Appendix C:
Field Sampling Methods

APPENDIX C - FIELD SAMPLING METHODS: DEVIATIONS FROM QAPP

All field sampling methods are described in the Quality Assurance Project Plan (QAPP) (King County 2016). This appendix describes field sampling activities that deviated from or were not described in the QAPP (King County 2016). Sampling locations referenced here are described in the main report and in the QAPP.

C.1 Flow measurement

C.1.1 General Flow Measurement Considerations

As described in the QAPP, flow rate was continuously monitored at the seven sampling sites. Each site posed its own challenges to flow measurement as the stormwater pipes were 1) not engineered for easy installation of flow meters, 2) prone to blockages by debris and other organic matter, and 3) not installed to precisely match the original design drawings. Notes about specific sampling locations are listed below.

- The wetland complex inlet (WCI) required confined-space entry, where an ISCO 750 area-velocity meter (AVM) was installed. During one high flow event, large chunks of concrete lodged up against the meter, which caused irregular velocity measurements. This site was also vandalized, which caused a malfunction/failure in the AVM.
- The QAPP specified the type of flow meter to be installed at each site; however, following observations at each site and consulting with ISCO Environmental Service support, it was determined that the type of flow meters specified in the QAPP would not be effective at some sites. The 750 AVMs were replaced with 730 Bubblers at east and west bioretention outlets (EBO and WBO) due to low and intermittent flow conditions. In addition, the 730 Bubbler specified for the combined outlet of the wetland complex and east bioretention facility (WCEBO) was replaced with a 750 AVM due to the continuous, higher flow rate at this site.
- The inlets to the east and west bioretention facilities (EBI and WBI) were only accessible at the upslope end of the pipe, which was not an ideal location for a flow meter. Also, because there was nowhere to install primary flow devices, these two pipes required the use of the Manning Formula to calculate flow rates. Initially, AVMs were installed at these sites and flow data were collected for a few storms (at higher flow rates), but it was decided that a 730 bubbler flow meter would be more effective to capture low flow rates at these sites. When the bubblers were installed, field personnel were then able to compare the new flow data (using the Manning equation) with flow data collected by the AVMs. This allowed field personnel adjust the Manning equation to match the flow recorded by the AVM.
- The EBO flow meter was initially installed in the end of a pipe that emptied to the same catch basin as WCEBO. However, it was later discovered that in addition to EBO effluent, untreated street runoff flowed into the pipe and interfered with the EBO flow measurement. The EBO flow meter was moved to a pipe that only drained the east bioretention facility. This pipe emptied to a catch basin that was small and prone to

filling, making it challenging to measure flow. To address this challenge a Thel-mar weir was installed to prevent backflow into the pipe. The weir also improved accuracy of the flow measurement. All of these changes were completed before any chemistry samples were collected.

- Conditions at WBO were similar to EBO in that it drained to a catch basin that had the potential for backflow (Figure 1); thus, a Thel-mar weir was also installed at this site. Additionally, at both EBO and WBO organic matter growth was prominent in the tubing, especially during the warmer months, and required constant maintenance to keep the bubbler flow meters from clogging. The clogging of the bubbler tube caused the meter to report high biased flow measurements, which resulted in unusable data.

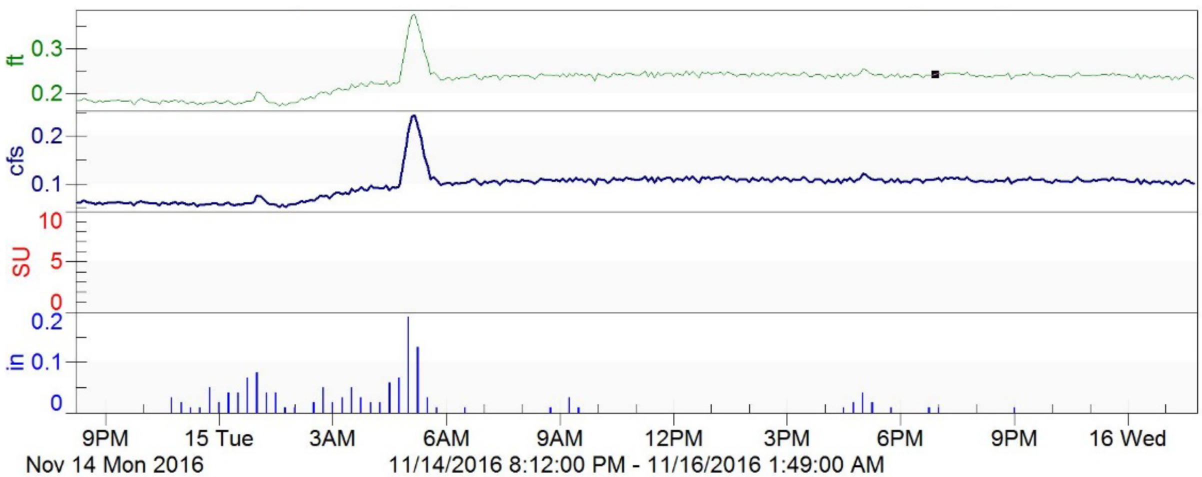

Figure 1. Example of an erroneous spike in water level and flow rate due to backflow in the catch basin that WBO flows to.

- Installation of the AVMs was more straightforward at WCEBO and at the creek site (North Fork West Hylebos Creek; NWFHC). As with the other outlet sites, WCEBO was prone to organic matter fouling and required regular cleaning. Occasionally during high flows, the AVM at NWFHC became blocked by cobblestones moving down the creek, which resulted in erroneous velocity values.

C.1.2 Development of Flow Charts

The QAPP specified that flow-weighted composite samples would be collected over the same time period in which 50% or more of the volume from a particular storm flowed through that location or the hydrograph peaked. These criteria were particularly challenging to meet at WBO and EBO due to the extended retention time within these facilities (over 72 hours in some cases). In order to collect a representative sample and minimize hold-times to the extent possible, storm criteria were altered to indicate that post-sampling criteria were met for samples in which 50% or more of the volume *from the first 24 hours of storm flow* was collected or the hydrograph peaked.

The revised sampling criteria were met for most samples and most locations, thanks to the excellent flow charts and "cheat sheets" developed by field personnel. After installing and calibrating the flow meters at each site, flow data were collected from a series of storms (up to 16 different storms at some sites). Using ISCO Flowlink software, total flow volumes for each storm were calculated at each site and MS Excel was used to chart volume against total rainfall for the storm, along with a line of best fit equation with the R^2 value. For example, the relationship for WCI is shown in Figure 2.

Rain	WCI
0.28	83653.47
0.36	94766.74
0.42	147110
0.58	145623.9
0.81	269995.2
1.1	357002.9
1.12	299672.1
1.28	416370.9
0.86	230000
0.53	114000
0.29	52405

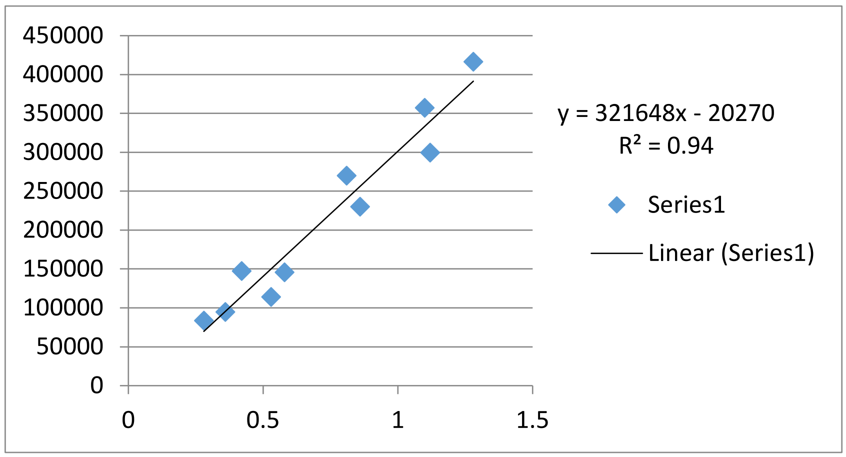

Figure 2. Example of flow data used to generate the flow chart described below. The plot illustrates rainfall during the storm event (inches [in.]) vs. flow volume (cubic feet [cf]) at the WCI location. Each dot represents a single storm event.

Using this equation, a "cheat sheet" was created to help determine how to pace the autosampler at each site to insure a representative flow-weighted composite sample was collected at each location during each storm. Autosamplers for this project were programmed to collect up to 36 aliquots of 500 milliliters (ml) per storm. Therefore, for each rainfall scenario (Table 1), total flow volume expected at each location was divided by 36. This volume was then programmed into the autosamplers to insure a sufficient number of representative aliquots were collected during the runoff event. For example, if the forecast called for 0.5 in. of rain, the autosampler at WCI was programmed to collect an aliquot every 4151 cf (Table 2). These relationships were critical to meet sample criteria and collection of a sufficient and representative composite sample.

Table 1. Estimated expected flow volume, to pass through the WCI facility between each of 36 aliquot collections under different forecast scenarios.

Rain Forecast (in.)	Total flow volume (cf) passing through location between sampling intervals						
	EBI	EBO	WBI	WBO	WCI	WCEBO	NFWHC
0.15	-3.20	-1.64	21.53	21.53	1067.47	1125.13	1561.90
0.2	9.43	14.01	33.71	33.71	1508.04	1614.17	2188.94
0.25	22.06	29.66	45.90	45.90	1948.61	2103.22	2815.98
0.3	34.69	45.31	58.08	58.08	2389.19	2592.27	3443.03
0.35	47.32	60.96	70.26	70.26	2829.76	3081.32	4070.07
0.4	59.95	76.61	82.45	82.45	3270.34	3570.37	4697.11
0.45	72.57	92.25	94.63	94.63	3710.91	4059.42	5324.15
0.5	85.20	107.90	106.82	106.82	4151.49	4548.47	5951.19
0.55	97.83	123.55	119.00	119.00	4592.06	5037.52	6578.24
0.6	110.46	139.20	131.18	131.18	5032.64	5526.57	7205.28
0.65	123.09	154.85	143.37	143.37	5473.21	6015.62	7832.32
0.7	135.71	170.50	155.55	155.55	5913.79	6504.67	8459.36
0.75	148.34	186.15	167.74	167.74	6354.36	6993.72	9086.41
0.8	160.97	201.79	179.92	179.92	6794.94	7482.77	9713.45

C.2 Additional deviations from the QAPP

The QAPP specified that 20 samples would be collected at each site, but the timing of a construction project along S. 356th St. prematurely ended the sampling season in April 2017 after 18 samples had been collected. See Appendix A for more information about how the site changed after the study period.