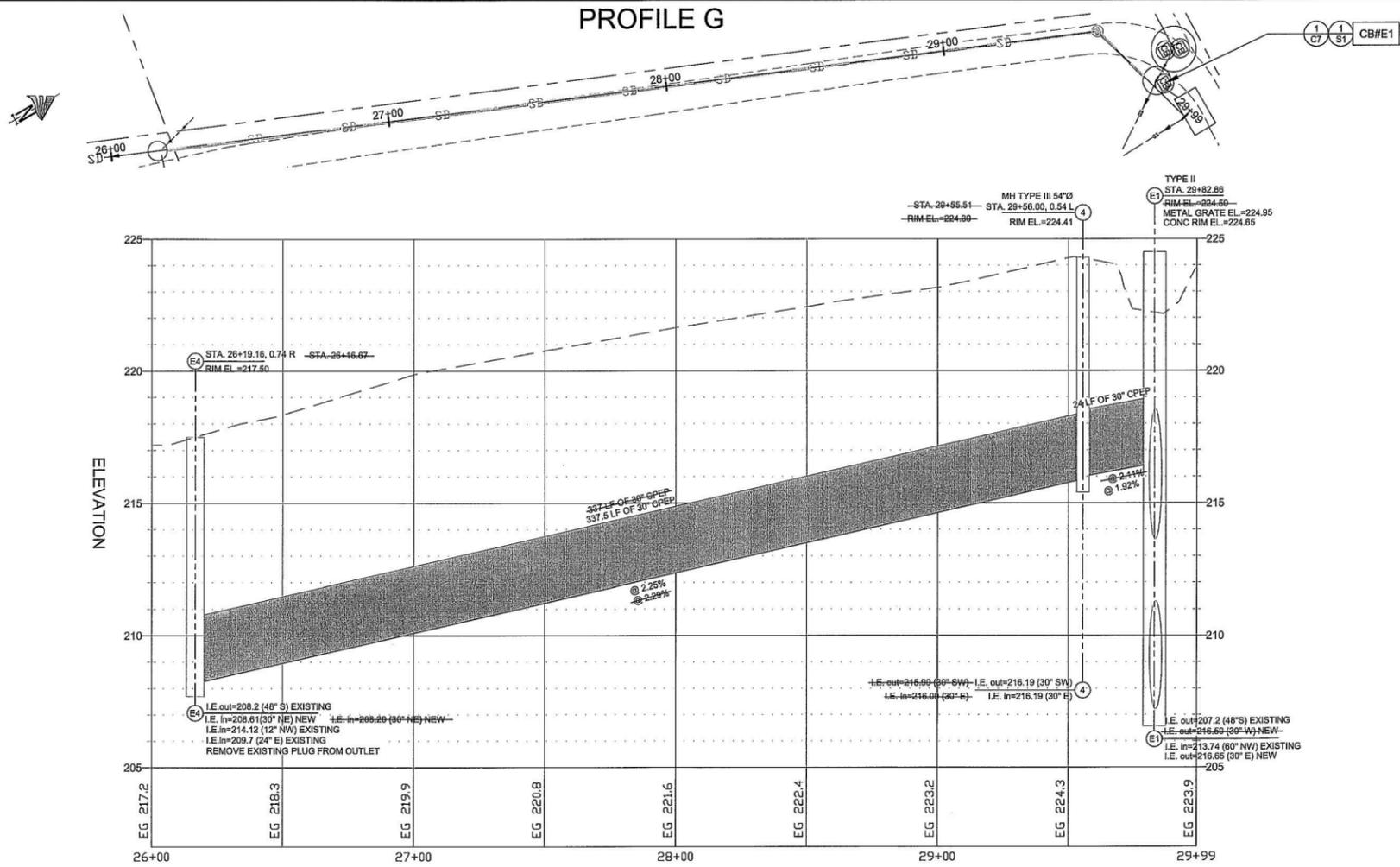
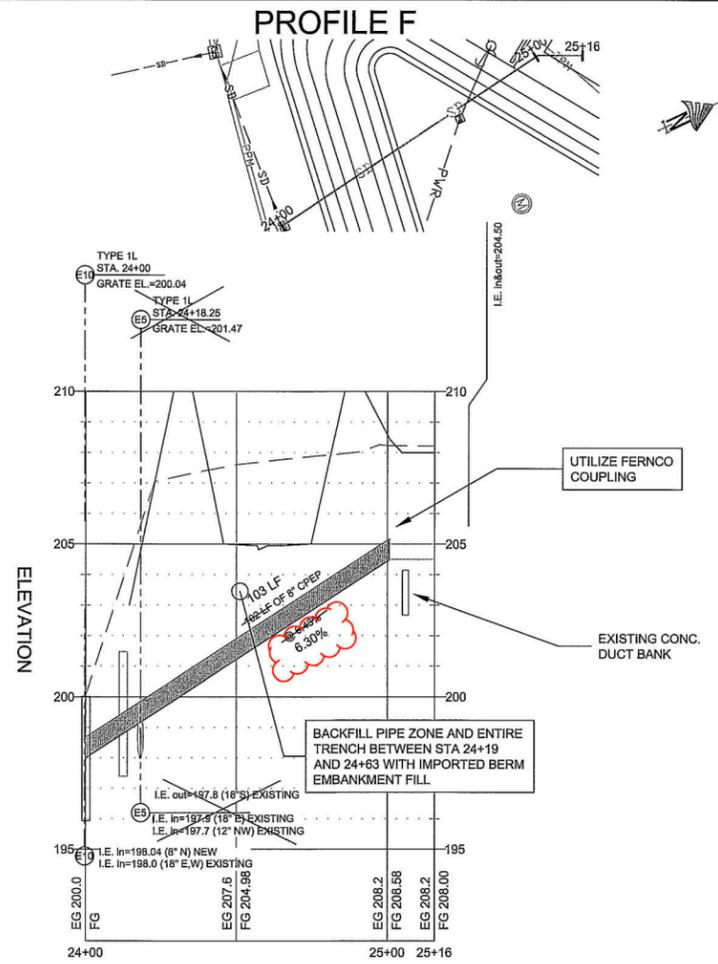
PROJECT ENGINEER: FEI TANG
DATE PROJECT BEGAN: 8/2010
DRAWN BY: PPH
EMAIL: FEI.TANG@CITYOFFEDERALWAY.COM
PHONE #: 253-835-2751
DRAINAGE BASIN: WEST HYLEBOIS

RFB #: 13-106

SHEET 5 OF 14

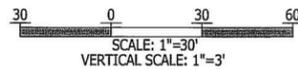
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GENERAL PROFILE NOTES

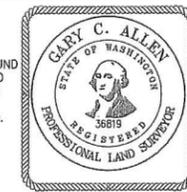
- STANDARD CB SUMP DEPTH = 2' UNLESS OTHERWISE NOTED.
- ALL CBS TO HAVE A CITY STANDARD GRATE UNLESS OTHERWISE NOTED.



AS-BUILT NOTE

I HEREBY CERTIFY THAT THE HORIZONTAL AND VERTICAL LOCATIONS OF THE STORM DRAINAGE FACILITIES, THAT ARE VISIBLE AND/OR ACCESSIBLE AT THE GROUND SURFACE LEVEL, SHOWN HEREON ARE THE RESULT OF A FIELD SURVEY PERFORMED BY MYSELF OR AN EMPLOYEE UNDER MY SUPERVISION. THE ABOVE CERTIFICATION IS BASED UPON WORK PERFORMED WITH GENERALLY ACCEPTED PROFESSIONAL SURVEY PRACTICES. I MAKE NO OTHER WARRANTY EITHER EXPRESSED OR IMPLIED.

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CALL BEFORE YOU DIG.jpg

REVISION LOG	
#	DATE

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Will's Seal.JPG

Fei's Seal.JPG

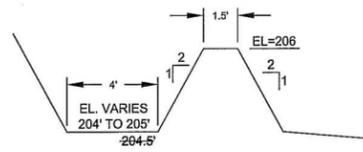
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SHEET NAME:	STORM DRAINAGE PLAN AND PROFILE [2]
PROJECT ENGINEER:	FEI TANG
DRAWN BY:	PPH
DATE PROJECT BEGAN:	8/2010
EMAIL:	FEI.TANG@CITYOFFEDERALWAY.COM
PHONE #:	253-835-2751
DRAINAGE BASIN:	WEST HYLEBOS

REF #: 13-106

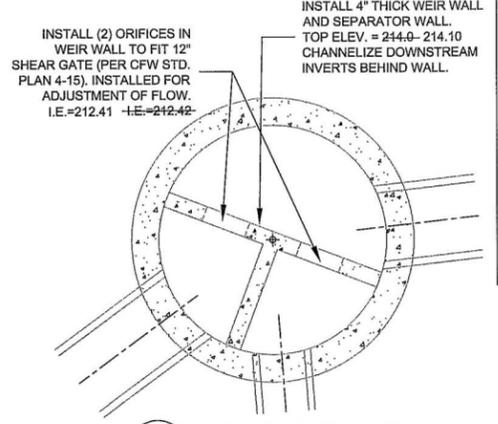
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SHEET 6 OF 14

CALL BEFORE YOU DIG
CALL 811 TWO BUSINESS DAYS BEFORE DIGGING

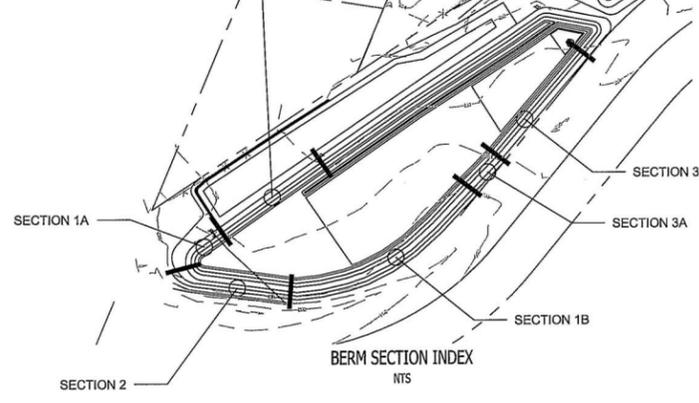


1 SEPARATOR BERM SECTION
NTS

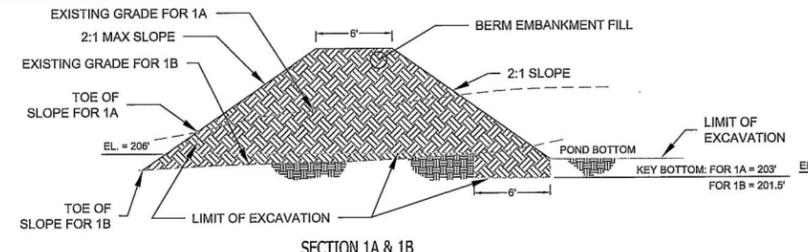


2 CB#2 FLOW SPLITTING DETAIL
NTS

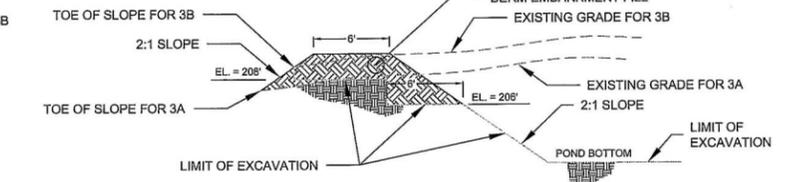
REMOVE UNSUITABLE MATERIAL AS DIRECTED BY ENGINEER.
CONSTRUCT EMBANKMENT WITH IMPORTED BERM EMBANKMENT FILL OR SUITABLE NATIVE MATERIAL AS DIRECTED BY ENGINEER.



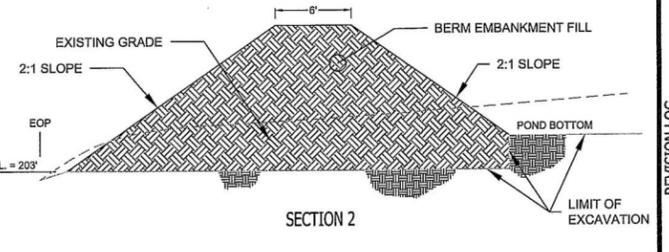
BERM SECTION INDEX
NTS



SECTION 1A & 1B



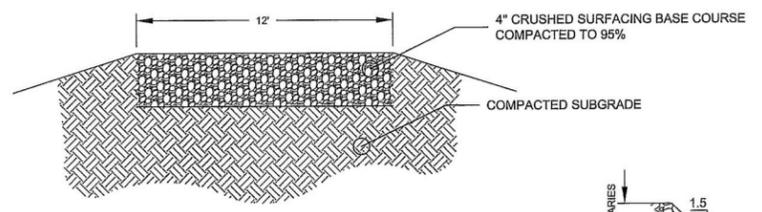
SECTION 3A & 3B



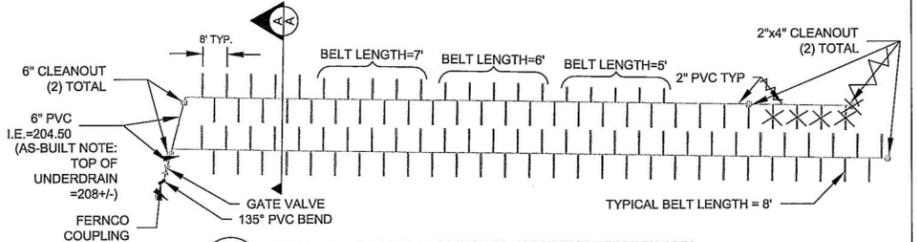
SECTION 2

NOTE: WHERE EXISTING GRADE IS AT OR BELOW LIMIT OF EXCAVATION, REMOVE TOP 6\"/>

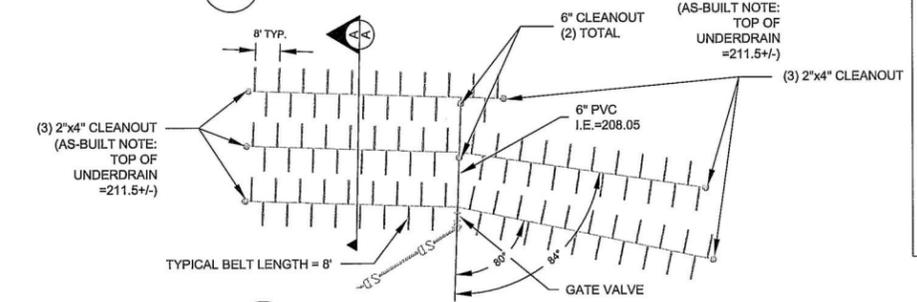
6 BERM SECTIONS
NTS



3 ACCESS ROAD SURFACING DETAIL
NTS

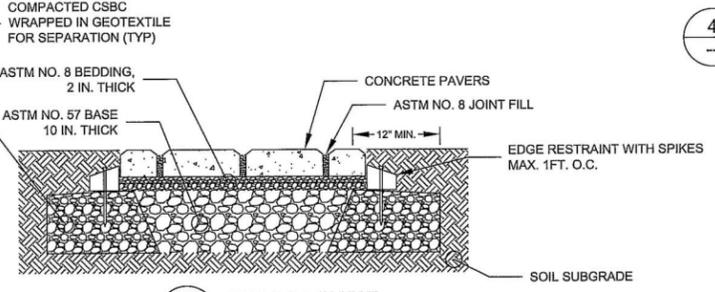


7 SMARTDRAIN UNDERDRAIN SYSTEM - WEST BIORETENTION AREA
NTS

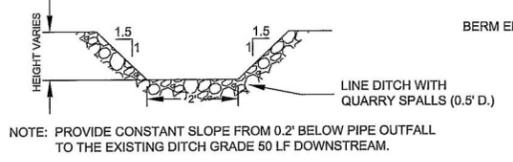


8 SMARTDRAIN UNDERDRAIN SYSTEM - EAST BIORETENTION AREA
NTS

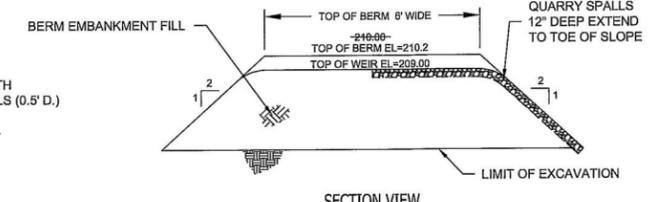
NOTES FOR DETAILS 7&8:
• USE 8\"/>



11 PERMEABLE PAVEMENT
NTS



4 DITCH SECTION
NTS

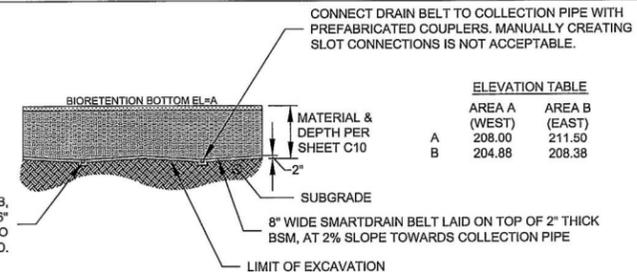
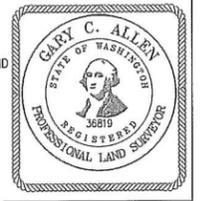


5 OVERFLOW SPILLWAY DETAIL
NTS

AS-BUILT NOTE

I HEREBY CERTIFY THAT THE HORIZONTAL AND VERTICAL LOCATIONS OF THE STORM DRAINAGE FACILITIES, THAT ARE VISIBLE AND/OR ACCESSIBLE AT THE GROUND SURFACE LEVEL, SHOWN HEREON ARE THE RESULT OF A FIELD SURVEY PERFORMED BY MYSELF OR AN EMPLOYEE UNDER MY SUPERVISION. THE ABOVE CERTIFICATION IS BASED UPON WORK PERFORMED WITH GENERALLY ACCEPTED PROFESSIONAL SURVEY PRACTICES. I MAKE NO OTHER WARRANTY EITHER EXPRESSED OR IMPLIED.

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BASELINE ENGINEERING, INC.



9 SECTION A-A: TYPICAL BIORETENTION SECTION
NTS

ELEVATION TABLE

	AREA A (WEST)	AREA B (EAST)
A	208.00	211.50
B	204.88	208.38

NOTE: BARBED WIRE ARM SHALL EXTEND OUTWARD FROM THE ADJACENT PRIVATE PROPERTY.

10 BARBED WIRE DETAIL
NTS

CALL BEFORE YOU DIG.jpg

CALL BEFORE YOU DIG
CALL 811 TWO BUSINESS DAYS BEFORE DIGGING

REVISION LOG	NOTES	DATE	BY
#			

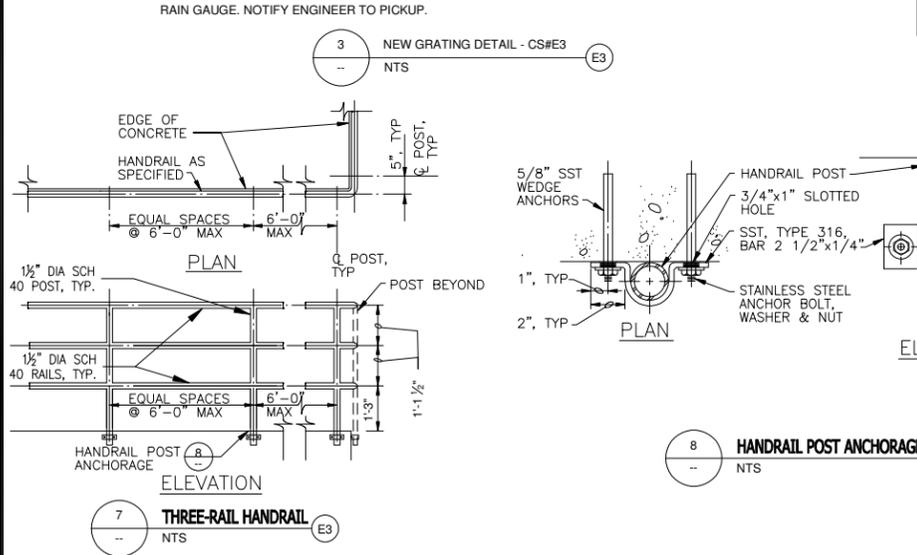
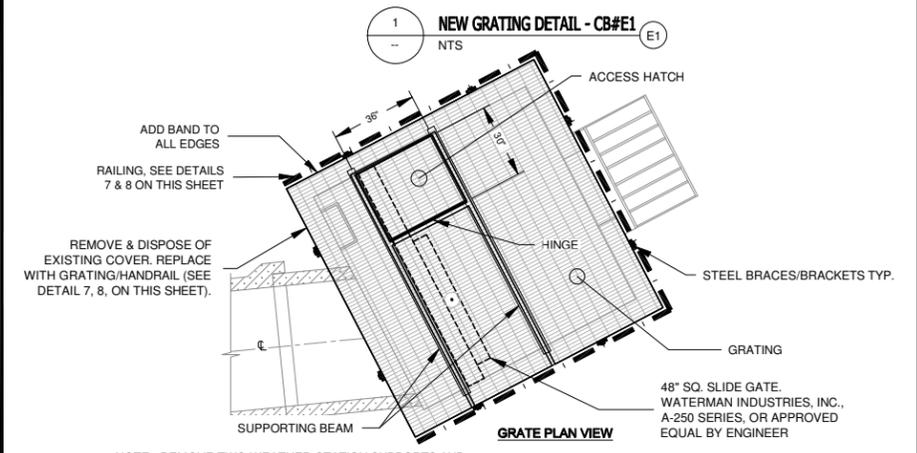
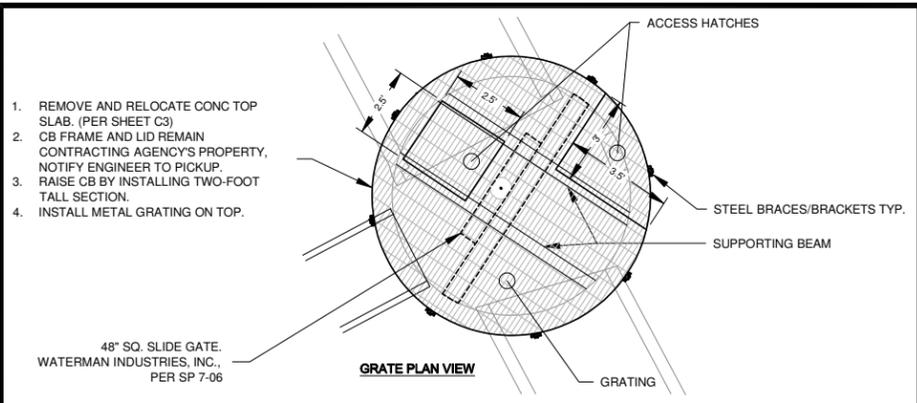
CITY OF Federal Way
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 33325 6TH AVE. SOUTH
 FEDERAL WAY, WA 98003
 FAX: (253) 835-2709
 www.CityOfFederalWay.com

Will's Seal.JPG
 Fei's Seal.JPG

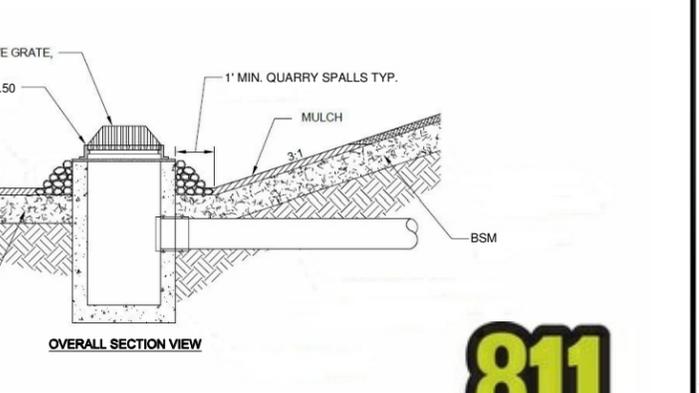
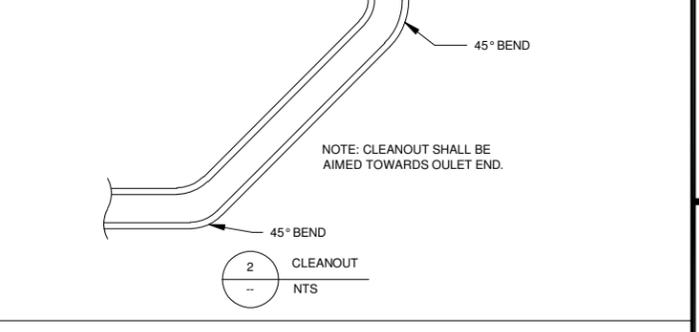
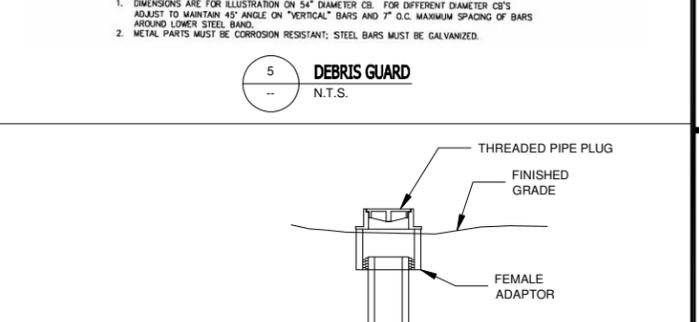
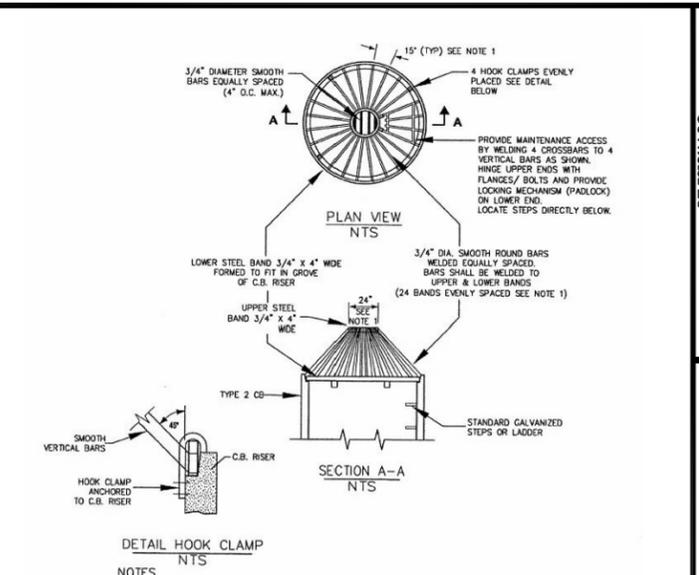
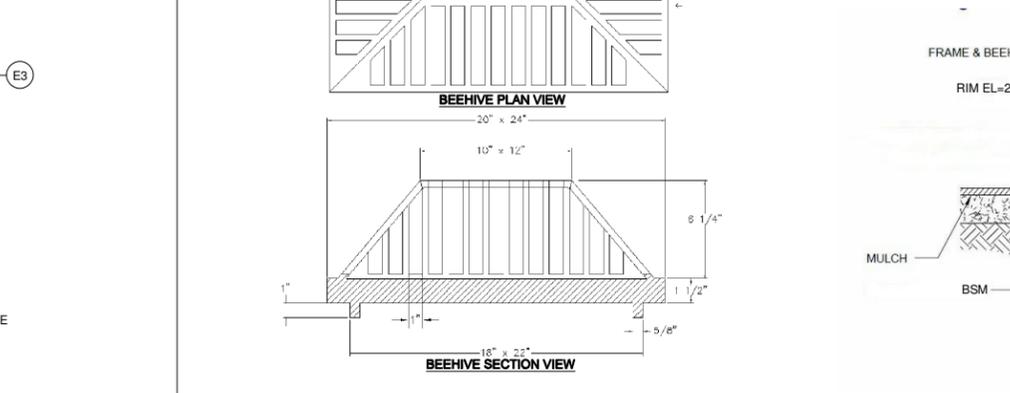
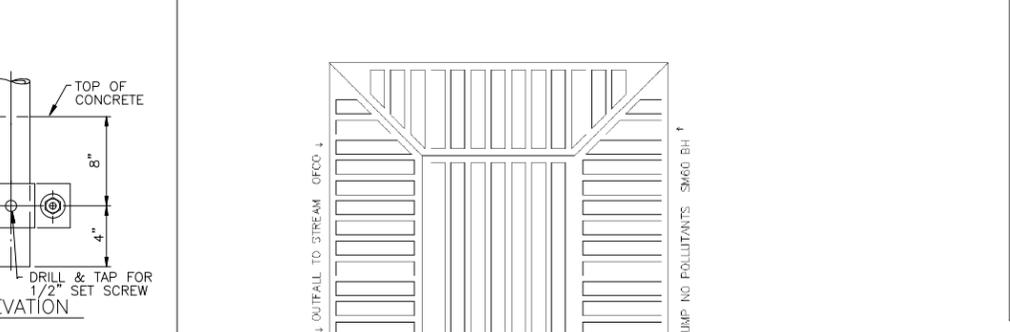
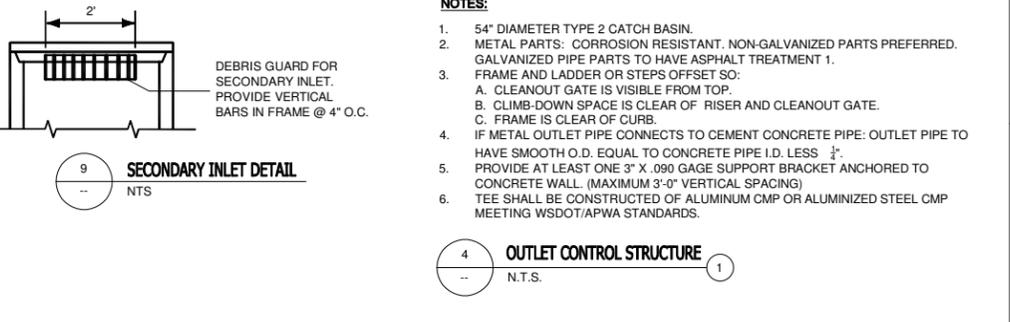
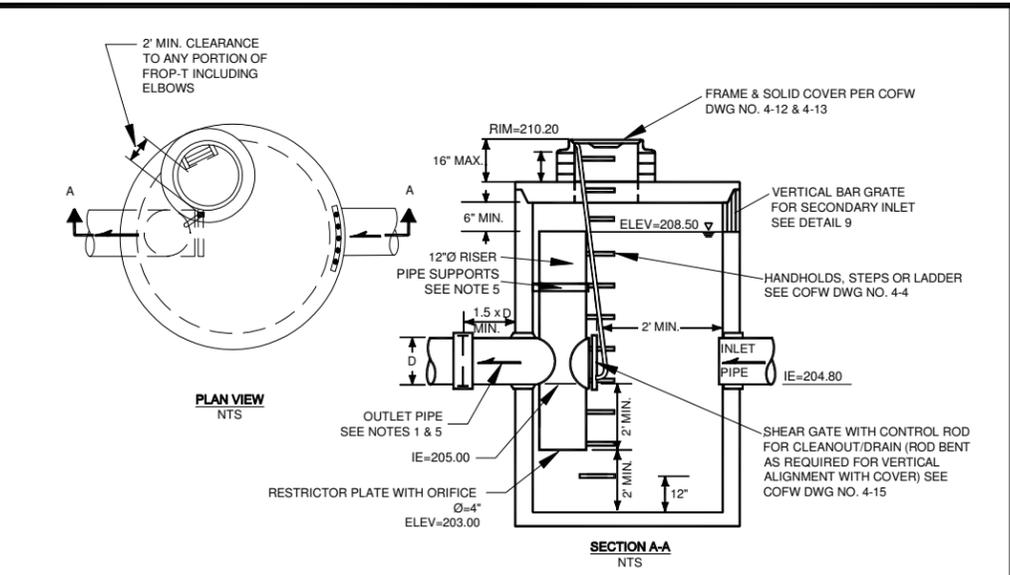
PROJECT TITLE: S. 356TH ST. REGIONAL STORMWATER FACILITY RETROFIT
 SHEET NAME: GENERAL DETAILS [1]
 PROJECT ENGINEER: FELIANG
 DATE PROJECT BEGAN: 9/2010
 DRAWN BY: PPH
 EMAIL: FELIANG@CITYOFFEDERALWAY.COM
 PHONE #: 253-835-2751
 DRAINAGE BASIN: WEST HYLBROS

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Apr. 26, 2013 - 10:45am - K:\SWM\Projects\9 - West Hyiebos\Programmed\S 356th RDJ Expansion\Final Design\Working.dwg

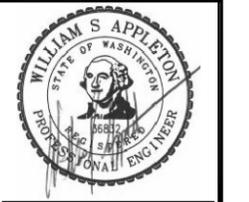


- GRATING NOTES:**
- GRATING MANUFACTURE TO VERIFY ACTUAL DIMENSIONS AND DESIGN GRATING AND SUPPORTING BEAMS TO MEET THE FOLLOWING CRITERIA:
FOR GRATING ON CS#E3: UNIFORM LIVE LOAD 150# PER SQ. FT, DEFLECTION NOT TO EXCEED 1/4".
FOR GRATING ON CB#E1: AASHTO HS-20 WHEEL LOADING.
 - SUPPORTING BEAMS SHOWN ARE ILLUSTRATIVE AND SHALL NOT LIMIT DESIGN OF ANY PARTICULAR TYPE.
 - ALL GRATING PANELS AND HATCHES SHALL BE SUPPORTED BY SUPPORTING BEAMS.
 - CONDITION OF EXISTING CONC STRUCTURES IS UNKNOWN. CONTRACTOR SHALL REPAIR DEFECTS ON EXISTING CONC STRUCTURES. GRATING SHALL BE SUPPORTED BY LEVEL AND NON-WOBBLY SURFACE.
 - TO PREVENT GRATING FROM LATERAL DISPLACEMENT, GRATING SHALL BE CONSTRAINED TO CONC STRUCTURE BY, AT THE MINIMUM, ADEQUATE STEEL BRACES OR BRACKETS BOLTED ONTO CONC STRUCTURE.
 - ALL MISC. METAL SHALL BE HOT DIP GALVANIZED UNLESS NOTED OTHERWISE.
 - BAND ALL EDGES WITH THE SAME STEEL USED FOR BEARING BAR.
 - PROVIDE MINIMUM 4 STAINLESS STEEL REMOVABLE HOLD DOWN CLIPS PER GRATING PANEL.
 - HINGES FOR HATCH SHALL BE DETAILED BY GRATING MANUFACTURE. USE CONTINUOUS HINGE OR MINIMUM 2 BUTT HINGES. HINGES SHALL BE STAINLESS STEEL.
 - CONTRACTOR TO VERIFY ACTUAL DIMENSION OF EXISTING CONCRETE STRUCTURES AND COORDINATE GRATING AND SUPPORT DETAILS WITH ACTUAL EXISTING STRUCTURE DIMENSION.
 - GRATING BAR SPACING NOT TO EXCEED 2".
 - HORIZONTAL CLEARANCE BETWEEN GRATING AND GRATING SUPPORTS SHALL NOT BE LESS THAN 1/4" NOR GREATER THAN 1/2".
 - PROVIDE MISCELLANEOUS GRATING FASTENERS AS REQUIRED.
 - NOTCH AND BAND GRATING FOR SLIDE GATE STEM NUT. FIT GATE GUIDE RAIL AND STEM NUT UNDERNEATH GRATING IF POSSIBLE, OTHERWISE NOTCH AND BAND GRATING FOR GATE GUIDE RAIL AS WELL. CONTRACTOR TO COORDINATE WITH GATE SUPPLIER PRIOR TO FABRICATION. FIELD MODIFICATION NOT ALLOWED.



REVISION LOG		NOTES
#	BY	DATE

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 FAX: (253) 835-2709
 www.CityOfFederalWay.com
 3325 8TH AVE. SOUTH
 FEDERAL WAY, WA 98003



PROJECT TITLE: S. 356TH ST. REGIONAL STORMWATER FACILITY RETROFIT

SHEET NAME: GENERAL DETAILS [2]

PROJECT ENGINEER: FEI TANG
DATE PROJECT BEGAN: 02/2010

DRAWN BY: FELIANG@CITYOFFEDERALWAY.COM
EMAIL: FELIANG@CITYOFFEDERALWAY.COM

PHONE #: 253-835-2751
DRAINAGE BASIN: WEST HYIEBOS

RPB #: 13-106

SHEET 8 OF 14



APPENDIX C: CHAIN OF CUSTODY (COC) FORM

The following page is an example of the Chain of Custody form that will be used by the King County Environmental Laboratory staff.

Project: 421879-240

CHAIN OF CUSTODY

<i>Relinquished by</i>	<i>Date</i>	<i>Time</i>
<i>Received by</i>	<i>Date</i>	<i>Time</i>
<i>Sample Numbers</i> [All]		

Sample Number	P64809-1	P64809-2	P64809-3
QC Link			
Locator	FW-EBI	FW-EBO	FW-WBI
Short Loc Desc	EBI	EBO	WBI
Locator Desc	EAST BIORETENTION FACILITY INLET	EAST BIORETENTION FACILITY OUTLET	WEST BIORETENTION FACILITY INLET
Site	KING COUNTY	KING COUNTY	KING COUNTY
Comments			
Start Date/Time			
End Date/Time			
Time Span			
Sample Depth			
Dept, Matrix, Prod	3 LG ALK 3 LG DOC 3 LG NH3 3 LG NO23 3 LG ORTHOP 3 LG TOC 3 LG TOTN 3 LG TOTP 3 LG TSS 6 LG CA-ICPMS 6 LG CD-ICPMS 6 LG CD-ICPMS, DISS 6 LG CU-ICPMS 6 LG CU-ICPMS, DISS 6 LG ICPMS-HARDNESS 6 LG MG-ICPMS 6 LG PB-ICPMS 6 LG PB-ICPMS, DISS 6 LG ZN-ICPMS 6 LG ZN-ICPMS, DISS 7 LG PAH-SIM 10 LG EPA1668PCB	3 LG ALK 3 LG DOC 3 LG NH3 3 LG NO23 3 LG ORTHOP 3 LG TOC 3 LG TOTN 3 LG TOTP 3 LG TSS 6 LG CA-ICPMS 6 LG CD-ICPMS 6 LG CD-ICPMS, DISS 6 LG CU-ICPMS 6 LG CU-ICPMS, DISS 6 LG ICPMS-HARDNESS 6 LG MG-ICPMS 6 LG PB-ICPMS 6 LG PB-ICPMS, DISS 6 LG ZN-ICPMS 6 LG ZN-ICPMS, DISS 7 LG PAH-SIM 10 LG EPA1668PCB	3 LG ALK 3 LG DOC 3 LG NH3 3 LG NO23 3 LG ORTHOP 3 LG TOC 3 LG TOTN 3 LG TOTP 3 LG TSS 6 LG CA-ICPMS 6 LG CD-ICPMS 6 LG CD-ICPMS, DISS 6 LG CU-ICPMS 6 LG CU-ICPMS, DISS 6 LG ICPMS-HARDNESS 6 LG MG-ICPMS 6 LG PB-ICPMS 6 LG PB-ICPMS, DISS 6 LG ZN-ICPMS 6 LG ZN-ICPMS, DISS 7 LG PAH-SIM 10 LG EPA1668PCB

APPENDIX D: HOBO[®] U20L WATER LEVEL LOGGER (U20L-0X) MANUAL



The HOBO U20L Water Level Logger is used for monitoring changing water levels in a wide range of applications, including streams, lakes, wetlands, tidal areas, and groundwater. Using HOBOWare® Pro, you can easily configure this logger to record absolute pressure and temperature data. This logger features a ceramic pressure sensor, durable housing, and a protective end cap for deployment in existing wells or stilling wells. Without cumbersome vent tubes or desiccants to maintain, this easy-to-use logger is an ideal solution for water level studies and research.

Specifications

HOBO Water Level Logger

Models:

- U20L-01 (30-foot depth)
- U20L-02 (100-foot depth)
- U20L-04 (13-foot depth)

Required Items:

- Coupler (COUPLER2-C) with USB Optic Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1, firmware version 3.2.0 or later)*
- HOBOWare® Pro, version 3.5 or higher

Accessories:

- Cable (CABLE-1-300 or CABLE-1-50) and Cable Crimp (CABLE-1-CRIMP)
- Replacement Coupler (COUPLER2-C)

**If shuttle firmware version 3.2.0 or later is needed, see the Onset website or contact Onset Technical Support.*

Pressure (Absolute) and Water Level Measurements U20L-01

Operation Range	0 to 207 kPa (0 to 30 psia); approximately 0 to 9 m (0 to 30 ft) of water depth at sea level, or 0 to 12 m (0 to 40 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 207 kPa (10 to 30 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.1% FS, 1.0 cm (0.03 ft) water Maximum error: ±0.2% FS, 2.0 cm (0.06 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.62 kPa (0.09 psi) maximum error
Resolution	<0.02 kPa (0.003 psi), 0.21 cm (0.007 ft) water
Pressure Response Time (90%***)	<1 second at a stable temperature; measurement accuracy also depends on temperature response time

Pressure (Absolute) and Water Level Measurements U20L-02

Operation Range	0 to 400 kPa (0 to 58 psia); approximately 0 to 30.6 m (0 to 100 ft) of water depth at sea level, or 0 to 33.6 m (0 to 111 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 400 kPa (10 to 58 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	500 kPa (72.5 psia) or 40.8 m (134 ft) depth
Water Level Accuracy*	Typical error: ±0.1% FS, 3.0 cm (0.1 ft) water Maximum error: ±0.2% FS, 6.0 cm (0.2 ft) water
Raw Pressure Accuracy**	±0.3% FS, 1.20 kPa (0.17 psi) maximum error
Resolution	<0.04 kPa (0.006 psi), 0.41 cm (0.013 ft) water
Pressure Response Time (90%***)	<1 second at a stable temperature; measurement accuracy also depends on temperature response time

Pressure (Absolute) and Water Level Measurements U20L-04

Operation Range	0 to 145 kPa (0 to 21 psia); approximately 0 to 4 m (0 to 13 ft) of water depth at sea level, or 0 to 7 m (0 to 23 ft) of water at 3,000 m (10,000 ft) of altitude
Factory Calibrated Range	69 to 145 kPa (10 to 21 psia), 0° to 40°C (32° to 104°F)
Burst Pressure	310 kPa (45 psia) or 18 m (60 ft) depth
Water Level Accuracy*	Typical error: ±0.1% FS, 0.4 cm (0.013 ft) water Maximum error: ±0.2% FS, 0.8 cm (0.026 ft) water
Raw Pressure Accuracy**	±0.3% FS, 0.43 kPa (0.063 psi) maximum error
Resolution	<0.014 kPa (0.002 psi), 0.14 cm (0.005 ft) water
Pressure Response Time (90%***)	<1 second at a stable temperature; measurement accuracy also depends on temperature response time

Specifications (continued)

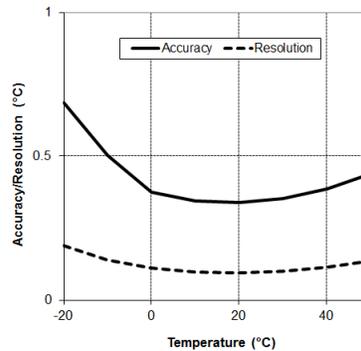
Temperature Measurements (All Models)

Operation Range	-20° to 50°C (-4° to 122°F)
Accuracy	±0.44°C from 0° to 50°C (±0.79°F from 32° to 122°F), see Plot A
Resolution	0.10°C at 25°C (0.18°F at 77°F), see Plot A
Response Time (90%)	10 minutes in water (typical)
Stability (Drift)	0.1°C (0.18°F) per year

Logger

Real-time Clock	±1 minute per month 0° to 50°C (32° to 122°F)
Battery	2/3 AA, 3.6 Volt lithium, factory-replaceable
Battery Life (Typical Use)	5 years with 1 minute or greater logging interval
Memory (Non-volatile)	64K bytes memory (approx. 21,700 pressure and temperature samples)
Weight	Approximately 154 g (5.43 oz) in air Approximately 53.9 g (1.9 oz) in fresh water
Dimensions	3.18 cm (1.25 inches) diameter, 15.24 cm (6.0 inches) length; mounting hole 6.3 mm (0.25 inches) diameter
Wetted Materials	Polypropylene housing and lanyard; Viton and Buna-N O-rings; ceramic sensor in acetyl end cap; stainless steel screws suitable for saltwater
Logging Interval	Fixed-rate or multiple logging intervals, with up to 8 user- defined logging intervals and durations; logging intervals from 1 second to 18 hours. Refer to the <i>HOBOWare User's Guide</i> for details.
Launch Modes	Immediate start and delayed start
Offload Modes	Offload while logging; stop and offload
Battery Indication	Battery voltage can be viewed in status screen and optionally logged in datafile. Low battery indication in datafile.
	The CE Marking identifies this product as complying with all relevant directives in the European Union (EU).

- * Water Level Accuracy: With accurate reference water level measurement, known water density, accurate Barometric Compensation Assistant data, and a stable temperature environment.
- ** Raw Pressure Accuracy: Absolute pressure sensor accuracy includes all sensor drift, temperature, and hysteresis-induced errors.
- *** Changes in Temperature: Allow 20 minutes in water to achieve full temperature compensation of the pressure sensor. Maximum error due to rapid thermal changes is approximately 0.5%.

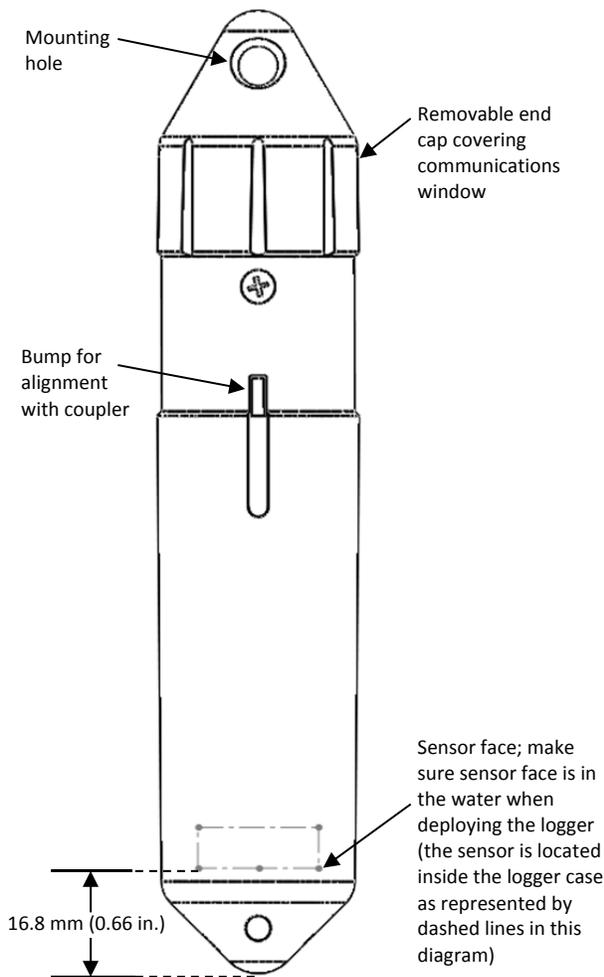


Plot A

Logger Operation

HOBOWare Pro software is required for logger operation. Using a reference water level, HOBOWare Pro automatically converts pressure readings into water level readings (see *Barometric Compensation* for more detail). The software also supports compensation for temperature, fluid density, and barometric pressure.

An LED in the communications window of the logger confirms logger operation. When the logger is logging, the LED blinks once every one to four seconds (the shorter the logging interval, the faster the LED blinks). The LED also blinks when the logger is recording a sample. When the logger is awaiting a start because it was configured to start “At Interval,” “On Date/Time,” or “Using Coupler,” the LED blinks once every eight seconds until logging begins.



The logger can record two types of data: samples and events. Samples are the sensor measurements recorded at each logging interval (for example, the pressure every minute). Events are independent occurrences triggered by a logger activity, such as Bad Battery or Host Connected. Events help you determine what was happening while the logger was logging.

Barometric Compensation

The logger records absolute pressure, which is later converted to water level readings by HOBOWare Pro software. In this application, absolute pressure includes atmospheric pressure and water head. Atmospheric pressure is nominally 100 kPa (14.5 psi) at sea level, but it changes with weather and altitude. Left uncompensated, barometric variations could result in errors of 0.6 m (2 ft) or more.

To compensate for barometric pressure changes, you can use another HOBO U20L Water Level logger as a barometric reference. The barometric reference is typically deployed in the same well or at the same location as the water level of interest, but rather than being placed in the water column, it is deployed above the water in air.

Barometric pressure readings are consistent across a region (except during fast-moving weather events), so you can generally use barometric pressure readings that are taken within 15 km (10 miles) of the logger or more without significantly degrading the accuracy of the compensation.

Therefore, one HOBO U20L or U20 Water Level logger or weather station (HOBO U30 recommended) can be used to compensate all the water level loggers in an area. The U20L-01 model with its 0–9m (0–30 ft) range or the U20L-04 with its 0–4 m (0–13 ft) range are both good barometric references due to their smaller range and temperature-compensated accuracy. HOBOWare Pro includes a Barometric Compensation Assistant for easy and accurate barometric compensation. See *Processing Water Level Data using Barometric Pressure Data* for more details.

Calibration

The pressure sensor in each HOBO U20L Water Level logger is individually calibrated. During calibration, raw pressure sensor data is collected at multiple pressures and temperatures over the calibrated range of the logger (see the specifications table). This data is used to generate calibration coefficients that are stored in the logger’s non-volatile memory. The calibration coefficients are then checked to be sure that the logger meets its stated accuracy over the calibrated range.

The pressure sensor can be used at pressures and temperatures that are outside of the calibrated range, but the accuracy cannot be guaranteed.

Important: Never exceed the burst pressure of the sensor!

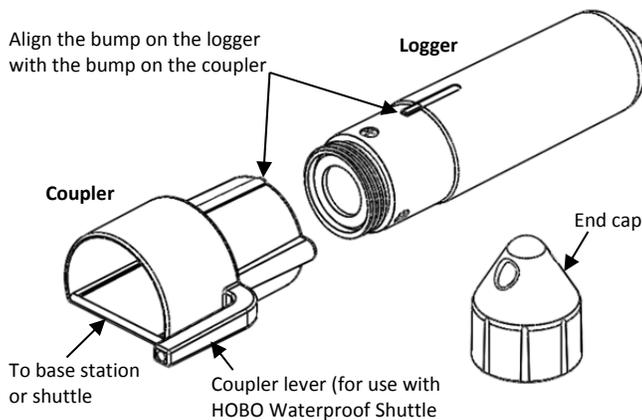
Connecting the Logger to a Computer

The HOBO Water Level Logger requires a coupler (COUPLER2-C) and Optic Base Station (BASE-U-4) or HOBO Waterproof Shuttle (U-DTW-1, firmware version 3.2.0 or later) to connect to the computer. The optical interface allows the logger to be offloaded without breaking the integrity of the seals. The USB compatibility allows for easy setup and fast downloads.

Important: USB communications may not function properly at temperatures below 0°C (32°F) or above 50°C (122°F).

1. Follow the instructions that came with your base station or shuttle to attach it to a USB port on the computer.
2. Unscrew the black plastic end cap from the logger by turning it counter-clockwise. **Note:** If the logger has been deployed, there may be water in the end cap. This is normal; this water will not penetrate the waterproof seal around the communications window in the logger.
3. Attach the coupler to the base station or shuttle.
4. Insert the logger into the coupler so that the alignment bump on the logger slides into the alignment bump on the coupler. Be sure it is properly seated in the coupler. It may take a few seconds for the new hardware to be detected by the computer.

NOTE: If you are using the Waterproof Shuttle, briefly press the coupler lever to put the shuttle into base station mode.



If the logger has never been connected to the computer before, it may take a few seconds for the new hardware to be detected by the computer.

WARNING: Do not leave the logger in the coupler for extended periods of time. When connected to a coupler, the logger is “awake” and consumes significantly more power than when it is disconnected and considered “asleep.” Always remove the logger from the Optic Base Station or HOBO Waterproof Shuttle as soon as possible after launching, reading out, or checking the status to avoid draining the battery. To “wake up” the logger, remove it from the coupler, wait a moment and then re-insert the logger.

Launching the Logger

Before deploying the HOBO U20 Water Level Logger in the field, perform the following steps in the office:

1. Open HOBOWare.
2. Connect the logger to the computer as described in the previous section.
3. From the Device menu, select Launch.
4. In the Launch Logger window, make sure both the Abs. Pressure and Temperature sensors are selected (temperature is required for temperature compensation of pressure).

5. Select any other launch settings as desired, including when to start logging and the logging interval. Click the Start button in the lower right corner of the Launch Logger window to send the launch settings to the logger (note that the Start button text changes based on the Start Logging selection).

Deploying the Logger

The HOBO Water Level Logger is designed to be easy to deploy in many environments. The logger uses an absolute pressure sensor, so no vent tube is required. The small size of the logger is convenient for use in small wells and allows the logger to be mounted and/or hidden in the field. Follow these guidelines when deploying the logger:

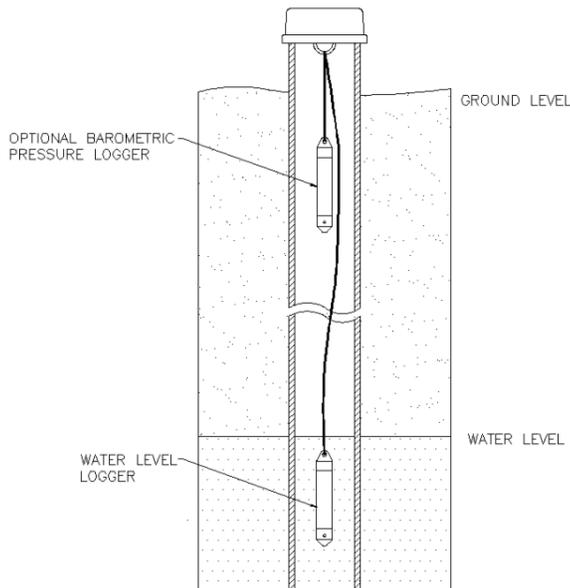
- The pressure sensor is temperature compensated over the range of 0° to 40°C (32° to 104°F). To obtain the highest level of accuracy, the logger should be allowed to come to full temperature equilibrium (approximately 20 minutes) before the reference level is recorded.
 - Sudden temperature changes should be avoided. When deploying a HOBO U20L Water Level Logger for barometric pressure reference, some consideration should be made to minimize the rate of temperature fluctuations. Ideally, the barometric pressure reference logger should be hung several feet below ground level in an observation well where ground temperatures are stable (while making sure the logger remains above the water level). If that is not possible (or if a well is not used), try to put the logger in a location where it will not be subject to rapid daily temperature cycles.
 - When deploying a HOBO Water Level logger in a well, make sure the well is vented to the atmosphere. Typically, a small hole can be drilled in the well cap to ensure that the pressure inside and outside the well is at equilibrium. If this is not possible, the barometric pressure reference logger should be used inside the same well.
 - Use a no-stretch wire to hang the water level logger. Any change in length of the wire will result in a 1-to-1 corresponding error in the depth measurement. Always pull-test a cable prior to deploying a logger in a well to make sure it does not stretch.
 - If you are deploying the logger in a lake, river, or stream, you must first build a stilling well to protect the logger from vibration, shock, and movement. A simple stilling well can be constructed with PVC or ABS pipe. A properly constructed stilling well helps to protect the logger from currents, wave action, and debris. Suspend the logger in the stilling well so it is always underwater, but not on the bottom to be buried by silt.
- For more information, see the Technical Application Note for Constructing a Stilling Well at:
http://www.onsetcomp.com/water_level_stilling_well.html
- To prevent the logger from moving in currents and to ensure the support cable is kept straight during deployment, you may need to add a weight to the suspension cable or hang a weight below the logger.

Alternatively, you could deploy the logger in a stilling well as described above.

- Be very careful not to exceed the burst pressure for the logger. The pressure sensor will burst if the maximum depth is exceeded (see specifications table). The logger should be positioned at a depth where the logger will remain in the water for the duration of the deployment, but not exceed the rated bursting depth.

To deploy the logger:

1. Cut wire to suspend logger.
 - a. Measure the physical depth to the surface of the water from the suspension point.
 - b. Cut a piece of stranded, stainless steel wire (Teflon coated is best) so that the logger will be deep enough to always be in the water. Estimate the low water level and make the cable length such that the logger will be about 2 feet below that level.
2. Attach the wire to the suspension point and to the logger cap.
3. Relaunch the logger if desired (if a laptop or a HOBO U-Shuttle is available).
4. Lower the logger into the well or stilling well.



5. Measure the water depth from the desired reference point (top of pipe, ground level, or sea level).
 - To maximize accuracy, allow 20 minutes after deploying the logger before measuring water depth to allow the logger to reach temperature equilibrium with the water.
 - If the well is too small in diameter to measure the water depth after deployment, measure the water depth before deployment, then deploy the logger immediately and record deployment time.
 - For well deployments: If the water level surface is below the reference point (such as referencing groundwater measurements to the top of the well), record the water

level as a negative number. If the water level surface is above the reference point (such as height above sea level), record the water level as a positive number.

- For lake, stream, and river deployments: If the water level is being referenced to some point above the logger (such as the top of the stilling well), record the water level as a negative number. If the water depth is being referenced to a point below the water surface such as the bottom of the stream, record the water level as a positive number.

6. Record the reference measurement date and time.

Deploying a Water Level Logger for Barometric Pressure Data (Optional)

If you are using a U20 or U20L logger to record barometric pressure data, install one logger in one of the wells as follows:

1. Cut wire for suspending the logger.
 - a. Measure the physical depth to the surface of the water from the suspension point.
 - b. Cut a piece of stranded, stainless steel wire (Teflon coated is best) so that the logger will hang about 2 feet below the ground surface but always above the water surface.
2. Attach the wire to the suspension point and to the logger cap.
3. Relaunch the logger if desired (if a laptop or a HOBO U-Shuttle is available).
4. Lower the logger into the well or stilling well. Make sure the logger does not go below the water surface. See the diagram in the previous section.
5. Record the deployment time.

Reading Out the Logger

To read out the logger for water level data (see later in this section for steps to read out a water level logger used for barometric pressure data):

1. Measure the water depth using the original reference point with the correct sign.
2. Record depth and date and time.
3. Pull the logger out of the well.
4. Remove the logger from its cap, leaving the suspension undisturbed. Check the communications window for any fouling and wipe it off if necessary. **Note:** There may be water in the end cap. This is normal; this water will not penetrate the waterproof seal around the communications window in the logger.
5. Read out the data using a laptop or shuttle.
6. Save the data in a test folder location.
7. Redeploy the logger (optional) as described later in this section.

To read out a U20L logger used for barometric pressure data:

1. Remove the logger from the well.
2. Read out the data using a laptop or shuttle.
3. Save the data in a test folder location.
4. Redeploy the logger (optional) as described below.

If you are redeploying the logger, you must first make sure that it is launched. If you used the HOBOWaterproof Shuttle to offload data, the shuttle automatically performs a synchronized relaunch of the logger so that data is logged on the same measurement intervals. If you wish to change the launch settings, you must launch the logger using HOBOWare Pro.

The existing suspension can be reused as long as the water level logger remained in the water and the barometric logger remained out of the water for the entire test interval. Take a new reference reading with the date and time as described in this section. Record this information in your field notebook to use later to calibrate the data, which will zero out any drift error.

Processing Water Level Data using Barometric Pressure Data

To determine water level using barometric pressure data, use the Barometric Compensation Assistant in HOBOWare Pro as described below.

If you are using barometric pressure data from a HOBO weather station, you can use the data file as if it were U20L barometric data. For data from sources other than Onset products, see *Barometric Data from Other Sources* below.

1. In HOBOWare Pro, open the water depth data file. The Plot Setup window appears.
2. Uncheck all boxes except “Abs. Pressure.”
3. Run the Barometric Compensation Assistant.
 - a. Select the assistant and click the Process button.
 - b. Select the water density box that best describes the water that you are measuring or enter the actual water density.
 - c. Check the Use a Reference Water Level box and enter the reference water level that you measured at the beginning of the deployment.
 - d. Select the date and time from the pull-down menu that is closest to the recorded date/time for the measurement. If you measured the depth before deployment because of pipe size, then select a date/time after the start of the deployment.
 - e. Check “Use Barometric Data file.”
 - f. Click the Choose button. This will allow you to select the data file to use for barometric pressure compensation.
 - g. Select and open the data file.

- h. Click the Create New Series button. A new Plot Setup window appears.

4. Select the Water Level checkbox and any other series that you want plotted. Click the Plot button to obtain a plot of the resulting water level data.

Measurement error can be caused by manual measurement error, sensor drift, or change in the suspension cable length.

To quantify measurement error (which is ideally zero), compare the calculated water level at the end of the plot with the water level measured just before you removed the water level logger.

Barometric Data from Other Sources

If you choose to use barometric pressure from a third-party weather station or barometric logger, you need to convert the date, time, and pressure data to a text file with special header requirements. For information on how to set up the text file, see the HOBOWare Help or User Guide. It is easiest to do this work in Microsoft® Excel® and then save it as a text file.

If you choose to use barometric pressure from an online weather station, such as the National Weather Service, the measured barometric pressure is modified to be at sea level. This sea level pressure is useable since all pressure offsets are zeroed when you enter the reference measurement.

When you select the barometric data file in the Barometric Pressure Assistant (see previous section), select the text file that you generated. Select tab or comma for the data format and data separation characters and then import the barometric data.

Maintenance

The logger requires the following periodic maintenance to ensure optimal operation:

- **Protect the logger. This logger can be damaged by shock.** Always handle the logger with care. The logger may lose its calibrated accuracy or be damaged if it is dropped. Use proper packaging when transporting or shipping the logger.

Important: Do not attempt to open the logger housing! Unscrewing the nose cone of the logger will cause serious damage to the pressure sensor and logger electronics. There are no user serviceable parts inside the case. Contact Onset Technical Support if your logger requires servicing.

- **Periodically inspect the logger for biofouling.** Biological growth on the face of the pressure sensor will throw off the pressure sensor’s accuracy. Organisms that grow inside the sensor nose cone and on the sensor itself can interfere with the sensor’s operation and eventually make the sensor unusable. If the deployment area is prone to biofouling, check the logger periodically for marine growth.

- **Be careful of solvents.** Check a materials-compatibility chart against the wetted materials listed in the Specifications table before deploying the logger in locations where untested solvents are present. The logger has Viton and Buna-N O-rings, which are sensitive to polar solvents (acetone, ketone), ammonia, chlorine, and brake fluids. The sensor is housed in an acetyl end cap. Acetyl is resistant to most solvents, fuels, and lubricants. The black polypropylene cap is provided to help protect the communications window. The polypropylene communications window is sealed as an additional barrier to prevent water and dirt from entering the logger housing.

Compensating for Drift

All pressure sensors drift over time. The drift for the pressure sensor and electronics in the HOBO U20L Water Level logger is less than 0.5% FS (worst case) per year. In most applications, drift is not a significant source of error, because the offset created by any drift is zeroed out when you take a manual reference level measurement and use the logger software to automatically calculate the level readings relative to the reference measurement. In effect, you are re-zeroing the sensor each time you apply a reference reading to the data file.

Pressure sensor drift matters only when absolute pressure values are needed, or if there are no recent reference level or depth measurements available. For example, if the logger is deployed for one year and no new reference level readings are taken during the deployment, it is possible that the sensor could have drifted as much as 0.5% FS by the end of the deployment.

It is possible to determine the actual amount of drift during a deployment if a reference level is taken at the beginning and the end of a long-term deployment. The results of applying the two different reference levels (once at the beginning of the data file, and again at the end of the data file) can be compared. Any difference between the files indicates the amount of sensor drift (assuming accurate reference levels).

Verifying Accuracy

You can check the *differential accuracy* of your loggers for water level measurements by deploying the loggers at two depths and comparing the difference in level readings. When verifying the accuracy this way, be sure to allow the loggers' temperature to stabilize at each depth. Use the logger software to convert the readings from pressure to level. The level readings should be taken close enough together that the barometric pressure does not change.

You can check the *absolute pressure accuracy* of your HOBO U20L Water Level Logger by comparing its ambient pressure readings to a second HOBO logger. Their readings should be within each other's specified accuracy. Alternatively, you can check the pressure reading against an accurate local barometer. If you use a non-local source of barometric information, such as the NOAA website, adjust for altitude.

Battery Guidelines

The battery in the HOBO U20L Water Level Logger is a 3.6 Volt lithium battery.

- **Battery Life.** The battery life of the logger should be about five years or more. Actual battery life is a function of the number of deployments, logging interval, and operation/storage temperature of the logger. Frequent deployments with logging intervals of less than one minute, and continuous storage/operation at temperatures above 35°C will result in significantly lower battery life. For example, continuous logging at a one-second logging interval will result in a battery life of approximately one month.

To obtain a five-year battery life, a logging interval of one minute or greater should be used and the logger should be operated and stored at temperatures between 0° and 25°C (32° and 77°F).

- **Battery Voltage.** The logger can report and log its battery voltage. If the battery falls below 3.1 V, the logger will record a "bad battery" event in the datafile. If the datafile contains "bad battery" events, or if logged battery voltage repeatedly falls below 3.3 V, the battery is failing and the logger should be returned to Onset for battery replacement.
- **Replace the Battery.** To have your logger's battery replaced, contact Onset or your place of purchase for return arrangements. Do not attempt to replace the battery yourself. Severe damage to the logger will result if the case is opened without special tools, and the warranty will be voided.

 **WARNING:** Do not cut open, incinerate, heat above 100°C (212°F), or recharge the lithium battery. The battery may explode if the logger is exposed to extreme heat or conditions that could damage or destroy the battery case. Do not dispose of the logger or battery in fire. Do not expose the contents of the battery to water. Dispose of the battery according to local regulations for lithium batteries.