Eastern Washington
Stormwater Effectiveness Studies

Quality Assurance Project Plan
Bioretention Soil Media Thickness Study

Study Classification: Structural BMP

Study Objective(s):

☑ Evaluate Effectiveness
☑ Develop Modified BMP
☑ Compare Effectiveness

June 23, 2020

Prepared For:

Spokane County
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Proposal and QAPP Publication Information

The Detailed Study Design Proposal (Proposal) and Quality Assurance Project Plan (QAPP) will be stored and accessible to the public on the Spokane County's website: https://www.spokanecounty.org/918/Stormwater-Utility. For questions regarding either document, please contact Matt Zarecor by email MZarecor@spokanecounty.org or phone (509) 477-7255.

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Document History

This document was developed following the Eastern Washington (EWA) Detailed Study Design Proposal and Quality Assurance Project Plan Template for Structural Best Management Practices (BMPs). A copy of the template is located on the City of Spokane Valley's website at the following web link: http://www.spokanevalley.org/content/6836/6896/6914/8301/10121/default.aspx

A Detailed Study Design Proposal (Proposal) was submitted to Ecology on June 30, 2017 and Ecology approved the Proposal via email to Spokane County on November 8th, 2017. Appendix A contains a copy of the email along with Ecology's comments on the Proposal. Appendix B contains a summary of HDR's responses to Ecology's comments including how the comments were incorporated into the Quality Assurance Project Plan (QAPP).

The study goal described in this QAPP has changed since the Proposal was approved by Ecology. Specifically, the Proposal goal was to evaluate the treatment performance of a bioretention cell that contains vegetation compared to a bioretention cell without vegetation. Both cells would have contained either the bioretention soil media (BSM) that is under development in western Washington (WWA) or the 60:40 BSM that is currently approved by Ecology. Whereas the goal of the study defined in this QAPP is to evaluate the treatment performance of a bioretention cell that contains 12-inches of the 60:40 BSM compared to a cell that contains 18-inches of the same BSM. Both study ideas were identified by the Eastern Washington Stormwater Permittees during earlier phases of the Effectiveness Studies and both studies were ranked as one of the top 14 top studies (with the same score) on the list submitted to Ecology on June 30, 2016. (Reference the weblink at the top of this page for more details about the history of the EWA Effectiveness Studies).

The study QAPP was submitted to Ecology on May 8, 2018 for their review and comment. Ecology provided their comments on the QAPP to Spokane County on August 23, 2018. Appendix C contain a copy of Ecology's QAPP approval letter and a summary of Ecology's comments along with HDR's responses to the comments including how the comments were incorporated into the final QAPP document. The final QAPP was submitted to Ecology on September 28, 2018.

Signature Page

Approved by:

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~~Jake Saxon~~Ethan Murnin, Lead Entity, Spokane County

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1.0 Table of Contents

2.0 Executive Summary

Current bioretention research suggests that TSS and dissolved metals removal typically occurs in the top 6-inches of the bioretention soil media (BSM) mix. Additionally, studies have indicated that the BSM leaches nutrients and that the higher the content of compost the higher the concentration of nutrients leaching from the media. Because of these findings, there is an interest in reducing the BSM depth from the 18-inches required by Ecology to a 12-inch depth. The goal of this study is to develop a modified bioretention BMP that uses the existing 60:40 bioretention mix to a minimum depth of 12 inches (rather than the current required 18-inch depth) for providing treatment of TSS and dissolved Cu and Zn. Evaluation of the modified BMP will be based upon:

- Pollutant removal efficiency of the 60:40 BSM mix at a depth of 18-inches compared to 12-inches.
- Change in the infiltration rate and saturated hydraulic conductivity of each cell over the duration of the study
- Achievement of treatment performance goals for basic (TSS) and metals (dissolved Cu and Zn) by comparing study results to the Technology Assessment Protocol Ecology (TAPE) treatment performance goals

The goals for this study will be achieved by conducting field testing two bioretention cells with 18-inch and 12-inch depths of BSM. The field testing will involve using automated equipment to collect data at a site at Gonzaga University in Spokane, Washington. The data to be collected includes precipitation, flow rate (influent and effluent), and pollutant concentrations from flow weighted composite water quality samples (influent and effluent). Data will be collected from a minimum of 12 qualifying storm events over two wet seasons starting in 2018. If the evaluation objectives can be met, the results from this study will be used to justify the development of a modified BMP that can be used on future projects, and subsequently lower the cost of bioretention construction.

3.0 Introduction and Background

3.1 Introduction to the Structural BMP

Bioretention cells are a common structural stormwater best management practice (BMP) in Spokane County (Figure 3.1). These BMPs are characterized as shallow landscaped depressions which are designed to capture stormwater runoff from small basin areas and provide treatment as stormwater infiltrates through engineered soils referred to as bioretention soil media (BSM) (Figure 3.2). Treated stormwater then infiltrates into the existing soils beneath the bioretention cell or is collected in an underdrain and conveyed to a storm drain network.

Figure 3.1. Example of a Bioretention area in the City of Spokane

The BSM mix specified in the Eastern Washington (EWA) LID Manual is composed of 60% sand and 40% compost by volume. This mix is approved by Ecology to provide runoff treatment for total suspended solids (TSS) and dissolved metals, copper (Cu) and zinc (Zn), to the level specified in the EWA Phase II NPDES MS4 Permit (Ecology, 2014). The primary treatment mechanisms responsible for reducing pollutants include sedimentation, as particles settle on the surface of the BMP; filtration, as runoff infiltrates into the BSM mix and particulates become physically trapped in the media pore spaces; and sorption, of dissolved metals onto the surface of organic materials amended into the BSM mix.

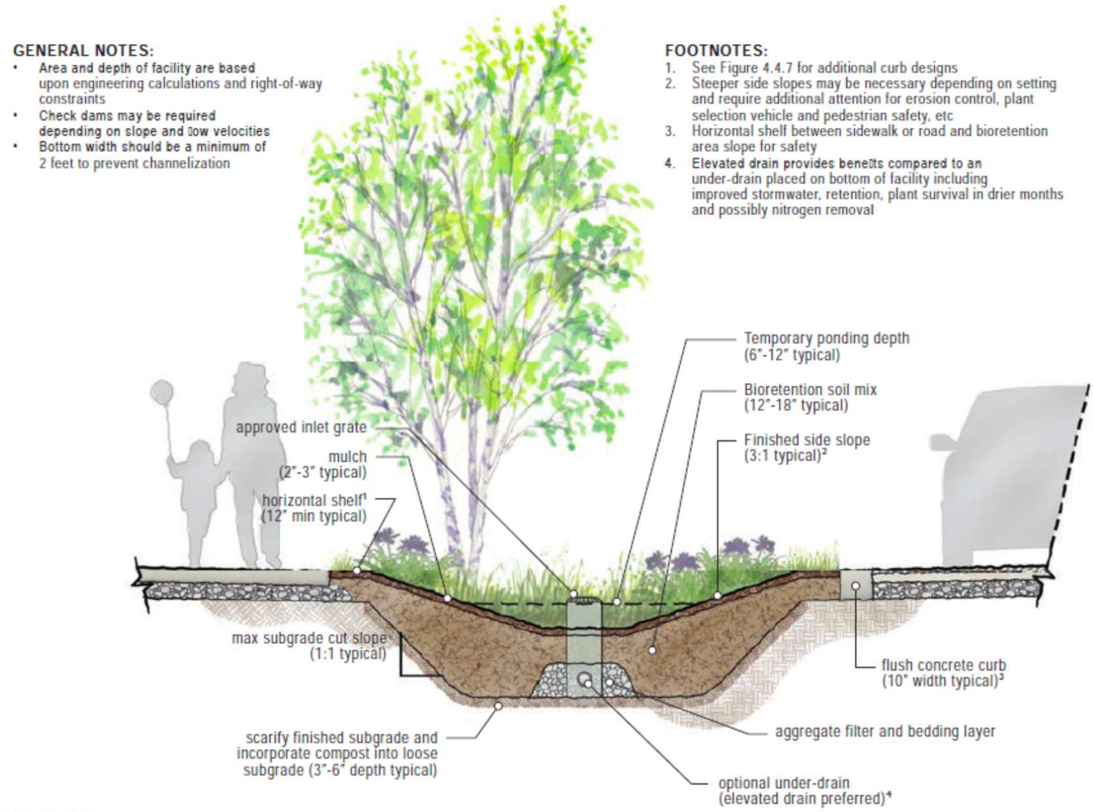

FIGURE **4.4.1**
Bioretention with primary design elements (Under-drain is optional)
Source: AHBL, Inc. courtesy of Low Impact Development Technical Guidance Manual for Puget Sound (2012)

Figure 3.2. Typical bioretention cell design (AHBL & HDR, 2013)

3.2 Background and Problem Description

The test-site for the proposed effectiveness study is located on the campus of Gonzaga University. The site was constructed in 2014 for the purpose of conducting bioretention soil media stormwater effectiveness studies. The study described in this QAPP specifically focuses on evaluating the effectiveness of a bioretention cell that contains a 12-inch depth of the 60:40 BSM mix compared to a cell that contains 18-inches of the 60:40 BSM. The effectiveness is based on the treatment performance of the different depths for reducing concentrations of TSS and dissolved metals (Cu and Zn). The 18-inch depth was selected because it is the minimum required by Ecology for bioretention cells. The study was proposed because a thinner depth mix would reduce costs associated with constructing bioretention cells. Furthermore, bioretention research suggests that TSS and dissolved metals removal typically occurs in the top 6-inches of the BSM mix. These findings support the theory that a 12-inch depth of BSM is sufficient when TSS and dissolved metals are the target pollutant (Hatt, 2008; Hunt & Lord, 2006; Davis, 2001).

Research conducted on the 60:40 mix in western Washington indicates that the media is leaching nutrients (Ecology, 2013; Ecology, 2016). Research has also demonstrated a relationship between the quantity of organic matter (i.e. compost) and nutrient leaching. Specifically, the higher the content of compost the higher the concentration of nutrients leaching from the media (Erickson et al., 2007; Minnesota Pollution Control Agency, 2014). As such reducing the depth of the BSM from the Ecology required 18-inch depth to the modified 12-inch depth is expected to reduce the quantity of nutrients leaching from the media.

3.3 Results of Prior Studies

The test site proposed for this study is located on the campus of Gonzaga University and consists of two bioretention cells located immediately adjacent to each other (Reference sections 4.2, 7.1, and 7.2 for a detailed description of the test site). Each cell contains the same type and configuration of the 60:40 BSM, except one cells contains a 12-inch thick BSM layer and the other contains an 18-inch BSM layer. Since construction in 2014, civil engineering students from Gonzaga University have been collecting water quality samples at the test site. Between 2015 and 2017, flow weighted composite samples (influent and effluent) were collected using a fire hose or synthetic stormwater to simulate rainfall events. In the fall of 2017 automated samplers were installed at the test-site allowing the students to collect flow weighted samples during natural rainfall events.

Results from all three years of data collection (n=10) are included in Appendix K. Specifically, plots of the pollutant reduction ratio (effluent concentration C_e divided by the influent concentration C_i) for TSS, dissolved metals (Cu and Zn), total phosphorus (TP), and nitrate-nitrite (NO3-NO2) are included. Some trends observed in the data include:

- The TSS and Cu pollutant reduction trend appears to improve with time
- Nutrient leaching (phosphorus and nitrate-nitrites) appears to declines with time

Data collected during the natural rainfall events is summarized in Table 3.1. There was a total of three storm events monitored (n=3) and for each event one influent and two effluent samples (one from the 12-inch cell and one from the 18-inch cell) were collected. Each storm event met the conditions for qualifying rainfall events defined in the Technology Assessment Protocol Ecology (TAPE) (Ecology, 2011) except for two events in which the rainfall depth was lower (0.07- and 0.08-inches) than the minimum 0.15-inches. In addition, the influent concentration for each parameter during each event was within range defined by TAPE.

The data was analyzed by conducting a statistical comparison of the pollutant concentrations and by calculating the average percent removal for each parameter ((Ci-Ce)/Ci*100%). The differences between the influent and effluent concentrations were compared, along with the difference between the effluent concentrations from each cell, to determine whether there is a significant difference in the data sets using a two sample t-test. Because of the very small sample size, p-values of both moderately significance ($p \leq 0.1$) and high statistical significance (≤ 0.05) were considered. As noted in table 3.1 there is a moderate to high significance between the influent and effluent concentrations for all parameters except for nitrate-nitrite. In addition, the difference between the effluent concentrations from the two cells is insignificant for all parameters. These results suggest that the BSM is reducing pollutant concentrations of TSS and dissolved metals (Cu and Zn) and that the depth of the BSM (12-inch compared to 18-inch) does not significantly influence the treatment performance for these parameters. These results also suggest that both the 12-inch and 18-inch cells can meet the Ecology treatment performance goals defined in TAPE (Table 14.1) for TSS and dissolved Cu. While neither cell met the treatment performance goals for dissolved Zn, the sample size is very small (n=3) and more data (minimum n=12) is needed to more accurately assess whether the performance goals can be achieved.

Table 3.1 Summary of Results from Water Quality Monitoring this Year (n=3)

Target Pollutant	Cell Effluent	Average (mg/L)		Normal Distribution (Y/N)	Percent Removal	p-value	Statistically Significant? (Y/M/N)	Ecology Treatment Goals Met
		Influent[2]	Effluent					
TSS	12-inch	26	2	Yes	92.3%	0.091	Moderately	✓
	18-inch		3	Yes	86.8%	0.103	Moderately	✓
	12-inch vs 18-inch					0.270	No	
Cu[1]	12-inch	0.0052	0.0023	Yes	47.5%	0.086	Moderately	✓
	18-inch		0.0018	Yes	59.5%	0.049	Yes	✓
	12-inch vs 18-inch					0.189	No	
Zn[1]	12-inch	0.040	0.022	Yes	43%	0.053	Moderately	✗
	18-inch		0.020	Yes	48%	0.080	Moderately	✗
	12-inch vs 18-inch					0.448	No	
TP	12-inch	0.072	0.297	Yes	-344%	0.049	Yes	✗
	18-inch		0.304	Yes	-359%	0.048	Yes	✗
	12-inch vs 18-inch					0.152	No	
NO_3-NO_2	12-inch	0.163	0.138	Yes	10.2%	0.423	No	N/A
	18-inch		0.181	Yes	-15.8%	0.638	No	N/A
	12-inch vs 18-inch					0.204	No	

1. The values reported for Cu and Zn represented the dissolved fraction of each parameter.
2. Influent concentrations were within the TAPE limits for all samples except TP samples and two Cu samples (0.004 mg/L) which was slightly below the TAPE influent limit (0.005 mg/L).

3.4 Regulatory Requirements

The Eastern Washington Phase II Municipal Stormwater Permit issued to the Spokane County by the Washington State Department of Ecology (Ecology) requires the Stormwater Management Program Effectiveness Studies. Specifically, *each city and county permittee listed in the permit shall collaborate with other permittees to select, propose, develop, and conduct Ecology-approved studies to assess, on a regional or sub-regional basis, effectiveness of permit-required stormwater management program activities and best management practices*. Spokane County proposes to serve as the lead entity for the following effectiveness study: Bioretention Soil Media Thickness Study. Section S5.B.5 of the permit (Ecology, 2012) is specifically addressed by this investigation.

- S5.B.5 requires permittees to implement and enforce a program to address post construction stormwater runoff to the municipal separate storm sewer systems (MS4) from new development and redevelopment projects.

4.0 Project Overview

4.1 Study Goal

The goal of this study is to develop a modified bioretention BMP that uses the existing 60:40 bioretention mix to a depth of 12-inches (rather than the current required 18-inch depth) for providing treatment of TSS and dissolved Cu and Zn. The results of this study will be used to justify approval of the 12-inch BSM as on future projects where treatment of pollutants regulated under Ecology's treatment performance criteria (i.e. basic and dissolved metals) is required per the NPDES Municipal Stormwater Permit (Ecology, 2011).

4.2 Study Description and Objectives:

The goal of this study will be accomplished through field monitoring and sampling following the modified TAPE process summarized in the Eastern Washington Effectiveness Study QAPP Template for Structural BMPs. The test-site is located at Gonzaga University which consists of a dual-cell bioretention area that contains 18-inches and 12-inches of the 60:40 mix in each cell (Figure 4.1). An automated monitoring system is installed at the test-site which collects flow weighted composite samples, rainfall depth, and flow rate (influent and effluent). The primary work associated with field monitoring and sampling will include: daily monitoring of the weather forecast to identify when qualifying rainfall events are likely to occur, operating and maintaining the equipment, collecting 3 composite flow weighted water quality samples for each rainfall event (one influent and two effluent) as well as duplicates for 10% of the samples, delivering the samples to the lab for analysis, and downloading data from the data logger (precipitation depth and runoff flow rate). Samples of the BSM mix were collected when the site was constructed and will be submitted to an Ecology certified lab for analysis to characterize the physiochemical properties. Testing is expected to occur over two wet seasons.

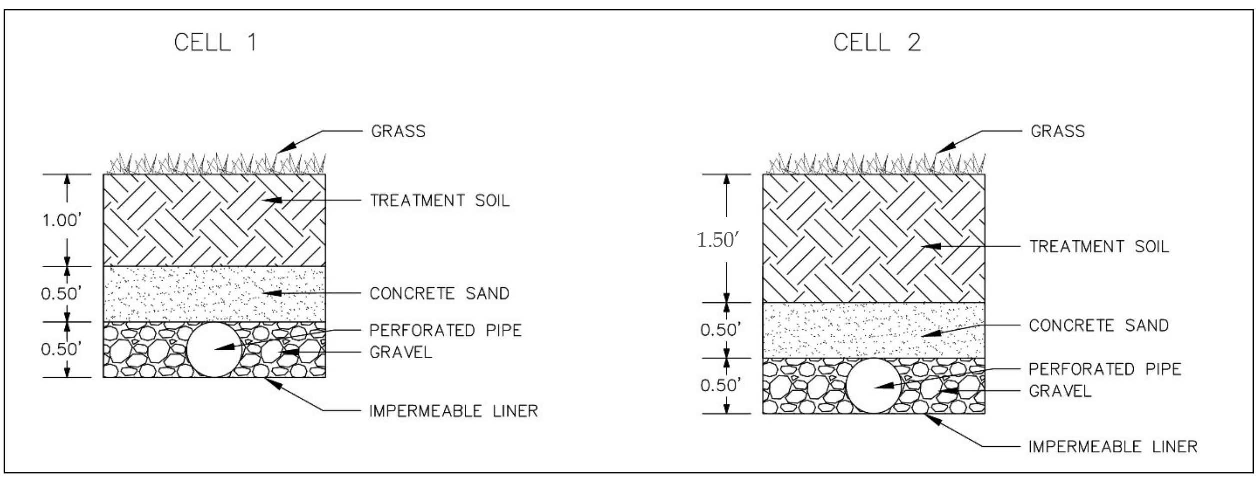

Figure 4.1 Cross Section of the Bioretention Cells: 12-inch BSM (cell 1) and 18-inch BSM (cell 2)

The goals of this study will be achieved by meeting the following objectives:

- Determine the pollutant removal efficiency of the 60:40 BSM mix at a depth of 18-inches compared to 12-inches

- Determine the change in the infiltration rate and saturated hydraulic conductivity of each cell over the duration of the study
- Determine whether the treatment performance goals were achieved for basic (TSS) and dissolved metals (Cu and Zn) by comparing study results to TAPE treatment goals
- Summarize the study results into a final report and submit the report to Ecology for approval of the modified BMP

4.3 Study Location

The test-site location is in the City of Spokane on the campus of Gonzaga University. Specifically, it is located south of the Rudolf Fitness Center, east of Luger Soccer Field, and north of the Law School. An aerial photograph of the test-site is shown in Figure 4.2. The contributing basin area is 0.42 acres of a paved parking lot and 0.08 acres from sidewalks and the access road to the parking lot. The basin area is delineated in Figure 4.3.

Figure 4.2 Aerial View of Test-Site Location

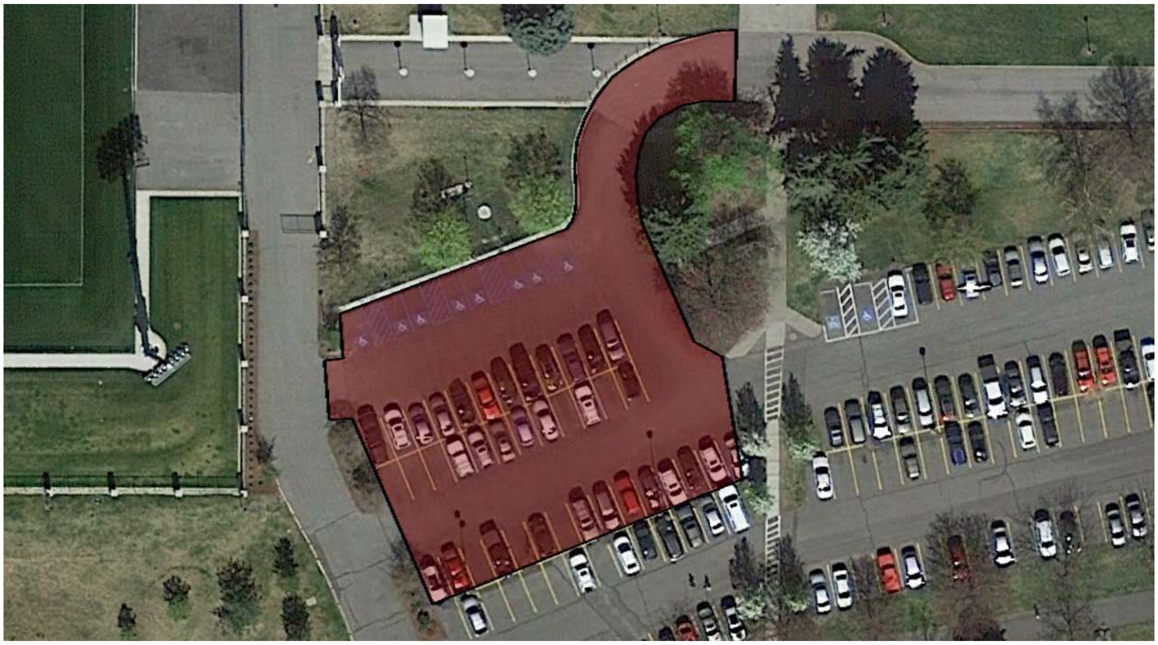

Figure 4.3 Contributing Basin Area

4.4 Data Needed to Meet Objectives

The data needed to complete this study is summarized in Tables 4.1. The water quality parameters to be tested to demonstrate that the BMP meets performance goals are summarized in Table 4.2.

Table 4.1 Data Needed to Meet Objectives

Data Type	How Data Will Be Collected	Purpose
BSM media physiochemical properties	Samples of the BSM material collected during construction will be sent to the lab for analysis	Identify physiochemical properties of the media
Precipitation	A rain gauge connected (via cable) to the data logger at the test site; data downloaded from the data logger at the test site	Determine whether a particular event meets TAPE guidelines for qualifying storm events
Flow (influent, effluent)	Measured continuously using a control weir and pressure transducer upstream of the weir	Calculate influent and effluent flow rates; determine when sampling should begin (if storm meets TAPE criteria)
Composite water quality samples (see Table 4.2)	Auto-samplers collect composite flow weighted samples when triggered by the data logger	Quantify parameters influent & effluent concentrations; assess media depth effectiveness
Sediment PSD	Collect composite flow weighted samples	Characterize the size of the sediment that enters & leaves the BMP
pH and Temperature Measurements	Collect pH, temperature measurements from small amount of composite sample	Quantify influent & effluent pH; verify sample is at or below 6°C for laboratory analysis
Saturated hydraulic conductivity	Falling head test (See Section 8.1.8 for SOP)	Calculate BSM infiltration rate

Table 4.2 Summary of Water Quality Testing (per TAPE requirements)

Performance Goal	Required Parameters	Required Screening Parameters
Basic	TSS	PSD, pH, TP, orthophosphate, hardness, total and dissolved Cu and Zn
Dissolved metals	TSS, hardness, total and dissolved Cu and Zn	PSD, pH, TP, orthophosphate
Oil	NWTPH-Dx, visible sheen	pH, TP, orthophosphate, hardness, total and dissolved Cu and Zn

4.5 Tasks Required to Conduct Study

Tasks required to conduct the study include:

- **Experimental Design – Task Complete**
    - Develop Detailed Study Design Proposal
        - Submit Proposal to Ecology for review and approval; respond to comments
    - Develop and apply for GROSS Grant funding
        - Submit Grant to Ecology for review and scoring
- **Monitoring Equipment – Task Complete**
    - Design, select, and order monitoring equipment
    - Install equipment at the test-site
    - Develop and provide monitoring equipment training for the sampling staff
    - Develop standard operating procedures (SOPs) for operating, maintaining, and calibrating equipment
- **Quality Assurance Project Plan (QAPP) – Task Complete**
    - Develop QAPP (this document) and respond to Ecology Proposal comments
        - Submit QAPP to Ecology and advisory panel for review; respond to comments
- **Advisory Review Panel**
    - Convene an advisory review panel to provide a peer review of the QAPP and technical evaluation report (required for studies with the goal of developing a modified BMP)
- **Technical Advisory Group (TAG) Meetings**
    - Schedule 4 meetings with TAG for the purpose of discussing the project status, upcoming tasks, and soliciting input from the TAG on the study documents
- **Prepare for Data Collection:**
    - Program and install monitoring equipment
    - BSM material testing
    - Maintain bioretention cells including cleaning catch basins upstream of cells at the test-site
- **Data Collection and Analysis:**
    - Test BSM media
    - Track and select storms (daily)
    - Maintain storm monitoring equipment (monthly)

  - Prepare stormwater monitoring equipment for storm sampling and calibrate equipment (immediately prior to sampling event)
  - Collect stormwater influent and effluent samples from a minimum of 12 rainfall events; submit samples to lab and test for required and screening parameters (immediately following qualifying rainfall events)
  - Following each monitoring event: download data (i.e., precipitation, influent, and effluent flow rate), analyze data
  - Conduct falling head testing twice a year
  - Develop and manage a database that contains all the collected data
- **Develop Technical Reports:**
  - Develop annual reports
  - Develop technical evaluation report (TER)
  - Develop study fact sheet
  - Submit TER to Ecology and advisory panel for review; request approval for bioretention area with 12-inch BSM to be functionally equivalent to bioretention area with18-inch BSM

4.6 Potential Constraints

Potential constraints are conditions that may impact the project schedule, budget, or scope. The potential constraints identified in this section, along with the steps that will be taken to reduce the impact of these conditions (mitigation approach), are based on the information that was available at the time the QAPP was written.

4.2 Summary of Potential Constraints and Mitigation Approaches

Potential Constraint	Mitigation Approach
Spills: oil or other chemicals	Large spills could impact the BMP treatment performance; Visually inspect the cell following each rainfall event; if a spill occurs conduct appropriate maintenance and note the incident in the data collection log
Uneven delivery of influent flows to each cell	Periodically measure flow and compare flows; balance flow rates at cell inlets as needed
Insufficient qualifying rainfall events	Extend monitoring period or collect data from lower depth (<0.15-inches) rainfall events
Campus facilities using fertilizer at test-site	Educate campus facilities about the study and adjust their maintenance practices
Campus facilities placing landscaping waste near the test-site	Educate campus facilities about the study and adjust their maintenance practices
Monitoring equipment malfunctions	Frequent inspection of equipment and review system output variables after each storm for any anomalies. If problems are encounters, equipment will be fixed promptly.

5.0 Organization and Schedule

The purpose of this section is to describe who is responsible for completing the tasks, when the tasks will be completed, and how the study will be funded.

5.1 Key Project Team Members: Roles and Responsibilities

Table 5.1 Key Project Team Members: Roles and Responsibilities

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Gonzaga University Civil Engineering Students	Sampling Staff[4,8]	Changes each academic year. *See notes about sampling staff[4] below.*

1. Lead Entity Project Manager – Responsible for ensuring the study is conducted as described in this QAPP. The Project Manager is the primary point of contact for the lead entity.

2. Principal Investigator – Responsible for developing an Ecology approved Proposal and QAPP. Serves as the primary point of contact for the laboratory manager, the project manager, sampling staff, the auditor, the TAG Members, the Advisory Review Panel and the students. Responsible for conducting the study as defined in the Ecology approved QAPP. Responsible for submitting the study documents to Ecology including the Proposal, QAPP, and Final Technical Report. Responsible for management of all study documents, scheduling audits, verifying and assessing the usability of data, and executing corrective actions. Responsible for developing the final report including data analysis, interpretation of results, and summarizing the study findings. Responsible for ensuring that staff working on this project are trained and have adequate experience to complete their assigned tasks. Responsible for maintaining and operating the monitoring equipment.
3. Researcher - Responsible for assisting the Principal Investigator.
4. Sampling Staff – Responsible for monitoring storms, assisting the Principal Investigator with maintaining and operating the equipment, collecting and processing samples (water quality or sediment) following the standard operating procedures in this QAPP including delivering the samples to the lab, assisting with the falling head test, assisting with transferring data from the lab and field forms to spreadsheets, and assisting with the data analysis. *Each year a team of three senior civil engineering students will be selected to work on this project to meet their requirements for senior design. Each year the students will be trained to perform the tasks defined for the sampling staff.*
5. Laboratory Manager – Responsible for supervision of laboratory personnel involved in conducting analytical testing for this study and ensuring that laboratory personnel are properly trained in conducting the testing methods defined for this study. Also responsible for: providing sample containers and other sampling supplies (i.e. labels); analyzing samples using the standard methods selected for this study; carrying out lab quality control (QC) procedures to confirm that the related MPCs have been met (section 6.0); reporting results for samples and QC procedures; and reviewing data and verifying results before the results are sent to the principal investigator and the lead entity.
6. Technical Advisory Group (TAG) Member - The goal of the TAG is to provide insight, suggestions, and professional opinions to the Principal Investigator and Lead Entity throughout the study. The primary responsibilities of TAG members include: attending project meetings (by webinar or in person) and participating in the meeting discussion; review/comment on research materials (i.e. QAPP, data collected, data analyzed, final report, etc.) prior to submitting the documents to Ecology.
7. Technical Advisory Group (TAG) Lead – Responsible for organizing/scheduling meetings with the TAG members and distributing the project/meeting documents prior to the meeting. During meetings the TAG lead is responsible for ensuring that the TAG member's comments are heard and addressed as well as developing/distributing meeting notes of any actions items from the meeting.
8. Data Verifiers - Data verifiers will review the analyzed data and verify the analysis is correct and that the data being analyzed matches the data collected. *See Section 11.0 of this document.*
9. Financial Support – Responsible for providing the lead entity with some level of financial support toward the cost of the study.
10. Auditor - Responsible for conducting audits to verify the study conforms to the plan and procedures as defined in *Section 12.0* of this document. This may include: verifying staff collecting the data are trained and follow SOPs for data collection; verifying data management procedures are followed including reviewing data records to ensure they are consistent, correct and complete, with no errors or omissions; and traveling where the data is stored to review the data records compared to the QAPP Data Management Plan. Auditors will report their findings directly to the lead entity Principal Investigator and Lead Entity.
11. Ecology Reviewer – Responsible for reviewing and approving the study documents: the Proposal, QAPP, and Final Report.

5.2 Project Schedule

A task timeline based on monthly activities is shown in Table 5.2.

Table 5.2 Proposed Study Timeline

Task Name	2017 Q2: Apr-Jun	2017 Q3: Jul-Sept	2017 Q4: Oct-Dec	2018 Q1: Jan-Mar	2018 Q2: Apr-Jun	2018 Q3: Jul-Sept	Study will be implemented no later than 15 months after QAPP Approval[1]	2018 Q4: Oct-Dec	2019 Q1: Jan-Mar	2019 Q2: Apr-Jun	2019 Q3: Jul-Sept	2019 Q4: Oct-Dec	2020 Q1: Jan-Mar	2020 Q2: Apr-Jun	2020 Q3: Jul-Sept	2020 Q4: Oct-Dec
Experimental Design																
Proposal Development																
Ecology Proposal Review																
GROSS Grant - Develop & Apply																
Ecology Grant Review																
Monitoring Equipment																
Design, Select, & Order Equipment																
Equipment Installation																
Equipment Training																
Develop Equipment SOPs																
QAPP																
QAPP Development																
Ecology QAPP Review																
Respond to Ecology Comments																
Advisory Review Panel																
Convene Advisory Board																
Advisory QAPP Review																
Respond to QAPP Comments																
TAG Meetings								1		2		3		4		
Data Collection & Analysis														**		
Technical Reports																*
Annual Reports													***			
Technical Evaluation Report (TER)															*	
Study Fact Sheet															*	
Ecology & Advisory Review															*	
Respond to TER Comments																*

1. The schedule was developed assuming the maximum time specified (90 days) for the Ecology QAPP review period as defined in S8.B.6 of the NPDES permit (Ecology, 2014b).

Note: dark gray squares indicate task is complete and light gray squares indicate tasks not complete.

* Per the Eastern Washington Phase II Permit, the report and fact sheet will be submitted to Ecology six months after completion of the study.
** Data collection will extend past June 30, 2020 and continue until enough qualifying storms are sampled.
*** Study progress will be described in the annual reports until the final report is submitted.

5.3 Budget and Funding Sources

Spokane County intends to pay for the study with financial contributions from participating entities.

Table 5.2: Study Budget

Task	Labor & Expenses	Equipment & Lab Fees	Total
Project Management	$17,000	$0	$17,000
Monitoring Equipment[1,4]	$24,100	$10,000	$34,100
QAPP Development[1]	$17,300	$0	$17,300
Data Collection and Analysis[2,3,6]	$31,800	$10,000	$41,800
Gonzaga Senior Design Fees[5]	$12,000	$0	$12,000
Reporting: Technical Evaluation Report[2]	$26,700	$0	$26,700
		Total	$148,900

1. The cost for developing the detailed study design proposal was paid for by the 2015-2017 Ecology GROSS Grant titled the *Eastern Washington Effectiveness Study Development Phases 2 & 3*.
2. The task budget includes hours for coordinating with Ecology, the advisory panel, and for managing the Technical Advisory Group (TAG).
3. Budget assumes Spokane County staff will maintain the test-site. The cost for this work is not included in the table.
4. The majority of the monitoring equipment described in the QAPP was purchased prior to the start of this study. This task includes the cost for purchasing replacement parts and consumable materials (such as tubing), installing equipment, and developing standard operating procedures (SOPs) for operating the equipment.
5. Task includes the cost to sponsor two senior design teams at Gonzaga University for two year ($6000 per year for a total of $12,000). The budget assumes senior design students will collect and process 8 samples as well as conduct K_{sat} testing. The remaining 4 samples will be collected and processed by the consultant.
6. Task includes the cost to maintain and calibrate the equipment, manage and analyze the data, conduct QC reviews and audits, and laboratory fees for water quality and BSM material testing.

6.0 Quality Objectives

This section of the QAPP provides a roadmap of the QA/QC plan that will be implemented in the experimental design and employed throughout the study.

The purpose of a QAPP is to ensure that the data collected during the study is scientifically and legally defensible (Ecology, 2011). The QAPP documents how quality assurance (QA) and quality control (QC) will be applied to a research project to assure that the results obtained are of the type and quality needed and expected. The QA/QC plan for this study is embedded throughout the QAPP and emphasizes how the data quality indicators (DQIs) and respective measurement performance criteria (MPCs) are addressed during the study.

DQIs are qualitative and quantitative measures that characterize the aspects of quality data (EPA, 2006). DQIs are goals for data quality that are specific to each study. DQIs are intended to minimize error and improve the accuracy of the data. DQIs guide the development of the experimental design as well as the process of creating and analyzing data. The six principle DQIs for Structural BMP studies are as follows (Ecology, 2004):

- Precision
- Bias
- Representativeness
- Completeness
- Comparability
- Sensitivity

Once established, the DQIs provide the basis for the MPCs which are the acceptance criteria for the DQIs that specifies how good the data must be to meet the project objectives. Table 6.1 first defines each DQI, then the approach for addressing DQIs and the respective MPCs for this study are described.

Reference Section 13.0 for details regarding the process that will be employed to evaluate the quality and usability of the data for meeting the project objectives which is based primarily on whether the MPCs were met for the applicable DQIs.

Table 6.1 Summary of the Data Quality Indicators (DQIs) and Measurement Performance Criteria (MPC) for Structural BMP Studies

Precision DQIs for This Study	Precision MPCs for This Study
Precision – A measure of agreement among repeated measurements of the same property taken under identical or substantially similar conditions (EPA, 2006; Erickson, 2013; EPA, 2002). Data is considered precise when the measured values are consistently the same and imprecise when the measured values are consistently different (Erickson, 2013). Random error is a common cause of imprecise data and is always present because of normal variability in the many factors that affect measurement results. For example variability in sampling or data collection procedures and/or variations of the actual concentrations in the media being sampled (Ecology, 2011).	
Develop and consistently following SOPs for collecting samples and measuring data will reduce the potential of collecting imprecise data.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs. Data will be considered acceptable if the sampling staff are consistently following the SOPs.
Duplicate analytical testing will be performed for the water quality parameters shown in Table 6.2.	If the results of the duplicate sampling meet the respective relative percent difference (RPD) for the parameters listed in Table 6.2, the results of the analytical testing will be considered acceptable. Reference Section 6.1.
Rain gauge and flow measurements will also be assessed.	If the flow measurements and rain gauge data meet the RPD defined in section 6.1, that data will be considered acceptable. Reference Section 6.1.
Bias DQIs for this Study	**Bias MPCs for This Study**
Bias – A systematic error that results in sample values that are consistently distorted in one particular direction from the "true" or known value (EPA, 2006; Erickson, 2013). Bias can result from improper data collection, poorly calibrated analytical or sampling equipment, or limitations or errors in analytical methods and techniques (Ecology, 2011).	
Calibration of instruments, including the pH meter, pressure transducers and ISCO, will occur according to manufacturer's specifications. Buffer solutions will be used to calibrate the pH meter to reduce the potential for bias.	To reduce the potential for biased measurements, the instruments requiring calibration will be calibrated according to the procedures and frequency outlined in Section 8.0, per in manufacturer's specifications. An audit (Section 12.0) will be conducted to verify sampling staff are following the calibration procedures.
Lack of maintenance at the site can be a source of bias in sample values or measurements. For example, if ISCO tubing is not cleaned regularly, sediment, oils, etc. can accumulate in the tubing and affect sample results. For that reason, manufacturer's recommendations for maintenance frequency and procedures will be followed to reduce the potential for bias.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0 (written to match manufacturer's specifications).

SOPs defined in Section 8.0 will be followed when collecting samples and measuring data to limit bias.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0.
Method blanks, rinsate blanks, matrix spikes, and field duplicates will be analyzed to check for bias.	Sample results will be accepted if results of the method blanks, rinsate blanks, matrix spikes, and/or field duplicates are below the limits shown in Table 6.2. *Note: the percent recovery for matrix spikes is defined in section 6.2.*
Representativeness DQIs for This Study	**Representativeness MPCs for This Study**
Representativeness – A qualitative term that expresses the degree to which the data accurately and precisely represents the conditions being evaluated (EPA, 2002). Common variables considered when determining the degree of representativeness include the selected sampling locations, sampling frequency and duration, and sampling methods (Ecology, 2011).	
The location selected for this study is at the downstream end of a parking lot with an expected high number of trip returns.	These conditions reflect the characteristics of a location where a bioretention cell are installed: an area where higher loading of TSS and metals are expected.
Hydrologic conditions at the site should be representative of a range of weather patterns and conditions seen throughout the wet season.	Local stormwater hydrologic conditions are represented by conducting the study over two wet seasons and collecting data from a minimum of 12 qualifying storm events (described in Section 7.5).
Rainfall data, flow data, and water quality samples should be representative of the site.	Equipment will be set up to achieve representative rainfall, flow, and water quality data as follows: • The rain gauge will be installed within the drainage basin of the bioretention cells and in a location where no buildings, trees, or other objects obstruct or divert rainfall from entering the rain gage • Pressure transducers will be installed upstream of weirs in influent and effluent pipes, which will mimic typical bioretention cell construction • Water quality samples will be collected as composite samples. pH measurements will also be taken from the composite samples. The composite samples will capture at least 10 aliquots and 75% of the qualifying rainfall event hydrograph to be representative of water quality during the storm
Equipment at the site will be installed per manufacturer specifications.	

Completeness DQIs for This Study	Completeness MPCs for This Study
Completeness - The amount of valid data needed to be obtained during the study to meet the project objectives (Ecology, 2004).	
A minimum of 12 qualifying rainfall events (Section 7.5) are required to be sampled for the duration of the study, per TAPE. Additionally, at least 10 aliquots and 75% of the hydrograph must be sampled during the qualifying rainfall event.	The number of rainfall events sampled will be compared to the minimum amount at the end of the project, and additional rainfall events will be sampled as needed. Samples which represent less than 75% of the hydrograph will not be accepted. If samples only consist of 7-9 aliquots, the samples may be accepted if rationale is provided in the TER as to why the sample was used (per TAPE).
A minimum of 95% of the samples analyzed by the lab must be considered valid prior to the end of the study.	95% of the samples must be accompanied by method blanks, rinsate blanks, matrix spikes, lab control spikes, and field duplicate results which are valid. Additionally, the samples must be received and analyzed within the appropriate temperatures and holding times. Temperature will be verified on the data results reported from the lab.
Define procedures for handling missing data, use appropriate coding for missing data, and report missing data with the results	Procedures for handling missing data and coding missing data are defined in section 11.0. The Final Technical Report for this study will include consideration for how missing data could limit the comparability of the data set.
Conduct routine maintenance for equipment at the site, in accordance with SOPs outlined in Section 8.0, to limit the possibility of missing or invalid data.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0 (written to match manufacturer's specifications).
An equipment checklist and Chain of Custody forms will be used to prevent loss of data resulting from missing containers, inoperable delivery and collection apparatus or sample delivery.	Equipment checklists and Chain of Custody are located in the appendix of this document.
Comparability DQIs for This Study	**Comparability MPQs for This Study**
Comparability - A qualitative term that expresses the measure of confidence that one dataset can be compared to another and can be combined or contrasted for the decision(s) to be made. Data is comparable if sample collection techniques, measurement procedures, analytical methods, and reporting are equivalent for samples within a sample set, and meet acceptance criteria between sample sets.	
The test site is located downstream of a parking area on the Gonzaga University campus with an expected high trip end count.	The process for selecting the study area is defined in section 7.2: the process focused on having a test site that is representative of locations where a bioretention cell would be installed.
Define and consistently follow SOPs for sample collection and field measurements	SOPs were developed and will be consistently followed during this study

All data and sample collection will be conducted in accordance with the SOPs outlined in Section 8.0.	An audit (Section 12.0) will be conducted to verify that sampling staff are following the SOPs outlined in Section 8.0.
Standard testing methods will be used to analyze samples submitted to the lab.	Anatek, the laboratory proposed for water quality testing in this study, is certified by Ecology and will follow standard methods approved by the US Environmental Protection Agency (EPA) (APHA et al. 1992, 1998; US EPA 1983, 1984). The methods to be used are listed in Table 9.1. Deviations from methods will be noted on analytical reports.
Sensitivity DQIs for This Study	**Sensitivity MPQs for This Study**
Sensitivity - The capability of a method or instrument to discriminate between measurement responses representing different levels of the variable of interest (EPA, 2002).	
Analytical results for water quality samples will be reported if they are above the reporting limit.	Reporting limits for water quality parameters are listed in Table 9.1. Data reported as below the detection limit will be calculated using the reporting limit.
All water quality testing methods selected have detection limits above the expected range of results.	The expected range of results and respective reporting limit were compared in Table 9.1.
Instruments capable of accurately measuring variables at the site will be used during the study.	The sensitivity of instruments at the site is included with the monitoring equipment specifications in Appendix G.

6.1 *Precision*

Water quality sample and measurement precision will be assessed using laboratory and field duplicates. Precision for laboratory and field duplicates will be ± 20 percent for all other water quality parameters. The exception is pH which has a RPD of ± 10 percent for field duplicates and there is no RPD for laboratory duplicates (Table 6.2). In all cases, the RPD of duplicate samples will be calculated using the following equation:

$$\text{RPD} = \frac{|C_1 - C_2|}{\bar{x}} \times 100\%$$

Where: RPD = relative percent difference
C_1 = concentration (or value) of original sample
C_2 = concentration (or value) of duplicate
$\bar{x}$ = mean of samples

Rain gauge and flow measurement precision will be assessed at the beginning and end of the study. The rain gage precision will be assessed by pouring a known quantity of water into the tipping bucket two times. Precision for the rain gage measurements will be ± 20 percent RPD. Precision for flow will be assessed by comparing repeated pressure measurements with a known depth of water over each of the respective pressure transducers. Precision for pressure transducer measurements will be ± 20 percent RPD.

6.2 *Bias*

Bias will be assessed based on analyses of method blanks, rinsate blanks matrix spikes, and control standards (Table 6.1). Method blank values will not exceed the reporting limit. Rinsate blank values will not exceed two times the reporting limit. The percent recovery of matrix spikes will be ± 25 percent for total phosphorus, ortho-phosphate, hardness, and total and dissolved metals. Duplicate matrix spikes will also be run on a portion of the samples. The laboratory control sample recovery will be ± 20 percent for total phosphorus, ortho-phosphate, hardness, and total and dissolved metals. Percent recovery (%R) for matrix spikes will be calculated using the following equation:

$$\%R_m = \frac{(X_S - X_O)}{C_S} \times 100\%$$

Where: $\%R$ = percent recovery
X_s = spike sample result
X_o = original sample amount
C_s = concentration of spike

If the analyte is not detected in the un-spiked sample, then a value of zero will be used in the equation. Percent recovery (%R) for control standards will be calculated using the following equation:

$$\%R_c = \frac{M}{T} \times 100\%$$

Where: %R = percent recovery
M = measured value
T = true value

6.3 Representativeness

Representativeness is the degree that the data accurately describe the conditions being evaluated based on the selected sampling locations, sampling frequency, and sampling methods. The BMP location selected for the Study is representative of an area which would preclude the use of a bioretention cell (see Section 7.2, Test-Site(s) Selection Process). Local stormwater hydrologic conditions are represented by conducting the study over two wet seasons and collecting data from a minimum of 12 storm sampling events. Qualifying storm events are described in Section 7.5. The rainfall tipping bucket gage will have a measurement resolution of 0.01 inches, which will be adequate to evaluate these qualifying storm criteria. Rainfall measurements will be made every 15 minutes and every 5 minutes during storm events, which will be an adequate resolution to characterize the storm hydrograph. The tipping bucket rain gage will be located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. The rain gage will be installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage.

Field and laboratory methods will have measurement ranges and reporting limits adequate to evaluate achievement of TAPE treatment performance goals (Ecology 2011). Grab samples will be collected during the rising limb of the storm hydrograph, per TAPE guidance. Composite samples will be collected by in-situ flow-weighted composite sampling. These methods will provide samples representative of the storm water quality.

Table 6.2 Measurement Performance Criteria (MPC) for Water Quality and Sediment Data

Matrix	Parameter	Units	Method	Method Blank	Rinsate Blank	LCS Recovery (Percent)	MS Recovery (Percent)	MSD (RPD)	Field Duplicate (RPD)[1]	Laboratory Duplicate (RPD)
Water Quality	Total Suspended Solids (TSS)	mg/L	SM 2540D	<RL	<2X RL	80 - 120	N/A	NA	≤20%	≤20%
	Particle Size Distribution (PSD)	%	ASTM D3977-97[2]	NA	NA	NA	NA	NA	≤20%	≤20%
	pH	std. units	EPA 150.1	NA	NA	NA	NA	NA	≤10%	N/A
	Dissolved Copper (Cu)	µg/L	EPA 200.8 (ICP/MS) or SM 3125 (ICP/MS)	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Dissolved Zinc (Zn)	µg/L		<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Total Copper (Cu)	µg/L		<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Total Zinc (Zn)	µg/L		<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Hardness as CaCO3	mg/L	SM 2340B (ICP)	<RL	<2X RL	70 - 130	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Ortho-phosphate (OP)	mg/L	SM 4500-P G	<RL	<2X RL	80 - 120	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	Total Phosphorus (TP)	mg/L	SM 4500-P F	<RL	<2X RL	80 - 120	75-125	≤20% or ± 2 x RL	≤20%	≤20%
	NWTPH-Dx	mg/L	EPA SW-846 8015B or Ecology 1997 Pub No. 97-602	<RL	<2X RL	70 - 130	70 - 130	≤40% or ± 2 x RL	≤40%	≤40%

1. The relative percent difference will be less than or equal to the indicated percentage for values greater than 5 times the reporting limit, and ± 2 times the reporting limit for values less than or equal to 5 times the reporting limit.
2. Modified Suspended Sediment Concentration (SSC) Method according to ASTM Method D3977-97 (ASTM 2002) using wet sieve filtration (Method C) and glass fiber filtration (Method B)

mg/L = milligrams per liter, µg/L = micrograms per liter, std. units = standard units
RL = Reporting Limit, LCS = Laboratory Control Sample, MS= Matrix Spike, MSD = Matrix Spike Duplicate, RPD = Relative Percent Difference, NA = Not Applicable
PSD = Particle Size Distribution

7.0 Experimental Design

7.1 Study Design Overview

This is a paired study with two bioretention cells that were constructed immediately adjacent to each other at the test-site. Each cell contains the same type and configuration of BSM, except one cells contains a 12-inch thick BSM layer and the other contains an 18-inch BSM layer (Figure 4.1). The BSM in each cell was installed in the fall of 2014. The site also includes 2 catch basins, an influent sampling sump, a manhole (effluent sampling), and equipment storage vault (Figures 7.1 and 7.2). Runoff from a parking lot is collected in a catch basin inlet located on the south end of the cells, which overflows into a covered sump that contains the influent piping with the pressure transducer (PT). Runoff discharges into a second covered catch basin located between the cells (influent sampling). Runoff is distributed equally to each cell through stormdrains located on opposite sides of the catch basin. Runoff infiltrates through the BSM in each cell and is captured by the impermeable liner and conveyed to a manhole through underdrain pipes where the effluent PTs are located and samples are collected (Figure 7.2).

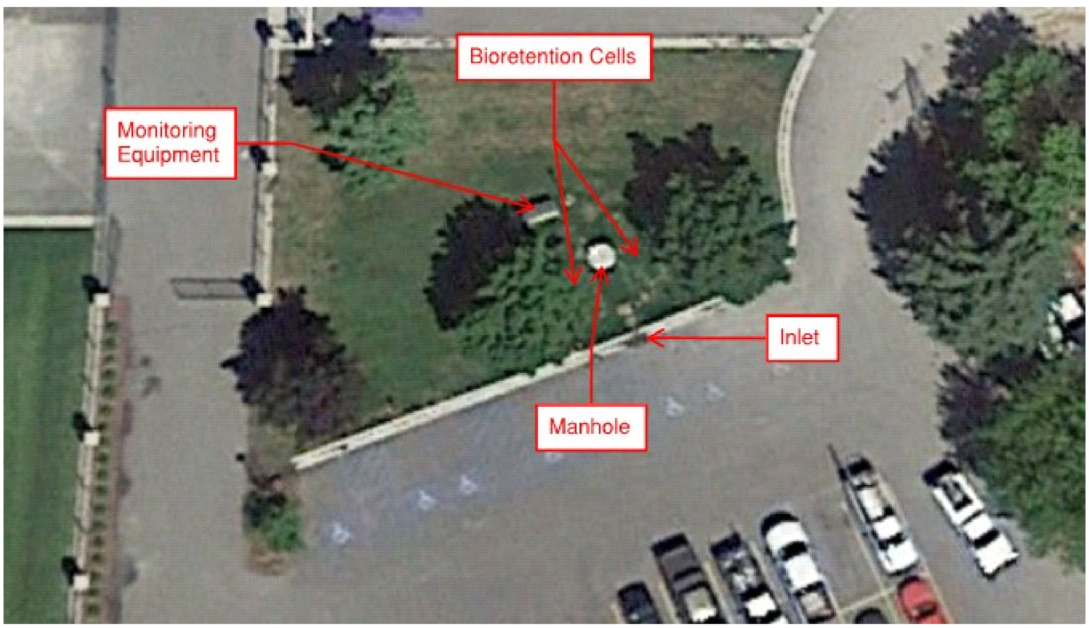

Figure 7.1 Aerial View of Test Site

Figure 7.2 Influent sampling sump (left), manhole-effluent sampling (middle), and weir (right)

Major components of the monitoring system are shown in Figure 7.2 and are defined below. The connections between these components and other instrumentation are shown in Figure 7.3.

- A rain gauge, adjacent to the monitoring vault, captures rainfall and relays precipitation data to the data logger
- Pressure transducers continuously measure flow upstream of the Thel-Mar weirs located in the influent and effluent pipes and transmit stage data to the data logger
- A data logger is located in the monitoring vault and triggers sampling at the automated samplers dependent on qualifying rainfall event criteria. For example, sample collection starts and ends when the storm start and end conditions occur (see Section 7.5).
- Three automated samplers stored inside the monitoring vault collect flow weighed composite samples from the influent pipe in the influent sampling sump (Figure 7.2) and from the effluent pipes in the manhole (Figure 7.2)

Composite samples from the influent and two effluent pipes will be collected from a minimum of 12 qualifying rainfall events (see Section 7.5 for details on qualifying events). Samples will be tested for the required parameters (each sampling event) and screening parameters (minimum 3 sampling events) in order to demonstrate treatment performance goals for basic and dissolved metals (Table 14.1). Testing is expected to occur over a minimum of 2 wet seasons.

Samples of the BSM, installed in the cells and stored since the test-site was constructed, will be submitted to the lab for analysis. The material physiochemical properties of the samples will be tested (at an Ecology certified lab) to verify that media meets the specification for the selected BSM mix. Section 7.9 provides more details on material testing.

Saturated hydraulic conductivity (K_{sat}) testing will occur twice per year using a falling head test. The cell will be filled using a fire hydrant and the rate of fall will be measured using yard sticks. The purpose of the K_{sat} testing is to monitor changes in the rate over the duration of the study. K_{sat} will also be measured using the effluent flow data as described in Section 14.0.

The focus of the study is to evaluate the influence of BSM depth on the runoff treatment performance of the cells. This will include statistically comparing the effluent concentrations from each cell to determine whether the treatment performance of the cell with a 12-inch BSM layer is significantly different than that of the cell with an 18-inch BSM layer for reducing TSS and dissolved metals (Cu and Zn). In addition the removal efficiency from the 12-inch BSM soil will be compared to the TAPE treatment goals to determine whether the 12-inch BSM cell achieved Ecology's treatment goals for basic and dissolved metals.

The final report will be submitted to Ecology at the end of the study and the annual reports will be included in Spokane County's annual stormwater report. For the pollutants in which the treatment goals are met, the final study report (TER) will be submitted to Ecology and the advisory review panel to request a '*functional equivalent*' designation for bioretention cells with 12-inches of BSM.

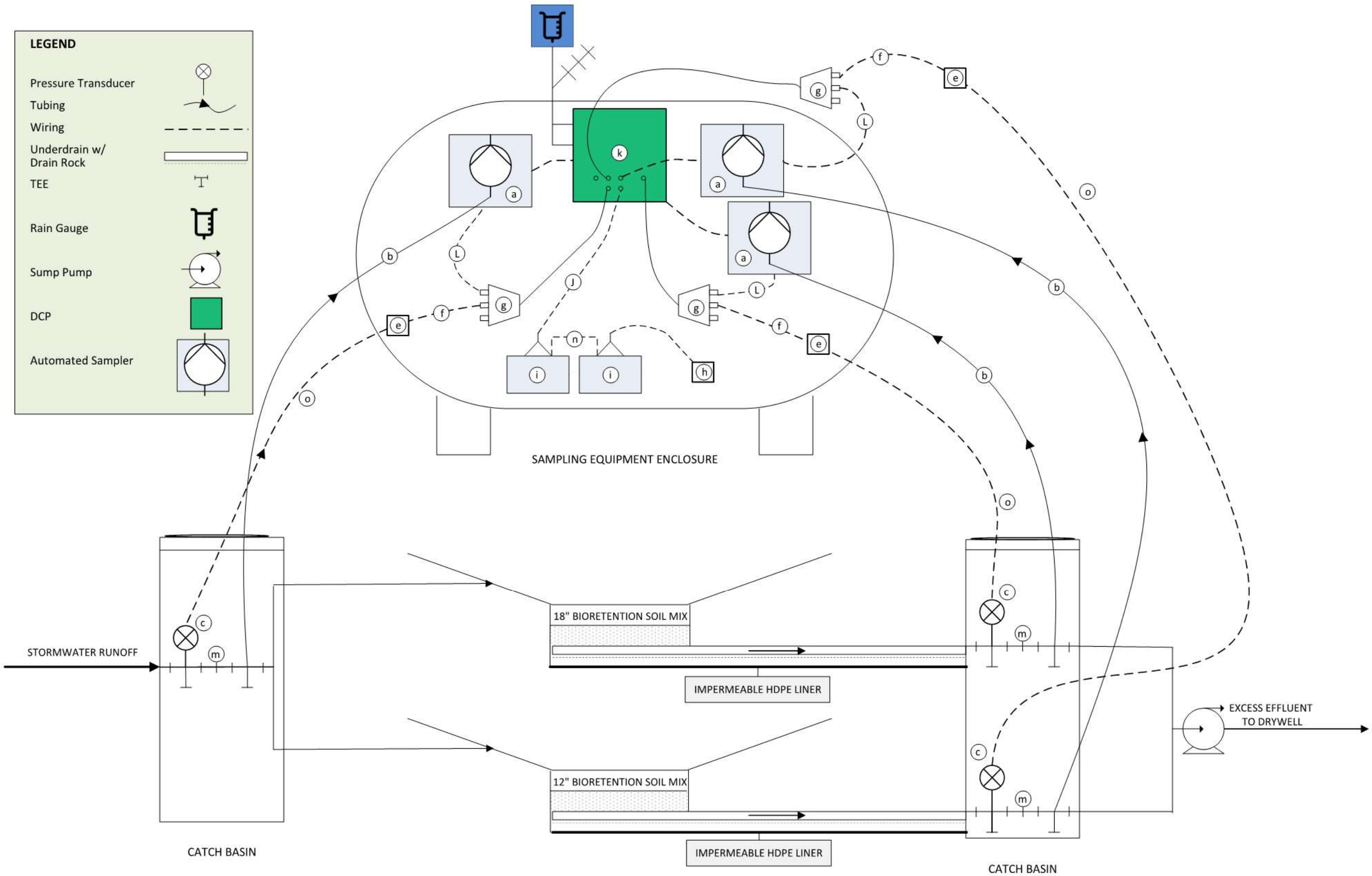

Figure 7.3 Process Diagram of Monitoring System

Table 7.1 Summary of Monitoring Equipment and Instrumentation

Symbol	Equipment Description	Equipment Function	Quantity
a	ISCO 6712 autosampler	Collects and stores influent and effluent samples	3
b	3/8 inch ID x 25 ft. long vinyl suction line with standard weighted polypropylene strainer. Includes tubing coupler.	Suction tubing conveys sample to the samplers	3
c	OTT PLS PRESSURE TRANSDUCER - aa PLS, PRESSURE LEVEL SDI12, 0-4M OTT PLS level sensor with 0-4 meter (13.1 ft) range and SDI-12 communication	Measures the depth of water in the pipe which is used along with the thelmar weir to calculate the influent and effluent flow rates	3
d	ISCO 674 Rain Gauge, Tipping bucket, 50 ft Armored Cable	Records rainfall data	1
e	JUNCTION BOX - HUMIDITY ABSORBER CONNECTION BOX FAD 5 Humidity absorber connection enclosure for use with OTT PLS level sensor	Houses the dessicant cartridges	2
	DESSICANT CARTRIDGE, REPLACEMENT OTT Replacement desiccant cartridge for use with OTT FAD 4 and FAD 5 humidity enclosures	Absorbs moisture that could damage the equipment	3
f	Cable, Terminal Strip to SDI Port, 1.5 ft	Extension cable which provides signal to Data Logger. Between junction box and data logger.	2
g	Cable, SDI Connectors to SDI Port, 2 ft	Connects PT to the humidity box and Samplers	2
h	Trickle Battery Charger (AC to DC Charger)	Continually charges batteries	1
i	Battery, GNB Sunlyte, 100AH, Starved Electrolyte	Battery powers samplers and data logger	2
j	Battery Cable, Dual 10A Fuse, F6 & H2, 8.5ft	Connects data logger and samplers to battery	1
k	Axiom data logger package (H2)	Records data over time via connected external instruments and sensors	1
l	SDI Interface,4.5ft Cable Logger to Isco 6712 Samp	Connects PT to humidity box and samplers	2
m	Volumetric Weir 6"	Used to measure influent and effluent flow rates	3
n	Cable, Two Batteries in Parallel	Connects two batteries together in parallel.	1
o	PLS PROBE CABLE, METERS - Integrated vented cable for use with OTT PLS level sensor - per meter Notes: Each PLS to have 15 meter cable.	Patch cable that provides the signal from the presssure transducer to the datalogger. This cable terminates at the junction box (humidity absorber).	2

7.2 Test-Site(s) Selection Process

In 2014, the test-site was constructed for the purpose of conducting an effectiveness study focused on bioretention soil media. A copy of the construction plan sheets is located in Appendix E. This site was selected because the contributing basin area is a parking lot located near the university soccer field, basketball center, and a recreation facility. During a typical day the parking stalls are occupied and there is a frequent turnover of vehicles. This type of land use is associated with a buildup of pollutants such as metals and TSS (Minton, 2013). As such, it is anticipated these pollutants will be of measurable quantity in the stormwater runoff and have the potential to meet the TAPE influent concentration range (see Table 14.1).

7.3 The Structural BMP System Sizing

The bioretention cells were designed following the design guidance from the EWA LID Manual (AHBL & HDR, 2013) and the Ecology Stormwater Management Manual for Western Washington (Ecology, 2014). The following is a summary of the cell design methods, assumptions, and results. Table 7.2 provides a summary of the cell sizing and a copy of the BMP sizing calculation are located in Appendix D.

- Both cells are 7-feet wide by 18-feet long by 2.5-feet deep
- The cells were sized to contain the water quality event (6-month 24-hour event) to a depth of approximately 6-inches and contain runoff from the 25-year 24-hour storm with between 0.5- to 1-foot of freeboards above the max ponding depth
- A single event model was used to size the cells using the Type 1A rainfall distribution
- Rainfall depths: 6-month 24-hour (1”) and 25-year 24-hour (2.20”)
- The contributing basin area (0.50 AC) was modeled assuming half of the runoff from the contributing basin area is distributed to each cell (0.25 AC per cell)
- BSM Infiltration rate: 1.5-inches/hour
  Note: 1.5-inches/hour applies to PGIS contributing basins >10,000 sqft. For PGIS contributing basins <10,000 sqft, 3-inches/hour is recommended (Ecology, 2018)
- The bioretention cells were modeled assuming the BSM has a 40% porosity. As such the live storage volume is the bottom of the BSM (as opposed to the bottom of the cell or the top of the BSM)
- BSM depth: one of the cells was modeled with 18-inches of BSM (as defined in the Ecology approved design guidance) while the other cell was modeled with 12-inches of BSM

Table 7.2 Summary of Bioretention Cell Sizing

Biotention Cell ID	Event	Effluent Peak Q (cfs)	Live Storage Elevation[1] (ft)	Max Pond Depth[2] (ft)	Bottom of Pond Elevation[3] (ft)	Max Ponded Elevation[4] (ft)	Vol (cf)	Time to Empty (hr)
12-inch Cell	6m 24hr	0.0143	99.00	1.64	100.00	100.64	152.43	2.00
	25yr 24hr	0.0243		3.00		102.00	547.34	6.17
18-inch Cell	6m 24hr	0.0145	98.50	2.02	100.00	100.52	155.98	2.50
	25yr 24hr	0.0246		3.45		101.95	549.72	6.50

1. The live storage elevation represents the bottom of the BSM. This is because the BSM was modeled assuming a 40% porosity (AHBL & HDR, 2013).
2. The max ponding depth represents the ponding depth starting at the bottom of the BSM.
3. The bottom of pond elevation represents the top of the BSM or the bottom of the cell.
4. The max ponded elevation represents the ponding depth starting at the bottom of the cell (or the top of the BSM).

7.4 Type of Data Being Collected

Sampling process design has been developed based on monitoring requirements identified in the Eastern Washington NPDES Phase II Permit (Ecology, 2014) and in TAPE (Ecology, 2011). This section addresses the steps and processes taken to develop these monitoring sites and sampling strategies and to ensure the data collection and monitoring methods satisfy the requirements of TAPE and the permit. Table 7.3 provides a summary of the type of data that will be collected along with the frequency of data collection, sampling method, and the sampling location.

Table 7.3 Overview of Monitoring Variables

Parameters	Frequency	Sampling Method and sampling location
Rainfall	Continuous[1], year-round	Rain Gage, on-site
Stage (Discharge)	Continuous[1], year-round	PT: influent and effluent
Temperature	Continuous[1], year-round	PT: influent and effluent
Time	Continuous[1], year-round	PT: influent and effluent
TSS, Metals, Hardness	Storm events (min. of 12 events)	Composite with Autosampler, Influent and effluent
OP, TP, pH, PSD	Storm events (min. of 3 events)	Composite with Autosampler, Influent and effluent
NWTPH-Dx, visible sheen observation	Storm events (min. of 12 events)	Grab sample, influent and effluent
Saturated Hydraulic Conductivity	Twice per year (4 times total)	Falling head test; fill cells using fire hydrant, measure rate of fall with yard sticks; Calculate infiltration rate using average effluent flow rate
BSM materials	Once, prior to start of study	Grab Sample; BSM installed at the test site (stored since the cell was constructed) will be tested

1. Measured in 5-minute intervals when storms are monitored and 15-minute intervals during all other times.

The study is expected to last two wet seasons. Water quality samples will be collected during a minimum of 12 qualifying rainfall events (see Table 7.4 for definition of qualifying rainfall events). This will include collecting flow weighted composite samples from the influent and the effluent. Composite samples collected will represent at least 75% of the storm event hydrograph (by volume). Additionally, sampled storm events will target a minimum of 10 aliquots per storm event. Samples will be tested for the required parameters (12 minimum samples) and screening parameters (three minimum samples) as defined in TAPE in order to demonstrate treatment performance goals for basic and dissolved metals.

The discharge flow rate for the influent and effluent are calculated by the data logger using stage values measured by the pressure transducers (PTs) combined with weir equations specific to the pipe diameter. Weirs are located downstream of the PT in the influent and effluent pipes. Weirs were selected for this test site because they are preferred over flumes in lower-flow “flashy” systems in order to more accurately characterize small-scale hydrological features (Rantz at al, 1982; USEPA, 2002c). However, weirs tend to be more influenced by debris than flumes (Church et al., 2003) and need to be carefully monitored and maintained. An equations for the weir was derived specifically for the size of weir (based on the pipe diameter) using depth and flow data provided by the manufacturer. The equation is programmed into the data logger logic and used to calculate the discharge flow rate at each time interval using the stage (feet) measured by the PTs. Flow over the weirs at the site (see Figure 7.2) is calculated from the following equations provided by the manufacturer for the 6-inch weirs (in the influent and effluent pipes):

6-inch Weir: $Q = 6085.1 \times (d_{PT})^{2.5756}$

Where:
Q=flow rate (liters per minute)
d_{PT}=depth measured at pressure transducer (feet)

The data logger will store data measured on site by the instrumentation on the internal logger memory. Data will be accessed by downloading to a USB drive at the site. Hydrographs and hyetographs will be created from the collected rain gage and discharge data to accurately compare and relate the two parameters.

7.5 Precipitation Monitoring

Precipitation monitoring consists of two parts: storm event prediction and rainfall measurements. This section describes the methods for both.

7.5.1 Storm Event Prediction

Sampling should be attempted for storms that are predicted to meet the storm event guidelines defined in TAPE (Ecology, 2011 p. 14). These events are referred to as ‘qualifying rainfall events’ in this document which have the characteristics defined in Table 7.4.

Table 7.4 Storm Event Guidelines for TAPE Monitoring

Parameter	Definition	Guideline [1]
Minimum storm depth	Total rainfall amount during the storm event	0.15 inches
Storm start (antecedent dry period)	Defines the storm event's beginning as designated by the minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Storm end (post storm dry period)	Defines the storm event's end as designated by minimum time interval without significant rainfall	6 hours minimum with less than 0.04 inches of rain
Minimum storm duration	Shortest acceptable rainfall duration	1 hour
Average storm intensity	Total rainfall amount divided by total rainfall duration (e.g. inches per hour)	Range of rainfall intensities[2]

1. Will provide justification in the Technical Evaluation Report (TER) for storm event data that does not meet the storm event guidelines, but is included in the data analysis. Currently the data logger is programed to only collect samples during qualifying events.
2. To assess performance on an annual average basis and performance at the system's peak design rate, samples will be collected over a range of rainfall intensities.

The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, Spokane forecast office website will be monitored daily for storm forecasts. (http://graphical.weather.gov/sectors/otx.php). These observations will determine if a predicted storm will meet the qualifying event criteria in which sample collection will occur. The SOPs for selecting and tracking a storm are defined in Section 8.1.1.

7.5.2 Rainfall Measurements

Precipitation monitoring will be conducted to quantify rainfall during storm events and to measure the duration, intensity and distribution of rainfall throughout a discrete storm event. Precipitation will be monitored in 15 minute increments by the data logger. The precipitation monitoring device used for this study is a jeweled bearing tipping bucket rain gage. The tipping bucket rain gage has a data resolution of 0.01 inches.

The tipping bucket rain gage is located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. The rain gage was installed in a secure, level fashion in a location where no buildings, trees, overpasses, or other objects obstruct or divert rainfall prior to entering the rain gage. Rain gage placement followed the National Weather Service specifications (http://www.weather.gov/om/coop/standard.htm) for the site.

If a deviation from NWS specification are needed, a notation will be made regarding the alteration and included in the TER. Rain gages will be mounted to the antenna mast approximately 6-8 feet from the ground unless otherwise specified. The rain gage will be calibrated prior to installation and maintained in accordance with the manufacturers' specifications.

The data collected from the rain gage will be logged every 15 minutes during typical operating conditions and every 5 minutes during sampling events, and can be downloaded via the data logger at the site. In order to determine when sampling crew need to deploy for sample collection, actual precipitation at a weather station approximately 0.75 miles southeast of the test site will be monitored during storm events (https://www.wunderground.com/personal-weather-station/dashboard?ID=MTPERR). During each station visit, the rain gage will be inspected, cleared of debris, and maintained in accordance with the manufacturers' specifications. Rain gage data will also be downloaded from the logger for each storm event or during the maintenance schedule.

7.6 Water Quality Sampling

Two methods will be used for water quality sampling depending on the parameter that will be tested: grab sampling and composite sampling. This section describes the methods for both. Figure 7.3 includes a process drawing of the monitoring system.

7.6.1 Grab Sampling

Grab samples are typically those collected manually in jars or measured in situ with a probe. For this study, only in situ measurements will be taken. pH and temperature are the required in situ measurements at the site. Both will be collected from a small amount of the composite sample in the autosampler for both influent and effluent. If grab samples are not collected or are missed during qualifying storm events, allowable non-qualifying sized storm events may be sampled to ensure statistical requirements are met. An allowable non-qualifying storm means that only the stormwater rainfall depth can be the reason the storm is non-qualifying. Samples collected from non-qualifying storms will be noted and flagged in the dataset.

7.6.2 Composite Sampling

TAPE specifies that stormwater runoff must be collected by in-situ flow-weighted composite sampling. Autosamplers such as an ISCO or a similar product will be used at each of the monitoring stations to collect stormwater samples during a qualifying storm event. Autosamplers are programmed to begin sampling at the predetermined rates required for the collection of at least 75 percent of the event hydrograph. Sample collection into autosampler bottles will be triggered by the characteristics of a 'qualifying rainfall event' as described in Section 7.5 and Appendix L. Specifically, the data logger is programmed to only trigger collection of samples by the autosampler when qualifying conditions occur. If conditions fall outside the limits of a qualifying event, the data logger is programmed to stop sampling. The characteristics (i.e., water temperature, rainfall, discharge, and time) are necessary to determine whether the antecedent criteria and rainfall criteria required by TAPE were met, stormwater runoff is occurring and the water is not frozen. Water temperature, rainfall, and discharge will be measured using external probes connected to the data logger. Time will be measured by the data logger itself. If these four thresholds are not met during the storm, samples will not be collected.

7.7 Saturated Hydraulic Conductivity Testing

The saturated hydraulic conductivity of the bioretention ponds will be measured twice a year using a falling head test. This will include filling the cells with water using a fire hose. Then measuring the rate of fall using yard sticks installed in the cells. The infiltration rate of the BSM will be calculated using following each qualifying storm event using the effluent flow rates and using effluent flow rates measured during the falling head test.

7.8 Influent Sediment Particle Size Distribution

Composite samples of sediment will be collected from the influent by the autosamplers at the site. The samples will be sent to the laboratory for determination of the particle size distribution (PSD).

7.9 BSM Material Testing

The BSM will be tested once prior to the start of data collection. BSM material installed in the bioretention cells when the cells were constructed has been stored in a sealed container. Samples will be collected from the container and submitted to the lab for analysis of the parameters described in Table 9.1.

The purpose of the testing is to verify that materials properties are consistent with the properties defined in the selected BSM specification. The testing anticipated for this study is summarized in Table 9.1. Please note: the compost component of the bioretention media was tested prior to installation and met Ecology requirements for the media.

8.0 Sampling Procedures

This section defines the field procedures for collecting samples, measuring data, as well as operating, maintaining, and calibrating the equipment.

8.1 Standard Operating Procedures

Water quality samples will be collected in the field, following standard operating procedures (SOPs). The SOPs developed for this study define how to conduct storm selection, sample collection, and equipment maintenance and calibration in detail, including the frequency of the activity. All visits to the site should be conducted with a partner or multiple personnel. SOPs included in this section are:

- Storm Selection and Tracking
- Storm Monitoring Equipment Maintenance
- Preparing Stormwater Monitoring Equipment for Storm Sampling
- Stormwater Grab Sampling – Not Used for This QAPP
- Stormwater Sample Collection and Processing
- Monitoring Equipment Data Download
- Accumulated Sediment PSD Sample Collection– Not Used for This QAPP
- Falling Head Test

8.1.1 Storm Selection and Tracking

The purpose of this SOP is to define the procedures for selecting and tracking storm events prior to and during stormwater monitoring activities.

Equipment Needed:

- A computer or mobile device with the ability to access weather forecasting websites or applications
- A cellular phone to allow communication between sampling staff and staff tracking the storm event
- A Storm Decision Log (Appendix H) to record the decision process, weather activity, and outcome of the event

Summary of procedures for storm tracking prior to the storm event and storm selection for sampling:

- Step 1: Review weather forecast daily to determine whether upcoming storm events meet the storm event guidelines defined in TAPE (qualifying rainfall event) and described in Section 7.5 of this document. Storm event probability will be tracked via the NOAA National Weather Service Spokane forecast office website at the following link: http://graphical.weather.gov/sectors/otx.php
- Step 2: The probability of a qualifying rainfall event will be determined based on the weather forecast and the following qualitative classification system:

  - Unlikely: a storm event that is classified as unlikely will produce less than the minimum depth (0.15-inches) for a qualifying rain event and has less than a 50% chance of occurring.
  - Marginal: a storm event that is classified as marginal will produce less than the minimum depth for a qualifying rain event and has a 50% to 75% chance of occurring.
  - Likely: a storm event that is classified as likely will produce greater than the minimum depth for a qualifying rain event and has a greater than 75% probability.
- Step 3: Based on the classification of the predicted rainfall event, the sampling staff will determine whether to prepare to collect samples during the event.
  - If the storm is deemed unlikely, sampling staff will not plan to collect samples during the event.
  - If the storm is deemed marginal, the principal investigator or project manager will determine whether the conditions of the storm look favorable or not using their professional judgment. The judgment will take storm physiology and sampling success to date into account. For storm events with a marginal chance of being a qualifying rainfall event, sampling staff may be informed several days in advance of a possible upcoming event.
  - If the storm is deemed likely, the principal investigator or project manager will inform sampling staff 24 to 48 hours in advance of the anticipated sampling event.
- Step 4: If a storm event is selected for sampling, the lab will be notified and equipment will be prepared in accordance with the procedures outlined in Section 8.1.3.
- Step 5: Prior to and during a storm event that is selected for sampling, actual precipitation will be monitored remotely via the nearest available weather station to the site through Weather Underground (weatherunderground.com), a website which presents forecast, actual, and historical weather data. The actual precipitation data presented on Weather Underground will be used to determine when sampling personnel will go to the site to collect composite samples.
  - The nearest available weather station (https://www.wunderground.com/personal-weather-station/dashboard?ID=MTPERR) is located approximately 0.75 miles southeast of the site.

8.1.2 Storm Monitoring Equipment Maintenance

The purpose of this SOP is to outline the steps required for maintaining stormwater sampling equipment at the test site. Maintenance of storm monitoring equipment will occur once in early fall, prior to the first monitoring event of the wet season, and monthly between monitoring events..

Equipment needed:

- Personal Protective Equipment (PPE) including: eye protection, gloves, high visibility vest, work boots, etc.
- Cordless drill and drill bits needed to open catch basin lids
- Periodic Maintenance Checklist Field Form (Appendix H)
- Wet-dry vacuum
- Soft brush

- Volt meter
- USB drive
- Screwdriver
- Replacement suction, head, and pump tubing
- Volumetric plastic beaker
- Adjustable wrench
- Telescopic mirror
- Torpedo level
- Flashlight
- Replacement battery
- Spare desiccant bags (for ISCO and PT)
- Electronic water level indicator (tapedown tool)
- Nitrile gloves
- Cellular phone

Summary of procedures for initial inspection of site conditions and monitoring equipment at the test-site:

- Step 1: Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the Periodic Maintenance Checklist Field Form (Field Form) in Appendix H.
- Step 2: Access the monitoring equipment vault, manhole, sump, and catch basins. Visually inspect pipes, cables, wiring, tubing, and monitoring equipment. Note any frayed wires or damaged equipment on the Periodic Maintenance Checklist Field Form. Contact principal investigator or project manager on how to proceed if damage is significant. *Note: When accessing the equipment in the manhole and catch basin, do not disturb pipes or pipe tees*.
- Step 3: Inspect pipes, tees and weirs for debris or obstructions. Note and describe any debris on the field form.
    - If debris or sediment are observed in pipes, tees, or weirs, clean pipes according to Steps 3 – 5 in Section 8.1.3. Then immediately replace the grate inlet.
- Step 4: Disconnect power supply to battery. Check voltage of battery using a voltage meter. Battery voltage reading should be above 10.3 volts. Record the voltage reading on the Periodic Maintenance Checklist and reconnect power to the battery.
    - If battery voltage is not within the specified range, replace battery with the spare, fully charged battery.
- Step 5: Connect the USB flash drive to the data logger, tap the screen to wake up the data logger, and start a visit report. *Note: when the visit report is ended in Step 14, the current conditions data is automatically downloaded to the USB.*
    - To start a visit report, press service on the main menu. Tap the visit report icon on the next page, and fill in the information as applicable for the visit report. Tap the start visit icon and follow the prompts to start the visit report.
- Step 6: Once every three months, unplug the rain gage from the data logger. Remove cover from rain gage and check instrument for levelness and cleanliness of internal parts. Clear

any debris carefully. Note any discrepancies and reset level of rain gage platform if needed. Replace cover on rain gage and plug rain gage back in to the data logger.

- Step 7: Inspect ISCO suction tubing, head tubing and pump tubing for wear. Note and describe condition on the Periodic Maintenance Checklist. If kinks or bellies are observed in the tubing, replace tubing. Document whether replacement of tubing occurred during the site visit on the Periodic Maintenance Checklist.
- Step 8: Check the Internal Humidity Indicator to the right of the keypad on the ISCO.
    - If all of the indicator is blue, no additional action is needed. Record the indicator color on Periodic Maintenance Checklist.
    - If the area of the indicator next to 20% is white or pink, no additional action is needed, though action may be required in the near future. The color change near the 20% indicates that the level of humidity inside the ISCO controls compartment is 20%. Record indicator color on Periodic Maintenance Checklist.
    - If the area of the indicator next to 30% or any of the other areas above 30% are white or pink, the desiccant inside the ISCO controls compartment needs to be replaced. Record indicator color and whether the desiccant was replaced on Periodic Maintenance Checklist.
        - Pull discharge and pump tube away from bulkhead fitting. Remove the distributor arm by unscrewing the nut that attaches the arm to the distributor shaft. Unscrew the 11 screws securing the cover for the ISCO controls compartment.
        - Remove the desiccant bag from the box inside the controls compartment and replace with a new desiccant bag.
        - Replace the cover for the controls compartment and replace the 11 screws needed to secure the cover. Reattach the distributor arm and discharge and pump tubing.
- Step 9: Check the colored indicator on each of the PT humidity absorbing systems. Record the observed color on the Periodic Maintenance Checklist.
    - If the indicator is orange/brown, the desiccant cartridge is dry and does not need to be replaced.
    - If the indicator is white, the desiccant cartridge must be replaced. Note that either the desiccant cartridge needs to be replaced, or has been replaced in the field on the Periodic Maintenance Checklist.
- Step 10: If the ISCO controller keypad is inflated, carefully reach behind the head unit and unscrew one of the bulkhead caps to relieve pressure. Retighten cap after pressure has been relieved to maximize desiccant lifespan.
- Step 11: Check the ISCOs pump capabilities by manually initiating a grab sample to test purging and pumping capabilities. Do this with the suction tubing disconnected to avoid falsely pumping a sample into clean sampling equipment.
    - Obtain the volumetric plastic beaker.
    - To manually initiate a grab sample, press the return arrow button on the control pad, navigate to “grab sample” and hit the return arrow button again. Follow the prompts to begin the grab sample.
    - Hold the beaker below the pump tubing. Once the sample has been pumped into the beaker, verify that the volume pumped matches what volume was reportedly

pumped by the ISCO. If the volumes do not match, perform volumetric verification test as detailed in Step 12.

- Step 12: Once every three months (quarterly), conduct a volumetric verification test to ensure accuracy of ISCO calibration. Do this with the suction tubing disconnected to avoid falsely pumping a sample into clean sampling equipment. Repeat test as necessary until volumes are accurate.
    - Press the return arrow button, and navigate to "calibrate volume". Enter the sample volume desired.
    - Hold a volumetric plastic beaker (large enough to hold sample volume) under the pump tubing, and hit the return arrow button when ready.
    - After the sample volume has been delivered, measure the actual volume delivered to the beaker and enter the amount on the ISCO screen as prompted. Press the return arrow button and follow the prompts.
    - The calibration is complete when the display on the ISCO screen returns to the list of manual functions.
- Step 13: Reconnect suction tubing to pump tubing.
- Step 14: Once all maintenance, cleaning, and calibration has been completed, end the visit report on the data logger, close the monitoring equipment vault, manhole, sump, and catch basins, and secure as needed before leaving the site.
    - To end the visit report, press service on the main menu. Tap the visit report icon on the next page, and tap the end visit icon near the bottom of the page. Follow the prompts as necessary, and remove the USB drive.

8.1.3 Preparing Stormwater Monitoring Equipment for Storm Sampling

The purpose of this SOP is to outline the steps required for cleaning and calibrating stormwater sampling equipment and the pH probe prior to monitoring and sampling storms, and preferably on the day of the storm event. Additional, general steps to prepare for stormwater sampling and processing are covered in this SOP. Note: prior to performing the steps outlined in this SOP, the lab will be notified that sampling is expected to occur, and that rinsate blanks and composite samples will be transported to the lab. An estimate of when each set of samples will be delivered will be provided to the lab.

Equipment:

- Cordless drill and drill bits needed to open catch basin lids
- Telescopic mirror
- Adjustable wrench
- Torpedo level
- Volt meter
- Flashlight
- Wet-dry vacuum
- Soft brush
- Water source or 5 gallon bucket (with lid) filled with tap water

- Cleaning solutions for tubing (10% HNO3 acid solution, liquinox soap solution) in 5-gallon buckets (one for each solution) with lids
- Carboy(s) filled with DI water
- Ice to fill ISCOs
- Replacement composite bottles for ISCOs
- Sample bottles for rinsate blanks
- Cooler for rinsate blank sample bottles
- Hard ice packs for cooler
- Trash bag (for any large debris)
- pH meter
- pH probe storage solution
- pH probe cleaning solution
- Buffer solutions for pH meter
- Two small plastic beakers
- Clean, powder-free nitrile gloves
- Personal Protective Equipment (PPE) including: eye protection, gloves, high visibility vest, work boots, etc.
- Electronic water level indicator (tape down tool)
- Cellular phone
- Pre-Storm Event Maintenance Checklist, Chain of Custody Form

Summary of procedures to prepare monitoring equipment for storm sampling:

- Step 1: Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering, or unsafe conditions. Note any findings on the Pre-Storm Event Maintenance Checklist.
- Step 2: Access the monitoring equipment vault, manhole, sump, and catch basins. Start a visit report on the data logger according to Step 5 in Section 8.1.2. *Note: In accordance with "clean hands/dirty hands" procedures, one staff member will be designated to install new ISCO composite bottles in Step 16. This staff member may not handle other equipment during the site visit. Additionally, the staff member will wear two pairs of gloves during sample handling: after obtaining samples from cooler and opening the bag containing the sample bottles, the outer set of gloves will be removed to handle the clean sample bottles inside the bag.*
- Step 3: Inspect pipes, tees, weirs, and pipe connections. If debris or sediment are observed, put on gloves and eye protection, as needed. Check for sharp or potentially hazardous materials before beginning to clean. *Note: When accessing the equipment in the equipment vault and catch basin, do not disturb pipes or pipe tees*.
- Step 4: Before starting to clean, collect a water surface elevation measurement from the reference point on the control tee. Record the measurement and reference elevation on the Pre-Storm Event Maintenance Checklist in the assigned space. Assign a + or – value to your reading if there is any uncertainty due to debris, blockage, etc. Subtract the measurement from the reference elevation to determine water surface elevation and record

the value on the form. Compare this value to the measurement collected by the data logger to identify any prior instrument drift.

- Step 5: Use the vacuum to remove sediment or debris from pipe, pipe tees, pipe connections, and weirs. Drain or vacuum any remaining liquid or sediment within the sampling and control tees. Then immediately replace the grate inlet.
- Step 6: Inspect the pump, suction, and head tubing for the ISCO. If kinks or bellies are observed in the tubing, replace the tubing. Clean any ISCO tubing that was not replaced as follows:
  - Triple rinse the tubing with 10% HNO3 acid solution, then wash the tubing with liquinox soap solution, and finally triple rinse the tubing with DI water.
- Step 7: Put on a new pair of clean nitrile gloves and obtain the sample bottles provided for the rinsate blank.
- Step 8: Access the influent autosampler. Place the end of the clean suction tubing for that autosampler in a carboy containing DI water, and place the end of the clean pump tubing over one bottle provided by the laboratory for the rinsate blank. Set the ISCO to "Pump Forward" and fill the bottle so that no airspace is remaining when the cap is replaced.
- Step 9: Replace the cap on the sample bottle, taking care to not touch the inside of the cap.
- Step 10: Repeat Steps 8-9 for the 12" and 18" effluent autosamplers and associated rinsate blank bottles.
- Step 11: Once the rinsate bottles have been filled, place bottles in the cooler and fill out the Chain of Custody form for the rinsate samples.
- Step 12: Use a level to check position of weirs and pipe tees. Adjust to a level position as needed, and note if weirs or tees were not level on the Pre-Storm Event Maintenance Checklist.
- Step 13: Inspect pressure transducers (PT) and mounts. If PTs and/or mounts are dirty, remove PT and gently scrub to remove material with a soft brush. Once PTs and mounts are clean, reinstall PTs in original position within the mounts.
- Step 14: Fill the control tee with clean water until water runs over the v-notch of the weir (This may take a few gallons of water to achieve). Once the water stops flowing over the weir (point of zero flow), use the data logger to get a current PT reading. The PT reading may take a few minutes to update.
- Step 15: Once the PT reading updates, verify using the data logger that the PT reading value is zero. Take another water surface elevation reading using the electronic water level indicator to verify the PT and data logger reading.
  - If the values do not match zero or the elevation of water at zero flow, record the observed value on the field form and reset the stage reading for the pressure transducer to zero in the data logger. Notify the principal investigator or project manager of the drift as soon as possible.
- Step 16: Access the sample bottles inside the ISCO and check bottle configuration. Remove bottles and pack ice in the bottom of the ISCO. If a new bottle is needed before a storm, install using clean hands/dirty hands procedures, as defined in Step 2 of this Section.
- Step 17: Add ice to the around the sample bottles after they are replaced to ensure the samples remain cold prior to pick up.
- Step 18: Make sure all tubing is connected properly, bulkhead caps are secured and that cables are properly attached.

- Step 19: Before leaving the site, set the data logger and ISCO autosampler mode to sample if the criteria for qualifying rainfall event (see Section 7.5) are met at the site during the forecasted storm.
  - On the ISCO, navigate to the main menu and set the ISCO to sample. The display should read, “Bottle 1 After 1 Pulses”.
  - On the data logger display, tap the processes icon on the screen, then the set sampl_enabl icon. Set the data logger to zero. This will set the data logger to sample if the criteria are met.
- Step 20: Additionally, set the threshold on the data logger to tell the system when to trigger influent and effluent sampling.
  - The threshold is determined through the spreadsheet calculator described in Appendix L.
  - The threshold values are set in the data logger by tapping the processes icon on the home screen, and then by tapping either of the threshold icons on the next page. The threshold value determined from the spreadsheet calculator in Appendix L is entered for both the influent and effluent thresholds.
- Step 21: Once all maintenance, cleaning, and calibration has been completed, end the visit report on the data logger (according to Step 14 in Section 8.1.2), close the monitoring equipment vault, manhole, sump, and catch basins, and secure as needed before leaving the site. Return rinsate samples and associated Chain of Custody to Anatek Laboratory in Spokane.
- Step 22: Upon returning to the Osborn Consulting lab, obtain the pH meter and turn on the meter. Put on nitrile gloves and eye protection.
- Step 23: Inspect the electrode for cracks in the electrode stem or bulb. If scratches or cracks are present, the electrode must be replaced.
- Step 24: Inspect the cable connecting the electrode to the meter. The cable must be intact with no points of broken insulation on the cable. If breaks are observed, the cable and probe may need to be sent in to the manufacturer. End maintenance of pH meter and refer to the manual for the pH meter for further instructions.
- Step 25: Inspect the electrode for oil, calcium, or sediment build-up on the electrode stem or bulb. If present, remove the protective cap and clean the probe using DI water. Replace the protective cap once cleaning is complete.
- Step 26: Inspect connectors and ensure they are clean and dry. Rinse off any deposits with deionized water.
- Step 27: Inspect the protective cap and replace or refill the storage solution as needed to keep the glass bulb and junction of the pH meter submerged.
- Step 28: Clean the probe by soaking the probe in cleaning solution for at least one half hour. Once the probe has been cleaned, replace the protective cap with storage solution and discard the cleaning solution.
- Step 29: Pour a small amount of each buffer solution into a clean beaker, so the probe will be immersed at least 1 ½ inches. Begin a new calibration on the pH meter.
- Step 30: Remove the protective cap on the probe and rinse the electrode with some of the buffer solution to be used for the first calibration point. Place the probe in the first buffer and stir gently.
- Step 31: The screen should show the first expected buffer value; change the expected buffer to a different value if needed. Wait for the measured pH value to stabilize.

- Step 32: Once the pH value is stable, confirm the reading and record on the Pre-Storm Event Maintenance Checklist.
- Step 33: Remove the probe from the buffer solution, rinse the probe with the second buffer solution, and place the probe in the beaker with the second buffer solution. Adjust the expected buffer value on the meter screen as needed.
- Step 34: Stir the probe gently in the buffer solution and wait for the reading to stabilize. Once the reading is stable, confirm the reading and record on the Pre-Storm Event Maintenance Checklist.
- Step 35: Navigate back to the measurement mode and turn off the pH meter; the meter will save the calibration data. Replace the protective cap on the probe and refill with storage solution as needed. Discard the used buffer solutions.

8.1.4 Stormwater Grab Sampling – Not Used for This QAPP

8.1.5 Stormwater Sample Collection and Processing

The purpose of this SOP is to outline the steps required for pH measurement and sample collection and processing at the test site.

Equipment:

- Cordless drill and drill bits needed to open catch basin lids
- USB flash drive
- Electronic water level indicator (tape down tool)
- Cellular phone to enable communication between staff and project manager or principal investigator
- Flashlight
- Volt meter
- Torpedo level
- pH meter
- Small, clean plastic beaker
- Personal Protective Equipment (PPE) including: eye protection, gloves high visibility vest, work boots, etc.
- Clean, powder-free, nitrile gloves
- Sample bottle kit (provided by Anatek)
- Gallon plastic bags
- Cooler for sample bottles
- Hard ice pack for cooler
- Syringe
- 0.45 µm filter
- Chain of custody form (Appendix I), sample tag, Sample Collection Field Form (Appendix H)

Summary of procedures for preparation of stormwater sampling equipment prior to monitoring and sampling.

- Step 1: At least one hour prior to departing for the site, place sample bottles in the plastic bag in the refrigerator to keep the bottles cool.
- Step 2: Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the field form.
- Step 3: Access the monitoring equipment vault, manhole, sump, and catch basins . Start a visit report on the data logger according to Step 5 in Section 8.1.2. *Note: In accordance with "clean hands/dirty hands" procedures, one staff member will be designated to handle sample bottles, collect samples, and package samples for the lab during a sampling event. This staff member may not handle other equipment during the sampling event. Additionally, the staff member will wear two pairs of gloves during sample handling: after obtaining samples from cooler and opening the bag containing the sample bottles, the outer set of gloves will be removed to handle the clean sample bottles inside the bag and return the bottles to the bag after collection of samples.* Step 4: Measure the water surface elevation using the electronic water level indicator. Note the current water surface elevation measurement on the field form.
- Step 5: Check the ISCO and data logger to verify that the ISCO has completed its sampling and/or that the data logger has disabled sampling. If neither scenario has happened, wait until sampling is complete before collecting the sample.
  - The ISCO will show that sampling is complete on the display if it says "sample X after 1 pulses".
  - The data logger will show that sampling is complete if the data logger sampl_enabl value (tap processes, then sampl_enabl icon) is set to 1.
- Step 6: Open the ISCO and put on clean, nitrile gloves. Visually check that the amount of water in the composite jar roughly correlates to the number of aliquots reported to have been collected by the ISCO (i.e., if the number of aliquots reported is 20, and very little to no water is present, there has been a malfunction).
- Step 7: Pour some of the sample into a small beaker to a depth of at least 1 ½ inches and place the pH probe in the beaker. Stir the liquid with the probe and proceed with Steps 8-9 while waiting for the reading to stabilize.
- Step 8: Replace the lid on the composite jar with a lab-cleaned, solid lid.
- Step 9: Remove jar from the ISCO and place the composite sample into a plastic bag within the cooler for transport to the Osborn lab.
- Step 10: Check the pH reading to see if it has stabilized. If it has, record the pH and temperature reading on the field form. If not, wait for the reading to stabilize before recording pH and temperature on the form. Remove the pH probe from the beaker, add the pH storage solution to the protective cap, replace the protective cap on the probe, and discard the small amount of sample.
- Step 11: End the visit report (according to Step 14 in Section 8.1.2) after all samples have been collected and the ISCO indicates that the program has been reset.
- Step 12: When ready to leave the site, close the monitoring equipment vault, manhole, sump, and catch basins, and secure as needed before leaving the site.
- Step 13: Return to the Osborn lab. Composite samples are transported to the Osborn lab prior to Anatek to transfer composite samples in ISCO bottles to the laboratory-specified bottles listed in Table 8.1 and to filter samples for dissolved metals and ortho-phosphate analysis.

- Step 14: Obtain the syringe, filter, DI water, and bottle for the dissolved metals blank bottle. Place the filter on the end of the syringe.
- Step 15: Fill the syringe with about 50 mL of DI water.
- Step 16: Fill the bottle for the dissolved metals blank with the 50 mL of DI water in the syringe and filtering into the blank bottle.
- Step 17: Once the bottle has been filled, cap the bottle and set it aside. Remove the filter from the syringe and discard or keep separate from the unused filters.
- Step 18: Place a new filter on the syringe. Fill the syringe with about 50 mL of composite sample and waste the sample onto the ground to rinse the filter and reduce any sample contamination.
- Step 19: Fill the sample bottle by taking consistent volumes of sample in the syringe and filtering into the bottle.
- Step 20: Repeat steps 17-19 until all sample bottles for dissolved metals and ortho phosphate (if required for the sampling event) are filled.
- Step 21: Use a funnel to fill the remaining sample bottles which do not require filtration (PSD, TSS, Hardness as $CaCO_3$, total metals, and TP, as applicable) with composite sample.
- Step 22: Place the filled laboratory bottles in the plastic bags provided by the lab, and place the plastic bag(s) in the cooler.
- Step 23: Fill out the Chain of Custody for the samples according to the procedures outlined in Section 8.5. Measure the temperature in the cooler using the thermometer and record the temperature on the Chain of Custody form.
- Step 24: Transport the samples to Anatek.
    - If samples have been collected after laboratory hours, keep samples below 6°C in a cooler or refrigerator until the laboratory reopens.

8.1.6 Monitoring Equipment Data Download

The purpose of this SOP is to outline the steps required to collect data from the data logger following the sampling event.

Equipment:

- Cordless drill and drill bits needed to open catch basin lids
- USB flash drive
- Cellular phone to enable communication between staff and principal investigator or project manager
- Flashlight
- Personal Protective Equipment (PPE) including but not limited to: high visibility vest, gloves, work boots, etc.
- Monitoring Equipment Data Download Field Form

Summary of procedures for download of data from test site:

- Step 1: Upon arrival at the site, visually inspect the monitoring site and vicinity for any signs of damage or tampering. Note any findings on the field form.

- Step 2: Open the monitoring equipment vault.
- Step 3: Insert USB flash drive and download the data. Remove the USB flash drive when the download is complete.
    - To download the data, tap data on the main screen, then tap the download (downward arrow) icon on the bottom of the screen. Select the desired range of data and press the checkmark.
- Step 4: Close the monitoring vault.

8.1.7 Accumulated Sediment PSD Sample Collection– Not Used for This QAPP

8.1.8 Falling Head Test

The purpose of this SOP is to outline the steps required to perform a falling head test on the BSM in the bioretention cell.

Equipment needed:

- Tools necessary to access fire hydrant and hose
- Personal Protective Equipment (PPE) including but not limited to: high visibility vest, gloves, work boots, etc.
- At least 4 yard sticks
- Timer
- Falling Head Test Field Form (Appendix H)
- Fire hose

Summary of procedures for the falling head test:

- Step 1: Contact Gonzaga University Plant Services and make arrangements for them to turn on the fire hose located just north of the test-site.
- Step 2: Connect the fire hose to the fire hydrant, turn on the hydrant, and spray the parking lot contributing basin area around the inlet. Runoff will flow into the grate inlet and be conveyed to the ponds. Fill the bioretention cells with water until the water has ponded 12 inches above the cell surface (yard sticks will be used to verify that 12 inches has been reached). Allow time for the media to become saturated. If needed use the fire hose to fill the water level in the cells back up to just above 6-inches.
- Step 3: Once the water level reaches 6-inches and start the timer.
- Step 4: Recording the time for water to drop 1-inch on the Falling Head Field Test Form. Continue recording time until K_{sat} is stable which is defined as when the value does not change more than 10% for 3 intervals.
- Step 5: Close and secure the monitoring vault and manhole before leaving the site.

8.2 Containers, Preservation Methods, Holding Times

Clean sample bottles and associated preservatives will be provided by Anatek Laboratory in Spokane, WA, according to Table 8.1. Sample containers and preparation will follow Code of Federal Regulations [40 CFR 136] guidelines. Spare sample bottles will be carried by the sampling staff conducting the testing in case of breakage or possible contamination.

Table 8.1 Sample Containers, Preservative, and Holding Times

Matrix	Parameter	Method	Sample Container & Amount Required	Preservative	Pre-filtration Holding Time	Total Holding Time
Water Quality	pH	pH meter	NA	NA	NA	NA
	PSD	Modified SSC: ASTM D3977-97	Plastic; 1L	NA	NA	NA
	Total Suspended Solids (TSS)	SM 2540D	Plastic; 1L	Cool, ≤ 6°C	NA	7 days
	Dissolved Metals (Cu, Zn)	EPA 200.8 (ICP/MS) or SM 3125 (ICP/MS)	Plastic; 125 mL	Cool, ≤ 6°C; filtration, 0.45 µm; HNO3 to pH < 2	12 hours	180 days
	Total Metals (Cu, Zn)		Plastic; 125 mL	Cool, ≤ 6°C; HNO3 to pH < 2	NA	180 days
	Hardness as CaCO3	SM 2340B (ICP)	Plastic; 500 mL	HNO3 pH < 2	NA	180 days
	Ortho-phosphate (OP)	SM 4500-P G	Plastic; 1 L	Cool, ≤6°C; filtration, 0.45 µm	12 hours	2 days
	Total Phosphorus (TP)	SM 4500-P F	Glass; 40 mL	Cool, ≤ 6°C; H2SO4 to pH < 2	NA	28 days
	NWTPH-Dx	EPA SW-846 8015B or Ecology 1997 Pub No. 97-602	Glass; 1 L	Cool, ≤ 6°C; HCl to pH < 2	NA	14 days
Bioretention Soil Media	Cation Exchange Capacity	S-10.10	Plastic; 2 grams	Cool, ≤ 6°C	NA	NA
	Saturated Hydraulic Conductivity (K_{sat}) @ 85% compaction rate	Modified ASTM D2434 (Ecology, 2014a)	Plastic; 500 grams	Cool, ≤ 6°C	NA	NA
	Total Elements (Zn, Cu)	EPA 6020	Plastic; 20 grams	Cool, ≤ 6°C	NA	NA
	Organic Matter Content	ASTM D2974 or TMECC 5.07A	Plastic; 50 grams	Cool, ≤ 6°C	NA	NA
Aggregate -Specific	Particle Size Distribution for the following sieve sizes: 3/8", No. 4, No. 10, No. 40, No. 100, No. 200	ASTM D422	Plastic; 500 grams	Cool, ≤ 6°C	NA	NA

8.3 Equipment Decontamination

Equipment decontamination will follow procedures in SOP "Storm Monitoring Equipment Maintenance, Cleaning and Calibration". The following equipment will be decontaminated between sampling events:

- pH Meter
- ISCO Sample Bottles (laboratory)
- ISCO Sample Tubing
- Pressure transducers

8.4 Sample Identification

All sample containers will be labeled with the following information, using waterproof labels and indelible ink and placed on dry sample container lids:

- Sample Identification
- Date of sample collection (month/day/year)
- Time of sample collection (military format)
- Sampler initials
- Parameters (pre-printed and provided by laboratory)

8.5 Chain of Custody

After samples have been obtained and the collection procedures properly documented, a written record of the chain-of-custody of each sample will be completed by field personnel to ensure that samples have not been tampered with or compromised in any way and to track the requested analysis for the analytical laboratory. Information that will be provided on the chain-of-custody form includes:

- Name(s) of field personnel
- Date and time of sample collection
- Location of sample collection
- Printed names, signatures and contact information of field personnel and laboratory personnel handling the samples
- Laboratory analysis requested and control information (e.g., duplicate or spiked samples) and any special instructions (e.g., time sensitive analyses)

After collection, samples will be immediately delivered to Anatek in Spokane, WA and/or shipped on ice to MTC in Olympia, WA. Sample custody will be tracked in the field and laboratory through the entire sample collection process, and the signed chain-of-custody forms and analytical results returned to the Osborn principal investigator or project manager. The sampling staff will record the date and time of sample deliveries for the project file. An example chain of custody form is in Appendix I.

8.6 Field Log Requirements

Field observations and measurements associated with a monitoring event will be recorded on the field forms (Appendix H). The field form will document all activities completed, measurements taken, and samples collected during the field event. The field form documents the following information:

- Date and time
- Field staff names
- Climate conditions
- Sampling equipment condition
- Samples collected (checklist)
- QC samples collected (checklist)
- Water temperature, pH, and oil sheen measurements/ observations
- Instrument calibration results
- Comments on activities or issues that may influence the quality of the data

9.0 Measurement Procedures

This section of the QAPP focuses on identifying the methods required to measure the data collected during the study including the equipment and instruments that will be used.

9.1 Procedures for Collecting Field Measurements

Field measurements will be made for precipitation, discharge (influent and effluent flow rate), water quality (stormwater influent and effluent), pH, and stormwater temperature. Precipitation and discharge measurements will be collected during data download (from the data logger) at the test-site as described in Section 8.1.6. Composite samples will be collected according to the procedures in Section 8.1.5. The pH and water temperature measurements will be instantaneous measurements collected with a calibrated pH meter, as described in Section 8.1.5.

Field measurement quality will be evaluated in terms of bias and precision (See Section 6.2 and 6.1). Measurement bias will be measured and corrected by calibrating the rain gauge at the beginning and end of the study, checking the depth measurements of the PTs during each maintenance cycle, calibrating the pH meter prior to sampling events, and calibrating the ISCO quarterly. Detailed calibration procedures are in the Sections 8.1.2 and 8.1.3. Measurement precision will be evaluated for pH and water temperature by collecting duplicate measurements for at least 10% of all measurements.

9.2 Laboratory Procedures

Laboratory analytical procedures will follow methods approved by the US Environmental Protection Agency (EPA) (APHA et al. 1992, 1998; US EPA 1983, 1984). These methods provide reporting limits that are below the TAPE criteria or guidelines and will allow direct comparison of the analytical results with these criteria. Preservation methods, analytical methods, reporting limits, and sample holding times are presented in Table 9.1. Osborn will filter for parameters requiring filtration (i.e., ortho-phosphate, dissolved copper, and dissolved zinc) and preserve the samples within four hours of their collection. The samples will be stored at the temperature noted in Table 8.1 and delivered to the laboratory during their business hours (Monday-Friday, 8:00am to 5:00pm). Anatek, the laboratory identified for the water quality samples for this project, is certified by Ecology. SoilTest Farm Consultants, Inc. Laboratory (SoilTest) is the lab identified for soil analytical samples. Stormwater PSD sample analysis will be performed by Materials Testing & Consulting, Inc. (MTC). These performance and system audits have verified the adequacy of the laboratory's standard operating procedures, which include preventive maintenance and data reduction procedures.

The laboratories will report the analytical results within 30 days of receipt of the samples. The laboratories will provide sample and quality control data in standardized reports suitable for evaluating the project data. The reports will also include a case narrative summarizing any problems encountered in the analyses.

Table 9.1. Laboratory measurement methods.

Matrix	Parameter	Units	Method	Reporting Limits	Expected Range of Results	Minimum Number of Sample Events	Samples Per Event
Water Quality Stormwater	pH	units	EPA 150.1	0.2	6.5-8.0	12	3
	PSD	%	ASTM D3977-97[1]	NA		3	1
	Total Suspended Solids (TSS)	mg/L	SM 2540D	1.0	20 - 500	12	3
	Dissolved Copper (Cu)	µg/L	EPA 200.8 (ICP/MS) or SM 3125 (ICP/MS)	0.1	0.1 - 20	12	3
	Dissolved Zinc (Zn)	µg/L		1.0	5 - 300	12	3
	Total Copper (Cu)	µg/L		0.1	0.1 - 40	12	3
	Total Zinc (Zn)	µg/L		5.0	5 - 600	12	3
	Hardness as CaCO3	mg/L	SM 2340B (ICP)	1.0	1 - 100	12	3
	Ortho-phosphate (OP)	mg/L	SM 4500-P G	0.01	0.01 - 0.5	3	3
	Total Phosphorus (TP)	mg/L	SM 4500-P F	0.01	0.01 - 0.5	3	3
	NWTPH-Dx	mg/L	EPA SW-846 8015B or Ecology 1997 Pub No. 97-602	0.25 - 0.50	0.5 - 2	12	3
Bioretention Soil Media	Cation Exchange Capacity	meq/100g	S-10.10	NA	Expected to meet specification	1	1
	Saturated Hydraulic Conductivity (K_{sat}) @ 85% compaction rate	ft/day	Modified ASTM D2434 (Ecology, 2014a)	NA		1	1
	Total Elements (Zn, Cu)	mg/kg	EPA 6020	5.0 (Zn); 0.1 (Cu)		1	1
	Organic Matter Content	Percent	ASTM D2974 or TMECC 5.07A	0.01		1	1
Aggregate -Specific	Particle Size Distribution for the following sieve sizes: 3/8”, No. 4, No. 10, No. 40, No. 100, No. 200	Percent	ASTM D422	NA		1	1

1. Modified Suspended Sediment Concentration (SSC) Method according to ASTM Method D3977-97 (ASTM 2002) using wet sieve filtration (Method C) and glass fiber filtration (Method B)

9.3 Sample Preparation Methods

Ortho-phosphorus, dissolved, copper, and dissolved zinc require filtration and preservation prior to delivery to Anatek. Osborn personnel will filter and preserve the samples which will be analyzed for those parameters according to the methods outlined in Section 8.1.5.

9.4 Special Method Requirements

Anatek, SoilTest, and MTC do not require any special methods for the parameters to be analyzed during the study.

9.5 Lab(s) Accredited for Methods

Anatek laboratory is accredited by Ecology for the stormwater parameters collected for this study (Table 9.1) and participates in audits and inter-laboratory studies by Ecology and EPA. SoilTest will analyze the BSM parameters collected for this study and is also accredited by Ecology. MTC will analyze the stormwater PSD samples collected for this study (Table 9.1). MTC is accredited by WSDOT and USACE for materials testing in accordance with ASTM and other standard methods. As of June 2020, MTC is in the process of attaining Ecology accreditation.

10.0 Quality Control

This section includes information on field quality assurance/quality control (QA/QC) and laboratory quality control.

10.1 Field QC Required

Field quality control will be maintained by personnel training, SOP development, equipment maintenance and calibration, and quality control samples.

At least two field staff will be trained in all field activities. Field staff will be trained to consistently follow field sampling procedures (see Section 8.1.4 and 8.1.5) and measurement procedures, (see Section 9.0). Field staff will become familiar with all associated SOPs (Section 8.0) which cover all field activities. Training will include conducting all procedures in the field at least one time under the supervision of the principal investigator or project manager. Completion of each element of training will be verified and documented by the principal investigator or project manager in a training completion log (Appendix H).

Equipment maintenance and calibration will ensure that the BMP, the sampling equipment, and the water quality meters are working properly. Equipment maintenance will occur once in early fall, prior to the first monitoring event of the wet season, and monthly between monitoring events. Calibration of the ISCO pumps will likely occur during equipment maintenance, according to the frequency specified by the manufacturer. Calibration of the remaining storm monitoring equipment, including the pH meter, will occur prior to field measurements, preferably on the day of a monitoring event. Details of equipment maintenance and calibration are provided in Sections 8.1.2 and 8.1.3 and will consist of the following activities:

- Inspection of all equipment for damage.
- Cleaning and/or repair of all equipment, connections, tubing, and influent/effluent pipes.
- Calibration of the pH meter, pressure transducer, rain gage, and ISCO pump.

Maintenance and calibration will be documented with either the Periodic Maintenance Checklist Field Form or the Pre-Storm Checklist Field Form (Appendix H). Recordkeeping procedures will be developed and consistently followed (see Section 11.0).

Field quality control samples will consist of rinsate blank and field duplicate samples. Rinsate blanks are samples of analyte free water poured over or through decontaminated field sampling equipment prior to the collection of environmental samples. The purpose of collecting rinsate blanks is to assess the adequacy of the decontamination process. Rinsate blanks will be collected for all water quality parameters collected by flow-weighted composite sampling (i.e. the collected in the autosamplers). They will be collected immediately after decontamination of each respective autosampler. After decontamination, the autosamplers will be filled with distilled deionized water and then dispensed through the autosampler to fill sample containers. Rinsate blanks will be collected three times throughout the study for TSS, total phosphorus, orthophosphate, hardness, and total and dissolved copper and zinc. The parameter concentrations in the rinsate blanks are expected to be less than two times the reporting limit concentrations (see Table 6.2, Table 9.1 for reporting limits).

A field duplicate is a second independent sample collected at the same time and location as the original sample. Field duplicates are primarily used to assess the variation attributable to sample collection procedure and sample matrix effects. Field duplicates will be collected for all water quality and sediment parameters (Table 10.1) and must meet the associated relative percent difference MPCs in Table 6.2. Field duplicates will also be collected for filter media variables.

10.2 Laboratory QC Required

Laboratory quality control will be maintained for the water quality samples by running method blanks and laboratory control standards, matrix spikes, and matrix spike duplicates, and laboratory duplicates (Table 10.1). MPCs associated with the quality control samples are in Table 6.1. Method blanks and laboratory control standards will evaluate bias, in terms of overall method accuracy. Matrix spike and matrix spike duplicates will evaluate bias in terms of method interferences. Laboratory duplicates will evaluate the precision of laboratory measurements. Each of these quality control samples will be run in the laboratory one time for each respective laboratory batch.

10.3 Corrective Action

The auditor will notify the lead entity and principal investigator in writing (via email) within 2 business days if corrective actions is needed based on the audit findings. The lead entity and principal investigator are responsible for developing and implementing a written corrective action plan within 30 days of being notified by the auditor. A record of the corrective action plan will be kept throughout the study (see example in Appendix J) and included in the final report.

11.0 Data Management Plan Procedures

This section defines the data management plans. It specifically describes how the data and other important project documents will be managed, stored, and archived during the study. These plans are developed to reduce the potential for errors during the data collection and analysis phases of the project.

11.1 Data Recording & Reporting Requirements

Field data will be recorded on standard field forms (Appendix H). The field form includes the date and time, data collectors name(s), sample identification, field measurements, field observations, a checklist of samples collected for laboratory analysis, and comment field. All field measurements will be entered manually into the project database (Microsoft Access) within 24 hours of sample collection. Osborn's quality assurance lead for the project will perform an independent review to ensure that the data were entered without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and crosschecking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found in the data. Osborn's quality assurance lead will qualify or reject field measurements based on field DQIs and associated MPCs (Section 6.0). All files will be archived for the duration of the study on an Osborn server and transferred to Spokane County after completion of the study.

Laboratory results from Anatek, SoilTest, and MTC will report the analytical results within 30 days of receipt of the samples. The laboratories will provide sample and quality control data in standardized Electronic Data Deliverable (EDD) spreadsheets and reports that are suitable for evaluating the project data. These EDDs and reports will include all quality control results associated with the data. The reports will also include a case narrative summarizing any problems encountered in the analyses, corrective actions taken, changes to the referenced method, and an explanation of data qualifiers. Osborn's quality assurance lead for the project will perform an independent data verification to ensure laboratory consistency with this QAPP, add additional qualifiers, or reject data based on field DQIs and associated MPCs (Section 6.0). A new qualifier column will be created in each EDD that represents Osborn's independent data verification and will include both field and laboratory qualifiers. Osborn's quality assurance lead for the project will perform an independent review to ensure that the data were uploaded without error. Specifically, 10 percent of the sample values will be randomly selected for rechecking and crosschecking with laboratory reports. If errors are detected, they will be corrected, and then an additional 10 percent will be selected for validation. This process will be repeated until no errors are found in the data. The information contained in the EDD and independent data verification will be stored in a database such as Microsoft Access on Osborn's server up to one year following approval of the Technical Evaluation Report.

11.2 Electronic Transfer Requirements

All field and calibration forms will be scanned and electronically filed on the Osborn server. The laboratory reports, original laboratory EDDs and verified laboratory EDDs will be electronically filed in Osborn's server. Verified EDDs will be uploaded into the project database for all subsequent data management and archiving tasks.

11.3 Laboratory Data Package Requirements

Anatek will provide Level II data packages, corresponding to Stage 2A verification and validation checks (USEPA 2009). These data packages will provide the following documentation:

- Sample submittal and receipt
- Analytical methods, sampling dates and times, data and time of laboratory receipt, sample conditions upon receipt at the laboratory, and sample analysis dates and times
- Evaluation of sample holding times
- Analyte results, units, detection limits, reporting limits, and laboratory data qualifiers
- Sample-related QC data and QC acceptance criteria (Tables 6.1 and 6.2)
- Frequency of QC samples
- Sample results are evaluated and qualified based on meeting holding times and sample-related QC results (Table 6.2)

11.4 Procedures for Missing Data

Missing data will be qualified as missing, and will have a qualifier code (M) that is unique from a rejected value. In addition a note will be added to the spreadsheet explaining the reasons why the data is missing (if known). Missing data will also be reported with the results and discussed in the "Data Summaries and Analysis" section of the TER along with a description of how the data set was analyzed without the missing data. All missing data contributes to the completeness DQI and MPC of 95% valid data collection.

11.5 Acceptance Criteria for Existing Data

No existing data will be used for this study.

11.6 Data Upload Procedures

Per section S8.B-9 of the MS4 permit, Spokane County will enter applicable data collected as part of the study into the International BMP database at the end of the study. Additionally, a spreadsheet of all data collected during the study should be sent to the municipal stormwater permit manager with the final report. This includes all the useable quality assured data used for the analysis and the rejected or un-useable data gathered as part of the study. Any rejected data should also be included, in a separate file or a different tab, along with a description of the reasons failure.

12.0 Audits

12.1 Technical System Audits

Technical system audits performed for field data collection will occur during the first monitoring event, and at one additional event, at the discretion of the project manager or principal investigator. The technical system audits will be performed by a third party. The field audit will verify that field staff are following the SOPs for sample collection, all field data are being recorded, and equipment and instruments are being maintained and calibrated per manufacturer's requirements. Results from these audits will be documented in field audit worksheets (Appendix H) that will be prepared for each batch of samples.

Technical system audits performed for laboratory data will occur within seven business days of receiving results from the laboratory. This review will be performed to ensure that all data are consistent, correct, and complete, and that all required quality control information has been provided. Specific quality control elements for the data (6.1) and raw data will also be examined to determine if the DQIs for the project have been met. Results from these audits will be documented in QA worksheets (Appendix H) that will be prepared for each batch of samples.
In the event that a potential QA issue is identified through these audits, Osborn's data quality assurance lead will review the data to determine if any response actions are required. Response actions in this case might include the collection of additional samples, reanalysis of existing samples if not yet past holding time, or advising the laboratory that methodologies or QA/QC procedures need to be improved.

12.2 Proficiency Testing

Proficiency testing is a quantitative determination of an analyte in a blind standard to evaluate the proficiency of the analyst or laboratory. No proficiency testing will be conducted as part of this study.

13.0 Data Verification and Usability Assessment

The section will define the process that the project will employ to evaluate the quality of the data and the usability of the data for meeting the project objectives. The following includes a list of the data that will be verified:

- Water quality data
- Flow measurements
- Rainfall data

13.1 Data Verification

Water quality results will first be reviewed at the laboratory for errors or omissions. Laboratory quality control results will be reviewed by the laboratory to verify compliance with acceptance criteria. The laboratory will also validate the results by examining the completeness of the data package to determine whether method procedures and laboratory quality assurance procedures were followed. The review, verification, and validation by the laboratory will be documented in a case narrative that accompanies the analytical results. Data will be reviewed and validated within 7 days of receiving the results from the laboratory. This review will be performed to ensure that all data are consistent, correct and complete, and that all required quality control information has been provided. Specific quality control elements for the data include the following:

- Reviewing all the data records to ensure they are consistent, correct and complete, with no errors or omissions
- Review data records to verify the entries are consistent, correct, and complete
- Review the results from the QC section

Results from these data validation reviews will be summarized in quality assurance worksheets (Appendix C) that are prepared for each sample batch. The Osborn quality assurance officer will be responsible for identifying and initiating corrective action. Values associated with minor quality control problems will be considered estimates and assigned “J” qualifiers. Values associated with major quality control problems will be rejected and qualified with an “R”. Estimated values may be used for evaluation purposes, but rejected values will not be used.

13.2 Data Usability Assessment

The Osborn quality assurance officer will provide an independent review of the water quality QC data from each sampling event by determining whether or not MPCs for each DQI identified in this QAPP have been met. The data usability assessment will be presented along with the data verification results in an appendix to the TER. The data usability assessment will summarize quality control results, identify when data quality objectives were not met, and discuss any resulting limitations on the use or interpretation of the data. Specific quality assurance information that will be noted in the data quality assessment report includes the following:

- Changes in and deviations from the QAPP

- Results of field and laboratory data verification
- Results of technical system audits
- Identification of significant quality assurance problems and recommended solutions
- Data quality assessment results in terms of precision, bias, representativeness, completeness, comparability, and reporting limits
- Discussion of whether the quality assurance objectives were met, and the resulting impact on decision-making
- Limitations on use of the measurement data

14.0 Data Analysis Methods

14.1 Data Analysis Methods

14.1.1 Storm, Hydrologic, and Pollutant Information

Storm, hydrologic, and pollutant data will be compiled for each sampling event that occurred during the data collection and summarized in tables. This will include:

- Storm date
- Total storm precipitation depth
- Storm duration
- Storm average and peak precipitation intensity
- Storm antecedent dry period
- Total influent and effluent runoff volume
- Influent and effluent peak and average flow rates
- Influent and effluent flow duration
- Number of influent and effluent aliquots
- Percentage of influent and effluent storm volume sampled
- Parameters monitored
- Pollutant removal efficiency
- Lab detection limits
- Data flags for identified QA issues

This information will be used to develop individual storm reports for each sampling event. The information will also be used to demonstrate that the data collected meets the requirements defined in TAPE (i.e., qualifying storm events, treatment performance goals, etc.) and define flow characteristics through BSM over a range of influent flow rates (i.e., infiltration rate). In addition, the individual storm reports may also provide justification for why data has been included that does not meet TAPE requirements. Details about data that will be graphed is summarized in Section 14.2.

14.1.2 Statistical Comparisons of Pollutant Concentrations

A statistical comparison will be conducted to determine whether there was a significant difference in the analytical results between influent and effluent pollutant concentrations, and between the cell datasets. This is expected to include evaluating whether the data was normally distributed using the Ryan-Joiner test (similar to Shapiro-Wilk test) (Helsel & Hirsch, 2002). Normality will be assumed if the tests produced a p-value greater than 0.05 (Ecology, 2008). If the data is normally distributed, a two-sample t-test was used to determine if there was a significant difference between the data sets. If the data was non-normally distributed, a Wilcoxon rank sum test (a nonparametric analogue to the paired t-test) was used instead. The specific null hypothesis (H_o) and alternative hypothesis (H_a) were evaluated as defined below. The statistical comparison was based on a confidence level of 95% (α=0.05).

Statistical comparison for each parameter between the influent concentration and the effluent concentration for each cell.

- H_o: Effluent pollutant concentration is equal to the influent concentration
- H_a: Effluent concentrations are less or greater than influent concentrations

The treatment performance of the two cells will evaluated to determine if there is a significant differences between the 12-inch cell and the 18-inch cell.

Statistical comparison for each parameter between the effluent concentration of the 12-inch cell and the effluent concentration of 18-inch cell.

- H_o: Effluent concentration from the 12-inch cell are equal to the effluent concentrations of the 18-inch cell
- H_a: Effluent concentrations from the 12-inch are less or greater than effluent concentrations of the 18-inch cell

14.1.3 Calculation and Evaluation of Pollutant Reduction Efficiencies

The effectiveness of the BMP will be evaluated based on the average removal efficiency and mean concentration for each parameter over at least the 12 qualifying rainfall events. This will include calculating the removal efficiency for each pollutant from each individual rainfall events using the equation below. Then the bootstrapping method will used to compute the average removal efficiency from all rainfall events for each pollutant. The boot strapping method is the Ecology recommended method which assumes the dataset is non-normally distributed (Ecology, 2011). If analytical results provided by the lab include effluent values that are non-detectable, the reporting limit for the respective pollutant will be used, as defined by the standard testing method, to calculate the pollutant reduction. Alternatively, if the analytical results provided by the lab include influent values that exceed the upper influent range shown in Table 14.1, upper concentration limit will be used to calculate the pollutant reduction.

$$\Delta C = 100x\,\frac{C_{in} - C_{eff}}{C_{in}}$$

Where:

C_{in} = influent concentration (mg/L)
C_{eff} = effluent concentration (mg/L)

14.1.4 Water Quality Treatment Performance

The water quality data will be evaluated against the Ecology performance goals for basic and dissolved metals (Zn and Cu). This includes comparing the average removal efficiency at the lower 95% confidence interval and influent concentration from all rainfall events to the Ecology information noted in Table 14.1. If the removal efficiency is equal to or greater than the treatment performance criteria and if the average influent concentration falls within the range specified by Ecology, the conclusion will be made that the treatment performance criteria was met for pollutant of concern.

Table 14.1 Ecology Treatment Performance Goals

Performance Goal	Pollutant	Influent Concentration Range	Treatment Performance Criteria
Basic Treatment	Total Suspended Solids (TSS)	100-200 mg/L	80% Reduction
Dissolved Metals Treatment	Dissolved Copper (Cu)	5.0-20.0 μg/L	30% Reduction
	Dissolved Zinc (Zn)	20-300 μg/L	60% Reduction

14.1.5 Saturated Hydraulic Conductivity (Ksat) Measurements

The change in saturated conductivity will be evaluated using the results from the falling head testing described in section 8.1.8. The K_{sat} will be determined using the following equation.

$K_{sat} = \frac{A_1}{A_2} \times \frac{L}{\Delta Time} ln \frac{H_1}{H_2}$Where:

H_1 = initial ponded water depth above the top of the cell (inches)
H_2 = final ponded water depth above the top of the cell for time interval (inches)
ΔTime = time interval for water to fall from Ho to Hi (seconds)
L = depth of BSM (inches)
A_1 = cell surface area at H1 (sqft)
A_2 = cell surface area at H2 (sqft)
L = depth of BSM (inches)

The infiltration rate may also be calculated using the effluent flow rate record by the data during the falling head test. Specifically, by calculating the average flow rate. The analysis should be repeated at each time interval data is recorded (5 minutes intervals) until the difference is less than 5% between three time intervals.

$$Q_{out} == \frac{Q_{out}}{A_{average}}$$

Where:

Q_{out} = average effluent flow rate recorded by the data logger over the duration of the test: from initial ponded depth to when water has completely infiltrated into the BSM or 0-inches of ponded water (cft/hr)

$A_{average}$= bioretention cell average surface area: average of surface area at initial ponded depth and surface area at 0-inches of ponded water (sqft)

The data collected will analyzed in a spreadsheet using standard statistical techniques. Specifically descriptive statistics (mean, minimum, maximum, and standard deviation) will be computed for all of K_{sat} measurements from each cell (see Table 14.2 for an example). The mean and standard deviation will also be graphed to illustrate the K_{sat} performance over study (see Figure 14.1 for an example).

Table 14.2 Saturated Hydraulic Conductivity (K_{sat}) Statistics for Study Duration

Cell Identification	Total Number of Tests	K_{sat} (in/hr)			
		Mean	Standard Deviation	Minimum	Maximum
12-inch Cell	4	2.4	0.5	2.0	2.8
18-inch Cell	4	2.0	0.7	1.5	2.5

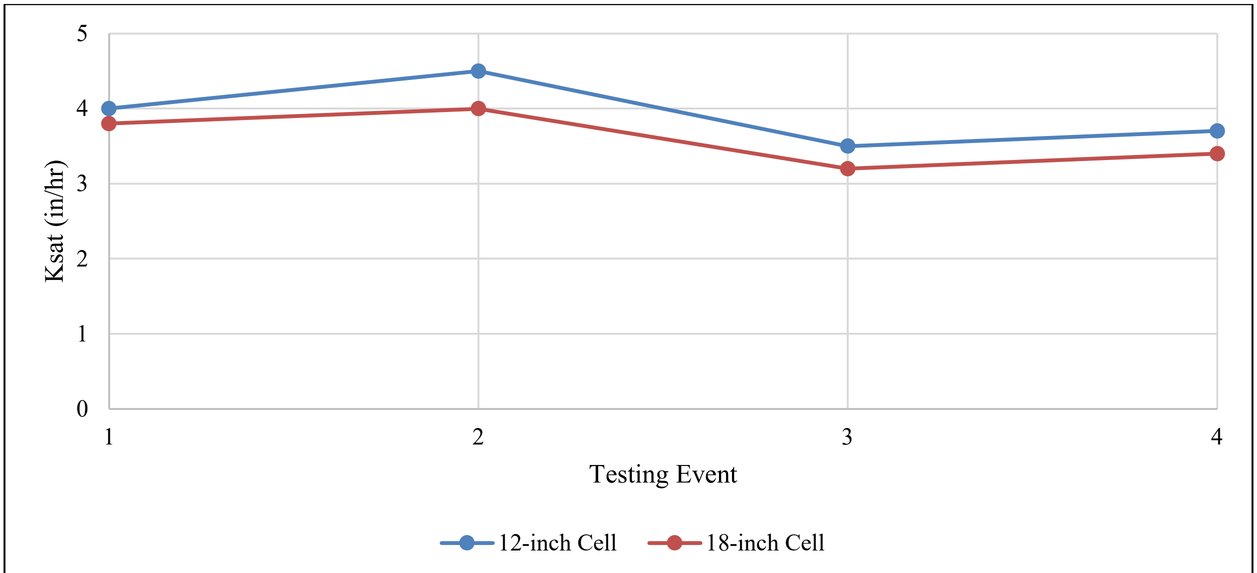

Figure 14.1 Summary of Mean and Standard Deviation K_{sat} Measurements for Each Testing Event

14.2 Data Presentation

The data will be presented (i.e., tables, charts, and/or graphs) in the final reports to illustrate trends, relationships, and anomalies. Examples of how the data may be presented is briefly described below:

- A table summarizing all the values/parameters measured for each testing event (i.e., pollutant information, storm data, hydrologic data, K_{sat}, etc.).

- A hydrograph for each storm during a sampling event that includes precipitation, influent and effluent flow rate, and influent and effluent aliquots

- Figure 14.2 - Box and Whisker Plots display the distribution of data collected during the study. This will include the average and range of influent and effluent concentrations and any outliers. When applicable, the concentration representing the Ecology treatment performance goal will be graphed (red dashed line) to illustrate the relationship to the influent and effluent average concentrations.

- Figure 14.3 - Log-Normal Graphs are line graphs of the pollutant reduction ratio (C_{eff}/C_{in}) for each sampling event. These graphs illustrate the trend in the treatment performance over the duration of the study.

- Table 14.3 – a summary of the water quality results will be include in a table. This will include the average influent and effluent concentrations, sample size, results from the hypothesis testing, and the removal efficiency corresponding to the 95% confidence interval.

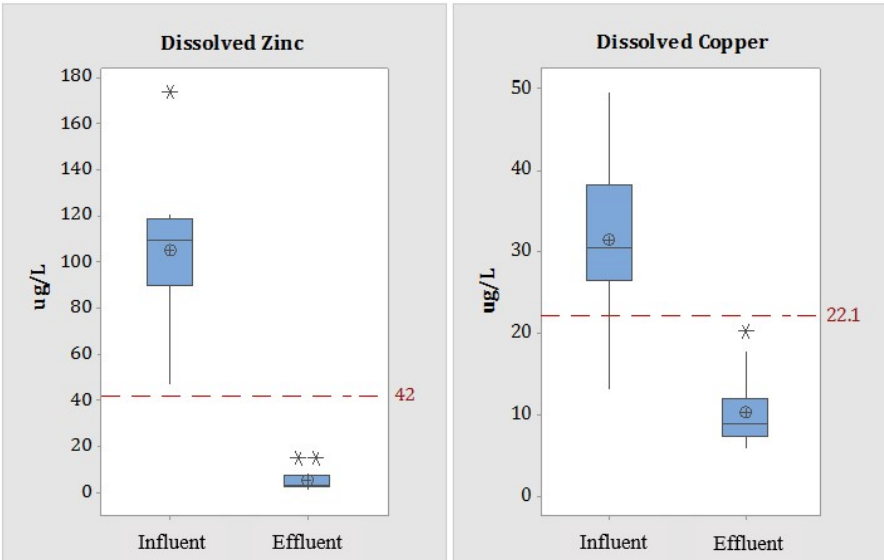

Figure 14.2 Example of Box Plots

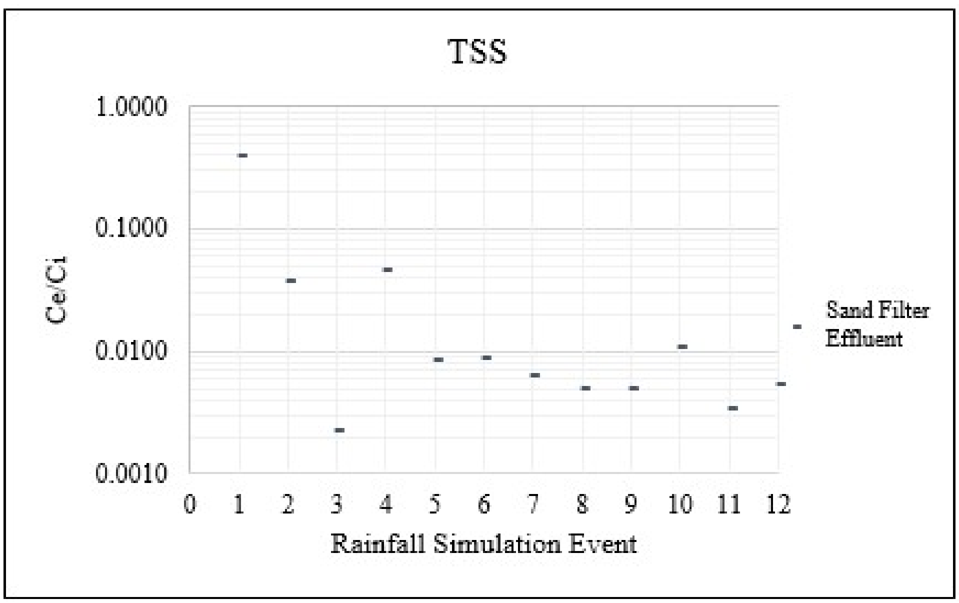

Figure 14.3 Example of Log-Normal Graphs line graphs: the removal efficiency (C_{eff}/C_{in})

Table 14.3 Summary of Water Quality Results (Example)

Column ID	Average Influent Concentration	Average Effluent Concentration	Sample Size (n)	Statistically Significant (Y/N)	95% CI Removal Efficiency	Ecology Performance Criteria	Pass Or Fail
TSS (mg/L)							
Cell 1	171.0	2.640	12	Y	92.0%	80%	Pass
Cell 2	126.4	2.390	12	Y	89.3%	80%	Pass

15.0 Reporting

The purpose of this section is to describe how the study findings will be reported and disseminated.

15.1 Final Reporting

The following provides a summary of the reports that will be produced for this study as well as the party responsible for preparing the reports.

- Annual Reports (Permit Section S8.B8) – the lead entity will develop the annual reports which will describe the interim results and status of the study
- Final Technical Report (Permit Section S8.B10) – the principal investigator will produce the final technical report which will summarize the results of the study and recommends future actions based on the study findings. Table 15.1 provides an outline of the final technical report. Since this study includes the goal of developing a modified BMP, the final report will also be developed to meet the requirements specified in the Ecology TAPE Guidance Document section *Preparing a Technical Evaluation Report (TER),* (Ecology, 2011).
- A Fact Sheet – a fact sheet (2-4 page) will develop by Gonzaga Civil Engineering students that summarizes the key points and findings of the study each year. A copy of the 2017-2018 project fact sheet is located in Appendix F.

Table 15.1 Proposed Effectiveness Study Report Content

Final Report Sections		Effectiveness Studies
0.0	Cover Letter	✓
1.0	Executive Summary	✓
2.0	Introduction	See Note 1
3.0	Technology Description	See Note 1
4.0	Sampling Procedures	See Note 1
5.0	Data Summaries and Analysis	✓
6.0	Operation and Maintenance (O&M) Information	✓
7.0	Discussion	✓
8.0	Conclusions	✓
9.0	Future Action Recommendations	✓
10.0	Appendices	✓
11.0	Third-Party Review[2]	✓

1. The Final Report will reference the noted sections in the approved QAPP (in lieu of rewriting the sections in the report). Any changes made in those sections of the study since the QAPP was approved will also be documented.
2. The principal investigator will convene an advisory review panel: three to five individuals (two of whom should be from Ecology) with technical skills necessary to provide a peer review of the TER. This is only required for studies with the goal of developing a modified BMP.

15.2 Dissemination of Project Documents

The Final Technical Report will be shared with the participating agencies and will be posted to the Spokane County webpage along with a video fact sheet about the study and study findings. https://www.spokanecounty.org

16.0 References

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https://ecology.wa.gov/Regulations-Permits/Permits-certifications/Stormwater-general-permits/Municipal-stormwater-general-permits/Eastern-Washington-Phase-II-Municipal-Stormwat-(1)

Washington State Department of Ecology (Ecology). (2016). Status Update on Bioretention Soil Media. Olympia, WA. Retrieved from: https://fortress.wa.gov/ecy/publications/documents/1310017.pdf

Washington State Department of Ecology (Ecology). (2108). DRAFT Stormwater Management Manual for Eastern Washington. Table 5.4.8 Sizing Methods and Assumptions for Bioretention. Olympia, WA. Retrieved from: https://fortress.wa.gov/ecy/ezshare/wq/permits/EWAStormwaterManual.pdf

17.0 Appendices

Appendix A. Ecology Proposal Approval Letter and Comments

DEPARTMENT OF
ECOLOGY
State of Washington

To: Karen Dinicola, Department of Ecology

From: Douglas C. Howie, P.E., Department of Ecology

Cc: Abbey Stockwell, Department of Ecology

Date: July 20, 2017

Subject: Comments on Eastern Washington Effectiveness Study Proposals

Here are my comments on the eight Eastern Washington Effectiveness Studies submitted to Ecology on July 11 and following days. The proposals follow a common format with significant portions of the documents left for later completion. There is still adequate information in each proposal to identify what the author intends to complete.

Documents Reviewed:

1. *Detailed Study Design Proposal: Elementary School Stormwater Education*, by HDR, Inc. June 30, 2017
2. *Detailed Study Design Proposal: BMP Inspection and Maintenance Responsibilities*, by HDR, Inc. and Drummond Carpenter, PLLC, June 30, 2017
3. *Detailed Study Design Proposal: Bioretention Soil Media Study*, by HDR, Inc. and D&H Technology Solutions, LLC, June 30, 2017
4. *Detailed Study Design Proposal: Sharp Avenue Porous Pavement*, by City of Spokane, June 2017
5. *Detailed Study Design Proposal: Garland Stormwater Gardens with Biochar Amended Soil*, by City of Spokane, June 2017
6. *Detailed Study Design Proposal: Mobile Contractor Illicit Discharge Education & Outreach Effectiveness Study*, by City of Wenatchee, June 28, 2017
7. *Detailed Study Design Proposal: Sand Filter Sidewalk Vault BMP*, by Spokane County, June 30, 2017
8. *Detailed Study Design Proposal: Street Sweeping and Catch Basin Cleaning Comparison*, by City of Ellensburg, June 30, 2017

General Comments on Proposals

1. There are still a number of significant issues left to fill in when producing the QAPP for these studies. I will probably have more comments when they submit the QAPP.

Comments on Elementary School Stormwater Education

1. It's a small thing, but they sometimes italicize *Drain Rangers* and sometimes not.

2. How will they adapt the WWA program to EWA students? There are no specifics identified, particularly when they include "engineering design processes" in the curriculum. In Section 4.1, they describe the study goals. These are universal issues, not a WWA or EWA specific issue.
3. Will the report on the WWA Drain Rangers project contain before and after information that they could use to help in the development of the before and after evaluations?
4. There is a reference to "See Section 4.5 for more information about IRB's". This reference is in Section 4.5 and there is no further information about IRB's in the document. There is a detailed discussion of IRBs in the BMP Inspection and Maintenance Responsibilities Proposal.
5. In Section 13, they discuss using the Likert Scale. What is the Likert Scale and how do they apply it to data from this study?
6. The information shown in Table 13.3 is quite limited. I think they should include gender in the data as well as age.
7. It would be good to include some thinking about following-up with the student in another 2 or 3 years to see what they retained and if they applied any of the lessons learned to their life.

Comments on BMP Inspection and Maintenance Responsibilities

1. I'm not seeing a lot in the way of evaluating the information they collect for effectiveness. As I read the Project Overview section, my final thought was that I still didn't know exactly what they plan to evaluate and compare.
2. Early in the text, they refer to "similar semi-arid jurisdictions", but in Section 7.0, the scope is limited to "Washington and Columbia River Basin". What happened to using information from eastern Oregon and southern Idaho?
3. Add two additional questions for the survey: What benefits do they derive from the inspections and what do they use to determine the need for maintenance?
4. I think the survey will take more than 10 minutes if they include all the bulleted items listed. There are some questions, which will take research on the part of the responder, such as funds spend, number of privately owned BMPs, and number inspected each year.
5. The proposed report information does not include information on the effectiveness of the inspections, it just reports on the information gathered.

Comments on Bioretention Soil Media Study

1. Please do not call bioretention facilities "ponds". They are "Swales" or "cells", but not ponds. While water does collect in the facility before passing through the media, they are not a pond.
2. In Section 4.2, they refer to the "TAPE Board of External Reviewers" as someone who will review the QAPP and TER. They also mention this elsewhere in the proposal. This is not necessary for this study. They need to create an advisory/review panel that will independently review the results of the monitoring, but it doesn't have to be the TAPE BER. This is a modification to an existing BMP that has already received a lot of study.

This work doesn't need to go through the full TAPE process. The study should still follow the TAPE protocol, but not to the extent of bringing in members of the BER for review.

3. In Section 5.0, they list Brad Daly multiple times. There may be a conflict between his tasks if he is both an Advisory Board lead/member and a reviewer. They also list Art Jenkins twice in the table.
4. I would expect to see the Bioretention sizing calculations in the QAPP.
5. There are several sections left to be completed, which have a bearing on the success of this study.
6. What happens if the grass proposed for the vegetated swale doesn't grow, or show sparse growth? When do they determine that they have adequate vegetation to compare the two cells accurately? Will they perform any analysis on the amount of vegetation in the cell?

Comments on Sharp Avenue Porous Pavement

1. They need to follow much of the protocol described in the TAPE Guidance Manual if they want to have permeable pavement approved for treatment. They don't need to use the TAPE Board of External Reviewers (BER), but they do need to develop a technical review panel that will independently review the results of the monitoring. They also need to collect water quality samples from a suite of pollutants, as described in the TAPE guidance. They haven't identified what pollutants they want to monitor in the document yet.
2. They need to evaluate the removal percentages for the various pollutants. They need to follow the statistical analysis described in the TAPE guidance manual for this analysis.
3. They should probably add Ray Latham, CRO Municipal Stormwater Permit Manager (rlat461@ecy.wa.gov) to the distribution list.
4. They will need to describe the basins that receive rainfall and direct runoff to the sampling stations better. Will there be run-on to the permeable pavement? Will runoff occur from lands other than the street?
5. The minimum rainfall for a qualifying event in TAPE is 0.15 inches, not 0.2 inches.
6. The statement at the start of Section 5.3 is confusing. Are they collecting only one sample per quarter, or will they attempt to collect samples from all potentially qualifying rainfall events throughout the year.
7. Will they want to collect grab samples during the monitoring? If so, they need to describe the process for collecting.

Comments on Garland Stormwater Gardens with Biochar Amended Soil

1. They should probably add Ray Latham, CRO Municipal Stormwater Permit Manager (rlat461@ecy.wa.gov) to the distribution list.
2. I'm confused about just what a Storm Garden is. I thought it is an Eastern Washington version of a Bioretention facility. In this proposal, they speak of it as a bio-infiltration swale. Bio-infiltration swales don't include engineered soil, so the BMP discussed this proposal is not a bio-infiltration swale. If they want to test a Bioretention Soil Mix that

uses biochar instead of compost, they need to remove references to bio-infiltration swales, and say that Storm Gardens are equivalent to Bioretention.

3. The previous laboratory study that found biochar could remove pollutants is important and they should include summary data from the study as an appendix to the QAPP.
4. Based on the text in Section 3.5 they will use grab samples to get their data. The effluent grab sampler does produce a pseudo-composite sample, but the influent sampler does not. The number of samples is very small and probably the calculations won't produce statistically significant data unless the level of treatment is very high. It is also very difficult to accept data as paired when one is a single grab and the other is a composite over time.
5. Section 5.3 appears to say that there will be only one sample per quarter. They should collect samples from all potentially qualifying rainfall events throughout the year, particularly if they have a limited volume of sample to work with and a large number of pollutants to sample. They could select some pollutants for testing and some to skip, knowing that they can reverse the pollutants tested after the next storm.
6. What pollutants to they propose to test for in this project. They list pollutants tested in the lab study on biochar, but they don't list anything for this study.
7. The minimum rainfall for a qualifying event in TAPE is 0.15 inches, not 0.2 inches.

Comments on Mobile Contractor Illicit Discharge Education & Outreach

1. They need to develop a distribution list by name along with specifying particular people for signatures.
2. In the first paragraph, they say there were two programs in eastern Washington and then mention Snohomish County as one of the programs. They explain this later, but it is confusing at the start. Maybe leave out the "eastern" at the first mention.
3. The text for the pledge in the third bullet should stand out as italics or in quote marks.
4. In Section 4.5, they have language that implies they will go for consultant selection twice, once for data collection preparation and once for data collection. Couldn't they combine the two pieces into a single project and save some time, money and effort?
5. In Table 4.1, they could include as a constraint the thought that the mobile business owner may fear some sort of penalty if they admit they discharge incorrectly. This may limit the number of responses you get from those who are not obeying the Dump Smart Program.

Comments on Sand Filter Sidewalk Vault BMP

1. Page 4: They identify an initial mix that meets Ecology's requirements for treatment of dissolved Cu and Zn and total phosphorus, but not TSS. All BMPs must meet the minimum level of TSS treatment before they perform any evaluation for other pollutants.
2. For TAPE approval, there is no maximum number of samples to collect. You need to collect a minimum of 12 samples and you need to meet the statistical requirements for confidence. If that takes more than 36 samples, you need to collect more than 36 samples. Typically, if someone needs to collect more than 25 samples to show treatment, they

realize the existing device doesn't work and they stop sampling. They might change the treatment technology and start the process again, or they move out of the TAPE program.

3. You need to add a goal of establishing a design flow rate in gallons per minute per square foot of the sand filter surface.
4. Highlight the location of the vault on Figure 4.1.
5. Section 4.4, you need to collect continuous flow measurements and water quality samples must include event mean concentrations, not just grab samples.
6. Section 4.5, Ecology must review and approve the QAPP.
7. Section 7.2, do you have values for the current influent concentrations? You might want to collect samples to get a feel for the influent pollutants.
8. Table 7.2, you should include an analysis of the organic content of the soils and possibly other parameters, such as carbon: nitrogen ratio.

Comments on Street Sweeping and Catch Basin Cleaning Comparison

1. There are a several places where sentences suddenly end, there are missing words, or text doesn't make sense. The proposal is still understandable and I assume the next edit will correct these issues.
2. Section 3.3, add a bullet that discusses the potential that sediment in the catch basin could resuspend and flow out of the catch basin during a large storm. A catch basin could catch some sediment, at least for a short time, and then discharge to the swale. The sediment bags should catch this sediment.
3. You are vacuuming the street with a hand held vacuum to collect samples. How will this work with the street sweeper volumes of sediment removed?

If you have any further questions, please contact me by email at douglas.howie@ecy.wa.gov or by phone at (360) 407-6444.

Appendix B. Proposal: Responses to Ecology's Comments

Comment #	Ecology's Comment	HDR's Response
1	Please do not call bioretention facilities "ponds". They are "Swales" or "cells", but not ponds. While water does collect in the facility before passing through the media, they are not a pond.	Changed "pond" to "area" or "cell" throughout the document.
2	In Section 4.2, they refer to the "TAPE Board of External Reviewers" as someone who will review the QAPP and TER. They also mention this elsewhere in the proposal. This is not necessary for this study. They need to create an advisory/review panel that will independently review the results of the monitoring, but it doesn't have to be the TAPE BER. This is a modification to an existing BMP that has already received a lot of study. This work doesn't need to go through the full TAPE process. The study should still follow the TAPE protocol, but not to the extent of bringing in members of the BER for review.	Applicable sections of the study have been revised to address comments.
3	In Section 5.0, they list Brad Daly multiple times. There may be a conflict between his tasks if he is both an Advisory Board lead/member and a reviewer. They also list Art Jenkins twice in the table.	Section 5.0 has been updated.
4	I would expect to see the Bioretention sizing calculations in the QAPP	See appendix D
5	There are several sections left to be completed, which have a bearing on the success of this study.	Comment noted.
6	What happens if the grass proposed for the vegetated swale doesn't grow, or show sparse growth? When do they determine that they have adequate vegetation to compare the two cells accurately? Will they perform any analysis on the amount of vegetation in the cell?	With the 60:40 BSM, it has been my experience that grass grows fast and dense. However, the study goal has changed and this study does not compare the treatment performance of a vegetated cell to a non-vegetated cell. For the new study, the grass has been established for several years.

Appendix C. Ecology QAPP Approval Letter, Comments, and Responses to Comments

DEPARTMENT OF ECOLOGY
State of Washington

To: David Duncan, Department of Ecology, Municipal Stormwater Permit Manager

From: Brandi Lubliner, P.E., Department of Ecology, QA Coordinator

Cc: Douglas C. Howie, P.E., Department of Ecology

Date: June 7, 2018

Subject: Eastern Washington Stormwater Effectiveness Study QAPP Review Comments

This *Eastern Washington Stormwater Effectiveness Studies Quality Assurance Project Plan: Bioretention Soil Media Thickness Study*, draft dated May 8, 2018, is well developed. I reviewed the entire document. The following revisions are necessary for approval, and other comment is for your consideration.

Necessary edits:

1. Revise section 11.6 title and paragraph to remove EIM from the QAPP. The data generated by this study need to be loaded to the International BMP database, not Ecology's EIM for receiving water data.
    a. In additional I recommend you ask that a spreadsheet of all the study data be sent to you the municipal stormwater permit manager with the final report. This spreadsheet should contain all the data from the study. This means all the useable quality assured data used for the analysis, and the rejected or un-useable data gathered as part of the study. The rejected data can be included in a separate file or a different tab and the reasons for its failure described.
2. There is a fair bit of disagreement between a number of the tables for parameters and methods. See Table #s: 4.1 vs 6.2 vs 7.3 vs 9.1
    a. Why is there a method for temperature in 6.2? It should be "field meter" right? Table 7.3 says PT is the sampling method.
    b. Table 6.2 Need to delete TPH-Dx row.
    c. pH row has conflicting message; instantaneous vs laboratory analysis; see also conflict in Section 7.6.1
    d. Table 9.1 repeats much of the info in Table 6.2, some differences in methods and RLs for pH and all the metals.
3. Based on a conversation with Doug Howie 6/7/2018, I recommend dropping the intended monitoring for sediment buildup at the top of the BMP surface. I don't anticipate a large sediment load that would foul the bioretention BMP, but more importantly the proposed

methods for measuring sediment build up are not going to result in good information. We both feel they'll probably be difficult to perform without accidentally sampling the surface of the BMP. Strike this sampling for accumulated sediment PSD from the QAPP.

   a. The following locations and text here for reference around this discussion and should be reviewed/deleted: Table 6.2 indicates water and sediment for PSD. Table 7.3 indicates two separate water-based approaches to sample PSD. One was supposed to be for sediment portion? Table 4.1 indicates there is only influent water sediment sampling, but Table 6.2 says sediment. See also section 7.8 and 8.1.7 SOP for sediment PSD sampling, still not clear how to assure sampling method stays at the accumulated sediment, not interfere with the BMP surface which is also sediment.

4. Figure 4.1 shows the "concrete sand" has different depths, which sounds like an error based on the text in other locations of the QAPP (Section 7.1) and as-built drawings.

General Comments:

5. Clarify that the BSM sample has not yet been run for soil characteristics testing.
   a. How has BSM sample been stored this whole time? (Table 4.1, Table 7.3 also, and section 7.9 verb tense error)

My role as QA Coordinator for municipal stormwater monitoring is relatively new, and was not yet established in the earlier drafts of this QAPP. Please send the final PDF for signature when ready. If you have any further questions, please contact me by email at brandi.lubliner@ecy.wa.gov or by phone at (360) 407-7140.

DEPARTMENT OF
ECOLOGY
State of Washington

To: Karen Dinicola, Department of Ecology

Via: Brandi Lubliner, Department of Ecology

From: Douglas C. Howie, P.E., Department of Ecology

Cc: Abbey Stockwell, Department of Ecology

Date: May 24, 2018

Subject: Comments on Detailed Study Design Proposal Bioretention Soil Media Thickness Study

Here are my comments on the package provided by Spokane County for our review.

Documents Reviewed:

1. *Eastern Washington Stormwater Effectiveness Studies Detailed Study Design Proposal Bioretention Soil Media Thickness Study,* by HDR, Inc., May 8, 2018

General Comments:

1. I did not review the entire document. I limited my review to Sections 1 – 5, 7, 8, 14, and Appendices A – F.
2. I am also a member of the Technical Advisory Group (TAG). Can I be a member of the TAG as well as an Ecology Reviewer?
3. Section 2.0: In the third bullet on page 2, the author mentions “enhanced treatment”. Enhanced treatment is a Western Washington term, In Eastern Washington the equivalent term is “Metals Treatment”.
4. Section 3.3:
    a. In the first paragraph below the two bullets the author mentions a rainfall depth of 0.8-inches. Based on the fact that the text is discussion an occasion with rainfall less than 0.15-inches, this might be a typo.
    b. It is interesting to note that the removal of dissolved Cu meets TAPE requirements while dissolved Zn does not. Studies on the west side of the state show the opposite with significant dissolved Zn removals.
5. Table 3.1: It is important to note if the influent concentrations were within the TAPE guidelines when evaluating the percent removal values.
6. Section 3.4: First Bullet insert the word “system” between “storm sewer” and “(MS4)”. Note the addition of () around “MS4”.
7. Section 4.0:

a. Delete the term “minimum” in the second line before “depth of 12 inches”.

b. The author deleted a reference to oil treatment in Section 2.0, yet they include oil in the list of performance criteria in this section.

8. Section 4.1: Add “composite” in the ninth line between “collecting 3” and “water quality samples”.

9. Table 4.1:

   a. The author states that they will collect a sample of the BSM material before installation. Isn’t the facility already built? How do they get a sample of the original material?

   b. Note that the Composite Water Quality Samples are flow weighted.

10. Section 4.5: Is the Quality Assurance Project Plan the author mentions in this section different from the one we are currently commenting on?

11. Section 7.1:

    a. Are they using the same BSM as installed for the original study, or are they installing new BSM?

    b. The author mentions testing over two wet seasons twice in the first paragraph after the bullets on page 27.

    c. There won’t be a General Use Level Designation for this media. It is more likely that it will receive a Functionally Equivalent designation or Ecology will revise the Design Criteria in the Manuals based on the results of this study.

12. Section 7.3: The design BSM infiltration rate is lower than usual. Ecology proposes a rate of 12 in./hr. with a correction factor of 2 to 4 depending on the area of the basin draining to the bioretention swale. This would result in infiltration rate of either 3 or 6 in./hr.

13. Table 7.2:

    a. Is the “Peak Q” value for inflow or discharge? Since it is different for the two different depths of BSM, it appears to be discharge flow.

    b. The “Max Ponded Elevation” for the 25-yr, 24-hr storm and the 12-inch Cell appears to be incorrect. The “Live Storage Elevation” is 99 and the “Max Pod Depth” is 3.0 feet giving a pond elevation of 102.0, not 101.50.

    c. The footnote numbering does not match the numbers in the table.

14. Table 7.3: The author lists two Saturated Hydraulic Conductivity tests per year here, but in Section 7.1 they say the test are quarterly.

15. Section 7.4:

    a. The author deleted a reference to oil treatment in Section 2.0, yet they include oil in the list of performance goals in this section.

    b. The author states “weirs are located upstream of the PT in the influent”. Shouldn’t you locate the weirs downstream of the PT in order to correctly measure the flow?

c. In the equation in this section you obtain flow in liters per minute. All the work on the project will likely be in gallons per minute. Why not adjust this equation to give you gallons per minute instead of liters per minute?

16. Table 7.4: Footnotes in this table use letters, but other tables have footnotes with numbers. This should be consistent between tables.
17. Section 7.7: The author lists two Saturated Hydraulic Conductivity tests per year here, but in Section 7.1 they say the test are quarterly.
18. Section 7.8: How will the sample collectors distinguish between sediment in the bioretention facility from sediment brought in by runoff?
19. Section 14.1.4: TAPE requires the use of the lower 95% confidence when looking at removal percentages. The author doesn't identify that they need to use the lower value.

If you have any further questions, please contact me by email at douglas.howie@ecy.wa.gov or by phone at (360) 407-6444.

Comment #	Reviewer	Ecology's Comment	HDR's Response
1	DH	I am also a member of the Technical Advisory Group (TAG). Can I be a member of the TAG as well as an Ecology Reviewer?	Comment noted
2	DH	Section 2.0: In the third bullet on page 2, the author mentions "enhanced treatment". Enhanced treatment is a Western Washington term, In Eastern Washington the equivalent term is "Metals Treatment".	Changed "enhanced" to "metals"
3	DH	Section 3.3: a. In the first paragraph below the two bullets the author mentions a rainfall depth of 0.8-inches. Based on the fact that the text is discussion an occasion with rainfall less than 0.15-inches, this might be a typo. b. It is interesting to note that the removal of dissolved Cu meets TAPE requirements while dissolved Zn does not. Studies on the west side of the state show the opposite with significant dissolved Zn removals.	a. Changed 0.8 to 0.08-inches b. Comment noted. Research suggests that deicers and cold climates can influence the treatment performance of bioretention soil media (BSM). Considering most of the data was collected during the winter that could explain the differences in the results between EWA and WWA. Part of the senior design student's project at Gonzaga will be investigating the influence of deicer and cold climates on the BSM treatment performance.
4	DH	Table 3.1: It is important to note if the influent concentrations were within the TAPE guidelines when evaluating the percent removal values.	Average influent and effluent parameter concentrations were added to the table. A footnote was added below the table that states: *Influent concentrations were within the TAPE limits for all samples except TP samples and two Cu samples (0.004 mg/L) which was slightly below the TAPE influent limit (0.005 mg/L).*
5	DH	Section 3.4: First Bullet insert the word "system" between "storm sewer" and "(MS4)". Note the addition of () around "MS4".	Updated per comment
6	DH	Section 4.0: a. Delete the term "minimum" in the second line before "depth of 12 inches". b. The author deleted a reference to oil treatment in Section 2.0, yet they include oil in the list of performance criteria in this section.	a. Deleted minimum b. Deleted reference to oils
7	DH	Section 4.1: Add "composite" in the ninth line between "collecting 3" and "water quality samples".	Added

8	DH	Table 4.1: a. The author states that they will collect a sample of the BSM material before installation. Isn't the facility already built? How do they get a sample of the original material? b. Note that the Composite Water Quality Samples are flow weighted.	a. Revised as follows: *BSM samples collected during construction from the cells will be sent to the lab for analysis*. b. Added flow weighted
9	DH	Section 4.5: Is the Quality Assurance Project Plan the author mentions in this section different from the one we are currently commenting on?	It is the same document. Added comment for clarification.
10	DH	Section 7.1: a. Are they using the same BSM as installed for the original study, or are they installing new BSM? b. The author mentions testing over two wet seasons twice in the first paragraph after the bullets on page 27. c. There won't be a General Use Level Designation for this media. It is more likely that it will receive a Functionally Equivalent designation or Ecology will revise the Design Criteria in the Manuals based on the results of this study.	a. The BSM was installed in the fall of 2014. Note added to paragraph for clarity. b. Deleted one of the two sentences regarding the wet season c. Changed 'General Use' to 'Functionally Equivalent'
11	DH	Section 7.3: The design BSM infiltration rate is lower than usual. Ecology proposes a rate of 12 in./hr. with a correction factor of 2 to 4 depending on the area of the basin draining to the bioretention swale. This would result in infiltration rate of either 3 or 6 in./hr.	~~The EWA LID Manual specifies 1.5 in/hr and the draft Ecology Stormwater Manual for EWA specifies 1.5 in/hr infiltration rate for PGIS contributing basin areas greater than 10,000 sqft. The contributing basin area at the test site is 0.50AC (0.25AC contributing to each cell). Note was added to Section 7.3 describing the change in infiltration rate based on PGIS area.~~ Updated infiltration rate to 3 in/hr per email from Brandi Lubliner dated 10/24/18
12	DH	Table 7.2: a. Is the "Peak Q" value for inflow or discharge? Since it is different for the two different depths of BSM, it appears to be discharge flow. b. The "Max Ponded Elevation" for the 25-yr, 24-hr storm and the 12-inch Cell appears to be incorrect. The "Live Storage Elevation" is 99 and the "Max Pod Depth" is 3.0 feet giving a pond elevation of 102.0, not 101.50.	a. Peak Q is the effluent flow rate. Effluent was added to the column for clarification. b. Corrected max ponded elevation

13	DH	Table 7.3: The author lists two Saturated Hydraulic Conductivity tests per year here, but in Section 7.1 they say the test are quarterly.	Section 7.1 was revised to 'twice per year'
14	DH	Section 7.4: a. The author deleted a reference to oil treatment in Section 2.0, yet they include oil in the list of performance goals in this section. b. The author states "weirs are located upstream of the PT in the influent". Shouldn't you locate the weirs downstream of the PT in order to correctly measure the flow? c. In the equation in this section you obtain flow in liters per minute. All the work on the project will likely be in gallons per minute. Why not adjust this equation to give you gallons per minute instead of liters per minute?	a. Deleted reference to oils b. Revised to 'downstream' c. All the units in the data loggers are in liters and for consistency the weir equations have been left in liters.
15	DH	Table 7.4: Footnotes in this table use letters, but other tables have footnotes with numbers. This should be consistent between tables.	Revised footnotes to numbers for consistency with the rest of the document
16	DH	Section 7.7: The author lists two Saturated Hydraulic Conductivity tests per year here, but in Section 7.1 they say the test are quarterly.	Twice per year is correct. This was updated in other sections of the QAPP.
17	DH	Section 7.8: How will the sample collectors distinguish between sediment in the bioretention facility from sediment brought in by runoff?	Collecting sediment from the top of the bioretention facility has been deleted from the QAPP. The section was revised to only include collecting sediment samples from the influent collected in the autosamplers
18	DH	Section 14.1.4: TAPE requires the use of the lower 95% confidence when looking at removal percentages. The author doesn't identify that they need to use the lower value.	Update to specify the lower 95% confidence interval.

19	BL	Revise section 11.6 title and paragraph to remove EIM from the QAPP. The data generated by this study need to be loaded to the International BMP database, not Ecology's EIM for receiving water data. a. In additional I recommend you ask that a spreadsheet of all the study data be sent to you the municipal stormwater permit manager with the final report. This spreadsheet should contain all the data from the study. This means all the useable quality assured data used for the analysis, and the rejected or un-useable data gathered as part of the study. The rejected data can be included in a separate file or a different tab and the reasons for its failure described.	Section has been undated per comment.
20	BL	There is a fair bit of disagreement between a number of the tables for parameters and methods. See Table #s: 4.1 vs 6.2 vs 7.3 vs 9.1 a. Why is there a method for temperature in 6.2? It should be "field meter" right? Table 7.3 says PT is the sampling method. b. Table 6.2 Need to delete TPH-Dx row. c. pH row has conflicting message; instantaneous vs laboratory analysis; see also conflict in Section 7.6.1 d. Table 9.1 repeats much of the info in Table 6.2, some differences in methods and RLs for pH and all the metals.	a. The PT which is used at the site contains a thermistor to monitor temperature, as does the pH meter. Reference to temperature was deleted from table 6.2. b. Deleted TPH-Dx row. c. Removed reference to "instantaneous" readings and clarified method in Section 7.6.1. d. Updated tables to be consistent and duplicate information was deleted
21	BL	Based on a conversation with Doug Howie 6/7/2018, I recommend dropping the intended monitoring for sediment buildup at the top of the BMP surface. I don't anticipate a large sediment load that would foul the bioretention BMP, but more importantly the proposed methods for measuring sediment build up are not going to result in good information. We both feel they'll probably be difficult to perform without accidentally sampling the surface of the BMP. Strike this sampling for accumulated sediment PSD from the QAPP. a. The following locations and text here for reference around this discussion and should be reviewed/deleted: Table 6.2 indicates water and sediment for PSD. Table 7.3 indicates two separate water-based approaches to sample PSD. One	Deleted references to monitoring sediment build up on top of the bioretention area. PSD is only tested in the influent collected at the autosampler

		was supposed to be for sediment portion? Table 4.1 indicates there is only influent water sediment sampling, but Table 6.2 says sediment. See also section 7.8 and 8.1.7 SOP for sediment PSD sampling, still not clear how to assure sampling method stays at the accumulated sediment, not interfere with the BMP surface which is also sediment.	
22	BL	Figure 4.1 shows the “concrete sand” has different depths, which sounds like an error based on the text in other locations of the QAPP (Section 7.1) and as-built drawings.	Figure has been updated to show correct concrete sand depth for both bioretention cells
23	BL	Clarify that the BSM sample has not yet been run for soil characteristics testing. a. How has BSM sample been stored this whole time? (Table 4.1, Table 7.3 also, and section 7.9 verb tense error)	Noted sections have been updated to address comment.

Appendix D. Bioretention Sizing Calculations

LPOOLCOMPUTE [BSM 12 Level Pool] SUMMARY using Puls, 24 hr Storm Event

Start of live storage:99 ft

Event	Match Q (cfs)	Peak Q (cfs)	Max Depth[1] (ft)	Max Depth Above BSM (ft)	Vol (cf)	Vol (acft)	Time to Empty (hr)
6 m 24 hr	0.05	0.0175	100.3946	0.39	108.2561	0.0025	0.1667
25 yr 24 hr	0.1224	0.0175	102.1323	102.13	598.3079	0.0137	8.00

1. The bioretention cells were modeled assuming the 12-inch BSM has a 40% porosity. As such the max depth noted starts at elevation 99 feet or 12-inches below the bottom of the pond (elevation 100 feet).

Summary Report of all Detention Pond Data

Project Precips

Event	Precip (in)
6 m 24 hr	1.00
2 yr 24 hr	1.40
25 yr 24 hr	2.20

BASLIST2
[Half Gonzaga Parking Lot] Using [TYPE1a.rac] As [6 m 24 hr] [24.0]
[Half Gonzaga Parking Lot] Using [TYPE1a.rac] As [25 yr 24 hr] [24.0]
LSTEND

BasinID	Event	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-cf)	Area (ac)	Method/Loss	Raintype
Half Gonzaga Parking Lot	6 m 24 hr	0.05	8.00	0.0165	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	6 m 24 hr	0.05	8.00	0.0165	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	25 yr 24 hr	0.1224	8.00	0.0411	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	25 yr 24 hr	0.1224	8.00	0.0411	0.25	SBUH	TYPE1a.rac

BASLIST
[Half Gonzaga Parking Lot]
LSTEND

Record Id: Half Gonzaga Parking Lot

Design Method	SBUH	**Rainfall type**	TYPE1a.rac
Hyd Intv	10.00 min	**Peaking Factor**	484.00
Storm Duration	24.00 hrs	**Abstraction Coeff**	0.20
Pervious Area	0.00 ac	**DCIA**	0.25 ac
Pervious CN	0.00	**DC CN**	98.00
Pervious TC	0.00 min	**DC TC**	5.00 min

DCI - CN Calc		
Description	**SubArea**	**Sub cn**
Impervious surfaces (pavements, roofs, etc)	0.25 ac	98.00
DC Composited CN (AMC 2)		98.00

DCI - TC Calc						
Type	**Description**	**Length**	**Slope**	**Coeff**	**Misc**	**TT**
Sheet		0.00 ft	0.0%	5.0	0.00 in	5.00 min
Pervious TC						5.00 min

HYDLIST SUMMARY
[6 m 24 hr out] [25 year out]
LSTEND

HydID	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-ft)	Cont Area (ac)
6 m 24 hr out	0.0175	8.00	0.0165	0.25
25 year out	0.0175	5.50	0.0407	0.25

STORLIST
[BSM 12 Compound] [BSM 12 Media] [BSM 12]
LSTEND

Record Id: BSM 12 Compound

Descrip:	Cell (trap pond) plus BSM (vault)	Increment	0.10 ft
Start El.	99.00 ft	Max El.	105.00 ft
Void Ratio	100.00		
Combination Storage Type Node			

Record Id: BSM 12 Media

Descrip:	12 inch media thickness	Increment	0.10 ft
Start El.	99.00 ft	Max El.	100.00 ft
Void Ratio	40.00		
Length	18.00 ft	Width	7.00 ft
		Consider Bottom Only	
Vault Type Node			

Record Id: BSM 12

Descrip:	cell with 12-inch BSM thickness	Increment	0.10 ft
Start El.	100.00 ft	Max El.	105.00 ft
Void Ratio	100.00		
Length	18.00 ft	Width	7.00 ft
Length ss1	2.00v:1h	Length ss2	2.00v:1h
Width ss1	2.00v:1h	Width ss2	2.00v:1h
Consider bottom area for infiltration			
Trap Type Node			

DISCHLIST
[BSM 12 Infiltration Rate]
LSTEND

Record Id: BSM 12 Infiltration Rate

Infiltration			
Descrip:	Prototype Structure	**Increment**	0.10 ft
Start El.	100.00 ft	**Max El.**	105.00 ft
Infiltration rate	3.00 in/hr	**WP Multiplier**	1.00

LPOOLCOMPUTE [BSM 18 Level Pool] SUMMARY using Puls, 24 hr Storm Event

Start of live storage:98.5 ft

Event	Match Q (cfs)	Peak Q (cfs)	Max Depth[1] (ft)	Max Depth Above BSM (ft)	Vol (cf)	Vol (acft)	Time to Empty (hr)
6 m 24 hr	0.05	0.0175	100.272	0.27	113.7908	0.0026	0.1667
25 yr 24 hr	0.1224	0.0175	102.111	2.11	614.6436	0.0141	8.6667

1. The bioretention cells were modeled assuming the 18-inch BSM has a 40% porosity. As such the max depth noted starts at elevation 98.5 feet or 18-inches below the bottom of the pond (elevation 100 feet).

Summary Report of all Detention Pond Data

Project Precips

Event	Precip (in)
6 m 24 hr	1.00
2 yr 24 hr	1.40
25 yr 24 hr	2.20

BASLIST2
[Half Gonzaga Parking Lot] Using [TYPE1a.rac] As [6 m 24 hr] [24.0]
[Half Gonzaga Parking Lot] Using [TYPE1a.rac] As [25 yr 24 hr] [24.0]
LSTEND

BasinID	Event	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-cf)	Area (ac)	Method/Loss	Raintype
Half Gonzaga Parking Lot	6 m 24 hr	0.05	8.00	0.0165	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	6 m 24 hr	0.05	8.00	0.0165	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	25 yr 24 hr	0.1224	8.00	0.0411	0.25	SBUH	TYPE1a.rac
Half Gonzaga Parking Lot	25 yr 24 hr	0.1224	8.00	0.0411	0.25	SBUH	TYPE1a.rac

BASLIST
[Half Gonzaga Parking Lot]
LSTEND

Record Id: Half Gonzaga Parking Lot

Design Method	SBUH	**Rainfall type**	TYPE1a.rac
Hyd Intv	10.00 min	**Peaking Factor**	484.00
Storm Duration	24.00 hrs	**Abstraction Coeff**	0.20
Pervious Area	0.00 ac	**DCIA**	0.25 ac
Pervious CN	0.00	**DC CN**	98.00
Pervious TC	0.00 min	**DC TC**	5.00 min

DCI - CN Calc		
Description	**SubArea**	**Sub cn**
Impervious surfaces (pavements, roofs, etc)	0.25 ac	98.00
DC Composited CN (AMC 2)		98.00

DCI - TC Calc						
Type	**Description**	**Length**	**Slope**	**Coeff**	**Misc**	**TT**
Sheet		0.00 ft	0.0%	5.0	0.00 in	5.00 min
Pervious TC						5.00 min

HYDLIST SUMMARY
[6 m 24 hr out] [25 year out]
LSTEND

HydID	Peak Q (cfs)	Peak T (hrs)	Peak Vol (ac-ft)	Cont Area (ac)
6 m 24 hr out	0.0175	8.17	0.0165	0.25
25 year out	0.0175	6.00	0.0407	0.25

STORLIST
[BSM 18 Compound] [BSM 18 Media] [BSM 18]
LSTEND

Record Id: BSM 18 Compound

Descrip:	Cell (trap pond) plus BSM (vault)	Increment	0.10 ft
Start El.	98.50 ft	Max El.	105.00 ft
Void Ratio	100.00		
Combination Storage Type Node			

Record Id: BSM 18 Media

Descrip:	18 inch media thickness	Increment	0.10 ft
Start El.	98.50 ft	Max El.	100.00 ft
Void Ratio	40.00		
Length	18.00 ft	Width	7.00 ft
		Consider Bottom Only	
Vault Type Node			

Record Id: BSM 18

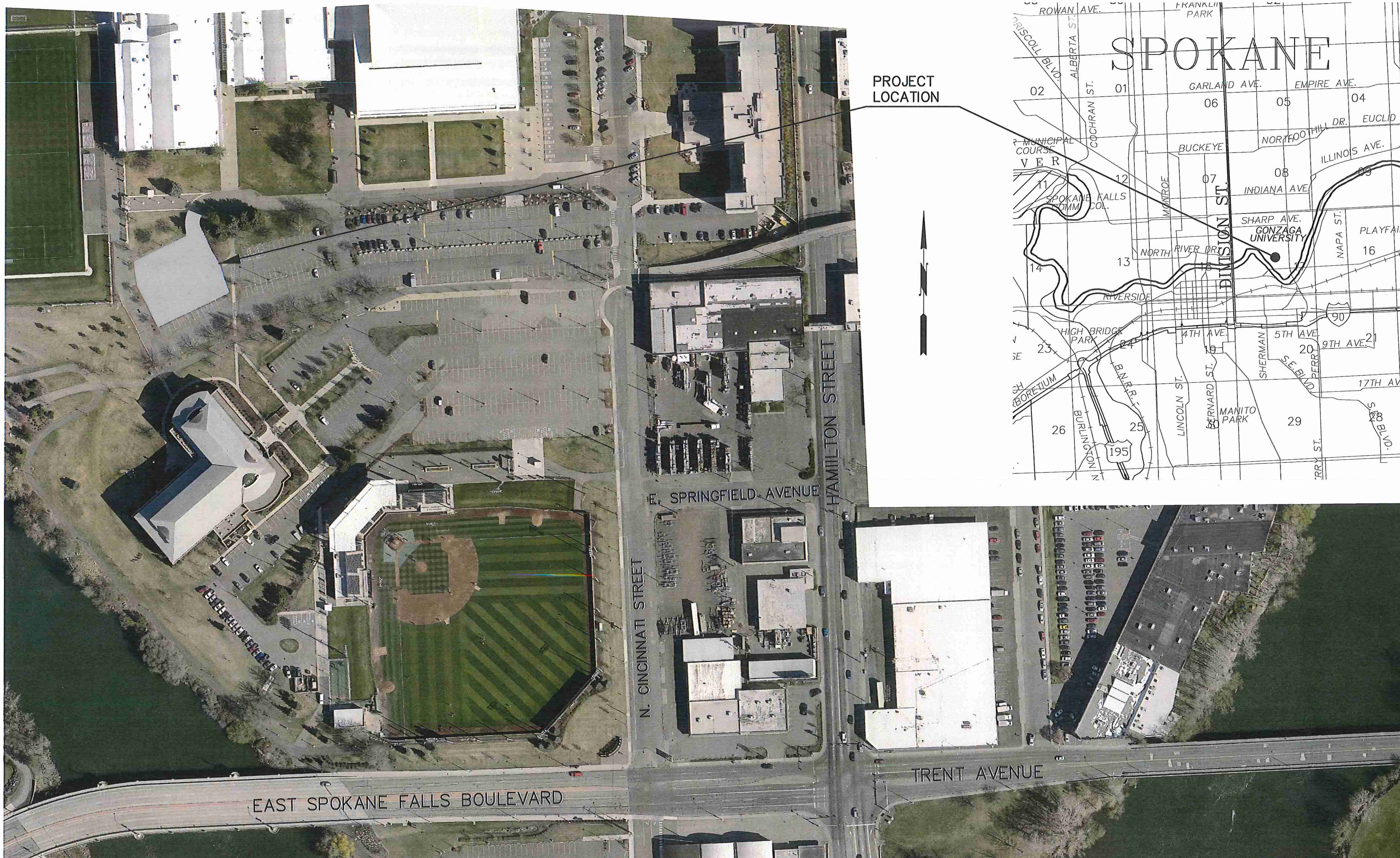
Descrip:	cell with 18-inch BSM thickness	Increment	0.10 ft
Start El.	100.00 ft	Max El.	105.00 ft
Void Ratio	100.00		
Length	18.00 ft	Width	7.00 ft
Length ss1	2.00v:1h	Length ss2	2.00v:1h
Width ss1	2.00v:1h	Width ss2	2.00v:1h
Consider bottom area for infiltration			
Trap Type Node			

DISCHLIST
[BSM 18 Infiltration Rate]
LSTEND

Record Id: BSM 18 Infiltration Rate

Infiltration			
Descrip:	Prototype Structure	**Increment**	0.10 ft
Start El.	100.00 ft	**Max El.**	105.00 ft
Infiltration rate	3.00 in/hr	**WP Multiplier**	1.00

Appendix E. Test-Site Construction Plans



I:_Civil 3D Projects\SWSA517G-1 Gonzaga\DRAWINGS\SWSA517G-1 Gonzaga Swale Project.dwg Sep 18, 2014 12:53pm

NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

NOT TO SCALE

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 18, 2014

SPOKANE COUNTY

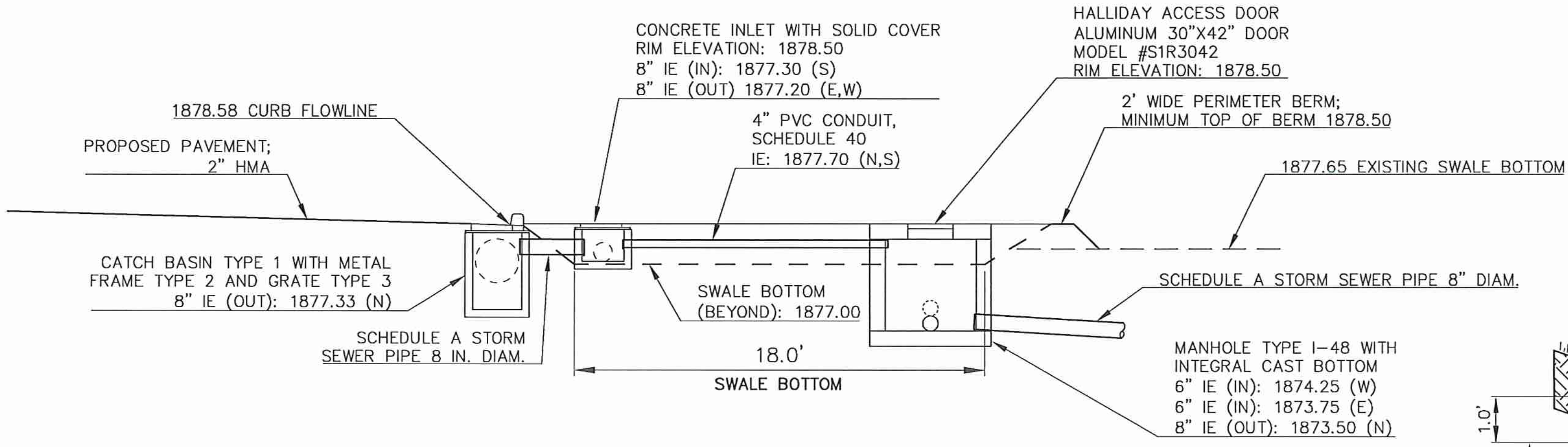
Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED:
STORMWATER ENGINEER
ENGINEER
Date:

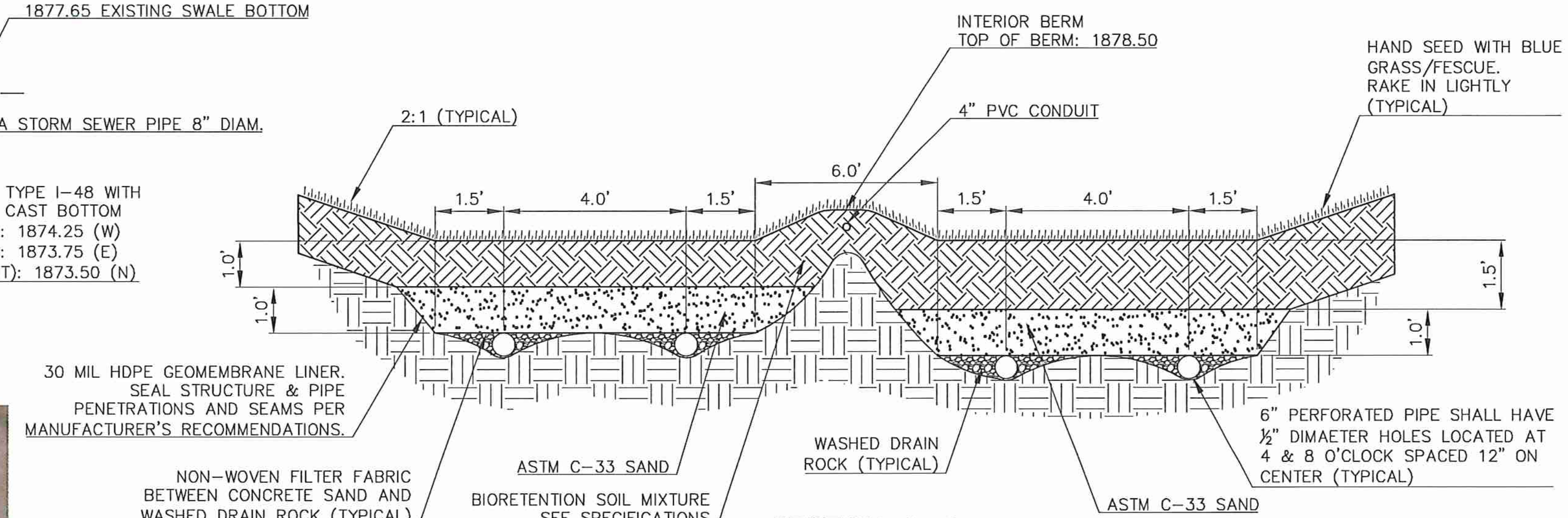
MATTHEW B. ZARECOR
STATE OF WASHINGTON
36216
REGISTERED PROFESSIONAL ENGINEER

COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
VICINITY MAP
PROJECT VICINITY

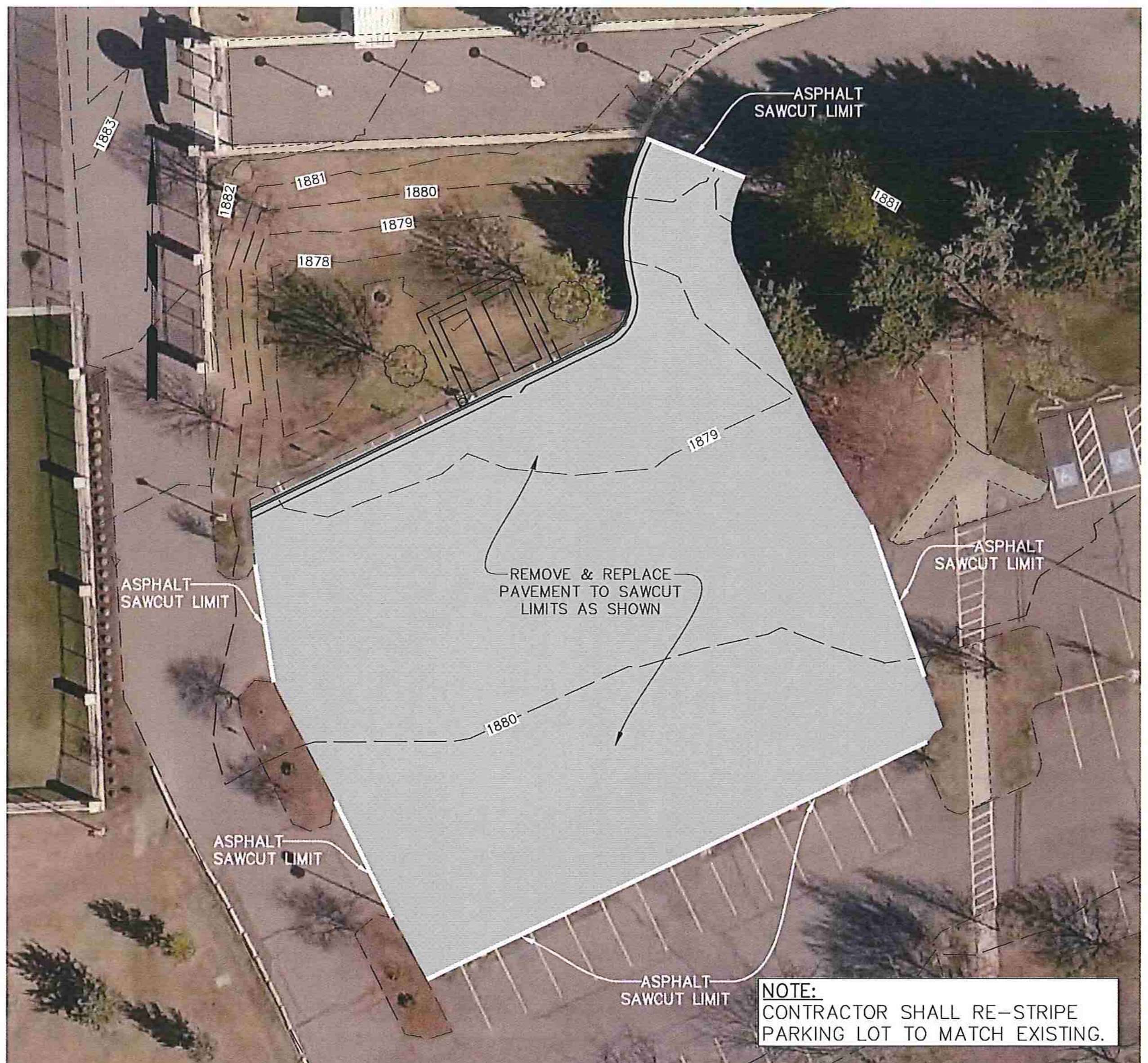
SHEET 1 of 3



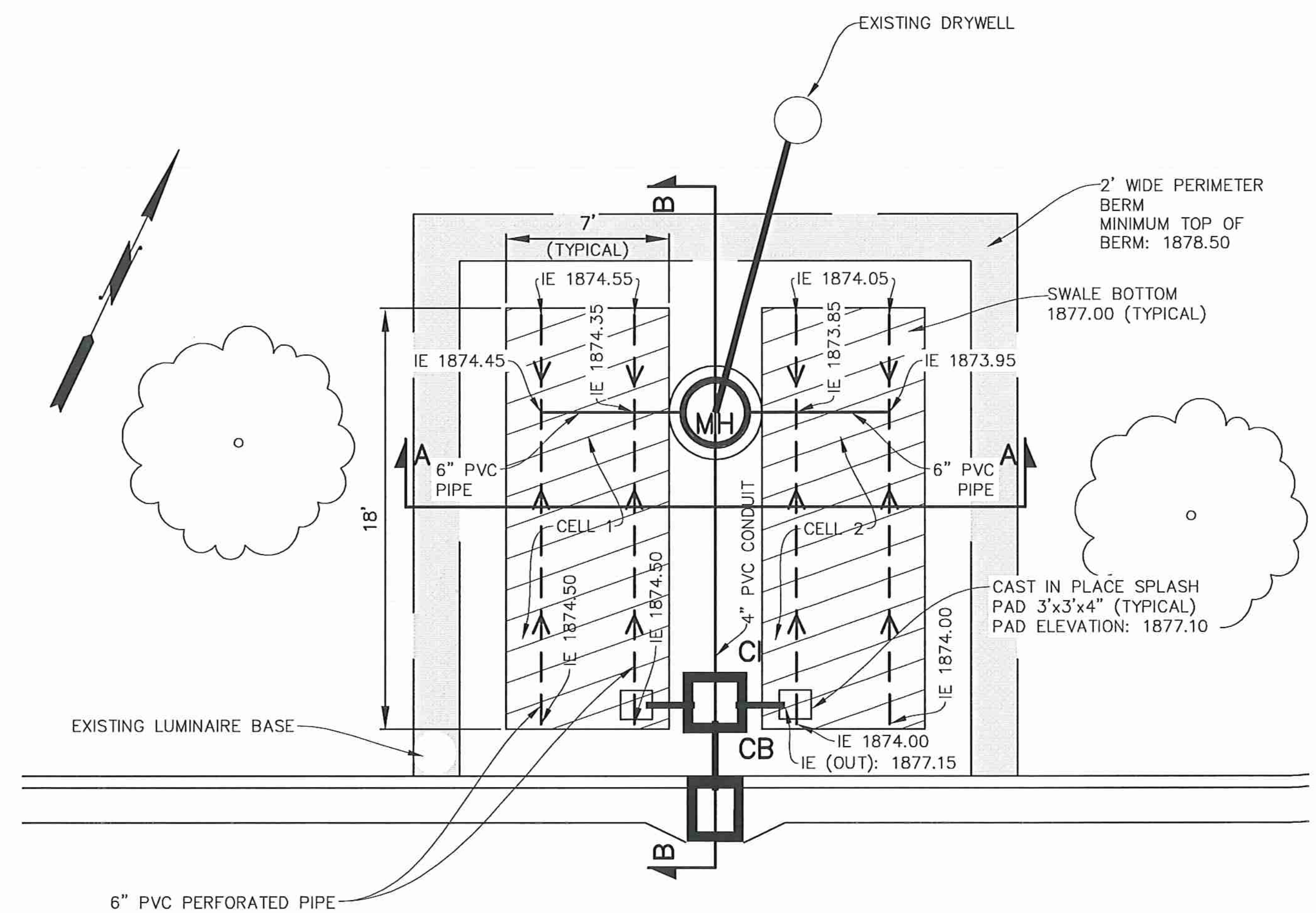
SECTION B–B
NOT TO SCALE



SECTION A–A
NOT TO SCALE



PAVEMENT REMOVAL
SCALE: 1"=40'



SWALE PLAN VIEW
SCALE: 1"=8'

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NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

SCALE: AS NOTED

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 22, 2014

Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

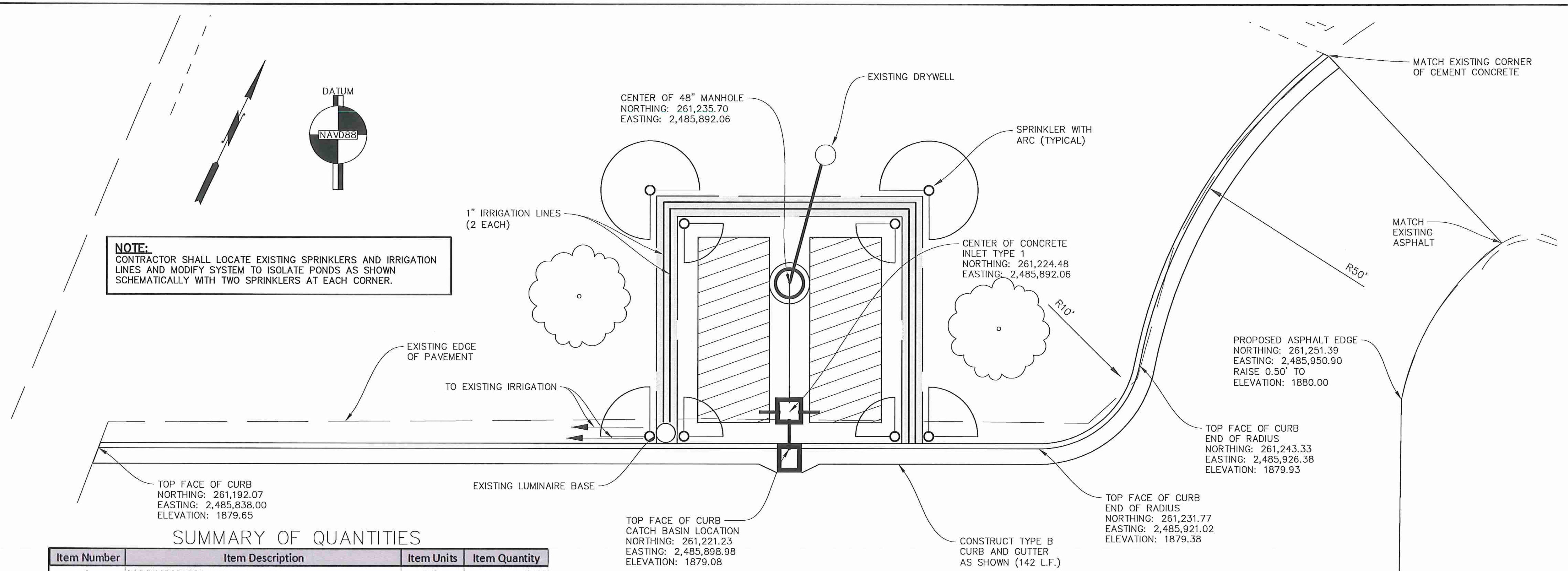
SPOKANE COUNTY

APPROVED:
STORMWATER ENGINEER
ENGINEER
Date:

MATTHEW B. ZARECOR, STATE OF WASHINGTON, 36216, REGISTERED PROFESSIONAL ENGINEER

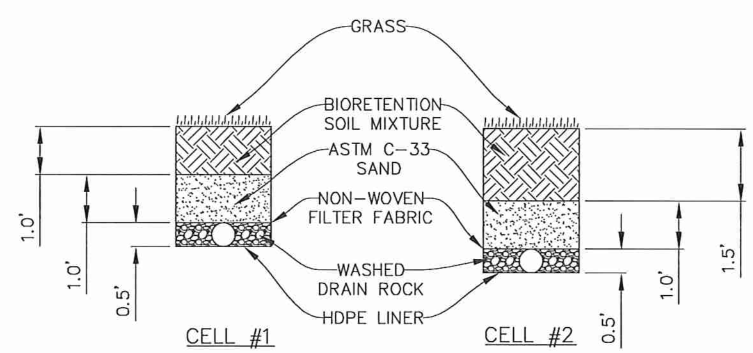
COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
PAVEMENT REMOVAL
SWALE LAYOUT AND CROSS SECTIONS

SHEET 2 of 3



SUMMARY OF QUANTITIES

Item Number	Item Description	Item Units	Item Quantity
1	MOBILIZATION	L.S.	1.00
2	SAWCUTTING ASPHALT CONC. PAVEMENT	L.F.	236.00
3	ASPHALT PAVEMENT REMOVAL INCL. HAUL	S.Y.	1,867.00
4	GRADING AND SHAPING	S.Y.	1,867.00
5	SWALE EXCAVATION INCL. HAUL	C.Y.	52.00
6	METAL FRAME TYPE 2 AND GRATE TYPE 3	EACH	1.00
7	HALLIDAY ACCESS DOOR MODEL #S1R3042	EACH	1.00
8	CATCH BASIN TYPE 1	EACH	1.00
9	CONCRETE INLET TYPE 1 INCL. FRAME & SOLID COVER	EACH	1.00
10	MANHOLE TYPE I-48	EACH	1.00
11	48" TOP SLAB	EACH	1.00
12	4" PVC CONDUIT, SCHEDULE 40	L.F.	12.00
13	SCHEDULE A STORM SEWER PIPE 8 IN. DIAM.	L.F.	35.00
14	6" PVC PIPE	L.F.	15.00
15	6" PVC PERFORATED PIPE	L.F.	72.00
16	CRUSHED SURFACING TOP COURSE	C.Y.	20.00
17	CRACK SEALING	L.F.	236.00
18	HMA CL. 1/2 IN. PG 64-28, 0.17 FT. DEPTH	S.Y.	1,865.00
19	BIORETENTION SOIL MIXTURE	C.Y.	22.00
20	ASTM C-33 SAND	C.Y.	14.00
21	WASHED DRAIN ROCK; 1"-2"	C.Y.	6.00
22	NON-WOVEN FILTER FABRIC	C.Y.	35.00
23	30 MIL HDPE GEOMEMBRANE LINER	S.Y.	130.00
24	GRASS SEED INSTALLATION	S.Y.	150.00
25	CEMENT CONCRETE CURB TYPE B	L.F.	142.00
26	IRRIGATION SYSTEM MODIFICATION	L.S.	1.00



CELL MATERIAL DETAILS

NOT TO SCALE

NO.	DATE	BY	CKD.	APPR.	REVISION DESCRIPTION

SCALE: 1"=10'

DRAWN BY:	FARNSWORTH	SEPT., 2014
DESIGNED BY:	GONZAGA	SEPT., 2014
CHECKED BY:	ZARECOR	SEPT. 22, 2014

SPOKANE COUNTY

Spokane County Department of Public Works
1026 W. Broadway Ave. SPOKANE, WA
99260-0170
(509) 477-3600

APPROVED: ______
STORMWATER ENGINEER
ENGINEER
Date: ______

MATTHEW B. ZARECOR · STATE OF WASHINGTON · 38216 · REGISTERED PROFESSIONAL ENGINEER

COUNTY STORMWATER PROJECT No: SWR 80-14
GONZAGA SWALE PROJECT
CURB CONSTRUCTION & GRADING INFORMATION
QUANTITIES AND IRRIGATION DETAILS

SHEET 3 of 3

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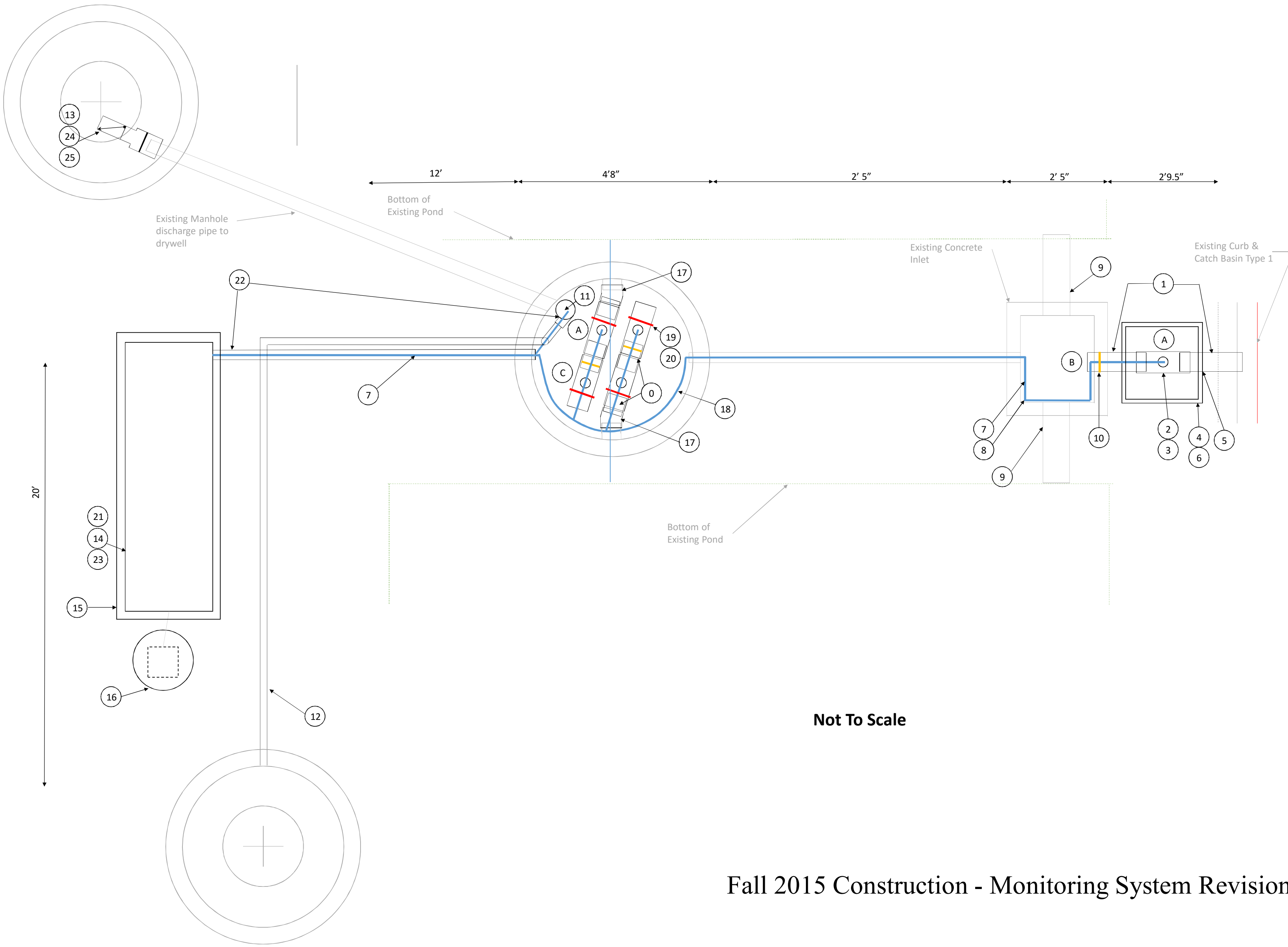


Fall 2015 Construction - Monitoring System Revisions

Item Number	Item Description	Item Units	Total Item Quantity	Construction Notes
0	6" Storm Sewer Pipe, SDR35	LF	20	Install as part of item 1 and as part of effluent sample collection Tees in the existing 48" manhole
1	Replace Existing 8" Pipe with 6" Storm Sewer Pipe SDR35 (cut pipe in half and connect to Tee, item 2)	LS		Locate 6" pipe outside crown elevation to match existing 8" outside crown elevations at each catch basin & concrete inlet
2	6x6x6 Sewer Tee, solvent weld	EA	5	Prior to Installation Gonzaga will: cut 4"x5" opening into top of Tee (PT access & maintenance)
3	6" cap H; for SDR35 pipe	EA	5	Prior to Installation Gonzaga will: installed the PT support onto the inside of cap
4	NDS 24-inch square two opening catch basin (#2400)	EA	1	route 6" storm sewer through outlets with water tight seal around pipes; drill four 1/8" weep holes in bottom of basin , place basin on top of 4" gravel base (prevent standing water)
5	NDS 6-inch Universal Locking Outlet (#1266)	EA	2	
6	24" square, solid & lockable lid	EA	1	lid need to fit on NDS 24" catch basin; vendor reps have not responded and/or I have gotten the wrong lid. This lid needs to be solid (not a grate) because it will cover an open sample location
7	1-1/4" PVC conduit	LF	40	route sample tubing and PT cord in 1.5" PVC conduit from each sample collection point, through existing 4" PVC, to each ISCO sampler; also need a way to support 1.5" (zip ties to stormdrain?)
8	1-1/4" PVC 90 degree elbows and Tee	EA	12	use elbows and some Tees to connect length of 1.25" PVC pipe
9	Remove & reinstall two 8" storm sewer pipe (from concrete inlet to each pond) for flow equilizer weir installation	LS		Gonzaga will install flow equilizer weir and metal adjustment plates (water tight seal around weir).
10	Install Thel-Mar Weir	EA	3	Gonzaga will Install weirs ~12" downstream of connection to Tee (w/ PT) and after weir, allow a minimum 1" between the weir and another fitting.
11	Install Sump pump with float valve	LS	1	locate in bottom of manhole; needs power connection and connect to 2" discharge pipe from pump to dry well
12	1-1/4" PVC discharge pipe from sump pump to dry well (+ vent)	LF	40	install connection through existing manhole for pipe, locate pipe underground between manhole and dry well. Additional pipe bedding maybe required. Will also need vent in discharge line.

13	6" valve backwater PVC IPS (see Harrington Quote from 08/14/2015)	EA	1	Locate adapter, eccetric reducer, and backwater valve on the existing 8" SDR35 storm sewer pipe inside the drywell. During installation, slope valve down 1/4" so flapper valve is installed in the normally clossed position.
14	Fiberglass Expanded Equipment Enclosure; Tracom Model 200-060-80; 8"Wx23"Dx29"H; Cost includes optional adders including; green color, shelf, as well as breaker box and panel.	EA	1	Locate north and immediately adjacent to monitoring pond in the bottom of the existing pond. Enclosure shall be green and capable of locking. Additional equipment also needs to be installed to adapt enclsure for monitoring equipment setup including; part shelf (for data logger) as well as breaker box and panel. Install per manufacturers recommendations.
15	cast in place concrete pad for enclosure	LS	1	
16	Rain gauge stand/installation			Locate gauge near equipment enclosure and connect to data logger. Aime is still working on this item and will coordinate with Gonzaga Facilities and machine shop about making something that will work at the site.
17	11.5 degree couplings for 6" SDR pipe	EA	2	Connect to existing 6" effluent discharge pipe to adjust sampling and flow monitoring collection setup (double Tee configuration)
18	1.5" flexible PVC (sprinkler pipe?)	LF	15	Locate sample tube and PT cord inside flexible tubing and install 2 suports along inside of manhole. Constractor will also install
19	Pipe supports (constructed from Hayden	LF	20	Construct 4 pipe supports using channels and install into base of existing manhole. Secure 2 supports to each effluent discharge sample/flow monitoring collection setup using 6" strut clamps (2 per pipe).
20	FNW 7873 strut clamps for 6" SDR35 pipe	EA	4	see item 19 notes
21	Trickle Charger (any type that will support two 100AH 12V battery)	EA	2	Locate in equipment enclosure and connect to power supply. Chargers will connect to each of the 2 batteries
22	Power Supply/installation	LS		Gonzaga will provide power; contractor will coordinate with Gonzaga and locate power from source to equipment enclosure and manhole.
23	Install/connect monitoring equipment			Gonzaga will connect batteries to ISCO equipment and data logger. As well as mount Logger inside equipment enclosure.
24	8" adapter SPIGxH for PVC to SDR 35 (See Harrington Quote 08142015)	EA	1	see item 13
25	8"x6" couplling eccentric reducer for PVC Schedule 40 (See Harrington Quote 08142015)	EA	1	see item 14

Appendix F. 2017-2018 Senior Design Student Fact Sheet

Stormwater Treatment and Monitoring

Gonzaga University Senior Design Group ENSC 02

May 2018

What is Bioretention?

Bioretention is the process of removing contaminants and sedimentation from stormwater runoff using a more natural approach. This process uses different types of soils and vegetation to target a variety of pollutants. Bioretention relies heavily on infiltration to mitigate downstream erosion. This is one of the preferred methods of LID (Low-Impact Development), which is required in the state of Washington.

Parameters Tested

Alkalinity	Potassium
Calcium	Sulfate
Chloride	Sulfide
Copper*	Sodium
DOC	TKN
Magnesium	pH
Nitrate-Nitrite	TSS*
Oil/Grease	Zinc*
Total Phosphorous*	

*Regulated in NPDES MS4 permit

The Problem

Bioretention ponds are best management practices (BMPs) used to reduce pollutant concentrations in stormwater runoff. For this project, a bioretention pond is used to collect, infiltrate, and remove pollutants from the adjacent parking lot's runoff. Within the pond, there are two cells, one with a 12" depth and one with 18". Those two cells are composed of bioretention soil media (BSM). The BSM is a mix of 60% sand 40% compost (60/40 mix). From previous research, this mix has been found to leach dissolved copper, phosphorus, and nitrogen.

Purpose of Project

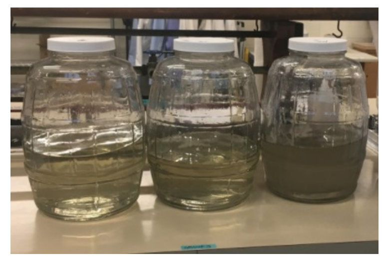
- Evaluate and compare the effectiveness of the 60/40 mix's treatment performance in both the 12" and 18" cells
- Investigate whether or not the pond was successful in reducing the toxicity of copper using the Biotic Ligand Model

GONZAGA UNIVERSITY
School of Engineering & Applied Science

Methods

Storm Monitoring & Sample Collection

We monitored three natural rainfall events. Automated equipment, including ISCO samplers, were set before the storm events and would collect samples throughout the storm. Influent and effluent samples were collected in jars that were inside the ISCO samplers and were later transported to Anatek Labs to be tested. See page 1 for the parameters tested.



Statistical Analysis

The process to determine the statistical analysis for the stormwater concentrations began with determining the descriptive statistics (mean and standard deviation) for each of the regulated pollutants for the influent and effluents from the storm events that occurred this year. The influent, 12", and 18" concentrations were tested for normality to determine which statistical test to run. The Ryan-Joiner test was used to determine normality for the regulated pollutants. Normality was determined based on the p-value. For data that is normally distributed, a paired T-test was used to determine the significance of the data. For data that is not normally distributed, the Mann-Whitney test was used to determine the significance of the data. The paired T-test and the Mann-Whitney test ran in three ways, Influent vs the 12”, Influent vs the 18”, and the 12” vs the 18”. The p-value from those two tests were than interpreted in one of three ways: Insignificant if the p-value was greater than 0.1, moderately significant if the p-value was between 0.051-0.1, and significant if the p-value was smaller than 0.05. We performed this detailed analysis on our data (n=3) as well as on the data collected since the project started (n=10). Our data was then compared to the entire data set of the project (n=10).

Biotic Ligand Model (BLM)

The change in toxicity of pollutants, specifically dissolved copper, was calculated using the BLM. This model calculates whether the acute or chronic toxicity of dissolved copper is changing after infiltrating through the BSM. The BLM uses a variety of parameters to form this analysis.

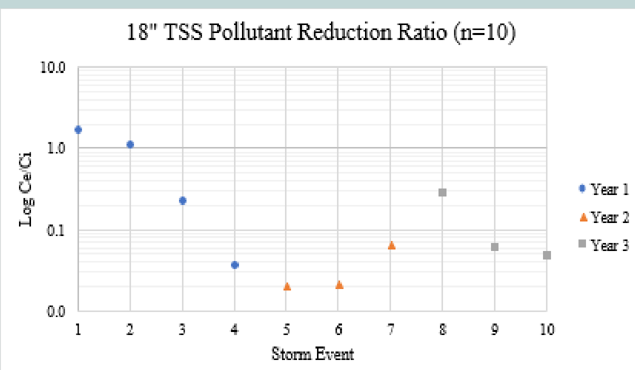
<u>BLM Parameters</u>

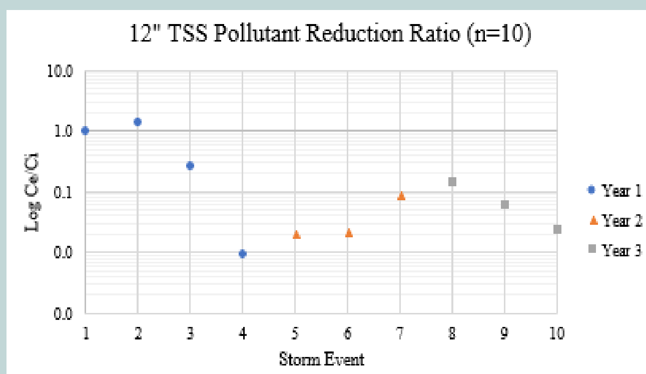
- Temperature
- pH
- Dissolved copper (Cu)
- Dissolved organic carbon (DOC)
- Humic acid (HA)
- Dissolved calcium (Ca)
- Dissolved magnesium (Mg)
- Dissolved sodium (Na)
- Dissolved potassium (K)
- Sulfate (SO4)

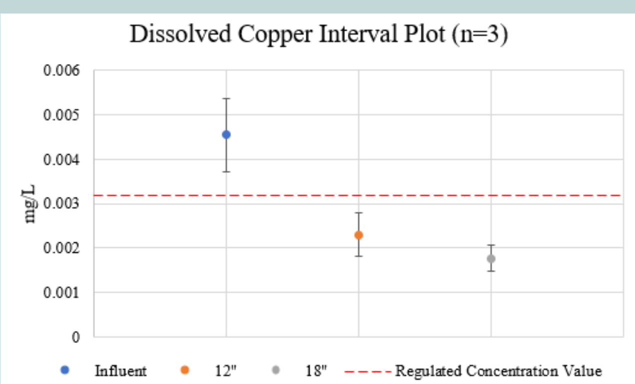
Results

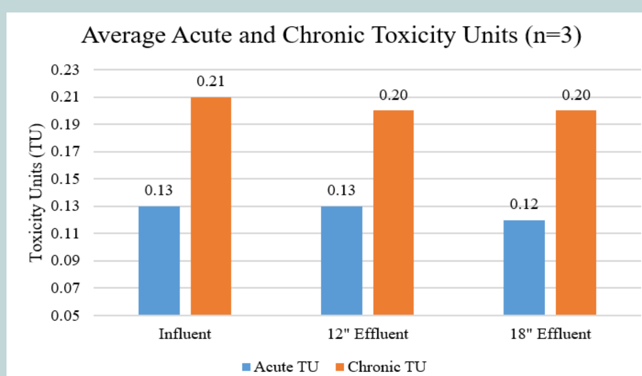
2017-2018 Data Set (N=3)						
Target Pollutant	Cell	Normal Distribution (Y/N)	Percent Removal	P value	Statistically Significant? (Y/M/N)*	Ecology Treatment Goal Achieved?
TSS	Effluent 12"	Yes	92.3%	0.091	M	✓
	Effluent 18"	Yes	86.8%	0.103	M	✓
	12" vs 18"	Yes	NA	0.27	N	✓
Dissolved Copper	Effluent 12"	Yes	47.5%	0.086	M	✓
	Effluent 18"	Yes	59.5%	0.049	Y	✓
	12" vs 18"	Yes	NA	0.189	N	✓
Dissolved Zinc	Effluent 12"	Yes	43%	0.053	M	×
	Effluent 18"	Yes	48%	0.08	M	×
	12" vs 18"	Yes	NA	0.448	N	×
Total P	Effluent 12"	Yes	-344%	0.049	Y	×
	Effluent 18"	Yes	-359%	0.048	Y	×
	12" vs 18"	Yes	NA	0.152	N	×
NO3/N+NO2/N	Effluent 12"	Yes	10.2%	0.423	N	N/A
	Effluent 18"	Yes	-15.8%	0.638	N	N/A
	12" vs 18"	Yes	NA	0.204	N	N/A

* Yes: P-value ≤0.05 , No: P-value > 0.05 , Moderately: P-value 0.1-.051









Conclusion and Contact Info

Results

- BSM mix leached total phosphorous from both cells and nitrate-nitrite from the 18-inch cell
- More research is needed to better understand the role of BSM in changing dissolved Cu toxicity

Recommendations

- Implement sediment control around the inlet grate to prevent clogging of the system when there is nearby construction
- Implementing chicken wire around the grate inlet to prevent gross solids (leaves, large debris, etc.) from entering into the system
- Investigate other BSM mixes that may be more suitable for Eastern Washington climate
- More testing of the 60/40 BSM mix to see how treatment performance changes with time

Contributors

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- Spokane County
- Department of Ecology
- Design Advisory Board
- Gonzaga University Engineering Department
- Kathy Sattler - Anatek Labs
- Bryan Putnam - Gonzaga Plant Services

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School of Engineering & Applied Science

Appendix G. Monitoring Equipment Specifications

EXTREME ENVIRONMENTS
EXTREMELY RELIABLE

AXIOM H1 / H2
DATALOGGER / DCP

**Tough on the outside.
Clever on the inside.**

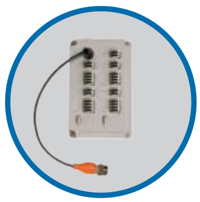
The Axiom Datalogger / DCP offers uncompromising reliability (borne out of our experience meeting the strict reliability demands of the North American fire weather market for over 35 years), extreme rugged construction and integrated waterproof touchscreen. These unique innovations result in lower post-purchase costs through reduced replacement from damage, higher data reliability and elimination of damage to (and even purchase of) laptops.

The Axiom Datalogger

Flexibility and expandability.

- Install new programs, firmware and operating system updates easily via any standard USB flash memory stick.
- Large internal memory capacity can store upwards of 10 years of data (assuming 8 sensors sampling once per hour).
- A virtually unlimited library of configurations can be stored, uploaded, downloaded and selected via the touchscreen, ideal for large network operators maintaining an inventory of spare equipment.
- Allows virtually unlimited expandability—up to 62 digital sensors. Calibration coefficients are not required.
- Can also be expanded with multiple analog sensors via optional SDI-AM analog interface module.

Transfer data or firmware updates via standard USB memory sticks



The SDI analog module provides analog sensor expansion

Integrated, preconfigured GOES, and optional 2-way cellular/Iridium.

The industry-leading G6 GOES transmitter—the same equipment that's a standard for all North American fire weather stations—is available as an integrated option in the Axiom. Extremely low power consumption and accurate time keeping enables reliable hourly data for up to 28 days even without a GPS fix.

For added reliability and 2-way remote management of the station, Iridium satellite telemetry can be easily added with Ubicom.

Ubicom
2-way remote management

Reliable connections.

We pioneered the use of military-style bayonet connectors for attaching external devices to our dataloggers. Why?

- The watertight, corrosion-resistant, positive-locking connection becomes incredibly reliable, eliminating the most probable point of failure.
- The color-coded, single-port design makes connecting sensors and other features during installation and maintenance dead simple and fast.
- All FTS sensors include bayonet connectors, and they can be added to any of your current SDI-12 sensors, power sources and rain gauges.

Leave the laptop at the office.

Integrated waterproof, daylight-readable touchscreen.

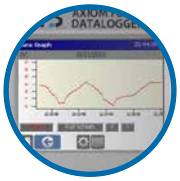
Built like a tank.

Fully watertight. 3 levels of lightning protection. Waterproof military bayonet connectors. IP67 aluminum case.

No laptop required.

The Axiom integrates a waterproof, industrial-grade, daylight-readable, color touch screen. By embedding the software right into the datalogger, we eliminate the need for field laptops and cables.

Create graphs of any parameter from any range of dates, to spot data anomalies.



View and export data in tabular format.

Simple diagnosis.

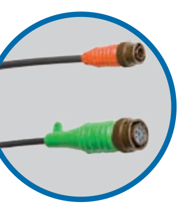
Axiom integrates a power manager and a solar charge regulator (H2 only) which is sealed inside the waterproof case. This reduces the chance of a problem with the power system—a common source of problems—and minimizes your time spent troubleshooting.

- The Axiom is constantly aware of parameters like solar voltage and current, battery voltage and current, battery and internal ambient temperature, and can transmit this information via any telemetry method. This allows the datalogger to provide a complete picture of power conditions for diagnosing power issues remotely, eliminating unnecessary site visits.
- At the site, this information is readily available as a graph on the integrated touchscreen with one click. Find out quickly when the problem occurred by viewing the log of data graphically.
- The integrated power manager adds an additional layer of intelligence to the Axiom by allowing the datalogger to directly talk to and manage the solar panel and battery.

Extreme ruggedness.

Because reliability is paramount and any downtime means lost data and increased liability, the Axiom is engineered for long-term durability in the harshest environments (minimizing site visits is nice too).

- Three levels of lightning protection. We have over 33 years of experience building equipment for the most extreme lightning strike locations, and it's in here.
- The entire unit—the cast aluminum, O-ring sealed case and all ports—is completely impervious to the elements. Even the touchscreen. And not just splashproof: fully watertight.
- Positive-locking, waterproof, color-coded, cadmium-plated, corrosion resistant, military-style bayonet connectors.



Extremely simple.

Clever graphical interface makes configuration and troubleshooting easy. Reduces the chance for things to go wrong.

Embracing SDI-12

The Axiom's waterproof SDI-12 ports are each on a **separate, electrically isolated SDI bus,** and each can supply **up to 500mA to sensors.**

Reduced risk of failure:

If one port becomes disabled because of one of the sensors that's attached to it, the other sensors on the other ports will continue to function. More independent SDI-12 ports means you can reduce the risk of failure by spreading out the sensors among more ports.

More responsive data throughput:

Because each SDI port is independent of the other, the datalogger can drive multiple sets of sensors without having to wait for the first to respond before polling the second, and so on.

Increased reliability for complex systems:

The DCP can issue simultaneous M commands to each port to manage long read-time, high power draw sensors such as side lookers. This allows sensors to collect data concurrently so all the data from the station is from the same time window.

Modular analog expansion:

The SDI-AM analog module permits analog sensor expansion on any of the SDI ports.

H1-R: Rain counter, 2 SDI-12 ports

H1-RS: Rain counter, 2 SDI-12 ports, Integrated solar charge regulator

Axiom H1

Simple hydrology applications where reliability, data integrity and a competitive price are important.

Axiom H2

Simple to complex hydrology or meteorology applications where reliability is paramount and/or the station is very remote.

DCP Comparison Table

ATTRIBUTE	Axiom H1	Axiom H2	Sutron 8310-N w/Satlink2	Sutron Satlink2-V2	Design Analysis H-522+
DISPLAY	Waterproof, daylight-readable, 3.5" color graphical display	Waterproof, daylight-readable, 3.5" color graphical display	40 character (2-line) monochrome LCD	No (optional 40 character monochrome LCD)	20 character monochrome LCD
USER INTERFACE	Graphical touchscreen or PC Software	Graphical touchscreen or PC Software	Basic configuration via 6-button membrane-type key panel; connected laptop for diagnosis, programming and more advanced configuration	None (connected laptop required); optional 6-button key panel	Basic configuration via 7-button key panel; connected laptop for diagnosis, programming, more advanced configuration
FILE TRANSFER (configuration/firmware update, data download)	USB memory stick or PC Software	USB memory stick or PC Software	SD card	Connected laptop	Connected laptop
PROGRAMMING	GUI on integrated touchscreen or GUI on PC	GUI on integrated touchscreen or GUI on PC	BASIC, C++ programming languages	GUI running on connected laptop	GUI running on connected laptop
POWER CONSUMPTION					
STANDBY	7mA	7mA	12mA	8.2mA	10mA
OPERATING - DISPLAY ON	60mA	60mA	73mA	n/a	250mA
OPERATING - DISPLAY OFF	12mA	12mA	up to 33mA	n/a	80mA
TRANSMITTING - 300 BPS	2.6A	2.6A	3.5A	3.1A	2.75A
SENSOR PORT TYPE	Waterproof, military-style bayonet connector	Waterproof, military-style bayonet connector	Unprotected terminal strip	Unprotected terminal strip	Unprotected terminal strip
SDI-12 PORTS					
HOW MANY?	2	4	2	1	1
NUMBER OF SDI-12 BUSES	2	4	1	1	1
ELECTRICALLY ISOLATED?	Yes	Yes	No	No	No
MAX. CURRENT OUTPUT PER PORT	500mA	500mA	100mA max output across all ports	No digital output	1A
ANALOG PORTS	Up to 62 available via modular expansion	1 rain counter, up to 62 available via modular expansion	8	4	6
ENVIRONMENTAL SEALING	NEMA Type 6P (IP67): completely protected against dust and dirt, protected against immersion in water up to 1m.	NEMA Type 6P (IP67): completely protected against dust and dirt, protected against immersion in water up to 1m.	NEMA Type 4 (IP65): Weatherproof (not submersible), must exclude at least 65 GPM of water from 1" nozzle delivered from a distance greater than 10' for 5 min.	None	None
LIGHTNING PROTECTION	3 levels	3 levels	Multistage input protection including spark gaps (analog ports only)	No	No
INTEGRATED SOLAR CHARGE REGULATOR	No (H1-R), Yes (H1-RS)	Yes, sealed in watertight enclosure	Yes	No	No
PC CONNECTION	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**	**RS232 Serial direct connect or BLE wireless**

CANADA 1065 Henry Eng Place | Victoria, BC | V9B 6B2
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EXTREME ENVIRONMENTS
EXTREMELY RELIABLE

Isco Product Data

Isco 674 Rain Gauge

Connects directly to 6712 and Avalanche™ Samplers, 4200 Flow Meters, and 4100 Flow Loggers

The Isco 674 Rain Gauge is a precision instrument that uses a tipping bucket design for rainfall measurement. It has an 8-inch diameter orifice and is factory-calibrated to tip at either 0.01 inch or 0.1 mm of rainfall. With a 674 Rain Gauge connected, an Isco flow meter or sampler will:

- Store rainfall data in internal memory for retrieval and analysis with Isco Flowlink® Software
- Activate sampling based on rainfall
- Plot graphs and print reports of rainfall data on the flow meter's built-in printer

The 674 rain gauge features a precision tipping bucket and 3-point leveling system for easy setup.

A 674 rain gauge connected to an Isco 6712 or Avalanche sampler is ideal for collecting rainfall data as well as runoff-triggered samples at remote monitoring sites.

Applications

- Stormwater runoff monitoring
- TMDL and Watershed surveys
- Inflow and infiltration studies
- cMOM and CSO/SSO programs (Sewer overflow monitoring and prevention)
- General rainfall measurement

Standard Features

- Three-point leveling and integral bubble level make it easy to align the rain gauge for maximum accuracy.
- Sapphire jewel bearings on the tipping bucket are spring-loaded to prevent damage to the bearings and ensure consistent operation over a wide temperature range.
- Screens cover all openings to prevent leaves, insects, and other debris from clogging the gauge.
- Included 50-foot cable connects directly to compatible Isco flow meters and samplers.

Specifications

Isco 674 Rain Gauge	
Type:	Tipping bucket
Compatible equipment:	Isco 6700, 6712, and Avalanche Samplers, 4200 Series Flow Meters, 4100 Series Flow Loggers
Connect cable:	50 ft. (15.2 m), 2 conductor with 4-pin plug
Bearings:	Spring-loaded sapphire jewel
Orifice Diameter:	8 in. (20 cm)
Sensitivity:	English - 0.01 inch; Metric 0.1 mm
Accuracy:	English - ±1% at 2 in/hour; +3%/-4% up to 5 in/hour Metric - ±1.5% at 5 cm/hour; +3.5%/-9% up to 13 cm/hour
Capacity:	English – 22 inches/hour Metric – 38 cm/hour
Output Signal:	Contact closure of at least 50 millisecond duration
Switch Type:	Hermetically sealed magnetic proximity switch. Normally open, 200V DC, 0.5 A maximum.
Height:	13 in. (33 cm)
Diameter:	9.5 in. (24 cm) (at mounting base)
Weight:	10 lbs. (4.5 kg)
Operating Temperature:	32° to 140°F (0° to 60°C)
Storage Temperature:	-40° to 140°F (-40° to 60°C)

The 674 Rain Gauge connects to any 6700 Series or Avalanche Sampler, 4200 Series Flowmeter, or 4100 Series Flow Logger. Rainfall data logged on the host instrument can be analyzed with Flowlink Software.

Ordering Information

The 674 rain gauge includes a 50 ft (15 m) cable for connection to an Isco 6700, 6712, or Avalanche Sampler, 4200 Series Flow Meter, or 4100 Series Flow Logger. Specify English or Metric version.

Description	Part Number
674 Rain Gauge	
English - Tips every 0.01 inch of rainfall	**60-3284-001**
Metric - Tips every 0.1 mm of rainfall	**68-3280-001**

TELEDYNE ISCO
Everywhereyoulook™

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Internet: www.teledyneisco.com

Isco 6712 Full-size Portable Sampler

Isco's 6700 Series Portable Samplers have set the industry standard, providing the most comprehensive and durable performance available. With the introduction of our new 6712, Isco takes another step toward the ultimate by including SDI-12 interface capabilities.

This full-size portable lets you take full advantage of the advanced 6712 Controller, with its powerful pump, versatile programming, and optional plug-in modules for integrated flow measurement. Setup is fast and simple, with online help just a key stroke away.

The environmentally-sealed 6712 controller delivers maximum accuracy and easily handles all of your sampling applications, including:

- Flow-paced sampling with or without wastewater effluent
- stormwater monitoring
- CSO monitoring
- permit compliance
- pretreatment compliance

In the Standard Programming Mode, the controller walks you through the sampling sequence step-by-step, allowing you to choose all parameters specific to your application. Selecting the Extended Programming Mode lets you enter more complex programs.

Optional land-line and GSM and CDMA cellular telephone modems allow programming changes and data collection to be performed remotely, from a touch-tone phone. They also provide dial-out alarm.

Bottle options are available for practically any sequential or composite application.

Versatile and Convenient

With eleven bottle choices, Isco's 6712 Sampler lets you quickly adapt for simple or intricate sampling routines. Up to 30 pounds (13.5 kg) of ice fits in the insulated base, preserving samples for extended periods, even in extreme conditions. The 6712 with the “Jumbo Base” option holds bottles up to 5.5 gallon (21 liter).

Tough and Reliable

The 6712 Portable Sampler features a vacuum-formed ABS plastic shell to withstand exposure and abuse. Its tapered design and trim 20-inch (50.8 cm) diameter result in easy manhole installation and removal. Large, comfortable handles make transporting safe and convenient—even when wearing gloves.

Isco's 6712 Portable Sampler carries a NEMA 4X, 6 (IP67) enclosure rating.

Superior capability, rugged construction, and unmatched reliability make the 6712 the ideal choice for portable sampling in just about any application.

Specifications

Isco 6712 Full-size Portable Sampler

Size (Height x Diameter):	27 x 20 inches (50.7 x 68.6 cm)
Weight:	**Dry, less battery - 32 lbs (15 kg)**
Bottle configurations:	24 - 1 Liter PP or 350 ml Glass 24 - 1 Liter ProPak Disposable Sample Bags 12 - 1 Liter PE or 950 ml Glass 8 - 2 Liter PE or 1.8 Liter Glass 4 - 3,8 Liter PE or Glass 1 - 9,5 Liter PE or Glass 1 - 5.5 gallon (21 Liter)PE or 5 gallon (19 Liter) Glass, (with optional Jumbo Base)
Power Requirements:	12 V DC (Supplied by battery or AC power converter.)

Pump

Intake suction tubing:	
Length	3 to 99 feet (1 to 30 m)
Material	Vinyl or Teflon
Inside dimension	3/8 inch (1 cm)
Pump tubing life:	Typically 1,000,000 pump counts
Maximum lift:	28 feet (8.5 m)
Typical Repeatability	±5 ml or ±5% of the average volume in a set
Typical line velocity at Head height: of	
3 ft. (0.9 m)	3.0 ft./s (0.91 m/s)
10 ft. (3.1 m)	2.9 ft./s (0.87 m/s)
15 ft. (4.6 m)	2.7 ft./s (0.83 m/s)
Liquid presence detector:	Non-wetted, non-conductive sensor detects when liquid sample reaches the pump to automatically compensate for changes in head heights.

Controller

Weight:	13 lbs. (5.9 kg)
Size (HxWxD)	10.3 x 12.5 x 10 inches (26 x 31.7 x 25.4 cm)
Operational temperature:	32° to 120°F (0° to 49°C)
Enclosure rating:	NEMA 4X, 6 (IP67)
Program memory:	Non-volatile ROM
Flow meter signal input:	5 to 15 volt DC pulse or 25 millisecond isolated contact closure.
Number of composite samples:	Programmable from 1 to 999 samples.
Clock Accuracy:	1 minute per month, typical, for real time clock

Software

Sample frequency:	1 minute to 99 hours 59 minutes, in 1 minute increments. Non-uniform times in minutes or clock times 1 to 9,999 flow pulses
Sampling modes:	Uniform time, non-uniform time, flow, event. (Flow mode is controlled by external flow meter pulses.)
Programmable sample volumes:	10 to 9,990 ml in 1 ml increments
Sample retries:	If no sample is detected, up to 3 attempts; user selectable
Rinse cycles:	Automatic rinsing of suction line up to 3 rinses for each sample collection
Program storage:	5 sampling programs
Sampling Stop/Resume:	Up to 24 real time/date sample stop/resume commands
Controller diagnostics:	Tests for RAM, ROM, pump, display, and distributor

Ordering Information

***Note**: Power source, bottle configuration, suction line, and strainer must be ordered separately. Many options and accessories are available for 6712 Samplers; see separate literature for 700 Series Modules and other components to expand your monitoring capabilities. Contact Isco, or your Isco representative for pricing and additional information.*

Description	Part Number
6712 Portable Sampler, Full-size Includes controller with 512kB RAM, top cover, center section, base, distributor arm, instruction manual, pocket guide.	**68-6710-070**
6712 Portable Sampler, with Jumbo Base As described above	**68-6710-082**

The 6712 Controller is also an SDI-12 data logger, and has many optional capabilities. Please contact Isco or your Isco distributor for more information.

TELEDYNE ISCO
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Robust ceramic pressure transducer for water level measurement

- Application
  Surface water, Groundwater
- Measurement technology
  Vented pressure cell
- Parameters measured
  Water level, Pressure, Temperature
- Product Highlights
  Water level and temperature measurement - for use with external data logger
- Measurement range
  0 ... 4, 10, 20, 40, and 100 m
- Accuracy
  ± 0.05% FS
- Internal data logger
  No
- Interface
  SDI-12, RS-485 (using SDI-12), or 4 ... 20 mA

The OTT PLS measures water level, depth to water, or pressure by means of an integrated controller and ceramic pressure-measuring cell. Design features such as multiple communication outputs (SDI-12 or 4 ... 20 mA), stainless steel housing, and a rugged cable make this sensor ideal for monitoring water level in a variety of applications.

Water level measurement	
Measurement range	0 ... 4 m, 10 m, 20 m, 40 m, 100 m

Accuracy	
SDI-12	±0.05 % FS (linearity and hysteresis)
4 ... 20 mA	±0.1 % FS (linearity and hysteresis) 10 ppm/°C at 20 °C
Resolution (SDI-12)	0.001 m; 0.1 cm; 0.01 ft; 0.1 mbar; 0.001 psi
Temperature compensated working range	-5 °C ... +45 °C (ice-free)

Temperature measurement	-25 °C ... +70 °C (ice-free)
Resolution	0.1 °C / 0.1 °F
Accuracy	±0.5 °C / ±0.9 °F

Electrical data	
Available interfaces (use as required)	4 ... 20 mA, SDI-12, RS485 (via SDI-12 protocol)
Supply voltage	+9.6 ... +28 V DC, typically 12/24 V DC

Power consumption (SDI-12)	
Sleep	<600 µA
Active	<3.6 mA

Pressure sensor	(capacitive pressure sensor) ceramic, temperature compensated, overload safe for up to 5 times the measuring range without permanent mechanical damage

Temperature sensor	NTC

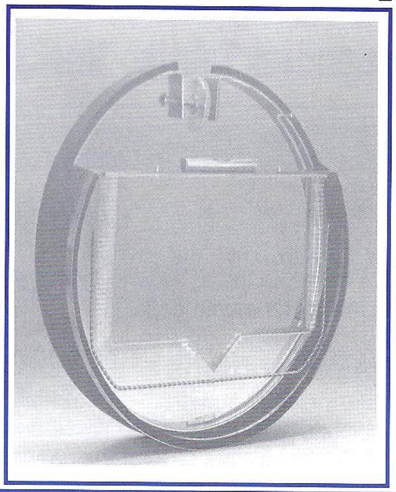
Dimensions	195 mm x 22 mm
Weight	approx. 0.3 kg

Environmental conditions	
Operating temperature	-25 ... +70 °C
Storage temperature	-40 ... +85 °C

Materials	
Housing	stainless steel 1.4539 (904L) resistant to sea water
Seals	Viton
Cable jacket	PUR
Protection type	IP68
Mechanical Strength	meets the mechanical shock tests of IEC 68-2-32

EMC limits	CE conformity; EN 61000-4-2/3/4/5/6 and EN 61000-6-3 Class B are adhered to

Volumetric Weir for Measuring Flows in Manholes and Open End Pipe

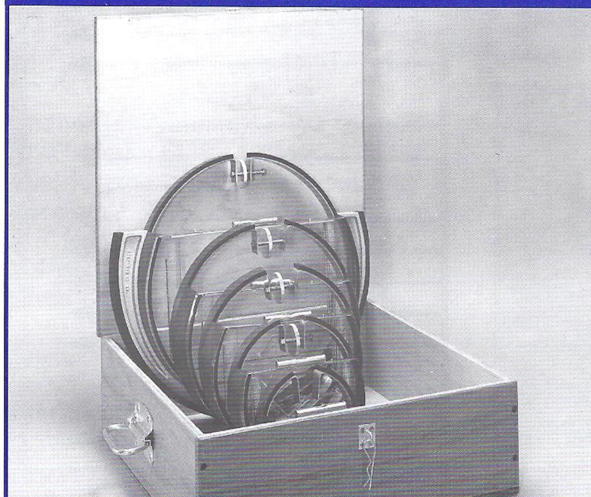


The Most Accurate Portable Flow Measuring Device Available

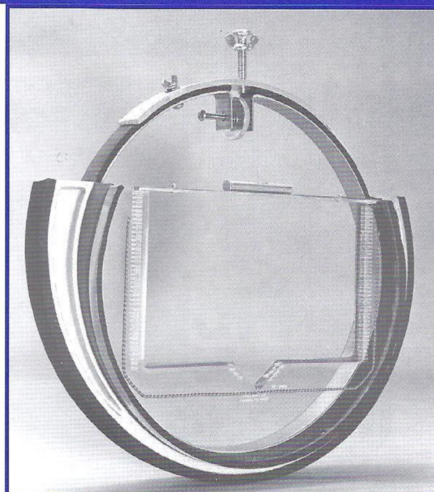
THEL-MAR COMPANY

Post Office Box 1529 • Brevard, North Carolina 28712
(828) 883-8908 • Fax: (828) 883-8908
TOLL FREE 1- 800-322-WEIR (9347)

WEIR SET



15" WEIR WITH 18" ADAPTOR



The Most Practical, Economical Instrument for Testing New Sewer Lines

A volumetric calibrated weir is a portable flow measuring device that is used to determine infiltration in newly installed sewer lines, or measure substantial flows in existing lines.

The Thel-Mar volumetric weir is basically a compound weir that incorporates the advantage of a 90° v-notch for measuring small infiltration flow where accuracy is of prime importance. The v-notch section measures from 57 gallons to 3700 gallons per 24 hours, which is the range of normal acceptance test requirements. The rectangular section of the weir is capable of measuring in gallons per day up to 35% of pipe capacity.

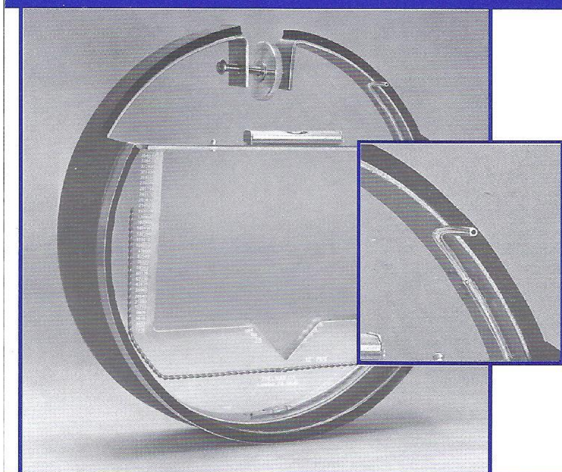
A bubble level is mounted at the top of the weir's face plate for easy visibility. Thel-Mar weirs are calibrated in U.S. gallons per 24 hours in large, easy to read type. Calibration lines are in 2 millimeter increments.

Discharge calibrations for the Volumetric Weir were accurately determined in a hydraulic laboratory where manhole conditions were duplicated. Therefore, there are no induced errors by insufficient drop of the nappe or by contractions, velocity of approach, submergency, or drawdown.

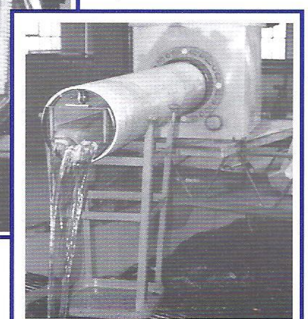
Rugged Construction and noncorroding materials make the Thel-Mar weir extremely reliable. There are no loose parts that require assembly. Installation is quick and positive and the weir requires a minimum of care.

Easy to read flow rate
Simply check water level at the face plate. The figure above the line matching the water level gives you the rate of flow in gallons per 24 hours.

WEIR WITH BUBBLER TUBE



University Tested



Lehigh University
Lab Photos

- Night Flow Studies of Existing Lines - Free Flow From Open Pipe.

A compound Weir offers minimum restriction to flow and is relatively free from becoming clogged by debris from sewage. **Thel-Mar Weirs** can be installed for extended periods of time without accumulation of sediment.

Errors in excess of 100% exist in other calibrated V-notch weirs.

Unlike the Thel-Mar weir these were calibrated by the Cone formula.

Bubbler Flow Meters

Especially designed for use with Bubbler Flow meters, all Volumetric Weirs are now available with an attached "Bubbler Tube". These weirs are manufactured with a ⅛-inch O.D. stainless steel tube attached to the right side of the adjustable ring. The bubbler tube protrudes forward approximately two inches from near the top of the ring for easy connection to a line. It runs for there down the inside of the ring to the center bottom approximately 1⅜-inch behind and below the V-notch. This bubbler tube does not in any way affect the function of the Volumetric Weir.

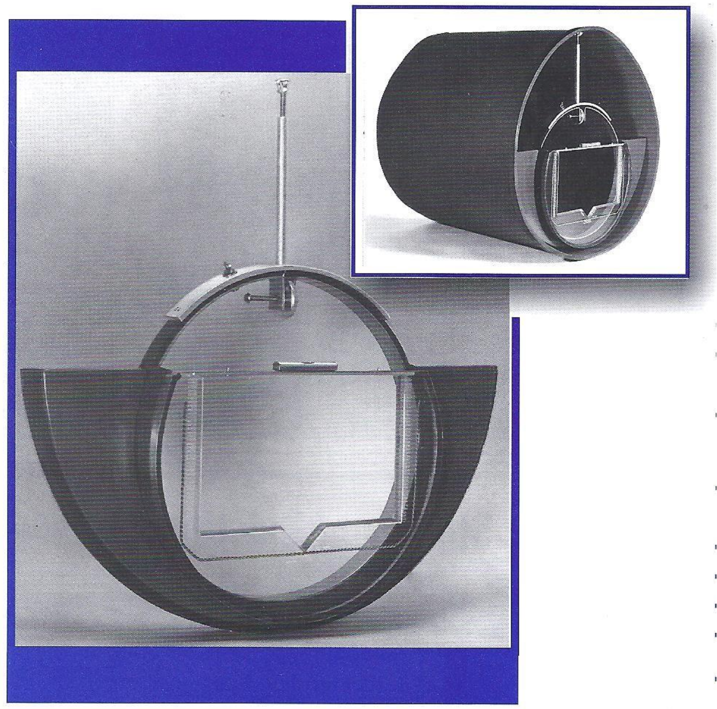
Installation Instructions

Prior to installation, the interior edge of the incoming pipe should be cleaned of sediment and foreign matter to assure seal of the gasket.

Turn thumb-wheel to extreme right. Place hand through weir opening, with thumb and index finger compress spring. Insert weir into incoming pipe about 1", adjust for leveling, press down and release tension from spring. Secure by turning thumb-wheel to left and finger tighten.

Allow sufficient time for water to back up behind the weir and establish a uniform flow; five to ten minutes for existing flow to an hour for accurate infiltration readings.

15" Weir with adaptor installed in 24" pipe



Individual Volumetric Weirs are available for 6", 8", 10", 12", 14", 15" and 16" pipe. The 14" weir uses a 12" face plate, while the 16" weir uses a 15" face plate. Adaptors for 18", 21", 24", 27", 30", 36", 42" and 48" pipe are used in conjunction with the 15" weir.

Volumetric Weirs are also available in sets.
Set A consists of 6", 8", 10", 12" and 15" weirs with an 18" adaptor
without a storage case.

Set B is the same as set A, but has Bubbler Tubes Attached to the weirs.

Set C consists of 21" through 48" adaptors **without a storage case.**

Adaptors are available individually or in sets.

WEIR CAPACITIES AND HEAD

Capacities*			Head**
6"	57 to 3700 GPD within V-notch,	rectangular to 46,000 GPD	2.8437
8"	57 to 3700 GPD within V-notch,	rectangular to 124,000 GPD	4.0000
10"	57 to 3700 GPD within V-notch,	rectangular to 234,000 GPD	5.1250
12"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
14"	57 to 3700 GPD within V-notch,	rectangular to 361,000 GPD	5.8125
15"	57 to 3700 GPD within V-notch,	rectangular to 620,000 GPD	7.3125
16"	57 to 3700 GPD within V-notch,	rectangular to 620,000 GPD	7.3125

*Calibration lines are in 2 millimeter increments
**In inches from top of rectangular opening to bottom of V-notch

Metric Flow Conversion Charts Available

Appendix H. Field Data Collection Forms

Sample Collection Field Form

Field staff name:			Date:
Test-Site Name:			Time:
Sample Number:	Weather Observation:		
Qualifying storm event Yes No			
Temperature Calibration:		pH Calibration:	
Sampling Equipment Condition:			
Oil Sheen Measurements/Observations:			
Sediment Composition:			
Water Temperature:		pH:	
Accumulated Sediment Volume:			
Pressure Transducer Staff Gauge Measurement (inches):			
Stormwater Samples Collected			
☐	Total Suspended Solids (TSS)		
☐	Metals (Zn, Cu)		
☐	Hardness as CaCO3		
☐	Ortho-phosphate (OP)		
☐	Total Phosphorus (TP)		
☐	Particle Size Distribution (PSD)		
QC Samples Collected			
☐	Rinsate Blank		
☐	Field Duplicate		
Comments:			

Storm Decision Log

<table>
<tr><th colspan="4">Pre-Storm</th></tr>
<tr><td colspan="3">Field staff name:</td><td>Date:</td></tr>
<tr><td colspan="3">Test Site Name:</td><td>Time:</td></tr>
<tr><td colspan="4">Source of Forecast:</td></tr>
<tr><td colspan="4">Location of Forecasted Storm (region):</td></tr>
<tr><td colspan="2">Predicted Rainfall:</td><td colspan="2">Predicted Rainfall is ≥ 0.15-inches? Y / N</td></tr>
<tr><td colspan="2">Predicted Storm Duration:</td><td colspan="2">Predicted Storm Duration is ≥ 1-hour? Y / N</td></tr>
<tr><td colspan="2">Predicted Antecedent Dry Period
Since the Last Storm:</td><td colspan="2">Predicted Antecedent Dry Period is ≥ 6-hours? Y / N</td></tr>
<tr><td colspan="4">Classification of Predicted Rainfall Event Meeting for Meeting Qualifying Rainfall Conditions:
Unlikely Marginal Likely</td></tr>
<tr><td>☐</td><td colspan="3">Attach a copy of the forecast to this sheet.</td></tr>
<tr><td>☐</td><td colspan="3">If deployment is OK'd, contact field staff and inform them of the storm characteristics and duration.</td></tr>
<tr><td>☐</td><td colspan="3">Monitor the precipitation data (available remotely) files. Notify field staff of storm status and if rain begins to fall on-site.</td></tr>
<tr><th colspan="4">Post-Storm</th></tr>
<tr><td colspan="2">Time of first rainfall on-site:</td><td colspan="2">Time of last rainfall on-site:</td></tr>
<tr><td colspan="4">Verify Storm event met qualifying rainfall event criteria (Section 7.5 of QAPP) Y / N
Note: If storm did not meeting qualifying conditions, water quality samples will not be submitted to the lab for analysis.</td></tr>
<tr><td colspan="4">Composite samples collected? Y / N</td></tr>
<tr><td colspan="4">Samples processed and sent to lab? Y / N</td></tr>
</table>

Periodic Maintenance Checklist Field Form

Field staff names:			Date:
			Time:
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):			

Maintenance Activities	**Activity Complete?**	**Notes (circle text as appropriate):**		
Debris/Obstruction Removal from piping		Debris removed? Y N		
Check voltage of battery		Measured voltage:	Voltage should be above 10.3V. If not, replace battery.	
Rain gage internal part cleanliness and level (quarterly)		Debris removed? Y N	Reset level of gage? Y N	
ISCO head tubing check		Tubing replaced? Y N		
ISCO pump tubing check		Tubing replaced? Y N		
ISCO suction tubing check		Tubing replaced? Y N		
ISCO Internal Humidity Indicator check		Indicator Color and Percent:		Desiccant replaced? Y N
PT #1 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
PT #2 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
PT #3 Humidity Indicator Check		Indicator Color:		Desiccant replaced? Y N
Deflate ISCO controller pad (as needed)				
ISCO pump capabilities				
ISCO volumetric verification (performed quarterly)		Service needed? Y N		

Pre-Storm Event Maintenance Checklist Field Form

Field staff names:			Date:	
			Time:	
Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):				
Maintenance Activities	**Activity Complete?**	**Notes (circle text as appropriate):**		
Check datalogger water surface elevation (WSE) against measured WSE		Reference elevation:	Uncertainty value (±) and reason:	
		Electronic water level indicator reading:	Measured WSE:	Datalogger WSE:
Debris/Obstruction Removal from piping		Debris removed? Y N		
ISCO head tubing check		Tubing replaced? Y N	Tubing cleaned? Y N	
ISCO pump tubing check		Tubing replaced? Y N	Tubing cleaned? Y N	
ISCO suction tubing check		Tubing replaced? Y N	Tubing cleaned? Y N	
Check level of weirs, pipe tees				
Pressure transducers (PT) and mounts cleaning		PTs cleaned? Y N	Mounts cleaned? Y N	
Pressure transducers (PT) reading check		PT reading zero flow? Y N	If no, PT reading:	Any drift observed? Y N Value:
Check tubing, bulkhead caps, and cable attachments				
Data logger and ISCO set to sample		DL set? Y N	ISCO set? Y N	
Threshold values set		Threshold value:		
pH meter inspection and cleaning		Service needed? Y N		
pH meter calibration		1st Calibration Point:	2nd Calibration Point:	

Monitoring Equipment Data Download Field Form

<table>
<tr><td rowspan="2">Field staff names:</td><td colspan="2">Date:</td></tr>
<tr><td colspan="2">Time:</td></tr>
<tr><td colspan="3">Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):</td></tr>
<tr><td colspan="2">Monitoring data covering the entire qualifying storm event and antecedent and post storm periods was downloaded:</td><td>☐</td></tr>
</table>

Falling Head Test Field Form

Field staff names:	Date:
	Time:

Any indication of damage/tampering during site inspection (surrounding area, pipes, cables, wiring, cords, tubing, monitoring equipment):

Trial #	H_1 (inches)	H_2 (inches)	ΔH (inches)	Time (seconds)	ΔTime (seconds)	A_1 (sqft)	A_2 (sqft)	Ksat (in/hr)	%Diff K_{sat}

$$K_{sat} = \frac{A_1}{A_2} \times \frac{L}{\Delta Time} \ln \frac{H_1}{H_2}$$

Where:

H_1 = initial ponded water depth above the top of the cell (inches)
H_2 = final ponded water depth above the top of the cell for time interval (inches)
Time = cumulative time for water to fall from H_o to H_i (seconds)
ΔTime = time interval for water to fall from Ho to Hi (seconds)
L = depth of BSM (inches)
A_1 = cell surface area at H_1 (sqft)
A_2 = cell surface area at H_2 (sqft)
L = depth of BSM (inches)

Field Audit Form

Note: items listed under each SOP are in order listed in the SOP. Reference the SOP to verify whether steps have been completed successfully.

Standard Operating Procedure (SOP)	**Actions Compliant with SOPs?**	**Comments:**
Storm Selection and Tracking	**Overall SOP audit notes:**	
All qualifying storm event criteria met		
Field staff contacted (as applicable)		
Laboratory contacted (as applicable)		
Precipitation data downloaded		
Storm Monitoring Equipment Maintenance	**Overall SOP audit notes:**	
Appropriate PPE		
General inspection of site, manhole, catch basin, and vault		
Inspection and/or cleaning of pipes, tees, weirs		
Battery voltage check		
Visit report started		
Rain gauge check (as applicable)		
ISCO tubing inspection and/or replacement		
ISCO internal humidity indicator check		
Pressure transducer humidity absorbing system check		
ISCO internal pressure check (indicated by keypad inflation)		
ISCO pump capabilities check		
ISCO volumetric verification test		
Visit report ended		
Equipment secured prior to leaving site		

Preparing Stormwater Monitoring Equipment for Storm Sampling	**Overall SOP audit notes:**	
Appropriate PPE		
General inspection of site, manhole, catch basin, and vault		
Start visit report		
Water surface elevation measurement check		
Inspection and/or cleaning of pipes, tees, weirs		
ISCO tubing inspection and cleaning (replace if needed)		
Obtain rinsate blank (using clean hands/dirty hands procedures)		
Rinsate blank sample bottles labeled		
COC filled out		
Check whether weirs, pipe tees are level		
Inspection and/or cleaning of pressure transducers, mounts		
Check and/or adjustment of pressure transducer reading		
Added ice to ISCO		
Install sample bottle (using clean hands/dirty hands procedures)		
Check and/or secure ISCO tubing, caps, and cable connections		
Data logger and ISCO set to sample		
Visit report ended		
Equipment secured prior to leaving site		
pH meter maintenance		
pH meter calibration		

Stormwater Sample Collection and Processing	**Overall SOP audit notes:**	
Appropriate PPE		
Start visit report		
Water surface elevation measurement check		
Check whether sampling has been disabled		
Visual verification of aliquots collected		
pH measurement		
Stormwater composite sample collection		
Sample bottles labeled		
COC filled out		
Clean hands dirty hands procedures followed		
End visit report		
Filtration for composite samples performed		
Monitoring Equipment Download	**Overall SOP audit notes:**	
Appropriate PPE		
Data downloaded covers entire event?		
Sediment Accumulation Rate	**Overall SOP audit notes:**	
Appropriate PPE		
Sediment samples collected		
Sample bottles labeled		
COC filled out		
Falling Head Test	**Overall SOP audit notes:**	
Appropriate PPE		
Falling head test performed		

QA Worksheet

Matrix	Parameter	Method	Chain-of-Custody Issues?	Completeness/ Methodology	Holding Times (days)		Cooler Temperature	Blanks/ Reporting Limit	Matrix Spikes/ Surrogate Recovery (%)		Lab Control Samples Recovery (%)		Lab Duplicates RPD (%)		Field Duplicates RPD (%)		Instrument Calibration/ Performance	ACTION
					Reported	Goal			Reported	Goal	Reported	Goal	Reported	Goal	Reported	Goal	OK	
Stormwater	Total Suspended Solids (TSS)	SM 2540D																
	Dissolved Copper (Cu) and Zinc (Zn)	EPA 200.8 (ICP/MS) or SM 3125 (ICP/MS)																
	Total Copper (Cu) and Zinc (Zn)																	
	Hardness as CaCO3	SM 2340B (ICP)																
	Ortho-phosphate (OP)	SM 4500-P G																
	Total Phosphorus (TP)	SM 4500-P F																
	PSD, Influent	ASTM D3977-97 Modified SSC method																
BSM	Cation Exchange Capacity	S-10.10																
	Saturated Hydraulic Conductivity	Modified ASTM D2434 (Ecology, 2014a)																
	Particle Size Distribution	ASTM D422																
	Total Elements (Zn and Cu)	EPA 3050A/6010B																
	Organic Matter Content	ASTM D2974 or TMECC 5.07A																

Training Completion Log

Employee Name	Date	Storm Selection and Storm Tracking	Equipment Cleaning and Calibration	Storm Monitoring Equipment and Setup	Water Quality Sampling

Appendix I. Chain of Custody Forms

Anatek Labs, Inc.

Chain of Custody Record

1282 Alturas Drive, Moscow ID 83843 (208) 883-2839 FAX 882-9246
504 E Sprague Ste D, Spokane WA 99202 (509) 838-3999 FAX 838-4433

Anatek Log-In #

Company Name:	Project Manager:	**Turn Around Time & Reporting**
Address:	Project Name & # :	Please refer to our normal turn around times at: http://www.anateklabs.com/services/guidelines/reporting.asp
City: State: Zip:	Email Address :	__Normal __Next Day* __2nd Day* __Other*______ *All rush order requests must be prior approved.
Phone:	Purchase Order #:	__Phone __Mail __Fax x Email
Fax:	Sampler Name & phone:	

Provide Sample Description

synthetic stormwater influent and effluent

List Analyses Requested

Note Special Instructions/Comments

Lab ID	Sample Identification	Sampling Date/Time	Matrix	# of Containers	Sample Volume										
				Preservative:											

	Printed Name	Signature	Company	Date	Time
Relinquished by					
Received by					
Relinquished by					
Received by					
Relinquished by					
Received by					

Inspection Checklist

Received Intact?	Y	N
Labels & Chains Agree?	Y	N
Containers Sealed?	Y	N
VOC Head Space?	Y	N

Temperature (°C):____________

Preservative:____________

____

Date & Time:____________

Inspected By:____________

Form COC01.00 - Eff 1 Mar 2015

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Samples submitted to Anatek Labs may be subcontracted to other accredited labs if necessary. This message serves as notice of this possibility. Sub-contracted analyses will be clearly noted on the analytical report.

soiltest farm consultants, inc.
2925 Driggs Dr., Moses Lake, Wa 98837 - www.soiltestlab.com
Office: (509)765-1622 - Fax:(509)765-0314 - (800)764-1622

Laboratory Chain of Custody

Client: Please fill out:	Copy of report sent to:
Company:	Company:
Contact:	Contact:
Address:	Address:
City, ST, Zip.:	City, ST, Zip.:
Telephone:	Telephone:
Fax:	Fax:
e mail:	e mail:

Date: ____________

Page ______ of ______

Job #/ Name: ____________

Payment Method: Credit Card____ Est. Acct.___

Write sample information in horizontal rows. Write test name(s) or code(s) in verticle boxes at left. Mark an "X" at the intersection(s) where appropriate.

				Analyses Requested					Lab Use Only	
Sample Identification	Date Sampled	No. of Containers	Sample Matrix						Sample Condition	LAB ID

Releasing	Date/Time	Receiving	Date	Time
Releasing signature 1		Receiving Signature 1		
Releasing signature 2		Receiving Signature 2		
Releasing signature 3		Receiving Signature 3		

Submission of samples to Laboratory with a Chain of Custody constitutes a contract for services requested. Provide payment detail with each COC. If no payment information is provided, you will be contacted by the laboratory. We will make every effort to provide an accurate analysis of this sample. For reasonable cause, we will repeat the tests, but because of factors beyond our control, in sampling procedures and inherent sample variability in compost, soils, plants and water our liability is limited to the price of the tests.

Appendix J. Corrective Action Plan Table

#	Date Need for Corrective Action Was Identified	Issue Identified	Summary of Corrective Action	Implementation Date of Corrective Action
1	6/18/2020	Lab which analyzes stormwater PSD samples was updated from Budinger to MTC	Updated references to laboratory used for stormwater PSD samples in QAPP	6/23/2020
2	6/18/2020	Change to Project Schedule	Added note to schedule	6/23/2020

Appendix K. Previous Data Collected at Test Site

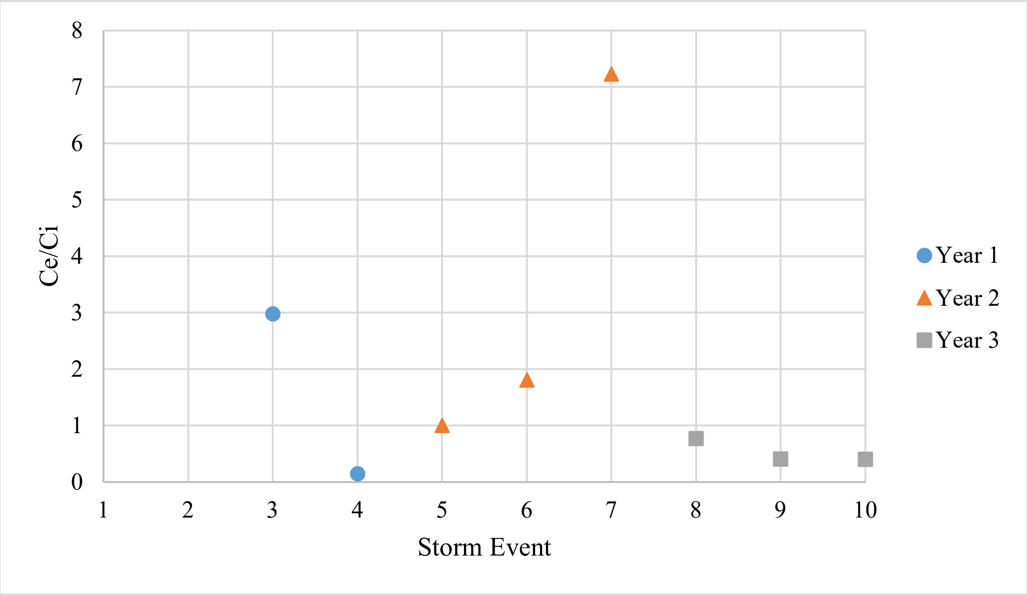

Figure 27: 12" Dissolved Copper Pollutant Reduction Ratio

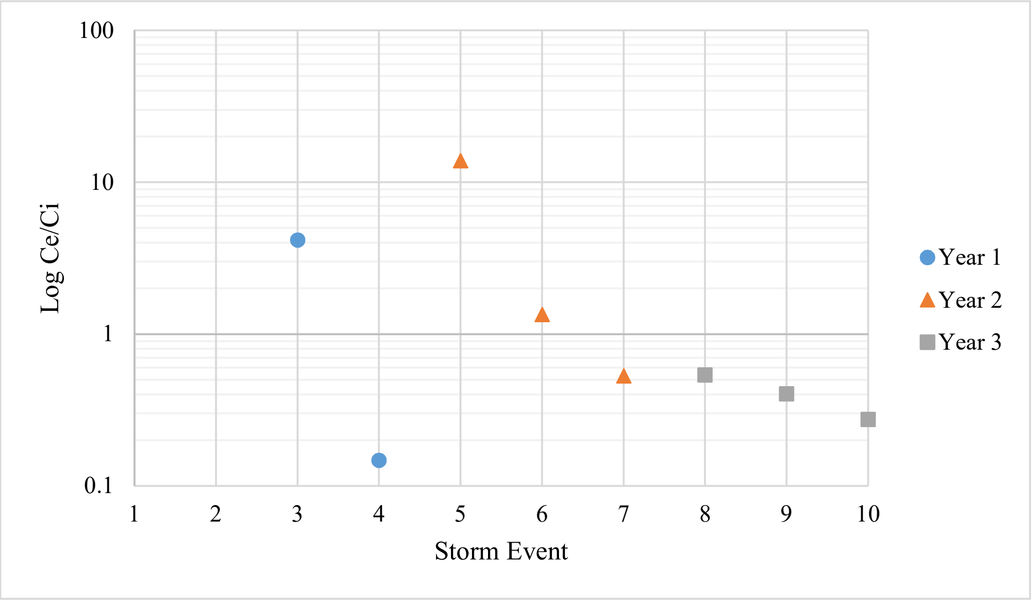

Figure 28: 18" Dissolved Copper Pollutant Reduction Ratio

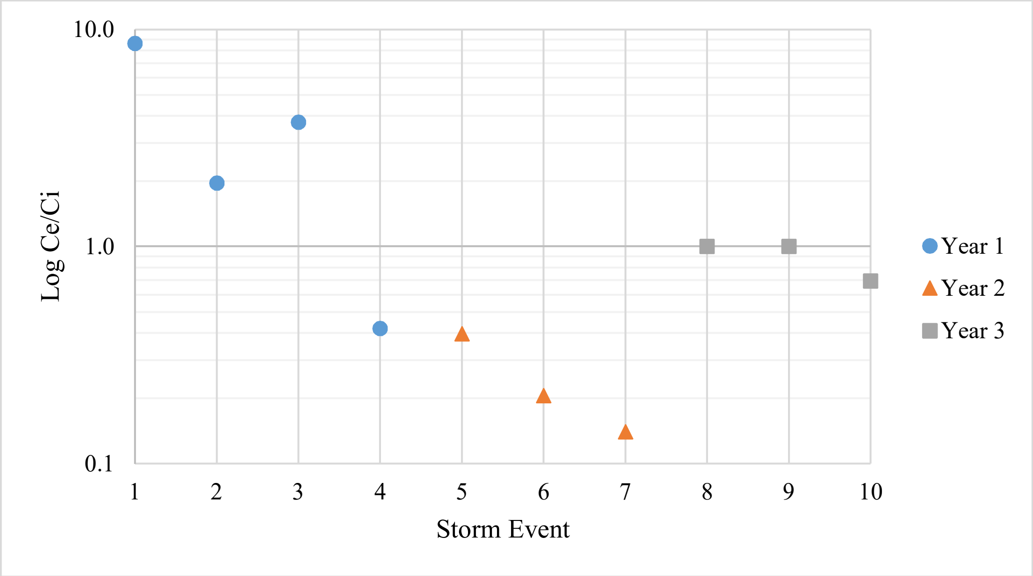

Figure 29: 12" NO3/N+NO2/N Pollutant Reduction Ratio

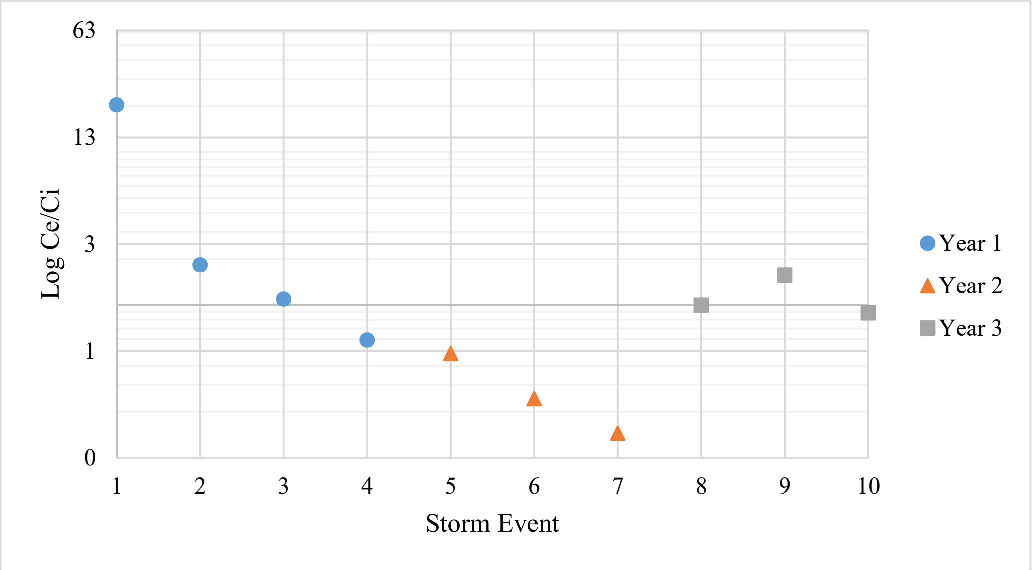

Figure 30: 18" NO3/N+NO2/N Pollutant Reduction Ratio

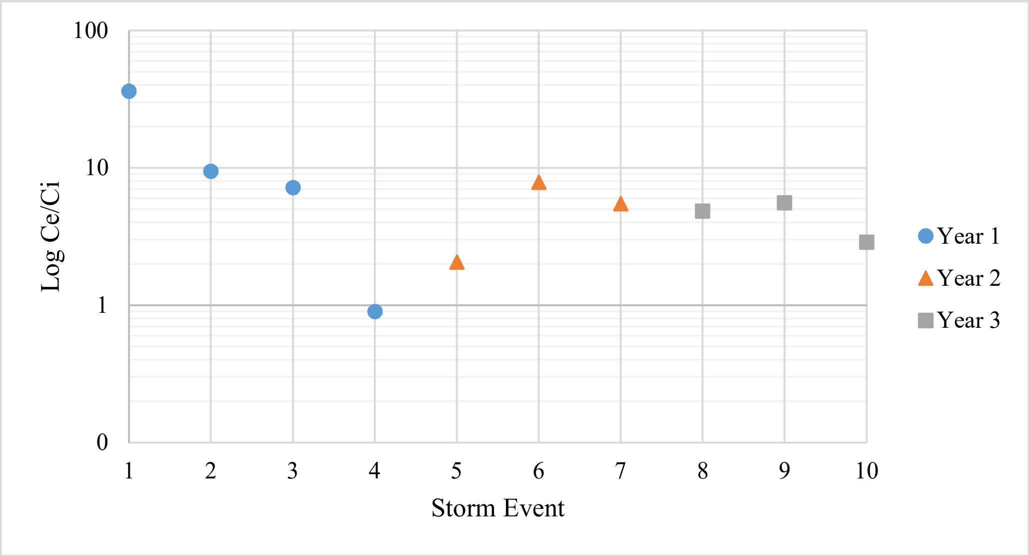

Figure 31: 12" Total Phosphorous Pollutant Reduction Ratio

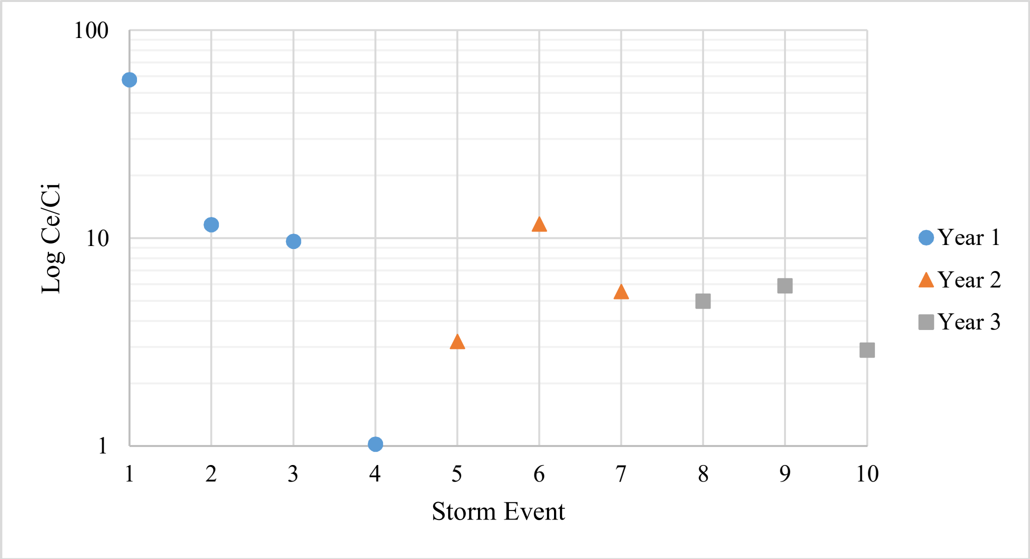

Figure 32: 18" Total Phosphorous Pollutant Reduction Ratio

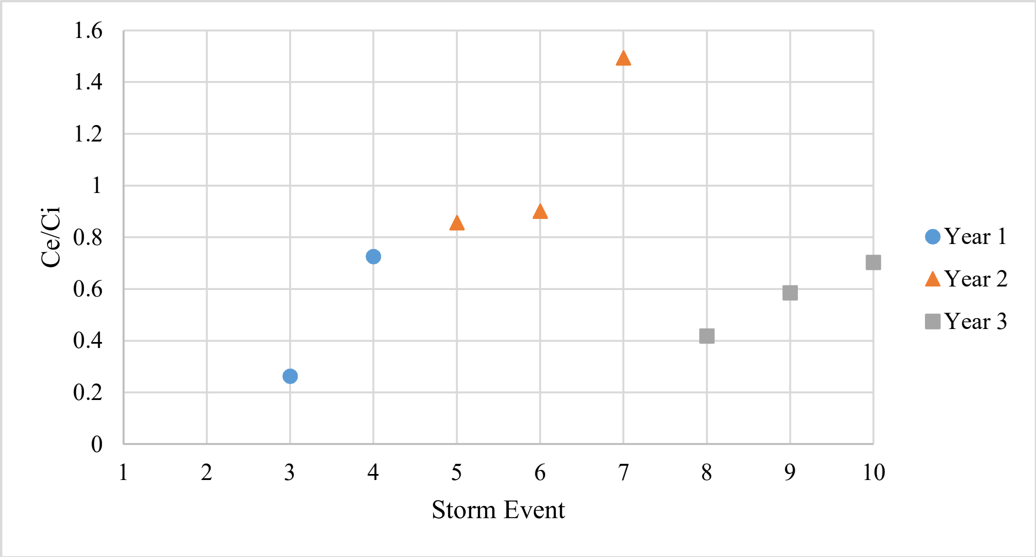

Figure 33: 12" Dissolved Zinc Pollutant Reduction Ratio

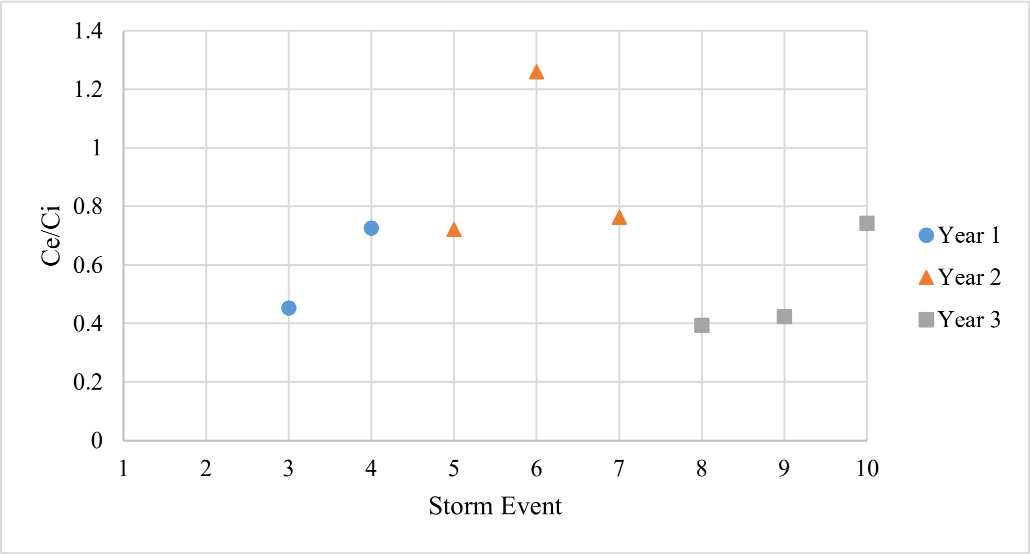

Figure 34: 18" Dissolved Zinc Pollutant Reduction Ratio

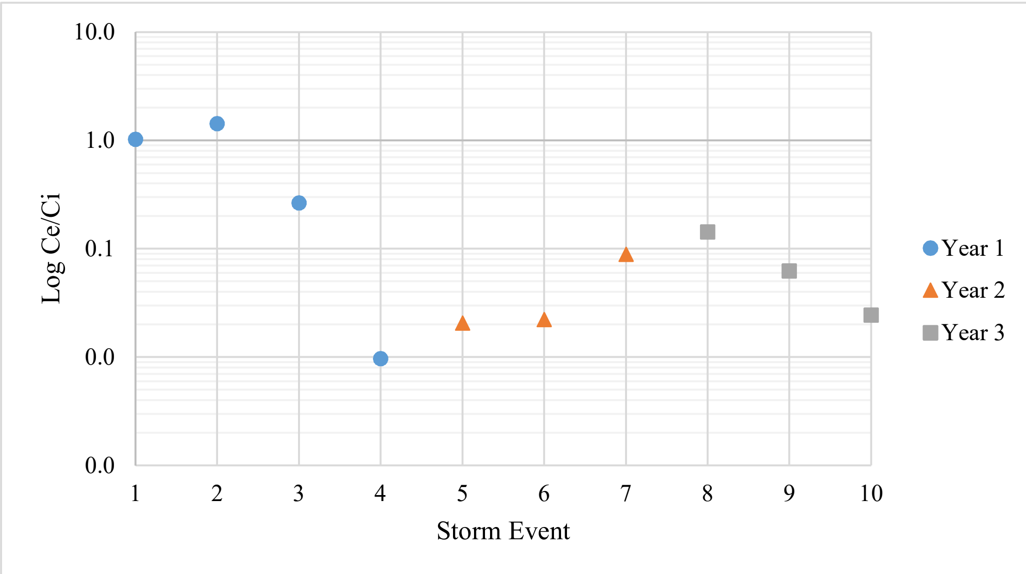

Figure 35: 12" TSS Pollutant Reduction Ratio

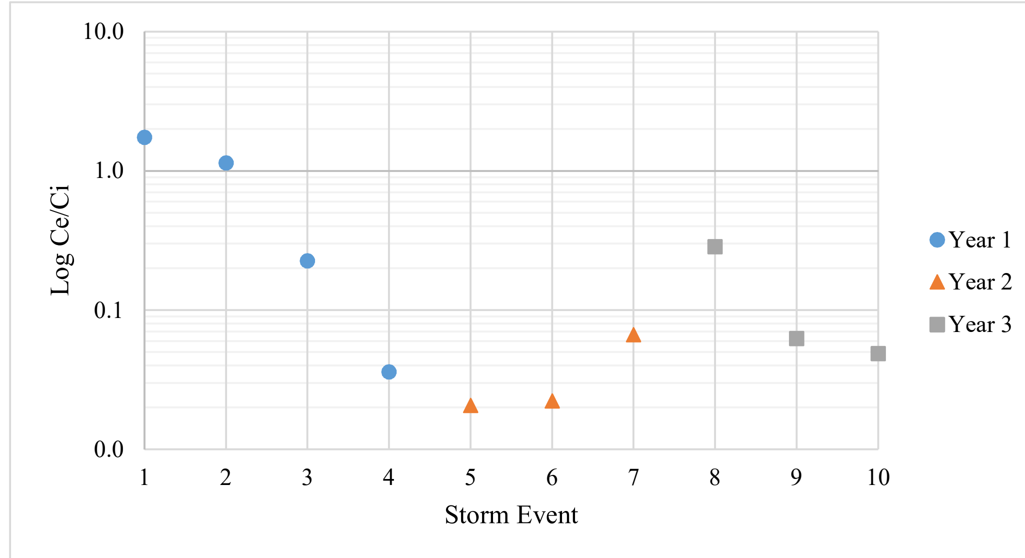

Figure 36: 18" TSS Pollutant Reduction Ratio

Note: Some of the Ce/Ci graphs used a log scale when it was difficult to decipher whether there was a trend in the data or not. Graphs with a log scale have the y-axis labeled as so.

Appendix L. Data Logger Threshold Spreadsheet Calculator

The threshold values entered into the data logger determine when the data logger and ISCOs initiate sampling: once a threshold is reached, the data logger sends the signal to the respective automated sampler to begin sampling. At the study location, the threshold values refer to the volume of water which is expected to enter the monitoring system and BMP. The values vary depending on the precipitation depth of the upcoming storm, and are calculated in Excel using a modified version of the Rational Method. An example of the spreadsheet is shown below and the analysis methods are described on the next page. *Note: the total volume sampled in the table below is for example purposes only and does not reflect the total volume to be sampled at the site.*

Table L.1 Example Threshold Calculation

Rainfall (in)	Runoff (cft)	Liters (cumulative)	Number of Samples	Aliquot Volume (L)	Interval	Total Volume Sampled (L)
0.000	0.00	0	0	0.250	0	0
0.01	16.34	463	28	0.250	17	7
0.02	32.67	925	28	0.250	33	7
0.03	49.01	1388	28	0.250	50	7
0.04	65.34	1850	28	0.250	66	7
0.05	81.68	2313	28	0.250	83	7
0.06	98.01	2775	28	0.250	99	7
0.07	114.35	3238	28	0.250	116	7
0.08	130.68	3700	28	0.250	132	7
0.09	147.02	4163	28	0.250	149	7
0.1	163.35	4626	28	0.250	165	7
0.11	179.69	5088	28	0.250	182	7
0.12	196.02	5551	28	0.250	198	7
0.13	212.36	6013	28	0.250	215	7
0.14	228.69	6476	28	0.250	231	7
0.15	245.03	6938	28	0.250	248	7
0.16	261.36	7401	28	0.250	264	7
0.17	277.70	7863	28	0.250	281	7
0.18	294.03	8326	28	0.250	297	7
0.19	310.37	8789	28	0.250	314	7
0.2	326.70	9251	28	0.250	330	7
0.21	343.04	9714	28	0.250	347	7
0.22	359.37	10176	28	0.250	363	7
0.23	375.71	10639	28	0.250	380	7
0.24	392.04	11101	28	0.250	396	7
0.25	408.38	11564	28	0.250	413	7
0.26	424.71	12026	28	0.250	430	7
0.27	441.05	12489	28	0.250	446	7
0.28	457.38	12952	28	0.250	463	7

Note: these calculations do not account for evaporation.

The first column lists possible (predicted) precipitation depths. The second column is runoff calculated from the following equation:

$$V = CiA$$

Where:

$V = predicted\ volume\ of\ runoff, ft^3$
$C = rational\ method\ coefficient\ for\ impervious\ surfaces, 0.90$
$i = precipitation\ depth, in.$
$A = contributing\ basin\ area, ft^2$

As mentioned previously, the precipitation depth is listed in the first column. The contributing basin area at the study location is approximately 18,000 square feet, as described in Section 4.3. The resulting volume of runoff is converted to liters in the third column.

The values in the fourth and fifth columns represent the number of aliquots and volume of each aliquot pulled by the ISCO, respectively. The minimum number of aliquots that can be taken by the ISCO is 10, and the maximum number of aliquots that can be taken is 35. During the study, the ISCO will be set to sample 35 aliquots. The product of the fourth and fifth columns is equal to the total volume pulled by the automated samplers, in the seventh column. The total volume pulled by the automated samplers must be sufficient for the quantity and types of samples needed at the study location. The threshold value is equal to the total runoff in liters divided by the number of aliquots pulled by the ISCO. This volume determines when the data logger should start in order to obtain a representative sample by obtaining equal volumes (aliquots) spaced evenly throughout the storm.

For example, Table N.1 displays the threshold value for a storm rainfall depth of 0.15 inches (highlighted in green). Given the amount of runoff that is expected for the rainfall depth, the ISCOs would need to start sampling once 205 liters had entered the influent and effluent pipes in order to obtain the aliquots and total sample volume needed during the storm.