Appendix 25 – Long-term PP Sidewalk Infiltration Performance Proposal

Eastern Washington
Stormwater Effectiveness Studies

Detailed Study Design Proposal:
Long-term Permeable Pavement Sidewalk Infiltration Rate

Study Classification:

☑ Structural BMP ☐ Operational BMP ☐ Education & Outreach

Study Objective(s):

☑ Evaluate Effectiveness ☑ Compare Effectiveness
☐ Develop Modified BMP ☐ Develop New BMP

June 30, 2017

Prepared For:

City of Spokane Valley
Public Works Department
11707 East Sprague Avenue, Suite 106
Spokane Valley, Washington 99206-6124
(509)720-5018

Lead Entity
Department
Street Address
City, WA Zip Code
Phone Number

Prepared By:

HDR, Inc.
1401 E. Trent Ave., Suite 101
Spokane, WA 99202
(509)343-8500

Drummond Carpenter, PLLC
9085 Montezuma Ave.
Kalamazoo, MI 49009
(248)763-4099

Proposal Publication Information

This Detailed Study Design Proposal (Proposal) will be stored and accessible to the public at the following weblink: Add Weblink where the Proposal can be accessed by the Public

For questions regarding the Proposal, please contact First and Last Name of Lead Entity Contact by email add email address or phone (509)XXX-XXXX.

Proposal Author and Contact Information

Donald D. Carpenter
Drummond Carpenter, PLLC
Principal
9085 Montezuma
Kalamazoo, MI 49009
dcarpenter@drummondcarpenter.com
248.763.4099

Proposal Peer Review and Contact Information

Aimee S. Navickis-Brasch
HDR, Inc.
Senior Stormwater Engineer
1401 E. Trent Ave., Suite 101
Spokane, WA 99202
(509)343-8515

QAPP Publication Information

This item will be added for the QAPP.

QAPP Author and Contact Information

This item will be added for the QAPP.

Signature Page - Proposal

Approved by:

Date 6/22/17

Donald D. Carpenter, Primary Author, Drummond Carpenter PLLC

Date 6/25/2017

Aimee Navickis-Brasch, Peer Review, HDR, Inc.

Date

Name, Lead Entity, Jurisdiction

Date

Karen Dinicola, Ecology, Phase 2-3a Gross Grant Project Manager

Date

Doug Howie, Ecology, Reviewer Structural and Operational BMP Studies

Date

Brandi Lubliner, Ecology, Reviewer Monitoring System Designs

Signature Page – QAPP Only

This section will be completed for the QAPP.

List each party responsible for the contents of the QAPP and the project along with their project title, and organization. Each party must sign and date this page before the study proceeds to the implementation phase (i.e. conduct the study).

Distribution List – Proposal

This section includes the distribution list for each party who will receive an Ecology approved copy of the Proposal.

Name, Title	Organization	Contact Information: Email, Telephone
Name Lead Entity Contact, Title	Lead Entity Jurisdiction	Email Phone number
Art Jenkins, Stormwater Engineer	City of Spokane Valley	ajenkins@spokanevalley.org 509.720.5018
David Haws, Water Resource Supervisor	Yakima County	David.Haws@co.yakima.wa.us 509.574.2300
Karen Dinicola, Phase 2-3a Gross Grant Ecology Project Manager	Department of Ecology	kdin461@ecy.wa.gov 360.407.6550
Doug Howie, Reviewer Structural & Operational BMPs	Department of Ecology	DOHO461@ecy.wa.gov 360.407.6444
Brandi Lubliner, Reviewer Monitoring System Designs	Department of Ecology	brwa461@ecy.wa.gov 360.407.7140
Donald Carpenter, Proposal Author	Drummond Carpenter	dcarpenter@drummondcarpenter.com 248.763.4099
Aimee Navickis-Brasch, Proposal Peer Review	HDR, Inc.	aimee.navickis-brasch@hdrinc.com 509.343.8515

Distribution List - QAPP Only

During the QAPP development, this section should be updated to include a list of each party who will receive copies of the approved **QAPP** as well as any subsequent revisions along with their contact information. This may include those who is responsible for the QAPP development and project implementation including project managers, QA managers, representatives of other groups/agencies involved, field staff, etc.

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3.0 Introduction and Background

3.1 Introduction to the Structural BMP

Permeable pavement is generally classified into one of four categories – permeable asphalt, pervious concrete, permeable interlocking concrete pavers (PICP), and reinforced grid systems (either plastic or concrete). Permeable pavement allows stormwater to infiltrate into the subsurface soils instead of running off into a traditional stormwater conveyance network. Permeable pavement can be installed over a wide range of pedestrian or low velocity vehicular applications and has been demonstrated to be effective in cold weather climates. The permeable pavement being evaluated in this effectiveness study is pervious concrete (Figure 1).

Figure 1: Picture of pervious concrete (Ecology (2013) c/o HDR Engineering).

Figure 2 provides the typical design cross-section for pervious concrete (Ecology 2014a). The Eastern Washington (EWA) Low Impact Development (LID) Guidance Manual (Ecology 2013) provides design recommendations for pervious concrete that are derived from 522.1-08: Specification for Pervious Concrete Pavement (ACI 2008). The specifications for pervious concrete are well described in the manual and include information on materials, preparation, placement, finishing, curing, and quality control. All specified design criteria will be followed during design and construction of the pilot segments by referring to appropriate documents in the project design specifications.

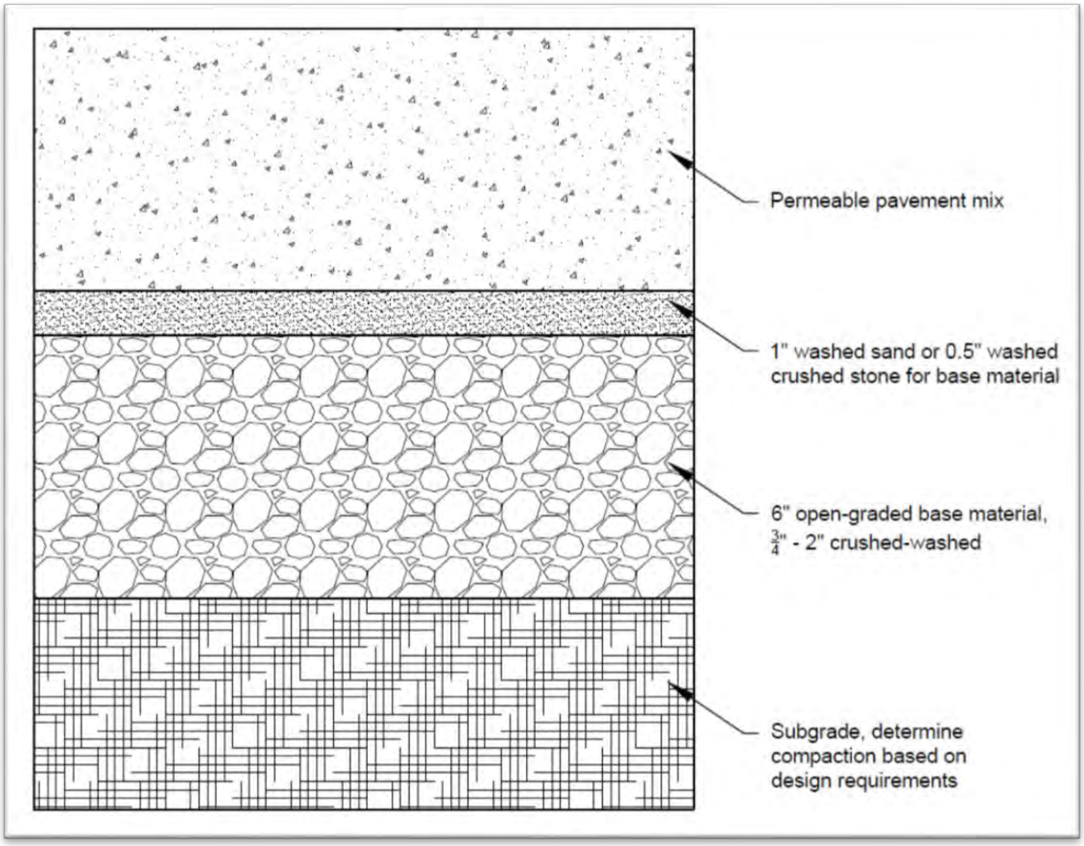

Figure 2: Typical pervious concrete cross-section (Ecology, 2014a).

The structural BMP being evaluated in this Effectiveness Study is pervious concrete (PC) sidewalks. The PC sidewalks will primarily receive influent from rainfall. When functioning properly, the effluent will flow through the stone sub-base and ultimately infiltrate into the ground. An effort will be made during design and construction to minimize, or at least account for, the effect of runoff from adjacent surfaces. For situations where influent from adjacent surfaces does occur, the control and test segments should be comparable and receive similar volumes of water. The overall contributing drainage area will be delineated as part of the design phase of the investigation.

Currently, the State of Washington Department of Ecology (Ecology) considers permeable pavement to be a flow control BMP but does not offer a water quality treatment credit for stormwater passing through a standard permeable pavement wearing course or the aggregate base (Ecology 2013, Ecology 2014a). However, water quality treatment requirements can be attained by infiltrating the water into a specified sub-base using one of the following design approaches (Ecology 2014a):

- *Infiltrate the runoff into subgrade soils that have a cation exchange capacity of ≥ 5 milliequivalents/100 grams dry soil, minimum organic matter content of 0.5 percent and a maximum infiltration rate of 12 inches per hour (short-term or measured rate).*
- *The soil must have the above characteristics for a minimum depth of 18 inches.*

- *Design a treatment layer into the aggregate base that has the characteristics described above for subgrade soils.*

As a flow control BMP, permeable pavements reduce the overall runoff volume from the tributary area by promoting infiltration. However, this only occurs if the infiltration rate of the permeable pavement surface is maintained.

3.2 Problem Description

Permeable pavement usage for sidewalks is becoming more common in Eastern Washington. Permeable pavement is more expensive than conventional paving materials, so its functionality as a stormwater BMP and service life is important to justify the additional per unit installation costs and increased maintenance. The advantage of permeable pavement is that it can reduce the size of the down-gradient stormwater conveyance network. However, there are concerns that Eastern Washington's harsh climate will affect both long-term infiltration performance and durability. Specifically, there are concerns that frequent freeze-thaw cycling may shorten the durable lifespan of the surface, and that deposition of sediments and organic matter may cause clogging and reduce infiltration rate of the pavement.

3.3 Results of Prior Studies

Section 3.3 is not required for the proposal (only for QAPP), but a preliminary literature review (Section 3.3.1) yielded several relevant findings including:

- Permeable pavements (PP) have proven effective in cold climates
- A vast majority of reported research findings are based on parking lots or roads; studies involving sidewalks were not prevalent in the literature
- Maintenance has shown to rejuvenate the infiltration rate of PP but research investigations were based on parking lot or road applications
- The effect of dry windy conditions, and atmospheric deposition of sediments, has not been investigated

The first above bullet makes the use of PP in EWA promising and the final three above bullets demonstrate the need for this Effectiveness Study. This section will be expanded during QAPP development.

3.3.1 Preliminary Literature Review

Based on numerous investigations, permeable pavements have been shown to effectively remove total suspended solids (TSS) along with removal of some heavy metals and nutrients (Leisenring et al 2014). In addition, studies regarding infiltration performance and durability of permeable pavement have been conducted in a range of locations and climates (Bean et al 2007, Brown and Borst 2014, Alizadehtazi et al 2016, Dietz 2007, etc.). While these studies have been rigorous, there are still questions about how permeable pavement would perform in Eastern Washington's dry, windy environment with cold winters and hot summers since these conditions have not been reported on in the literature.

Several studies (e.g., Lebens and Troyer 2012, Schauss 2007, Roseen et al 2009) address performance in cold climates where freeze thaw cycling is common. These studies have shown that when appropriate asphalt or cement mixes are used, the durability of the pavement can nearly equal that of conventional paving materials and that infiltration performance does not suffer as a result of freeze-thaw cycling. Specifically, there are two recent research reports that will inform this investigation:

- Drake, J., Bradford, A., Van Seters, T., and MacMillan, G. (2012). *Evaluation of Permeable Pavements in Cold Climates Kortright Centre, Vaughan.* Toronto and Region Conservation and University of Guelph. Downsview, Ontario.
- Weiss, P. T., Kayhanian, M., Khazanovisch, L., Gulliver, J. S. (2015). *Permeable Pavements in Cold Climates: State of the Art and Cold Climate Case Studies.* MN/RC 2015-30. Minnesota Department of Transportation Research Services & Library. Minneapolis, MN.

Drake et al (2012, 2014) reported on a three-year investigation on the performance of permeable pavement under Ontario conditions including low permeability native soils and cold climates. The investigation included two PICP systems and PC. They found that the systems delayed the time to peak discharge and reduced peak flows and volumes in all seasons and completely captured (through infiltration and evaporation) small events despite the poorly draining underlying native soils. After two years without maintenance, the systems did exhibit reduced surface infiltration capability. However, there was a partial restoration of the infiltration performance after vacuum cleaning and the researchers recommend vacuum cleaning of PC every two years to maintain infiltration. With regards to winter performance, they observed infiltration even during freezing conditions. They also determined the PP did not require salting as frequently as traditional pavements since there was less snow and ice buildup.

The Weiss et al (2015) report is very comprehensive and included a summary of Drake et al (2012) along with research performed in Minnesota, Colorado, and Washington. They reviewed structural design, hydrologic design, infiltration, maintenance, and cold climate performance and provided numerous recommendations on all facets of PP. The Minnesota-specific PP research investigations documented water quantity and quality findings that were consistent with other investigations, citing significant reductions in runoff and pollutant loads. Regarding winter performance, the Minnesota research reported infiltration rates were maintained during the entire year. The Minnesota investigations also reported that PP resisted freeze/thaw effects, increased skid resistance, and enhanced melting rates required which reduced plowing and the use of de-icing materials. Several of the Minnesota projects have been in place for 10 years and are still performing very well with high infiltration rates and limited surface structural degradation. There was a reduction in surface infiltration rates due to clogging, but that did not affect the overall hydrologic performance as long as periodic maintenance was performed. They recommend annual vacuuming and/or pressure washing of permeable pavements but mechanical sweeping was not recommended because it can push particles further into the system.

With regards to maintenance, it has been documented that some pervious concrete sites have continued to infiltrate for years without any routine maintenance (Roseen et al 2009, Lunn 2015, Brown and Borst 2014); however, ongoing infiltration performance is highly variable due to loading ratios (ratio of drainage area to BMP surface area) and amount of sediment and debris deposited on to the surface. It could be desirable to lengthen the time between maintenance as a cost savings measure, but there is a risk of the surface area being clogged. However, it has been documented that a clogged surface can be rejuvenated through maintenance (Figure 3). As such, effective maintenance is a balance and some operators recommend only cleaning when inspections or infiltration rate tests indicated a specific reduced performance (i.e. a threshold infiltration rate) below which the system should be cleaned (Brown and Borst 2014).

Figure 3: Comparison of PC that has and had not been maintained (NRMCA 2015).

3.4 Regulatory Requirements

The Eastern Washington Phase II Municipal Stormwater Permit issued to the lead entity by the Department of Ecology Washington State requires the Stormwater Management Program Effectiveness Studies. 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. The lead entity proposes to serve as the lead entity for the following effectiveness study: Long-term Permeable Pavement Sidewalk Infiltration Rate Study. Section S5.B.5 and S5.B.6 of the permit (Ecology 2014b) are specifically addressed by this investigation.

S5.B.5 Post-Construction Stormwater Management for New Development and Redevelopment

> According to the permit issued by Ecology (2014b), "all Permittees shall implement and enforce a program to address post-construction stormwater runoff to the MS4 from new development and redevelopment projects that disturb one acre or more, and from projects of less than one acre that are part of a larger common plan of development or sale (Ecology 2014b)." This study evaluates the effectiveness of a PP sidewalks as a flow control BMP.

S5.B.6 Municipal Operations and Maintenance

> According to the permit, "permittees shall implement an operation and maintenance program that includes a training component and has the ultimate goal of preventing or reducing pollutant runoff from municipal operations (Ecology 2014b). This study evaluates the effectiveness of maintenance practices for PP sidewalks.

4.0 Project Overview

4.1 Study Goal

The purpose of this study is to evaluate the effectiveness of a pervious concrete (PC) sidewalk as a structural BMP in Eastern Washington including the operation and maintenance (O&M) requirements. The effectiveness evaluation will focus on the useful life span of the material with respect to infiltration performance and deterioration in surface condition. If the infiltration performance and durability of PC sidewalks are stable over time, with either routine or periodic maintenance, then PC may be adopted by more jurisdictions as a stormwater flow control BMP in appropriate locations. The study will also inform municipal stormwater managers about the type and frequency of required maintenance for PC to ensure long-term performance. Results from this study may be used to improve permeable pavement design guidance for sidewalks and recommend O&M procedures for Eastern Washington. When appropriate, the findings could be transferred to roads.

4.2 Study Description and Objectives:

This is a paired study with four block-long PC sidewalk segments constructed at two locations. Two of the segments will be in commercial setting (one test and one control) and two will be located in a residential setting (one test and one control). The control sites will undergo routine maintenance as described in the EWA LID Manual (Ecology 2013). Maintenance techniques generally include either pressure washing or mechanical vacuum sweeping or a combination of the two. The test segments will undergo no maintenance during the entire investigation. The routine PC maintenance listed in the EWA LID Manual (Page 226) was not specifically established for sidewalks so this study will determine if the type and frequency of maintenance recommended is appropriate for sidewalk applications. In addition, previous research conducted on PC, has shown that maintenance can increase the infiltration rate of clogged pervious concrete; however previous research is based on road applications in non-EWA locations. This study will serve to determine if PC will perform similarly under EWA conditions and whether the type and frequency of maintenance on PC sidewalks should be adjusted. The objectives of this effectiveness study are to:

- determine the useful life span of PC sidewalks
- determine the infiltration capability over time at sites with and without maintenance
- evaluate durability based on visual observations of deterioration in surface condition
- recommend maintenance protocols (type and frequency) of PC in sidewalk applications
- synthesize and provide study results to stormwater operators in EWA so they can determine the usefulness of PC sidewalks for their jurisdictions.

Newly implemented and properly installed pervious concrete should have a design infiltration rate of 200 inches per hour (Ecology 2013). The infiltration rate will be confirmed post construction and then tracked for a period of 10 years. Visual observations to assess surface structural integrity and visual clogging will also be conducted. The visual inspection will be recorded on a standardized report created for this project but based on those used by other agencies (Erickson et al 2013). Visual inspection of structural integrity will include noting signs of surface deterioration, cracking, spalling, or loose aggregate.

4.3 Study Location

This study will be conducted at residential and commercial sidewalk sites potentially in the lead entity. The locations will be determined by the lead entity, considering both project objectives and sidewalk replacement needs. It is a paired investigation, so the environmental conditions of both the test and control sites will be similar.

4.4 Data Needed to Meet Objectives

The data required to meet the project objectives are infiltration measurements for both test and control sites over a 10-year period, visual observations of surface condition to assess clogging and/or pavement degradation, and maintenance records for the control sites to evaluate the effect maintenance has on long-term infiltration rates.

4.5 Tasks Required to Conduct Study

There are six tasks required to conduct the study:

1. Select Test and Control Segment Locations (see Section 7.2)
    a. Site due diligence for suitability for permeable pavement
    b. Comparative analysis of drainage areas for potential locations
2. QAPP Development
3. Develop Plans, Specifications and Engineering (PS&E) package.
    a. Final design of four block-long PC sidewalk segments
        - Two residential segments (test and control)
        - Two commercial segments (test and control)
    b. Select contractor, material supplier, etc.
    c. Obtain Permits
4. Construct four block-long PC segments
    - Two residential segments (test and control)
    - Two commercial segments (test and control)
5. Data Collection
    a. Conduct infiltration measurements (at 10 random locations per segment) twice per year (April and October)
    b. Record visual assessment of pavement condition (at same locations of infiltration measurements) twice per year (April and October)
6. Maintenance

    a. Perform routine maintenance on one residential segment and one commercial segment throughout the study to serve as control sites; maintenance is twice per year after infiltration tests are performed.
7. Reporting
    a. Annual Report (March 31)
    b. Final Report

4.6 Potential Constraints

In the context of the proposal, constraints are any conditions that may impact the schedule, budget, and scope of the project. There are two primary types of constraints associated with this project – those associated with construction of the stormwater BMP and those associated with the research phase of the study.

4.6.1 Potential Constraints - Construction

With regards to construction, the potential constraints include:

- Selecting appropriate locations for implementation to ensure paired-testing conditions are met
- Hiring qualified professionals for design
- Hiring certified installers for construction implementation
- Consistency of installation across four segments
- Weather

4.6.2 Potential Constraints – Research

With regards to research phase, the potential constraints are:

- Hiring qualified professionals or availability of staff for infiltration testing
- Consistency of infiltration testing protocols
- Hiring qualified contractors or availability of staff for maintenance
- Consistency of maintenance practices
- Weather
- Possible changes to the drainage area conditions over time (effects influent and loading conditions)
- Long-term commitment to implementing investigation

5.0 Organization and Schedule

5.1 Key Project Team Members: Roles and Responsibilities

Key Team Members	Role	Responsibility
Lead Entity Contact Name Phone Number Email	Proposed Lead Entity	Responsible for executing the study.
Name Organization Phone Number Email	Participating Entity	Define.
Karen Dinicola Ecology 360.407.6550 kdin461@ecy.wa.gov	Ecology Reviewer	Phase 2-3a Gross Grant Ecology Project Manager
Doug Howie Ecology 360.407.6444 DOHO461@ecy.wa.gov	Ecology Reviewer	Responsible for the technical review of Structural and Operational BMP Proposals
Donald D. Carpenter Drummond Carpenter, PLLC 248.763.4099 dcarpenter@drummondcarpenter.com	Proposal Author	Responsible for developing proposal.
Aimee Navickis-Brasch HDR, Inc. (509)343-8515 aimee.navickis-brasch@hdrinc.com	Proposal Peer Review	Responsible for the technical review of this proposal prior
Name Organization Phone Number Email	QAPP Author	To be defined when the QAPP is developed.
Name Organization Phone Number Email	Key Team Member Project Role	Define when the QAPP is developed if applicable.

5.2 *Project Schedule*

An overview of the project schedule as depicted during the public commentary period is shown in Figure 4. A task timeline based on quarterly activities is shown in Table 5.2.1.

Table 5.2 Proposed Study Timeline

	2017		2018				2019...				...Final Year			
Task Name	Q3: July - Sept	Q4: Oct. - Dec.	Q1: Jan. - March	Q2: April - June	Q3: July - Sept.	Q4: Oct. - Dec.	Q1: Jan. - March	Q2: April - June	Q3: July - Sept.	Q4: Oct. - Dec.	Q1: Jan. - March	Q2: April - June	Q3: July - Sept.	Q4: Oct. - Dec.
1. QAPP														
2. Select Locations														
3. BMP Implementation														
a. Design														
b. Select Contractor, Supplier, etc.														
c. Permit														
d. Install														
4. Data Collection														
5. Maintenance														
6. Reporting														
a. Annual Report														
b. Final Report														

Figure 4: Overview of proposed project schedule.

5.3 Budget and Funding Sources

Task	Hours	Cost Per Hour	Equipment Fees	Sub-Contract	Total
Select Test and Control Segments	80	$54[1]	0	0	$4,320
QAPP Development[2]	120	$150	0		$18,000
PS&E Package	20[3]	$54		$12,000[4]	$13,080
BMP Construction	40[5]	$54		$48,000[6]	$50,160
Data Collection					
Infiltration Measurements[7]	1600	$60	$1000		$97,000
Visual Assessment[8]	320	$60			$19,200
Maintenance[9]					
Reporting					
Final Analysis & Report[10]	160	$200			$32,000
Annual Report(s)	200[11]	$60			$12,000
				Total	**$245,760**

[1] $54/hour rate was estimated by lead entity for 2017. All tasks performed internally by lead entity with the exception of QAPP Development and Final Report. The lead entity rate was increased to $60/hour for later tasks to account for inflation.
[2] QAPP Development performed by consultant
[3] PS&E Package Development is sub-contracted. These represent Project Management hours for the lead entity.
[4] PS&E Package Development is assumed to be 25% of BMP construction costs and includes all design, construction specifications, and bid documents.
[5] BMP Construction is sub-contracted. These represent Project Management hours for the study lead.
[6] This cost is based on $20 / ft^2 of installed PC sidewalk (including demolition and haul away of existing sidewalk, stone base layer and pervious concrete) and approximately 2400 ft^2 of PC sidewalk inclusive of control and test segments. This does not include the cost to purchase any property.
[7] It is assumed that a field technician will need two 8-hour work days per segment (8 work days for infiltration testing) and another two 8-hour work days for reporting for a total of 10 work days (80 hours) per testing season. This equates to 160 hours per year for 10 years.
[8] Visual assessment of pavement condition twice per year per segment for 10 years (80 total visual assessment). It is assumed each visual assessment (including reports and photo documentation) will take 4 hours for a total of 320 hours.
[9] Maintenance to be performed as part of regular jurisdictional responsibilities.
[10] Final Analysis and Report performed by consultant.
[11] Assumes each annual report will take 20 hours.

6.0 Quality Objectives – QAPP Only

This section will be completed for the QAPP.

7.0 Experimental Design

7.1 Study Design Overview

This is a paired study with four block-long PC sidewalk segments constructed at two locations. Two of the segments will be in commercial setting (one test and one control) and two will be located in a residential setting (one test and one control). The control sites will undergo routine maintenance as described in the EWA LID Manual (Ecology 2013). Maintenance techniques generally include either pressure washing or mechanical vacuum sweeping or a combination of the two. The test segments will undergo no maintenance (i.e., sweeping, vacuuming, pressure washing) during the entire study even if a decrease in infiltration performance is observed at the test sites. The segment locations should be located where there is a grass buffer strip between the roadway and the sidewalk, to ensure that snow and associated street debris is not deposited onto the sidewalk by plowing. Two of the locations will be in a commercial setting (one test and one control) and two will be located in a residential setting (one test and one control).

Infiltration rate of each of the sidewalk segments will be measured twice per year (April and October) for a period of at least 10 years. Infiltration measurements will be taken at 10 locations to account for spatial variability in infiltration rate. These evaluations will consist of qualitative visual assessments. As part of the inspection process, an effort will be made to categorize depositions on the pavement that might cause clogging.

Maintenance on the control segments will be performed in accordance with the EWA LID Manual (2013) which provides a list of maintenance requirements for pervious pavement surfaces. For pervious concrete, that includes annual inspections for excess sediment or plant debris that could settle on the pavement surface and induce clogging and cleaning of permeable pavement surface at least once a year. Another good resource for developing a maintenance plan is the Pervious Concrete Pavement Maintenance and Operations Guide (NRMCA 2015). They recommend maintenance logs with the following information:

- Date of maintenance
- Name of individual/company performing service
- Type of maintenance
- Amount and type of sediment/debris removed
- General observation of pavement condition

Maintenance records should be maintained for the duration of the project for analysis of maintenance protocols.

7.2 Test-Site(s) Selection Process

This effectiveness study proposed test site location is the lead entity. The locations of PC sidewalks will be defined in the QAPP, considering both project objectives and sidewalk replacement needs. It is a paired investigation, so the environmental conditions of both the test and control sites will be equivalent regardless of site selection.

Factors that will effect site selection include:

- Similar drainage area size and characteristics
- Similar impervious surface of drainage area (i.e. concrete, asphalt, roofs, etc.)
- Similar volumes of pedestrian traffic
- Similar tree canopy conditions
- Potential for additional construction projects in the area that could generate sediment (windblown or runoff)
- Access for testing

In addition to the above site selection factors, the EWA LID Manual (Ecology 2013) and Stormwater Management Manual for Western Washington (Ecology 2014a) list conditions that make the use of permeable pavement infeasible including specific geotechnical considerations, ground water quality concerns, poorly infiltrating soils (< 0.3 inches/hour), high groundwater table, etc. During the site selection, the permeable pavement infeasibility criteria will be consulted and sites selected for study segments will not violate any of the criteria listed.

7.3 The Structural BMP System Sizing

The PC sidewalk BMP will be designed according to recommended design criteria (Ecology 2014a, Ecology 2013) and standard sidewalk geometric design parameters for the jurisdiction that conducts the study. For the residential segments, the standard sidewalk width is four feet. For the commercial segments, the standard sidewalk width is typically six to eight feet depending on location. The extra width in a commercial application is to allow for pedestrian shopping traffic and extra width for wheeled traffic to pass including strollers, wheelchairs, and bikes. The length will depend on site characteristics, but the minimum length of each segment should be 100 ft.

7.4 Type of Data Being Collected

Table 1 provides the summary of the data being collected as part of this investigation. There are three categories of data being collected including infiltration rates, visual observations, and maintenance records. The data collection procedures and document will be finalized for the QAPP.

Table 7.1: Summary of data being collected.

Data Type	**Purpose**	**Frequency**	**Total**
Infiltration Rate	Evaluate the capacity of the PC segments being studied.	Twice per year per test segment	800
Visual Observations	Evaluate surface condition for structural integrity and visual clogging.	Twice per year	80
Maintenance Records	Evaluate the maintenance protocols being utilized.	Twice per year	80

7.4.1 Infiltration Rate

The ASTM (2009) protocols for infiltration rate (2009) recommended an initial infiltration a rate of at least one test per 5000 square feet after installation. Based on EWA LID Manual (Ecology 2013) and ASTM (2009) recommendations, only one infiltration measurement per segment is required to evaluate for design performance purposes, but given the nature of this investigation, an infiltration test will be taken for approximately every 10 feet of sidewalk length (10 tests per segment twice per year).

Destructive infiltration rate measurements are accomplished when a core sample of the material is extracted and tested in a laboratory. This investigation will use non-destructive infiltration rate measurements to preserve surface integrity of the sidewalks. There are multiple ways to assess infiltration of rainfall and runoff into permeable pavements using non-destructive infiltration measurements including (1) **visual inspection** of ponding during a rain event or surface clogging with debris immediately after a rain event; (2) **capacity testing** by measuring surface infiltration in discrete locations; (3) **synthetic runoff testing** by generating synthetic rainfall and measuring runoff; and (4) **continuous monitoring** of rainfall and surface runoff (Erickson et al 2013). This project will utilize **visual inspection** and **capacity testing** with discrete surface infiltration measurements.

There are multiple methodologies for measuring surface infiltration including using a single ring infiltrometer, double ring infiltrometer, and the embedded ring infiltrometer. A single ring infiltrometer (Figure 5) is the method recommended in ASTM 1701 Standard Test Method for Infiltration of In-Place Pervious Concrete and the recommended method for this study. In this method, a single infiltration ring made of rigid materials (PVC, steel, aluminum, etc.) is adhered to the concrete pavement using plumber’s putty. A disadvantage of using plumber’s putty is the possibility of leaving residual rings in desirable areas (such as commercial pedestrian areas). An alternative is the use of a circular neoprene gasket and a weighted cylinder to provide for a tight seal (Figure 6; Brown and Borst 2014). The disadvantages to the weighted cylinder and gasket option is it takes time to construct the apparatus, is more cumbersome to set-up than using plumber's putty, and it's not listed as an option in ASTM 1701 which is the established standard. The method implemented for this study will be determined as part of the QAPP development.

After the concrete is pre-wet through an initial application of water, a known weight of water (either 8 lbs. or 40 lbs. depending on concrete condition) is added to the ring and the time it takes for the water to infiltrate is recorded. The infiltration rate is than determined using a standard equation. ASTM reports that the coefficient of variability between repeated tests is less than 5%.

Figure 5: Application of water in a single ring infiltrometer test (NRMCA 2015)

Figure 6: Use of neoprene gasket and a weighted cylinder to provide for a tight seal (Brown and Borst 2014).

For each infiltration test, a standardized report will be generated including the following information:

- Person performing the test
- Date/time of test
- Weather at time of test
- Unique identification number of the test
- Location of the test – identified on map of the site
- Date and amount of rain during most recent measured rainfall prior to the test
- Visual inspection notes of the surface and photograph
- Notation if debris had to be removed to perform test (light sweeping of surface to remove trash and debris that might interfere with test is permitted under ASTM C1701)
- Time elapsed during pre-wetting phase of infiltration test
- Weight of infiltrated water
- Inside diameter of infiltration ring
- Time elapsed during infiltration test
- Calculated infiltration rate

The standardized report will be finalized for the QAPP and described in detail in Section 8.6.

7.4.2 Infiltration Test Locations

ASTM standards require at least 3 feet of distance between tests and at least 6 inches of distance from any pavement edge. The locations for the tests can be selected by using an EXCEL random number generator multiplied by the length and width of the test segment to determine the location for testing (Table 2). If the random selection of infiltration testing location violates the proximity constraints, the location will be adjusted accordingly. The infiltration test locations can then be translated onto a map and provided to the field technician (Figure 7).

Table 2: Example of random location selection for infiltration test locations.

Date of Test	Test Area	Width Location	Length Location	Random Number
4/15/2018	1	4.23	52.85	0.53
	2	3.67	45.88	0.46
	3	2.00	25.00	0.25
	4	0.99	12.34	0.12
	5	3.40	42.45	0.42
	6	3.90	48.80	0.49
	7	2.27	28.36	0.28
	8	6.50	81.26	0.81
	9	5.68	71.00	0.71
	10	2.18	27.24	0.27

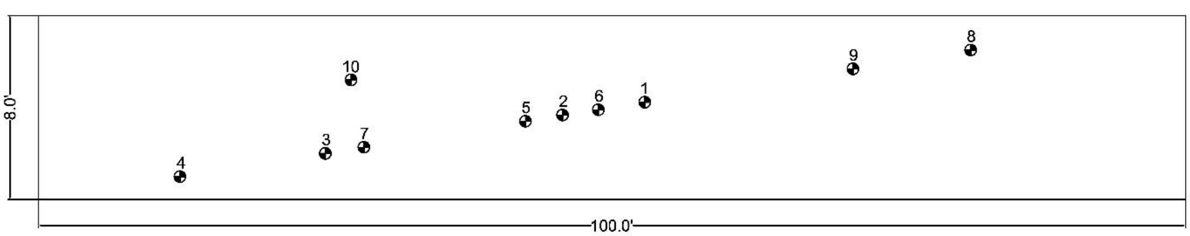

Figure 7: Map of randomly generated infiltration measurement locations (8ft by 100 ft segment).

7.4.3 Visual Observations

Visual inspection of structural integrity should include noting signs of surface deterioration, cracking, spalling, or loose aggregate using a defined rating scale. The visual inspection will be recorded on a standardized report created for this project during the QAPP phase but based on those used by other agencies (Erickson et al 2013). Photo documentation of each segment will be attached to the form and kept to compare the surface condition of the pavement.

7.4.4 Maintenance Records

Maintenance on the control segments will be performed in accordance with the EWA LID Manual (2013) which provides a list of maintenance requirements for pervious pavement surfaces. Maintenance records should be maintained for the duration of the project for analysis of maintenance protocols. The maintenance records will be recorded on a standardized report log created for this project during the QAPP phase, but based on maintenance reports used by other agencies.

7.5 Precipitation Monitoring

Not Applicable

7.6 Water Quality Sampling

Not Applicable

7.7 Sediment Sampling

Not Applicable

8.0 Sampling Procedures – QAPP Only

This section will be completed for the QAPP.

8.1 Standard Operating Procedures

This section will be completed for the QAPP.

8.2 Containers, Preservation Methods, Holding Times

Not Applicable

8.3 Equipment Decontamination

Not applicable

8.4 Sample Identification

This section will be completed for the QAPP.

8.5 Chain of Custody

Not Applicable.

8.6 Field Log Requirements

This section will be completed for the QAPP.

9.0 Measurement Procedures – QAPP Only

This section will be completed for the QAPP.

9.1 Procedures for Collecting Field Measurements

This section will be completed for the QAPP.

9.2 Laboratory Procedures

Not Applicable

9.3 Sample Preparation Methods

Not Applicable

9.4 Special Method Requirements

Not Applicable

9.5 Lab(s) Accredited for Methods

Not Applicable

10.0 Quality Control – QAPP Only

This section will be completed for the QAPP.

10.1 Field QC Required

This section will be completed for the QAPP.

10.2 Laboratory QC Required

Not Applicable

10.3 Corrective Action

This section will be completed for the QAPP.

11.0 Data Management Plan Procedures – QAPP Only

This section will be completed for the QAPP.

11.1 Data Recording & Reporting Requirements

This section will be completed for the QAPP.

11.2 Electronic Transfer Requirements

This section will be completed for the QAPP.

11.3 Laboratory Data Package Requirements

Not Applicable

11.4 Procedures for Missing Data

This section will be completed for the QAPP.

11.5 Acceptance Criteria for Existing Data

This section will be completed for the QAPP.

11.6 Environmental Information Management (EIM) Data Upload Procedures

This section will be completed for the QAPP.

12.0 Audits – QAPP Only

This section will be completed for the QAPP.

12.1 Technical System Audits

This section will be completed for the QAPP.

12.2 Proficiency Testing

This section will be completed for the QAPP.

13.0 Data Verification and Usability Assessment

The section defines the process the project will employ to evaluate the quality of the data and the usability of the data for meeting the project objectives.

13.1 Field Data Verification

As described in Section 7.4, there are three types of data being collected for this effectiveness study – infiltration measurements, visual observations, and maintenance records. This data will be verified by a project QA/QC manager designated by the jurisdiction that is selected as the lead entity. After each field data collection effort, the QA/QC manager will:

- Review the field logs of infiltration testing and visual observations to ensure they are consistent, correct and complete, with no errors or omissions
- Review the maintenance logs to ensure they are consistent, correct and complete, with no errors or omissions.

Once per year, the QA/QC manager will:

- Observe an infiltration measurement to confirm it was conducted properly
- Observe maintenance to confirm it was conducted properly
- Verify visual observation logs with their own inspections

The QA/QC manager's findings should be included in the annual report.

13.2 Laboratory Data Verification

Not applicable

13.3 Data Usability Assessment

To be completed for the QAPP.

14.0 Data Analysis Methods

This section defines the process and methods the study will use to analyze the data to address the study goals outlined in Section 4.0 and how the data will be presented in reports.

14.1 Data Analysis Methods

Infiltration measurements will be analyzed in a spreadsheet using standard statistical techniques and graphical representation of BMP performance over time. Each segment will have approximately 10 infiltration measurements performed randomly over its area. Descriptive statistics (mean, minimum, maximum, and standard deviation) will be computed for each set of infiltration measurements (see Table 3 for example). A summary table of the four segments can be presented together (see Table 4 for example).

Table 3: Infiltration rate (inches per hour) statistics of residential control segment (04/15/2018).

Mean	205.10
Std Dev	4.79
Min	199.10
Max	214.00

Table 4: Infiltration rate statistics for 04/15/2018.

		Infiltration Rate (in/hr.)		
	Total # Tests	**Mean**	**Standard Deviation**	**95% Confidence Interval**
Residential Control	10	205.1	4.79	197.0 – 212.2
Residential Test	10	201.3	3.15	197.0 – 205.1
Commercial Control	10	200.0	3.2	196.2 – 204.6
Commercial Test	10	204.5	7.8	195.1 – 214.0

The effectiveness will be determined by comparing the control and test sites for each segment (residential and commercial) over time using both hypothesis testing and graphical representation. In addition to testing control segment versus test segment, the segments can be tested temporally by comparing each subsequent year to the previous year or the initial conditions. In this situation, the specific null hypothesis (H_o) is that the infiltration rates for each test is equivalent and alternative hypothesis (H_a) is that the infiltration rate is not equivalent. The hypothesis testing will investigate whether setting (residential versus commercial) and routine maintenance effect long-term infiltration rates. Below is as summary of the null hypothesis that will be tested:

- The infiltration rate will be equivalent for test and control segments of the residential sidewalk
- The infiltration rate will be equivalent for test and control segments of the commercial sidewalk
- The infiltration rate will be equivalent for the test segments of the residential sidewalks.
- The infiltration rate will be equivalent for the test segments of the commercial sidewalks.
- The infiltration rate will not decrease with time for the control sections of the sidewalks.
- The infiltration will not decrease with time for the test sections of the sidewalks.

The above hypothesis tests are depicted visually in Figure 7. The top two grey boxes represent the test segments for both residential and commercial. The bottom two grey boxes represent the control segments for both residential and commercial. The two headed black arrows represent spatial comparison tests between pervious concrete segments. The testing would be repeated annually.

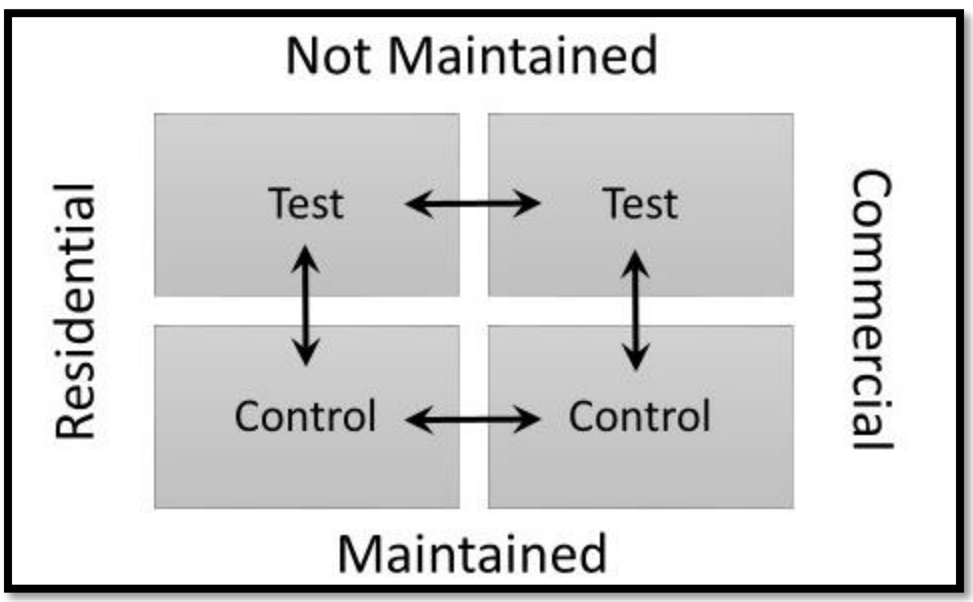

Figure 7: Visual depiction of hypothesis tests between test and control segments.

In addition to analyzing infiltration data, the visual inspection reports will be analyzed each year to determine the progression of any signs of surface deterioration, cracking, spalling, or loose aggregate (Section 7.4.3). This will be a qualitative analysis based on the defined rating scale that will be defined in the QAPP.

14.2 Data Presentation

Individual infiltration measurements and summary statistics will be presented in tables (presented in Section 14.1) and graphs. Figure 9 is an example graphical presentation of infiltration tests. Each point represents the measured infiltration rate at a random location (numbered one through ten) for both the residential control (blue square) and test (orange diamond) site. Each measurement is independent of the other measurements on the figure. Also included are error bars around each data point based on all ten measurements to establish the variability of the data and a horizontal line of mean infiltration rate of all ten measurements for each segment to depict the differences between the means.

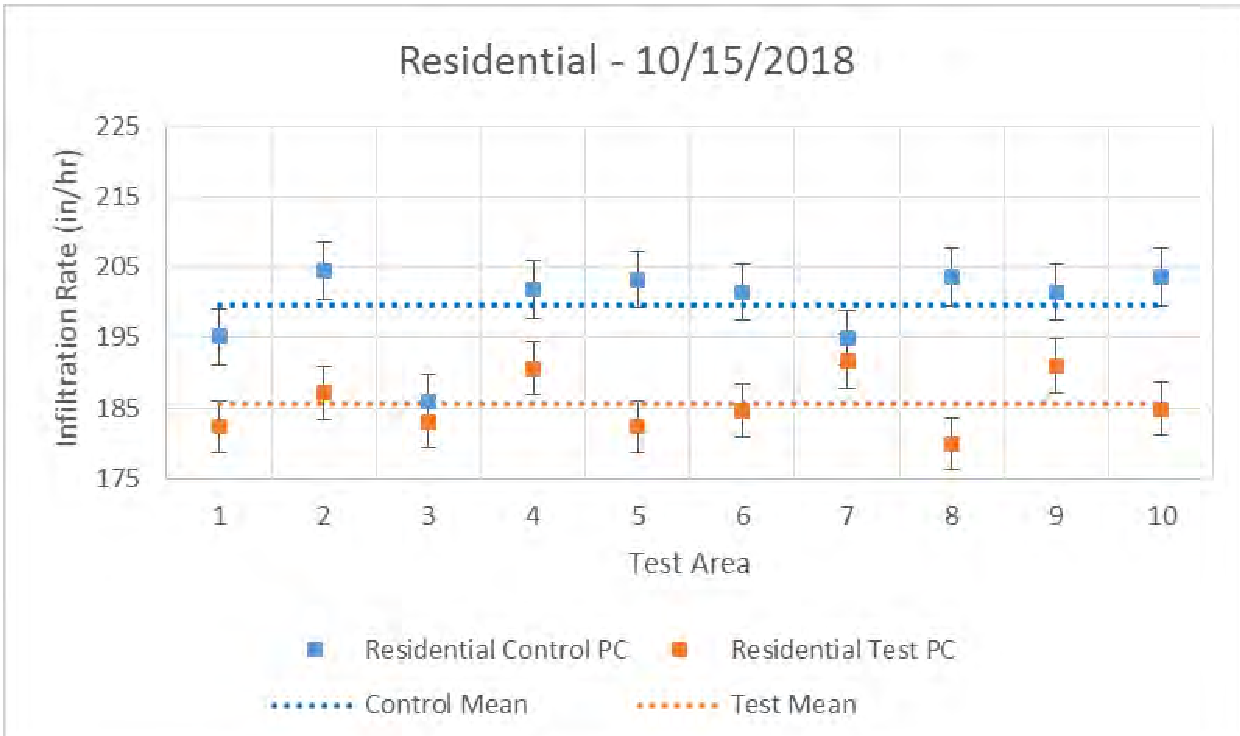

Figure 8: Alternative method of data presentation including error bars and connected points.

Figure 9 is an example of how infiltration measurements can be graphically depicted over time to demonstrate reduction in infiltration. Each data point in Figure 9 represents the mean infiltration rate of ten measurement for either the residential control (blue square) or residential test (orange diamond) along with error bars based on standard deviation. Finally, a linear best-fit line is included to demonstrate trends. If Figure 9 was based on actual data, the observation would be that over three years there is a steady decline of infiltration capacity for both the residential control and test segments, but the test segment is declining at a more rapid rate. The test segment is also exhibiting greater variability than the control segment as indicated by the error bars.

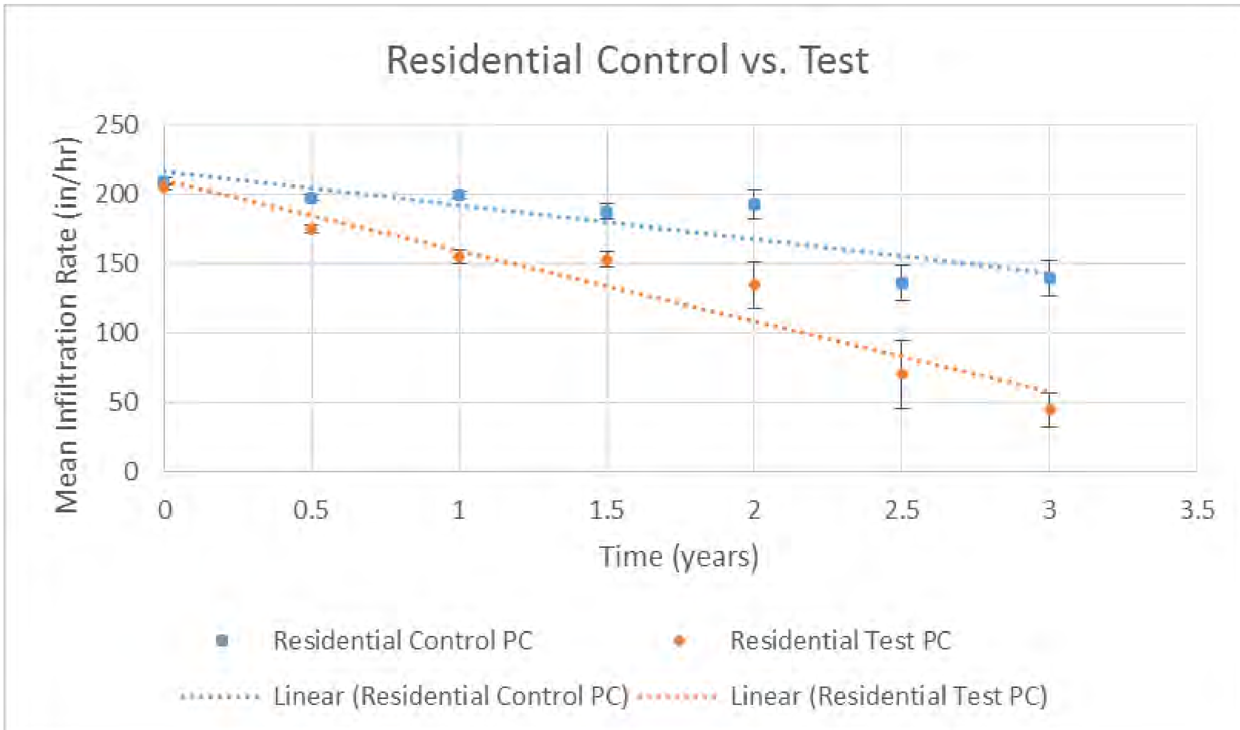

Figure 9: Temporal presentation of mean infiltration rates and error bars for control and test segments.

Photo documentation of each segment will be presented chronologically to demonstrate how the surface condition evolves with time. The photos will be accompanied with the technician description of the surface condition. Chronological representation of each segment in this fashion will allow for easy interpretation of the effect of time. In addition, the test and control segments (for residential and commercial) will be presented side by side (similar to Figure 7) for each data collection effort to document the difference between segments.

15.0 Reporting

15.1 Final Reporting – QAPP Only

This section will be completed for the QAPP.

15.2 Dissemination of Project Documents

The final report will be shared with the participating agencies and will be posted to the lead entites webpage: add website

16.0 References

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17.0 Appendices

The appendices should include all supporting information for the items described in the body of the QAPP.

Appendix 26 – Use of Non-Vegetated Swale with Native Soils Proposal

Eastern Washington
Stormwater Effectiveness Studies

Detailed Study Design Proposal

Use of Non-Vegetated Swale with Native Soils

Study Classification:

☑ Structural BMP ☐ Operational BMP ☐ Education & Outreach

Study Objective(s):

☑ Evaluate Effectiveness ☐ Compare Effectiveness
☑ Develop Modified BMP ☐ Develop New BMP

Note: This Proposal is only partially complete. The work complete has been included (black text). The brown instructional text from the QAPP template has been left in the document to highlight the sections not complete. For general instructions on completing the Proposal sections of the QAPP Template, please see the City of Spokane Valley's EWA Effectiveness Studies website, Structural QAPP Template: http://www.spokanevalley.org/filestorage/6836/6914/8301/10121/1-Structural_BMP_QAPP_Template_Final.pdf

This Proposal was not completed because the EWSG decided not proceed with this study after the stormwater lead from the intended lead entity changed jobs. The Bioretetion Soil Media Study replaced this study and that Proposal was completed and submitted to Ecology on June 30, 2017.

Month, Date Year

Prepared For:

Lead Entity Jurisdiction
Department
Address
City, Washington, Zip Code
Phone Number

City of Spokane Valley
Public Works Department
11707 East Sprague Avenue, Suite 106
Spokane Valley, Washington 99206-6124
(509)720-5018

Prepared By:

Organization
Address
City, Washington, Zip Code
Phone Number

Proposal Publication Information

This Detailed Study Design Proposal (Proposal) will be stored and accessible to the public at the following weblink: Add Weblink where the Proposal can be accessed by the Public. For questions regarding the Proposal, please contact First and Last Name of Lead Entity Contact by email add email address or phone (509)XXX-XXXX.

Proposal Author and Contact Information

Aimee S. Navickis-Brasch
HDR, Inc.
Senior Stormwater Engineer
1401 E. Trent Ave., Suite 101
Spokane, WA 99202
(509)343-8515

Zack Holt
D&H Technology Solutions, LLC
Owner
15206 131st Ave Ct KPN
Gig Harbor, WA 98329
holt.zackary@gmail.com
(360)509-0996

Proposal Peer Review and Contact Information

Name
Organization
Title
Address
City, State, Zip Code
email address
phone number(s)

QAPP Publication Information

Proposal - Not required. Leave the header, along with the following note "Will be completed for the QAPP", as a place holder for the development of the QAPP.

Insert information about where the QAPP will be stored and accessible to the public (see section 15.2). Include a weblink and/or contact information.

QAPP Author and Contact Information

Proposal - Not required. Leave the header, along with the following note "Will be completed for the QAPP", as a place holder for the development of the QAPP.

Insert author and contact information here:

Name
Organization
Title
Address
City, State, Zip Code
email address
phone number(s)

Signature Page

This page lists signatories to the document. Each party responsible for the contents of the QAPP and the project must sign and date this page before the study proceeds to the implementation phase (i.e. conduct the study).

Proposal – Only the parties responsible for the contents of the Proposal and the project must sign and date this page before the study proceeds to the QAPP development phase.

Approved by:

Date
Name, Lead Entity, Jurisdiction

Date
Aimee Navickis-Brasch, Primary Author, HDR, Inc.

Date
Name, Ecology Contact with Approving Authority

Date
Name, Title

Date
Name, Title

Distribution List

Proposal – At a minimum include: the lead entity, participating entities, Ecology, and the author of the document

List each party who will receive copies of the approved **QAPP** as well as any subsequent revisions along with their contact information. This may include those who are responsible for the QAPP development and project implementation including project managers, QA managers, representatives of other groups/agencies involved, field staff, etc.

Name, Title	Organization	Contact Information: Address, Telephone, E-mail

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The Table of Contents (TOC) provides an outline of the QAPP content and organization including section headers, subsection headers, figures, tables, and appendices. The TOC should be auto generated using a word processing program.

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2.0 Executive Summary

Proposal - Section 2.0 is not required. Leave the section, along with the following note "This section will be completed for the QAPP", as a place holder for the development of the QAPP.

The executive summary is a brief (300-500 word) and non-technical summary of the project that is typically written for a more general audience and includes the "key" elements of the study. This should include:

- Description of the BMP(s) that is the focus of the study
- The study goals including whether the study focuses on: evaluating effectiveness only, developing a modified BMP, or developing a new BMP
- The study objectives
- How those objectives will be accomplished
- Estimated duration of the study
- The location of the test-site(s)
- The anticipated study outcomes and modifications the permittee expects to make to their stormwater management program using the study findings

3.0 Introduction and Background

After reading this section, the reader should understand: the Structural BMP(s) that is the focus of this study, the reason(s) why the study is being conducted including results from prior studies, and the Stormwater Management Program conditions in the EWA NPDES Municipal permit the study addresses.

3.1 Introduction to the Structural BMP

Bioretention ponds are a common structural stormwater best management practice (BMP) in urban areas (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). Pollutant removal primarily occurs as stormwater infiltrates through the BSM. Stormwater then infiltrates into the existing soils beneath the pond or is collected in an underdrain and conveyed to a storm drain network. Flow control is provided when the volume of runoff infiltrates into the underlying soils beneath the bioretention area.

Figure 3-1. Example of a Bioretention area in the City of Spokane

The BSM specified (default mix) in the eastern Washington (EWA) LID Manual is composed of 60% sand and 40% compost by volume (60:40) (AHBL & HDR, 2013). This mix is approved by Ecology to provide flow control and runoff treatment of total suspended solids (TSS) and dissolved metals, copper (Cu) and zinc (Zn), to the level specified in the EWA Phase II NPDES MS4 Permit. The primary treatment mechanism responsible for reducing pollutants include:

- sedimentation, as particles settle on the surface of the BMP
- filtration, runoff infiltrates into the BSM and particulates become physically trapped in the media pore spaces
- Sorption of dissolved metals onto the surface of organic materials amended in the BSM

This study proposes to evaluate the effectiveness of a modified bioretention BMP, specifically the runoff treatment (TSS and dissolved Cu and Zn) and flow control functions. The modification is to the engineered soils specification: in lieu of using the default 60:40 mix specification, a native soil specification would be used. The modified bioretention BMP will be sized following the existing bioretention design guidance defined in the EWA LID Manual. See section 4 for more details about this specification.

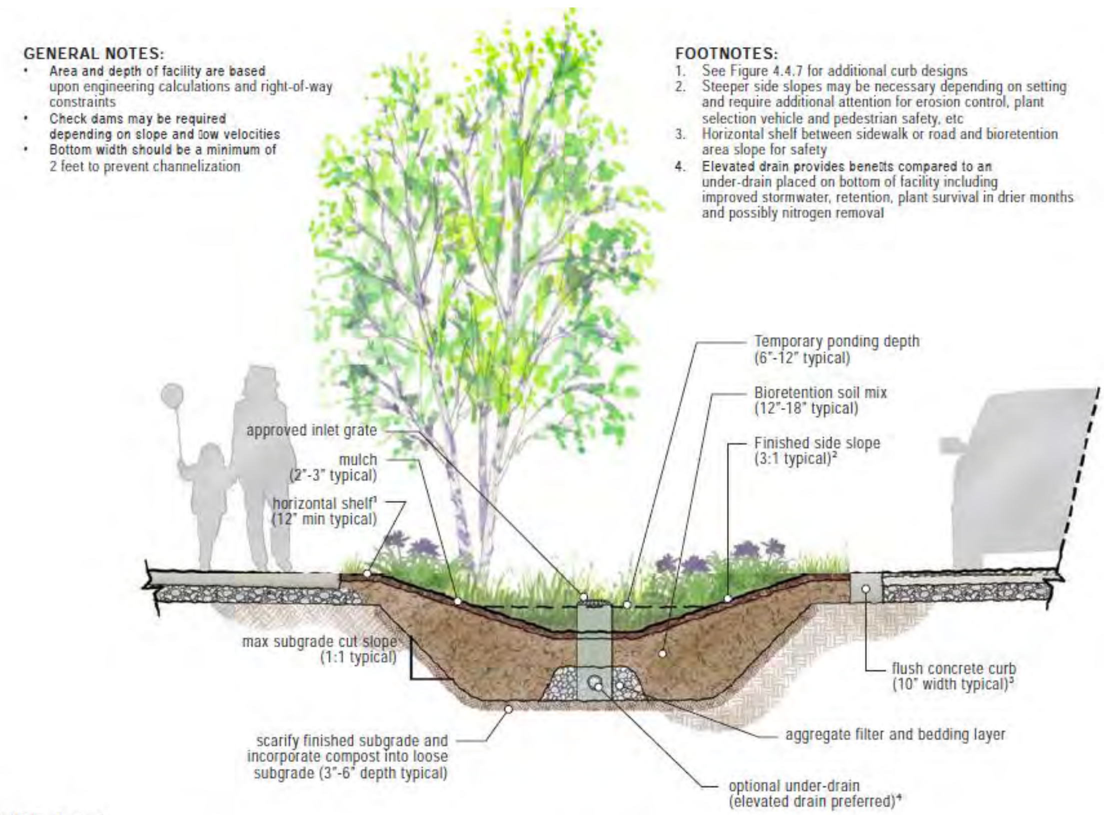

FIGURE **4.4.1**
Bioretention with primary design elements (Under-drain is optional)
Source: AHBL, Inc. courtesy of Low Impact Development Technical Guidance Manual for Puget Sound (2012)

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

3.2 Problem Description

A number of BMP options in the Eastern Washington Stormwater Management Manual (Ecology, 2004), such as bioinfiltration swales and bioretention ponds, include the installation of plants as part of the design. While plants, and their root structure, are known to enhance pollutant removal and/or infiltration capacity and aesthetics (Kadec, 2008), there presence also creates extra maintenance needs, including watering and mowing. In semi-arid locations like eastern Washington, evaporation greatly exceeds rainfall during the dry season, creating conditions that make irrigation essential to sustain plants (Caraco, 2000). In the dryer parts of Eastern Washington, plant irrigation needs often exceed the average annual rainfall by tenfold. This problem is compounded during drought years when the availability of irrigation water is restricted. All too often the solution is to install the BMP with vegetation but not provide irrigation which results in BMPs with dead, brown vegetation similar to the one shown in Figure 3.3. Research on the pollutant removal performance of these type of BMPs is mixed (Caraco, 2001), which suggested they are not a reliable BMP for providing runoff treatment

A practical strategy for stormwater management in semi-arid regions is select BMPs that provide treatment without a supplemental water source. Common examples include BMPs without vegetation such as sand filters, infiltration trenches, evaporation ponds, and permeable pavements. Nonvegetated bioretention BMPs are not as common however the primary treatment mechanisms (filtration, sedimentation, and sorption) provided by the BMP are a function of the physiochemical properties of the engineered soils (BSM) and many of these properties are found in native soils. For example, TSS removal rates are dependent upon graduation and permeability rates: larger grain soils have more void spaces and a higher permeability resulting in lower TSS removal rates from stormwater compared to fine grained soils (Hunt & Lord, 2006; Hsieh & Davis, 2005). Whereas dissolved metals removal is associated with the sorptive properties of the soils such as cation exchange capacity (CEC): soils with a higher CEC have a larger capacity for removing dissolved metals from stormwater (Hunt & Lord, 2006; Hunt, 2003). Considering the target pollutants identified for this study (TSS, Cu, Zn) and that the engineered soils portion of bioretention BMPs provide the primary treatment functions for removing these pollutants, it is anticipated that bioretention BMPs that use native soils (with physiochemical properties that are known to provide these treatment mechanisms) without vegetation will still provide some level of treatment that will reduce these pollutants.

It is well documented that vegetation contributes to the total pollutant reduction provided by bioretention BMPs, particularly for nutrient uptake (Davis, 2006; Henderson, 2009; Barrett, Limouzin, Lawler; 2013). A question of importance to this study is to what extent does vegetation contribute to pollutant reduction and is the treatment provided by the native soils alone sufficient for achieving Ecology treatment goals for basic and dissolved metals.

Figure 3.3 Biofiltration swale in EWA during the dry season

3.3 Results of Prior Studies

Proposal - Section 3.3 not required. Leave the section header, along with the following note "This section will be completed for the QAPP", as a place holder for the development of the QAPP.

This section describes findings from previous studies that support the need for the study and/or the potential success of the study. This may include:

- A summary of a literature search of studies previously conducted or in progress (including relevant results) regarding the specific Structural BMP(s) that is the focus of this study
- Provide references for any reports that are sources of information or data provided

3.4 Regulatory Requirements

This section identifies the specific Stormwater Management Program conditions or other conditions in the EWA NPDES Phase II Municipal Stormwater permit that the study will address. Include the relevant permit section(s) including S5.5 Post-Construction Stormwater Management for New Development and Redevelopment.

4.0 Project Overview

The purpose of this section is to provide an overview of the entire study. If the reader only read this section, they should generally understand what the study intends to accomplish as well as how it will be accomplished *(save the detailed project description details for the subsequent sections).*

4.1 Study Goal

The goal of this study is to evaluate the effectiveness of a modified bioretention BMP. The modification is to the engineered soils specification: in lieu of using the default 60:40 mix specification, a native soil specification would be used. The modified bioretention BMP will be sized following the existing bioretention design guidance defined in the EWA LID Manual. The effectiveness evaluation will focus on determining whether a bioretention BMP constructed using the native soil specification without vegetation can achieve Ecology's treatment goals for basic (TSS) and dissolved metals, Copper (Cu) and Zinc (Zn). If some of these goals are met, the results will be used to justify the development of a modified BMP that is approved for 'general use' on future projects (Ecology, 2011).

Note: This study includes the goal of developing a modified BMP, as such the experiment design for this study will follow the modified BMP effectiveness requirements defines in Appendix A.

4.2 Study Description and Objectives:

As written, this section includes an overview of the study in a bullet format. This section should be revised to include the following items:

The section briefly describes how the study goal(s) will be accomplished *(the detailed description will be provided in Section 7.0)*. This should include: a short description (one paragraph) of the proposed study (a detailed description will be provided in Section 7.0) and a list of all the study objectives *(note: an objective is a measurable statement that includes an action verb that defines how the project goal will be accomplished)*

The study proposed will likely include multiple phases to meet the study goal: Phase 1 develop the specification and Phase 2 field evaluation.

- Develop a specification that defines the physiochemical properties (or range of properties) of native soils that are suitable for providing stormwater treatment. This will may include conducting an extensive literature search and identifying properties based on common citations in the literature.

- Verify (through analytical testing of the soils) that the properties of the native soils that will be used at test site(s) are within the range of suitable properties identified in the specification.

- Design and construct the bioretention BMP following the design guidance in the Ecology Stormwater Manual for EWA (or an equivalent manual) except without vegetation and using the native soils specification

- Design and install an automated water quality monitoring system capable of collecting composite influent and effluent water quality samples; monitoring flow rates; and measuring rainfall depth.

- Collect water quality samples from a minimum of 12 qualifying events.

- Visually observe the site after each rainfall event to document weed growth, evidence of vandalism, impacts to the BMP from blowing sand, etc.

- Analyze the data and evaluate whether the pollutant reduction meet Ecology's treatment performance requirements defined in TAPE. This study also includes submitting a TAPE application that enters the new BMP into the evaluation program, and submitting a technical evaluation report to Ecology and the TAPE board of external reviewers (BER) for review and approval. The BER for this study will be composed of experts from EWA.

4.3 Study Location

This study will be conducted in a residential or commercial location in EWA, Washington. The locations will be determined by the lead agency with consultation from participating agencies.

Proposal – At the proposal phase the test-site may not be selected. It is only necessary to describe the general characteristics of the proposed test-site and indicate the number of potential sites.

Identify and provide an overview of the test-site location where the study will be conducted *(the process and justification for selecting the site(s) will be described in Section 7.0)*. This may include:

- Identify the test-site(s) locations, where the study will be conducted including the number of sites if applicable
- Briefly describe the various site characteristics (i.e. major land uses, average daily traffic, climatic conditions, soil conditions, etc.)
- If the study includes multiple test-sites; briefly, address how the sites compare (*more specific details regarding how sites should be compared are provided in Section 7.0*)
- Use maps, photos, and/or drawings to identify the location and boundaries of the test-site as well as any relevant stormwater features

4.4 Data Needed to Meet Objectives

Add data that will be needed for Phase 1.

Data that will be needed for the field testing includes: Influent and effluent samples will be collected from a minimum of 12 qualifying events. Samples will be submitted to an Ecology certified lab for analytical testing of the following constituents: TSS, dissolved Cu and Zn, total phosphorus, and total petroleum hydrocarbons. Analytical testing of the native soils will also be conducted to verify the physiochemical properties and the infiltration rate would be measured every four months during the data study.

4.5 Tasks Required to Conduct Study

Tasks required to conduct the study include:

Phase 1

- Devlop native soil specification
  - Conduct a literature search
  - Material testing of native soils to verify properties (prior to column testing)
  - Conduct flow through column testing

Phase 2

- Enter BMP in the TAPE Evaluation Program
  - Develop and submit application
  - Convene a Board of External Reviewers (BER) from Ecology and (EWA) made up of stormwater experts/researchers
- Develop Quality Assurance Project Plan (QAPP)
  - Submit QAPP to Ecology and BER for review
- Prepare for Data Collection:
  - Program and install monitoring equipment
  - Construct test site
  - Native soil material testing (verify properties meet the specification)
- Data Collection:
  - Monitor weather daily
  - Collect influent and effluent samples from 12 rainfall events; test samples for required and screening parameters: basic, dissolved metals treatment goals
  - Measure infiltration rate quarterly
  - Clean and prepare sampling equipment before sampling events
  - After each sampling event, download from data logger: precipitation and flow rate
  - Develop and manage a database that contains all the collected data
  - Analyze data
- Develop Technical Report:
  - Write annual reports
  - Develop technical evaluation report
  - Respond to comments from Ecology and BER regarding report

4.6 Potential Constraints

Proposal – Provide a description based on the information known about the study.

Potential constraints are conditions that may impact the project schedule, budget, or scope. The potential constraints need to be identified section along with the steps that will be taken to reduce the impact of these conditions (mitigation approach). Both the potential constraints and mitigation approaches should be summarized in Table 4.2.

Table 4.2Summary of Potential Constraints and Mitigation Approaches

Potential Constraint	Mitigation Approach

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

Proposal – At a minimum include the Lead Entity, Participating Entities, Partner Entities, and the Ecology Reviewer.

Include key members of the project team, decision-makers, and/or stakeholders (i.e. lead and participating entities, project manager, test site owner/manager, analytical laboratory contacts, field personnel, third-party reviewer(s), etc.) and describe who is going to do what for the project.

Key Team Members	Role	Responsibility
Name Organization Phone Number Email	Lead Entity	Define
Name Organization Phone Number Email	Participating Entity	Define
Name Organization Phone Number Email	Partner Entity	Define
Name Organization Phone Number Email	Ecology Reviewer	Define
Name Organization Phone Number Email	Proposal Author	Define
Name Organization Phone Number Email	QAPP Author	Define
Name Organization Phone Number Email	Key Team Member Project Role	Define

5.2 Project Schedule

Proposal - Include the task duration, permit deadlines, and estimated time to complete the study.

This section defines the schedule for the proposed study. Organize the schedule into a table format that includes the same tasks and sub-tasks as listed in section 4.5, the expected start-end dates, deliverables, and deadlines for deliverables.

	2017		2018				2019				2020			
Task Name	Q3: Jul - Sept	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec	Q1: Jan - Mar	Q2: Apr - Jun	Q3: Jul - Sep	Q4: Oct - Dec
Finalize Detailed Study Design Proposal														
Ecology Proposal Review Period														
Develop Native Soil Specification														
Submit TAPE Application														
QAPP Development														
QAPP Review Ecology & BER														
Prepare for Data Collection														
Data Collection														
Analyze Data & Reports														
TER Review Period Ecology & BER														

5.3 Budget and Funding Sources

Proposal – Provide an estimated budget for the study broken down by the primary tasks (in Section 4.5). Identify potential funding sources if known or indicate funding needs and any plans for obtaining study funds.

This section defines the project budget for the implementation phase of the study and identifies the study funding sources. Organize the budget into a table and separate the budget by study tasks and subtasks. Include items such as labor for sample/data collection, lab analyses fees, equipment purchase and assembly, test-site construction, any specialized contracting needed. Describe how the study will be funded and/or indicate if additional funding is needed to complete the study.

Table 5.2: Study Budget

Task	Hours	Cost Per Hour	Responsible for Task (consultant, jurisdiction, participating entity)	Equipment Fees[3]	Total
Project Management					
Finalize Detailed Study Design Proposal					
Develop Native Soil Specification					
QAPP Development					
Prepare for Data Collection					
Data Collection					
Analyze Data and Study Reports					
				Total	

Monitoring Equipment

Item	Quantity	Cost	Total Cost	Vendor
FTS H2 Data Logger	1	$5,775.00	$5,775.00	FTS
Thel-Mar Weir 6"	2	$235.00	$470.00	Thel-Mar
ISCO Interface Cable	2	$675.00	$1,350.00	Teledyne
Rain Gage	1	$909.00	$909.00	FTS
Terminal Connector Cables	4	$80.00	$320.00	FTS
FWS Cap for Telemetry Port	1	$75.00	$75.00	FTS
ISCO Avalanche Refrigerated Autosampler	2	$5,141.00	$10,282.00	Teledyne
Avalanche 10L Glass Sample Bottle w/Teflon Lid	4	$165.00	$660.00	Teledyne
FTS TTS Enclosure	1	$3,527.00	$3,527.00	FTS
OTT PLS Pressure Transducer W/ Accessories	2	$1,361.10	$2,722.20	OTT
PTFE Suction Tubing for ISCO (1 roll @ 200ft)	1	$500.00	$500.00	Teledyne
Starved Electrolyte Deep Cycle Battery (100Ah)	1	$347.00	$347.00	FTS
H2 Battery Cable	1	$250.00	$250.00	FTS
OTT PLS Desiccant Replacement	2	$100.00	$200.00	OTT
Tapedown Indicator	1	$436.82	$436.82	D&H
Pipe cleaning kit	1	$296.15	$296.15	D&H
		TOTAL	**$28,120.17**	

$4,000.00 for construction costs

fittings, conduit, bolts, nuts, washers, strut, wiring, straps, pipe, caps, etc. for station installation

6.0 Quality Objectives

This section will be completed for the QAPP

7.0 Experimental Design

The purpose of this section is to describe the experimental design that will be used to evaluate (and/or compare) the BMP effectiveness. This section also provides the basis for why the experimental design was selected (which may include a literature search). The information contained in this section is intended to provide the user with an overview of the section contents and address conditions specific to the EWA Effectiveness Studies for Structural BMPs. Consult the **Ecology TAPE Guidance Document [1]** for detailed guidance on developing this section (see Preparing a QAPP, Experimental Design).

This section should also describe how the applicable **DQIs** are addressed**.** Include references to **MPCs** defined in Section 6.

7.1 Study Design Overview

Proposal – Provide a summary of the conceptual study design.

This section provides an overview of the experimental design (level of detail expected is similar to an executive summary). This section introduces the reader to the study design and the primary elements of the study. This should address the primary experimental design elements including (if applicable):

- Monitoring site
- BMP treatment and flow system sizing
- Precipitation monitoring
- Flow monitoring
- Water quality sampling
- Sediment sampling

7.2 Test-Site(s) Selection Process

Proposal – Describe the proposed selection process and criteria. If the sites have been selected, provide information about the actual process and criteria.

This section provides a detailed description of the test-site(s) along with the justification for selecting the sites. This should include:

- Identify the site location(s)
- Provide a detailed description of the process and criteria for selecting the test-site(s) including the assessment for determining the suitability of the site for a monitoring
- Include maps, photos, and/or drawings (refer to section 4.3) as well examples of the tools/methods used for selection

- Define the variables that will influence selection and summarize the variables in tables. Variables will vary depending on the specific study goals. Examples include geographical area, land use classification, average daily traffic, accessibility to sites, soil conditions, influent pollutant concentrations, receiving waters, etc.
- Provide a justification for selecting the sites
- Access and other field crew safety considerations are common criteria when selecting a test site or sites

7.3 The Structural BMP System Sizing

Proposal – Provide a summary of the conceptual BMP sizing

This section describes how the BMP was sized for the selected monitoring site. Reference the **Ecology TAPE Guidance Document [1]**, the Experimental Design section, for guidance on developing this section.

Effectiveness and Develop Modified BMP Studies – This section should be completed using the BMP design criteria defined in an Ecology approved stormwater manual. Include a reference to the manual.

Develop Modified BMP – Describe any modifications to the existing Ecology approved BMP design criteria

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 and in TAPE. 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. See Figure 7.X for an overview of the monitoring system design proposed for this study.

Table 7.1 Overview of Monitoring Variables

Parameters	Frequency	Sampling Method and sampling location	Telemetered Data
Rainfall	Continuous, year-round	Rain Gage, on-site	Yes
Stage (Discharge)	Continuous, year-round. Discharge calculation activated per-storm	Pressure Transducer, influent and effluent	Yes
Temperature	Continuous, year-round	In Situ Probe at influent and effluent	Yes
Water Quality, except grab samples	Discrete storm events (min. of 12 samples)	Autosampler, Influent and effluent	No
Infiltration	Quarterly	Single ring infiltrometer; TBD	No
Maintenance	Twice/year	-	No
Native Soil Material Testing	Once, prior to start of study	TBD	No

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 will be located on-site within the drainage basin for the facility to accurately represent on-site rainfall characteristics. Rain gages must 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. Rain gage placement will follow the National Weather Service specifications (http://www.weather.gov/om/coop/standard.htm) as closely as practical for the site. Minor deviations from NWS specifications may be needed due to site specific constraints.

If a deviation from NWS specification is needed, 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 and will be broadcast hourly via telemetry to remotely identify on-site weather characteristics and determine when sampling crew need to deploy for sample collection. During each station visit, the rain gages 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

Grab Sampling

TAPE states that grab samples should be collected on the rising limb of the hydrograph. Sampling staff are to collect grab samples as early in the runoff event as practical to ensure representativeness of the sample. A minimum of twelve samples will be collected for statistical comparison following TAPE guidelines.

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.

Grab samples are typically those collected manually in jars or measured in situ with a probe. For oil control BMPs NWTPH-Dx, pH, temperature, and visible sheen are required grab samples. If oil control is desired, NWTPH-Dx grabs will be collected by hand, visible sheen will be noted by observation. pH and temperature will be measured using a probe.

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 will be programmed to begin sampling when initiated by the data logger. 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 a four-step threshold system. Four thresholds (water temperature, rainfall, discharge and time) are necessary to determine whether the antecedent criteria and rainfall criteria was 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. Each monitoring station will be equipped with an autosampler and a 2.5-gallon glass bottle for sample containment.

Composite Sample Handling –

Composite samples will be collected as quickly as possible after a storm event to reduce potential for holding time issues. At the end of a targeted storm event, sampling staff verify whether the event met permit criteria for storm qualification (rainfall quantity and number of aliquots collected over the runoff hydrograph) before determining whether they process or dispose of samples. The autosampler continues refrigerating the samples until sampling staff are able to recover the sampled stormwater. At the end of a qualifying storm event, the data logger will automatically resume its programming and await resetting by sampling staff before the next qualifying event.

Sampling staff wear nitrile gloves at all times during sample collection and follow standard clean hands procedures to minimize contamination. Preservation and filtration of samples (if needed) occur as soon as feasible after composited samples have been collected.

Upon completion of sampling, labels are documented and samples are placed in coolers for transport. Sample coolers must contain ice packs or loose ice to ensure temperatures remain below the laboratory-required temperatures for specific parameter analyses. Samples are packed carefully to minimize sample bottle breakage. Chain of custody (COC) forms are filled out completely and sent to the lab with the coolers. Collection of QC samples occurs on a routine schedule and will be included in the sampling process. Extra bottles will be present in a cooler for QC collection.

After composite samples are collected, the autosampler is inspected, cleaned, restocked, and reprogrammed per established SOPs. Ecology's *Standard Operating Procedure for Automatic Sampling for Stormwater Monitoring* (Ecology, 2009b) will serve as additional guidance.

Sample verification

Before sending the samples to the laboratory, sampling staff are required to fill out sampling forms (see example form in Appendix L). Additionally, sampling staff verify that the storm event met the requirements for storm sampling (rainfall quantity and number of aliquots collected over the runoff hydrograph). However, when sample qualification is questioned, sampling staff will send the collected samples to the laboratory as soon as possible. The Storm Controller (or delegate) will call the laboratory to cancel the analysis if it is determined that the storm event did not meet established criteria. Communication between sampling staff and the Storm Controller (or delegate) is critical and requires frequent interaction.

Sampling staff determine the final volume of the sample captured and number of aliquots sampled by checking the information collected in the data logger. If inadequate sample volume is collected for analysis of all parameters, parameters will be analyzed according to importance and number of previous samples collected. Upon delivery of samples to the laboratory, sampling staff will hand in their sampling notes and copies of COC documents to the Storm Controller for review within 24 hours of the storm event.

The Storm Controller will review collected storm reports, hydrographs, sampling notes, COC forms, and maintenance forms for completeness and to determine whether any data quality errors were made. If errors are found, notice is given to the laboratory regarding the type of error, which sample was collected in error, and whether the sample should be flagged or disqualified from analysis based on the error.

Hydrology data are reviewed regularly to determine if any drift or gaging errors occurred during the storm event and to ensure that at least 75 percent of the storm event hydrograph has been sampled. Errors will be identified either by sampling staff during a storm event or through post-storm review of the hydro/hyetographs by the Storm Controller. This data is used to verify that precipitation requirements have been met once samples have been collected. The information is also used to verify that the monitoring station is operating successfully. A data shift may be applied to a discharge rating if warranted to better fit the runoff hydrograph to actual measurements and account for instrument drift.

Automated sample collection

Each station's data logger is preprogrammed to continuously collect temperature, stage, antecedent time and rainfall data. Temperature, rainfall, and stage data are collected and logged every 15 minutes and transmitted hourly via telemetry. Since much of the peripheral data collected is not transmitted hourly, sampling staff will frequently download the data and save it to secure storage. Upon receipt of data, data are qualified, tabulated, and stored in a central storage location until they are able to be reviewed. The field downloaded data serves as the master version and is used for data verification and reporting purposes.

Equipment management and maintenance

At a minimum, maintenance of monitoring instrumentation meets or exceeds manufacturers' specifications and is conducted as needed by trained staff. Generally, maintenance consists of equipment inventories, inspections, testing, and replacement of worn or missing components. Routine site maintenance and DCP preparation occurs prior to a potential storm event, as needed, following established SOPs.

Decontamination of monitoring equipment

Equipment used to collect stormwater samples is only allowed for sampling use after cleaning in accordance with the procedures listed below:

1. Wash equipment with nonphosphate detergent in hot tap water
2. Rinse equipment with hot tap water
3. Rinse clean equipment with 10 percent nitric acid when sampling for metals
4. Rinse equipment with deionized water three times
5. Air drying in clean area free of contaminants

After drying, equipment is stored in polyethylene bags until used in the sampling. Suction tubing is swapped annually or if contamination is noted via blank sampling or visible observation. All clean sample tubing is capped after drying at both tube ends with corners of polyethylene bags and taped to the outside of the lined tubing to prevent contamination of the inside of the tubing. All sampling equipment and containers will be pre-cleaned and prepared prior to each sampling event. The autosampler glass bottle, metals and orthophosphate filters, or other materials coming into contact with the sampled stormwater are decontaminated prior to each use or certified as precleaned by the laboratory prior to use.

Adaptive Management

As practical experience is gained through monitoring, the process of adaptive management will be considered for minor changes. Minor changes to the monitoring program shall not require authoritative signature approval for implementation. Some examples of small changes include, but are not limited to:

- Size or type of bottles used in the automatic sampler
- The type of equipment used for field filtration of metals samples

- Changing to a different brand of monitoring equipment but still retaining functional equivalency
- Adjustments to the programming of the data logger

Minor changes will be noted and included in the annual report. Major changes require Ecology approval prior to implementation.

7.7 Sediment Sampling

Proposal – Provide a summary of the conceptual sediment sampling system

This section describes the monitoring locations and equipment, sampling methodology, and the monitoring duration for sediment sampling. Reference the **Ecology TAPE Guidance Document**, the Experimental Design Section, for guidance on developing this section.

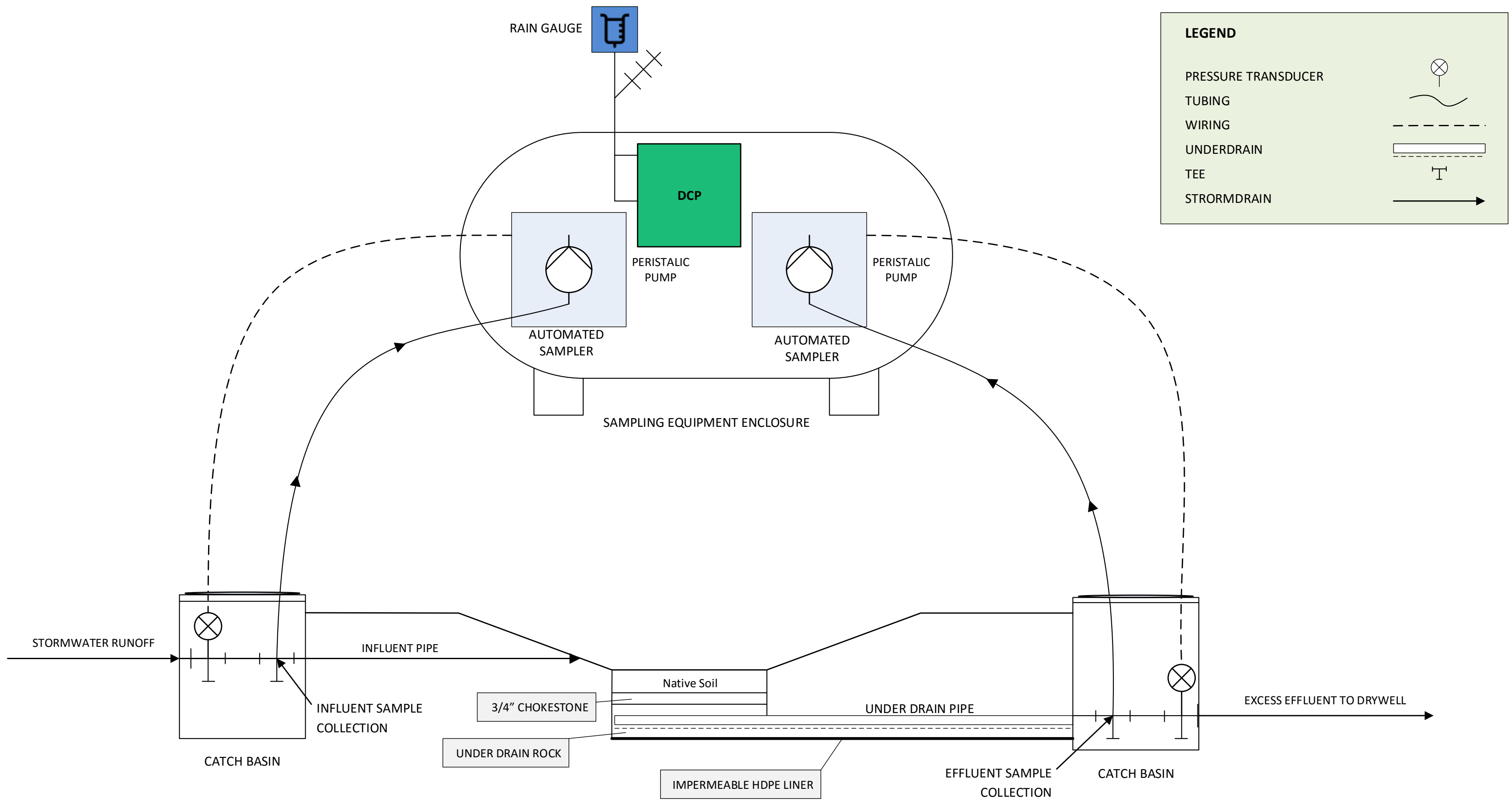

Figure 7.X Process Diagram of Proposed Monitoring System

8.0 Sampling Procedures – QAPP Only

This section will be completed for the QAPP.

8.1 Standard Operating Procedures

This section will be completed for the QAPP.

8.2 Containers, Preservation Methods, Holding Times

This section will be completed for the QAPP.

8.3 Equipment Decontamination

This section will be completed for the QAPP.

8.4 Sample Identification

This section will be completed for the QAPP.

8.5 Chain of Custody

This section will be completed for the QAPP.

8.6 Field Log Requirements

This section will be completed for the QAPP.

9.0 Measurement Procedures – QAPP Only

This section will be completed for the QAPP.

9.1 Procedures for Collecting Field Measurements

This section will be completed for the QAPP.

9.2 Laboratory Procedures

This section will be completed for the QAPP.

9.3 Sample Preparation Methods

This section will be completed for the QAPP.

9.4 Special Method Requirements

This section will be completed for the QAPP.

9.5 Lab(s) Accredited for Methods

This section will be completed for the QAPP.

10.0 Quality Control – QAPP Only

This section will be completed for the QAPP.

10.1 Field QC Required

This section will be completed for the QAPP.

10.2 Laboratory QC Required

This section will be completed for the QAPP.

10.3 Corrective Action

This section will be completed for the QAPP.

11.0 Data Management Plan Procedures – QAPP Only

This section will be completed for the QAPP.

11.1 Data Recording & Reporting Requirements

This section will be completed for the QAPP.

11.2 Electronic Transfer Requirements

This section will be completed for the QAPP.

11.3 Laboratory Data Package Requirements

This section will be completed for the QAPP.

11.4 Procedures for Missing Data

This section will be completed for the QAPP.

11.5 Acceptance Criteria for Existing Data

This section will be completed for the QAPP.

11.6 Environmental Information Management (EIM) Data Upload Procedures

This section will be completed for the QAPP.

12.0 Audits – QAPP Only

This section will be completed for the QAPP.

12.1 Technical System Audits

This section will be completed for the QAPP.

12.2 Proficiency Testing

This section will be completed for the QAPP.

13.0 Data Verification and Usability Assessment

Proposal – Identify the data that will be verified

The section defines 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. More specifically, to determine whether the **MPCs** were met for the applicable **DQIs**. The information contained in this section is intended to provide the user with an overview of the section requirements and address conditions specific to the EWA Effectiveness Studies. Consult the **Ecology QAPP Guidance Document** [4] and **TAPE Guidance Document** [1] details on developing this section.

This section should also describe how the applicable **DQIs** are addressed. Include references to **MPCs** defined in Section 6.

13.1 Field Data Verification

This section will be completed for the QAPP.

13.2 Laboratory Data Verification

This section will be completed for the QAPP.

13.3 Data Usability Assessment

This section will be completed for the QAPP.

14.0 Data Analysis Methods

14.1 Data Analysis Methods

Flow Control Performance

The following information will be compiled for each sampling event that occurred during the data collection period to evaluate the flow control performance of the BSM:

- Influent, effluent, and bypass volume of water
- Storm precipitation depth
- Storm duration
- Storm average precipitation intensity
- Storm peak precipitation intensity
- Storm antecedent dry period
- Peak discharge at the Influent and Effluent Monitoring Station
- Runoff volume at the Influent and Effluent Monitoring Station
- Flow duration at the Influent and Effluent Monitoring Station

Once this information is compiled, additional analyses will be performed to identify a subset of storms that had sufficient precipitation totals and/or intensities to produce measurable runoff into the sand filter. Specifically, any storm event that produced a measurable flow volume at the Influent Monitoring Station will be flagged as runoff-producing.

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 included comparing the average removal efficiency at the 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

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. 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 influent and effluent concentrations. 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 pond.

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

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 95% confidence interval for 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 included values that are non-detectable, the reporting limit for the respective pollutant will be used as defined by the standard testing method.

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

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

Infiltration Measurements

Infiltration measurements for each pond will be taken quarterly and analyzed in a spreadsheet using standard statistical techniques and graphical representation of BMP performance over time. Descriptive statistics (mean, minimum, maximum, and standard deviation) will be computed for each set of infiltration measurements (see Table 14.2 for an example). A summary table of all tests for each pond can be presented together (see Table 14.3 for example). The effectiveness will be determined by comparing the infiltration rates against time using graphical representation.

Table 14.2: Infiltration rate (inches per hour) of pond (04/15/2018).

Mean	205.10
Std Dev	2.79
Min	199.10
Max	214.00

Table 14.3: Infiltration rate statistics for 04/15/2018.

	Infiltration Rate (in/hr.)	
	Mean	Standard Deviation
Test 1	2.4	0.5
Test 2	2.0	0.7

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 shown in Figures 14.1, 14.2, and Table 14.1 and briefly described below:

- Figure 14.1 - 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 14.2 - Log-Normal Graphs are line graphs of the removal efficiency (C_{eff}/C_{in}) for each sampling event. These graphs illustrate the trend in the treatment performance over the duration of the study.

- Table 14.2 – 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.

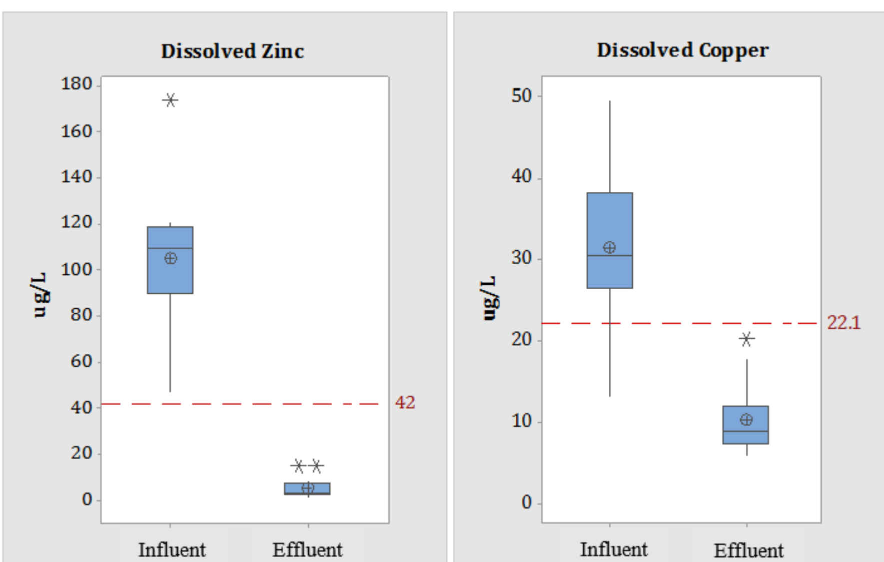

Figure 14.1 Example of Box Plots

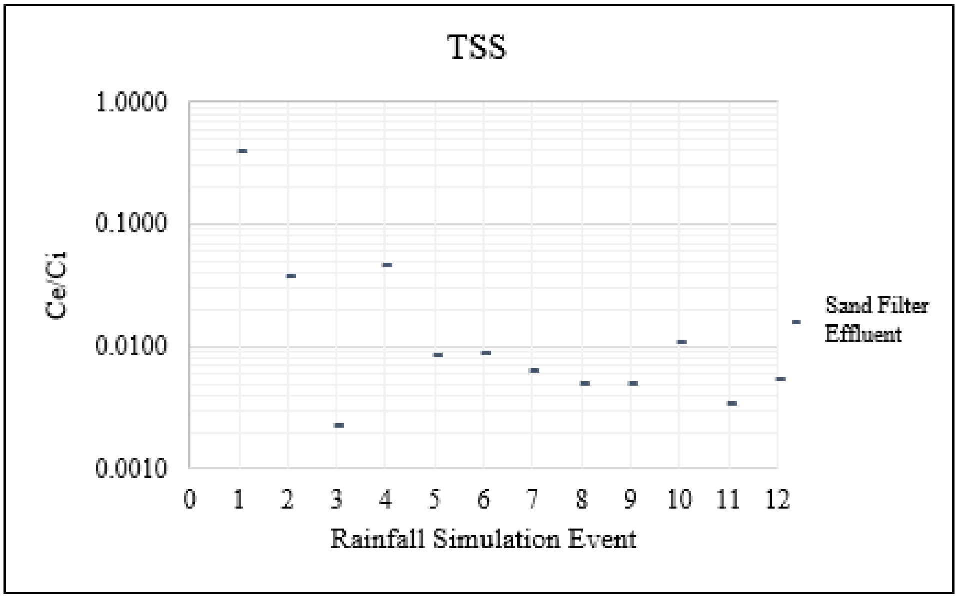

Figure 14.2 Example of Log-Normal Graphs line graphs: the removal efficiency (C_{eff}/C_{in})

Table 14.1 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	Performance Criteria	Pass Or Fail
TSS (mg/L)							
Pond 1	171.0	2.640	12	Y	92.0%	80%	Pass

15.0 Reporting

This section describes how the study findings will be reported and disseminated.

15.1 Final Reporting

This section will be completed for the QAPP.

15.2 Dissemination of Project Documents

The final report will be shared with the participating agencies and will be posted to the lead entities webpage: add website

16.0 References

AHBL and HDR, *Eastern Washington Low Impact Development Guidance Manual*. 2013, Washington State Department of Ecology: Puyallup, WA.

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Davis, A.P., et al., Laboratory study of biological retention for urban stormwater management. Water Environment Research, 2001: p. 5-14.

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Hatt, B.E., Hydraulic and Pollutant Removal Performance of Fine Media Stormwater Filtration Systems. Environmental Science and Technology, 2008: p. 2535-2541.

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Li, H. and A.P. Davis, *Urban particle capture in bioretention media. I: Laboratory and field studies.* Journal of Environmental Engineering, 2008. **134**(6): p. 409-418.

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Technical Guidance Manual for Evaluationg Emerging Stormwater Treatment Technologies. 2011, Washington State Department of Ecology: Olympia.

17.0 Appendices

Appendix A – Overview of Requirements for Modified BMPs

Study Elements	Evaluate Practice Effectiveness	Develop Modified BMP	Develop New BMP
TAPE Application	No application required	No application required	Application required - Jurisdictions are exempt from TAPE fees
Define BMP Materials[1]	• Verify BMP material properties and quantities are consistent with the BMP design guidance. • Determine BMP material properties using manufacturer provided specifications or through material testing • For BMPs that contain compost, define material source. • For BMPs that contain topsoil, define material source.	Same as Effectiveness plus: • Define BMP design criteria material modifications	Same as Effectiveness plus: • Define BMP material properties and quantities proposed for new BMP design criteria
Study Duration	1.5 maintenance cycles or 2 wet seasons	Same as Effectiveness Study	Same as Effectiveness Study
Water Quality Testing[1]	Test influent & effluent for the pollutants concentrations the BMP is approved to provide runoff treatment for.	Test influent & effluent for the following: • Pollutants BMP is approved to provide runoff treatment for plus the additional required parameters[2] • Test for the required screening parameters 3 times during the study[2]	Same as Modified BMP plus: • Evaluate the treatment performance at the peak and average flow rate using field monitoring information only
Sample Size	Collect samples from a minimum of 12 natural rainfall events (maximum of 35) that meet the qualifying conditions[3].	Collect samples from a minimum of 12 and maximum of 35 natural rainfall events that meet the qualifying conditions[3].	Same as Modified BMP plus: • Collect samples from 50% to 125% of the design flow rate using field monitoring information only
Design Flow Rate	• Define Design Flow Rate specified in the BMP design criteria • Measure the influent and effluent flow rate as defined in the TAPE requirements	Same as Effectiveness Study	• Define design flow rate for proposed BMP design criteria • Measure initial flow rate using standard methods (i.e. Modified ASTM D2434) • Measure the influent and effluent flow rate as defined in the TAPE requirements
Audits	• Technical system audits and proficiency audits <u>are recommended</u> • Audits maybe conducted by the Project Manager	• Technical system audits and proficiency audits <u>are required</u> • Audits maybe conducted by the Project Manager	Same as Modified BMP except: • Audits shall be conducted by a 3rd party

Study Elements	Evaluate Practice Effectiveness	Develop Modified BMP	Develop New BMP
Data Analysis	• Evaluate if difference between influent and effluent pollutant concentrations is statically significant and indicate the confidence interval. • Determine average pollutant removal efficiency. • Bootstrap Method is recommended to determine efficiency and associated confidence interval.	• Hypothesis testing: statistically significant difference between influent and effluent pollutant concentrations to a 95% confidence interval and 80% power • Evaluate BMP using Ecology treatment performance goal[4]: 95% confidence interval for removal of pollutants the BMP is approved and/or proposed to provide runoff treatment for. • Use Bootstrap Method to determine removal efficiency at 95% confidence interval.	Same as Modified BMPs
Final Report	• Final report should contains elements defined in S8.B10 of the NPDES permit • Use TAPE TER requirements as a guide for developing report[5] • QAPP may substitute for relevant sections including: introduction, technology description, and sample procedures	• Use TAPE TER requirements as a guide for developing report[5] • QAPP may substitute for relevant sections including: introduction, technology description, and sample procedures	Follow TAPE TER requirements [5]
Document Review Process	• Ecology reviews/approves QAPP • Ecology reviews final report (*no requirements for Ecology approval defined in permit*)	Jurisdiction must convene a Board of External Reviewers (BER): 3-5 individuals (2 from Ecology) with technical skills necessary to provide a peer review of the QAPP and TER.	QAPP & TER Review by Board of External Reviewers (BER)

1. All water quality and material testing should be conducted at an Ecology Accredited Laboratory. Reference the following link for a full list of laboratories: https://fortress.wa.gov/ecy/laboratorysearch/
2. See TAPE Guidance document, Table 8 for a list of the required parameters and required screening parameters
3. Qualifying conditions include but are not limited to: minimum rainfall depth and duration, minimum time between rainfall events, and range of influent pollutant concentration. See TAPE guidance document for more details, specifically Tables 2, 5-7.
4. The Ecology treatment performance goals define the pollutant removal efficiency for the BMP: 80% TSS, 60% dissolved Zinc, 30% dissolved Copper, 50% Total Phosphorus, and < 10mg/L of Total Petroleum Hydrocarbons (TPH). The specific requirements are in Table 2 of the TAPE guidance document.
5. TAPE Technical Evaluation Report (TER) guidance is define on page 35 of the **TAPE Guidance Document**.