Quality Assurance Project Plan: Garland Avenue Biochar Amended Storm Garden Pollutant Removal Efficacy –SWMP Effectiveness Study

February 2019

City of Spokane, Washington
Wastewater Management Department
909 East Sprague Avenue
Spokane, Washington 99203

Quality Assurance Project Plan: Garland Avenue Biochar Amended Storm Garden Pollutant Removal Efficacy – SWMP Effectiveness Study

Prepared for:

Washington State Department of Ecology
(In accordance with S8.B.6 of the Eastern Washington Phase II Municipal Stormwater Permit [WAR046505])

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1.0 INTRODUCTION

Stormwater and combined sewer overflows (CSO) have been identified as a source of pollution of waterways throughout our nation. In a traditional regulatory and municipal setting, the sewer and stormwater systems are treated as separate entities with separate time frames for pollution reduction strategies. The focus of stormwater management has increasingly shifted from collection system disposal to treatment and infiltration. Stormwater and combined sewer overflows were identified, nationwide, as sources of pollution to surface waterways.

Bio-infiltration channels, herein referred to as "storm gardens" for the purposes of this study, are a type of low impact development (LID) method that intercepts and treats stormwater through plants and engineered soil mixtures prior to discharging the treated water through infiltration or underdrains. Both eastern and western Washington LID guidance manuals recommend a standard soil mixture of sandy soils and compost for bio-retention. However, recent research concluded that phosphorus, nitrogen, and copper can leach from the compost component of the soil mix. Nutrients and some metals are a concern for the Spokane River and the SVRP aquifer. Permittees have been lacking alternative tools for soil mixture applicable to their region for LID methods. The Garland storm garden study supports the City of Spokane's overall investigation into the effectiveness of incorporating additional green infrastructure practices to manage stormwater.

Biochar could be a potential alternative to the compost portion of the soil mixture. It is a carbon-rich material produced from thermal decomposition of biomass at elevated temperatures with little or no oxygen. The biomass originates from a multitude of different feed stocks, such as wood or grass. Its high surface area and porosity are desirable characteristics for capturing pollutants.

The Spokane Regional Stormwater Manual 2008 (SRSM) provides treatment goals for stormwater facilities, and bio-infiltration channels are approved for basic treatment of total petroleum hydrocarbons and some metals. Storm gardens amended with biochar would preferably need to achieve treatment at least equal to or greater than the bio-infiltration swale treatment goals identified in the SRSM, and would optimally also achieve phosphorus treatment. The biochar amended storm garden is anticipated to achieve a reduction of nutrients (nitrogen and phosphorous) by approximately 30-70%, selected heavy metals (cadmium, chromium, copper, lead, and zinc) by approximately 50-80%, and petroleum hydrocarbons (diesel and residual range organics) by approximately70-80%.

The Garland Avenue Biochar Amended Storm Garden Pollutant Removal Efficacy – SWMP Effectiveness Study is one of two effectiveness studies the City of Spokane is the lead entity on. The focus of this study pertains to real world field application of a storm garden with engineered soil amended with biochar. Garland Avenue was the location selected for construction of the gardens, and this study measure the percent reduction of nutrients, selected heavy metals, and petroleum hydrocarbons.

2.0 BACKGROUND

The City of Spokane manages stormwater with infrastructures consisting of a municipal separate storm sewer system (MS4), combined sewer overflow (CSO), and underground injection controls (UIC). The combined sewer system collects and conveys both wastewater and stormwater to the Riverside Park Water Reclamation Facility (RPWRF). Stormwater flows to the CSO system predominantly on the south side of the City, where geology does not readily allow infiltration. During large storm events, the extra flow from stormwater can exceed the capacity in the collection system and RPWRF. Therefore, the excess combined stormwater and wastewater overtops flow regulators and discharges into the Spokane River. These combined sewer overflows are referred to as CSO.

Conversely, the City of Spokane's MS4 is a dedicated system to collect and convey only stormwater. It collects stormwater runoff from within City limits predominantly on the north side of the City and conveys it to the Spokane River and Latah Creek. It serves residential land use areas and receives limited runoff from commercial and industrial land use areas. It is a conventional stormwater system designed to efficiently remove excess water from the public right-of-way to prevent localized flooding.

Construction of the CSO collection system began as early as the 1890s and expanded as the City developed. The unpredictable and large peak flows of stormwater to the CSO system is a recognized issue, both for system capacity as well as water quality. In the 1980s and 1990s, the MS4 was constructed to alleviate stormwater flows to the CSO system. In addition, the City began constructing more infiltration facilities to further reduce stormwater flows to CSO basins, and that policy was enhanced with the adoption of the Integrated Clean Water Plan.

2.1 Spokane River Basin

The City is located in the Upper Columbia basin within the Spokane River watershed. The Spokane River begins at the outlet of Lake Coeur d'Alene, Idaho, and flows 112 miles westward to its confluence with the Columbia River. The Spokane River flows through multiple cities and urban areas in both Idaho and Washington, including Long Lake and the Spokane Indian Reservation, prior to discharging to the Columbia River. The Spokane River basin encompasses more than 6,000 square miles and the City encompasses only approximately 18 miles of the river. In addition, much of the Spokane region, upstream from Long Lake, is located above the Spokane Valley Rathdrum Prairie (SVRP) Aquifer. This sole-source aquifer provides drinking water to nearly half a million people. An interconnection between the Spokane River and SVRP aquifer exists as some reaches of the river feeds into the aquifer and in others the aquifer feeds into the river. This interconnection can potentially lead to contaminant migration through the ecosystem.

2.2 Biochar

Biochar is a carbon-rich material produced from thermal decomposition of biomass at elevated temperatures with little or no oxygen. It can be comprised of many different feedstocks, including grass stubble, wood chips, and other organic materials. Its high surface area and porosity provides good sorption characteristics for removal of common pollutants from stormwater runoff. As a result of the various feedstocks and processing techniques, biochar can be a variable amendment to treatment soils. The following illustrates the two different types of biochar used in this study.

Figure 1. Kentucky Bluegrass Biochar (Left) and Wood Biochar (Right)

2.3 Regulatory Requirements

The Environmental Protection Agency (EPA) phase II regulations went into effect in early 2003 and apply to all regulated small MS4. In 2007, the Department of Ecology Washington State (Ecology) issued the first Eastern Washington Phase II Municipal Stormwater Permit (permit) to the City of Spokane. In 2012, the City received the current permit with an effective date of 2014. The permit requires the Stormwater Management Program to allow non-structural preventive actions and source reduction approaches such as LID techniques, measures to minimize the creation of impervious surfaces, and measures to minimize the disturbance of native soils and vegetation.

The Spokane River is an impaired waterbody with a Total Maximum Daily Load (TMDL) for metals (cadmium, lead and zinc), dissolved oxygen (phosphorus, ammonia, and CBOD), and sections of the river are also on Washington's Section 303(d) list for PCBs, chromium, arsenic, pH, temperature, and sediment bioassay.

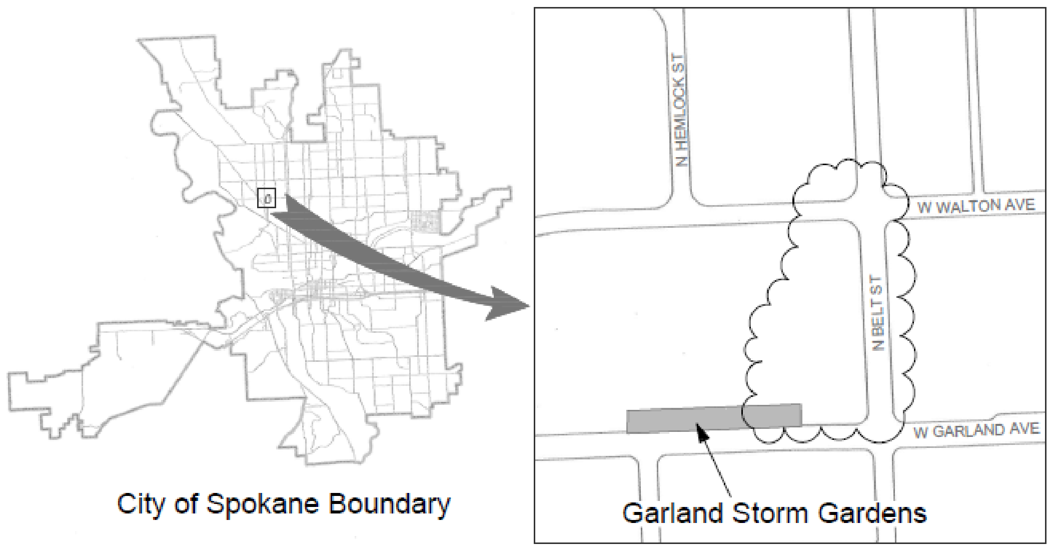
Furthermore, the City obtains its drinking water from the SVRP Aquifer. This unconfined aquifer was designated by EPA as a sole source aquifer in the mid-1970s.

As a permit requirement the City adopted the *Eastern Washington Low Impact Development Guidance Manual June 2013,* an ordinance that allowed for the exploration of LID approaches throughout the City. LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. It employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product. Permeable pavement is an LID approach that the City is interested in developing a better understanding of its capabilities and effectiveness of treating stormwater runoff.

2.4 Project Location Area

The study is located in the northwest quadrant of the City along Garland Avenue west of Belt Street within the CSO 06 basin. This area is primarily a residential land use area. Runoff from within this basin typically flows to the RPWRF. During overflow events, excess runoff travels to an outfall on the Spokane River located 0.25 miles upstream of the RPWRF. A series of three storm gardens, capturing stormwater runoff via curb cuts, were constructed on the north side of Garland Avenue. See Section 6 of this plan for a more detailed discussion on the design area of the storm garden study.

Figure 2. Map of the Study Area



2.5 Preliminary Study

The City of Spokane and University of Idaho funded a laboratory research study to develop a soil/biochar design mix for application in the storm garden discussed in this QAPP. The study used bench-scale laboratory testing of two different types of biochar available in the Spokane Region: 1) wood, and 2) Kentucky bluegrass stubble. The results of the preliminary study on the soil/biochar mixtures are provided in Appendix A.

The laboratory study conducted at Gonzaga University included bench scale laboratory testing to identify a soil mixture for field application. Column testing was performed at the Gonzaga University hydraulics laboratory. A series of columns were constructed containing various quantities of the different types of biochar, loamy sand, and other additives such as oyster shells, basalt containing iron, and limestone dolomite. A synthetic concoction of stormwater runoff was created to mimic municipal stormwater runoff. This concoction was used to infiltrate through each column at a rate mimicking precipitation events. Effluent samples were collected and analyzed for the following parameters:

- total suspended solids (TSS)
- total and dissolved metals (lead, copper and zinc)
- total and dissolved phosphorus
- ammonia
- nitrate
- nitrite

- total kjeldahl nitrogen (TKN)
- hardness
- pH

Results from the study determined that the wood biochar with loamy sand (and no other additives) removed the most pollutants. As a result, it was selected for use in the storm garden field application phase. The soil/biochar mixture details is included as Appendix A.

3.0 LOGISTICAL CHALLENGES

This eastern Washington region is comprised of inter-mountain areas and includes areas near Okanogan, Spokane and the Palouse, and storm events within the region are sporadic. The hydrology in eastern Washington is highly influenced by landscape, topography, and intermittent precipitation. Across the region much of the winter precipitation falls as snow, which does not melt until warmer temperatures of spring that cause high-runoff to occur from April to June, and by July, most of the mountain snow has melted and stream flows are low. Additionally, the nature of intermittent storm events produces challenges for sample collection because a portion of the City could receive rain; and, other portions do not.

The unpredictable nature of storm events poses one of the greatest logistical challenges for this study. The location, timing, duration, magnitude, and intensity of storm events cannot be forecast with certainty, and only storms of particular rainfall volumes, antecedent dry periods, etc. will result in "qualifying storm events." Since long-term forecasts have greater uncertainty, mobilization of the sampling team and equipment setup for a potential storm sampling event cannot occur more than two days ahead of a forecasted storm.

Given the logistical challenges and limited drainage basin being studied (see Section 6 for a detailed discussion of storm criteria), first-flush samples will be collected in lieu of collecting samples representative of the full hydrograph of the storm event.

3.1 Practical Constraints

Monitoring water quality from an infrastructure that was engineered and designed accordingly as a storm garden is a new concept for the City. Sampling stormwater runoff and infiltrated stormwater runoff from a collection system utilizing underdrains can be very challenging and the sampling design makes many assumptions about the ability to collect and analyze samples.

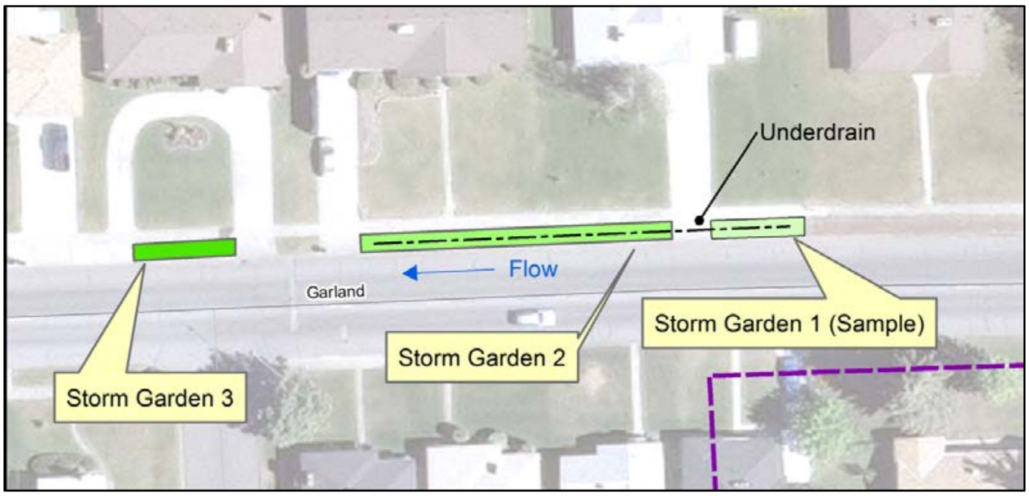
Vortox Air Technology FS8A fluid samplers will be used to collect first-flush composite samples from the storm garden in this study. This sampler does not require electricity and can be set to collect samples until the sampler is full. The volume of the sampler is 0.8 gallons (3 liters), which limits the sample volume number of constituents that can be monitored.

4.0 PROJECT DESCRIPTION

4.1 Project Goals

The goal of this study is to measure the percent reduction of monitored pollutant concentrations between the influent and effluent at Storm Garden 1. To achieve this, the City will sample the influent (pre-infiltration) and effluent (post-infiltration) stormwater concentrations. Influent sample concentrations will be measured prior to infiltration, and effluent sample concentrations will be measured after infiltration through the storm garden comprised of the amended soil.

Figure 3. Study Boundaries



A liner and underdrain was installed in Storm Garden 1 to collect treated stormwater runoff. The underdrain flows beneath the driveway approaching into Storm Garden 2, and is detailed in Figures 5-7. Storm Garden 1 contains soils amended with wood-based biochar, and is the focus of this water quality effectiveness study. Storm Garden 2 contains soils amended with Kentucky bluegrass-based biochar, and Storm Garden 3 contains standard bio-retention soil mix for visual comparison to the other two. Storm Gardens 2 and 3 will not be sampled for water quality, but will be visually observed to determine any differences in plant growth. The Lands Council should be monitoring plant growth, and the plant growth study is outside the scope of this water quality effectiveness study.

Figure 4. Storm garden and Sample Structure Location

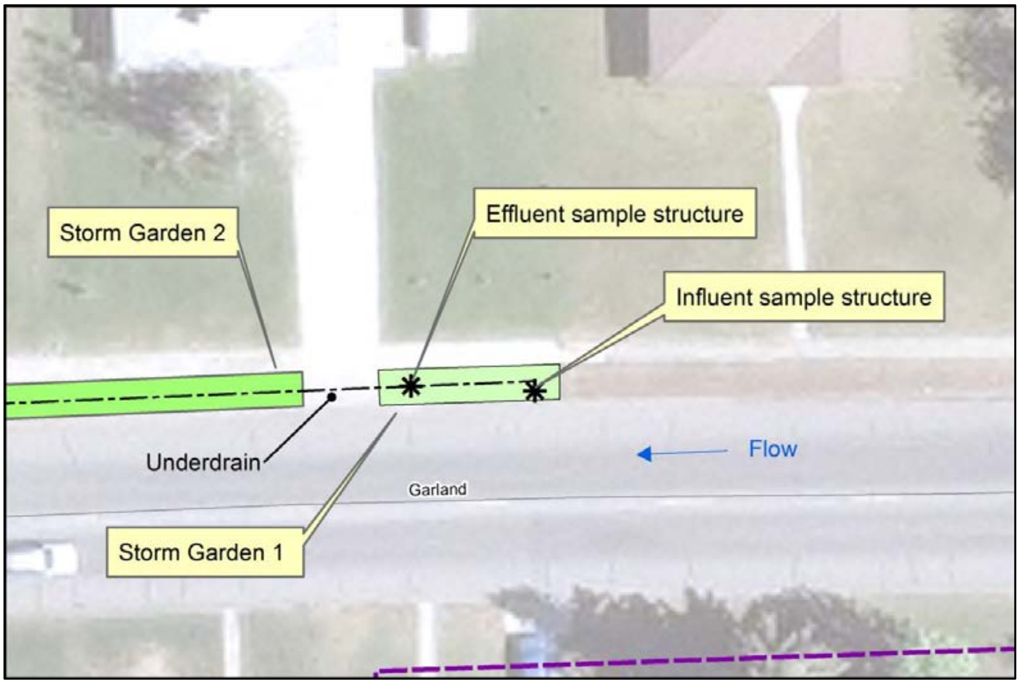


Figure 5. Cross Section of Sample Location

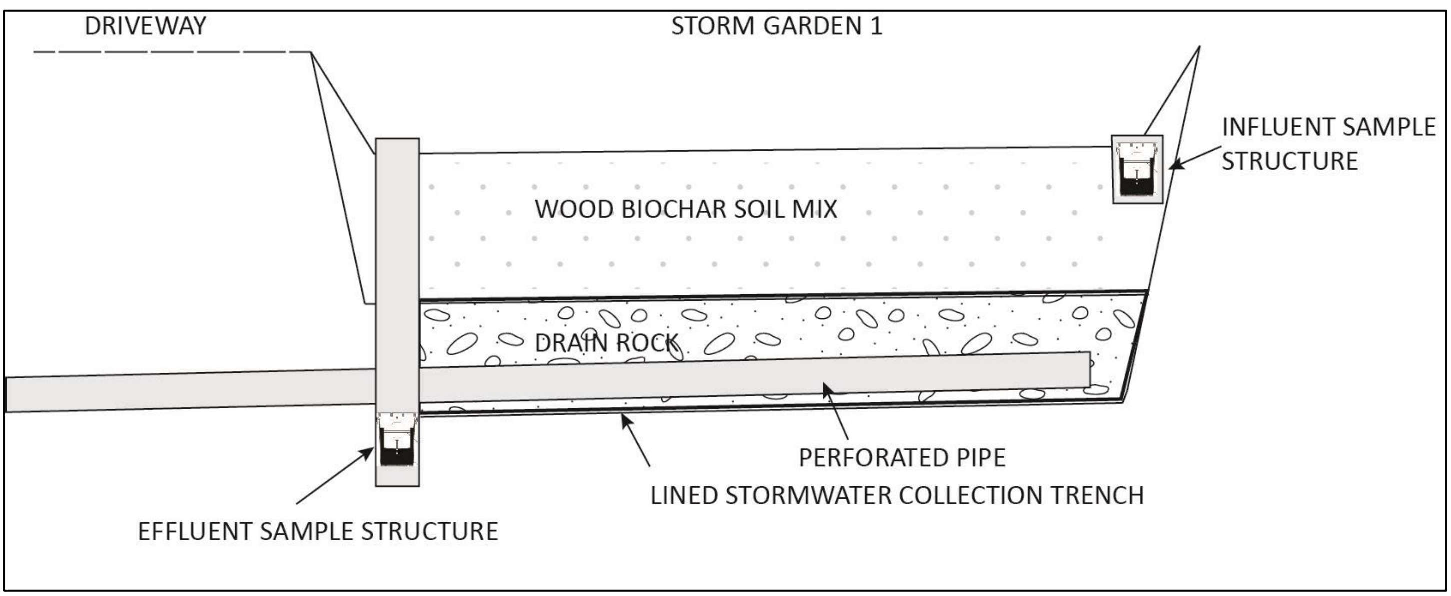


Figure 6. Cross Section of Influent Sample Structure

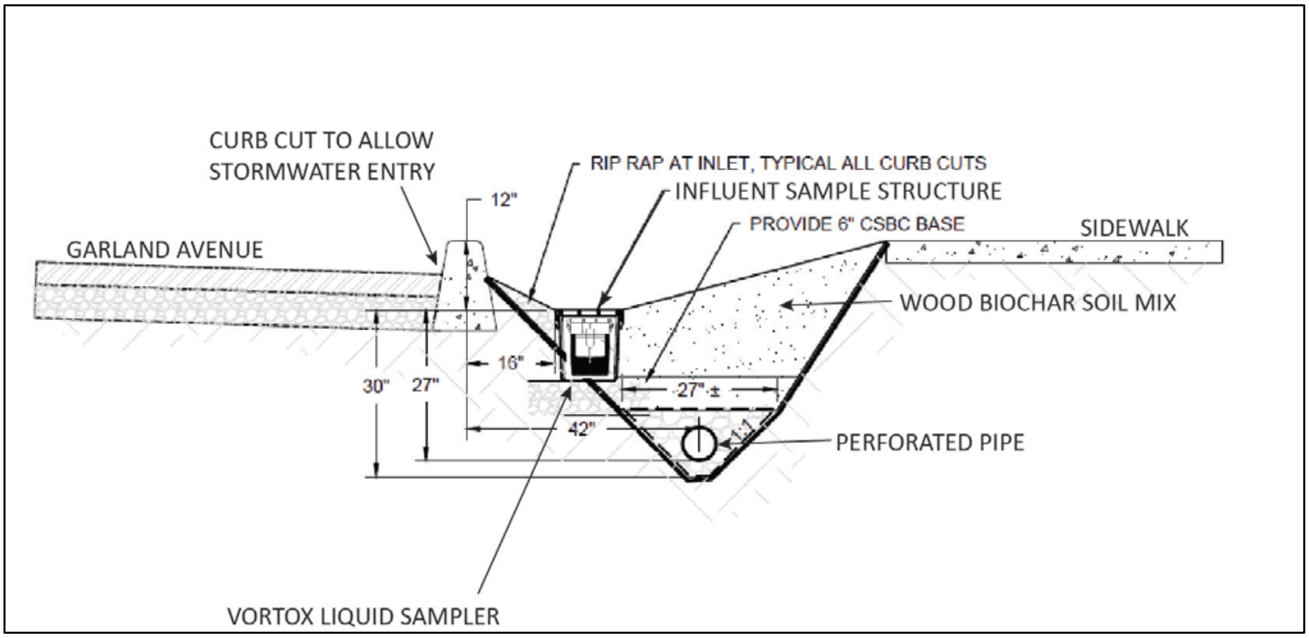
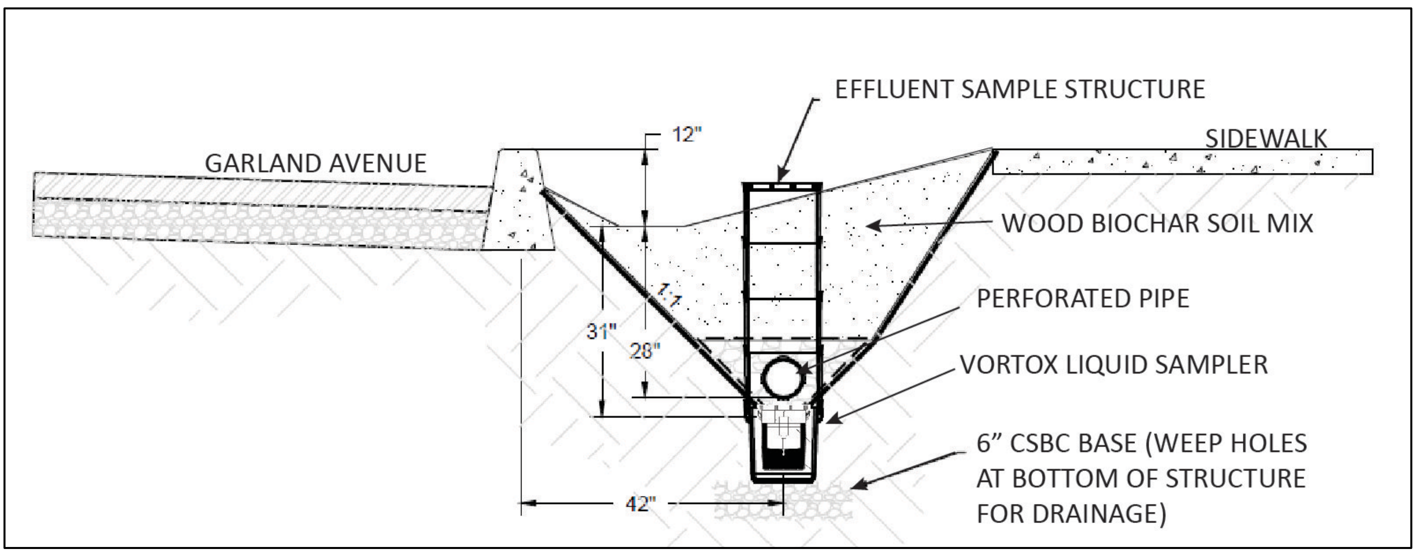


Figure 7. Cross Section of Effluent Sample Structure



4.2 Sampling Parameters of Interest

Pollution sources that may affect stormwater quality include land use activities, operation and maintenance activities, illicit discharges and spills, atmospheric deposition, and vehicular traffic conditions. Many of these sources are not under the direct control of a municipality that own or operate storm sewers.

According to a study prepared for the California Department of Transportation (CTSW-RT-03-059.73.15), roadway and pavement runoff could contain organic and inorganic contaminants that can impair receiving water quality and disrupt aquatic and benthic ecosystems. Potential contaminants in roadway runoff include suspended solids, heavy metals, hydrocarbons, indicator bacteria and pathogens, and deicing salts. Runoff from roadways can contribute as much as 50% of the total suspended solids, 16% of the total hydrocarbons, and 35 to 75% of the total metal pollutants inputs to impaired receiving waters. The principal sources of contaminants in roadway runoff from roadways are atmospheric deposition (precipitation and dust fall), automobiles, and the road surfaces themselves.

For this study, samples will be analyzed for a suite of constituents including:

- Total suspended solids (TSS)
- Total and Dissolved Metals (arsenic, cadmium, calcium, chromium, copper, magnesium, lead, zinc)
- Hardness
- Total petroleum hydrocarbon
- Total phosphorus
- Nitrate-Nitrite-Nitrogen
- pH
- Temperature

5.0 ORGANIZATION AND SCHEDULE

5.1 Roles and Responsibilities

This study consists of representatives from key groups with varying roles in sampling collection, data analysis, data evaluation, and reporting. Team members include both internal and external members. Key group members consist of internal team members that will execute different protocols. For example, team members within the Laboratory Manager and Laboratory Pre-Treatment Program Manager's group will carry out sampling collection protocols. Team members within the Flow Monitoring Manager's group will carry out protocols for operation and maintenance of rain gauge monitoring equipment.

The organizational structure is designed to provide project control and proper quality assurance/quality control (QA/QC) for laboratory analysis and field investigations. The roles of key groups and their responsibility in this study are presented in the following table.

Table 1. Key Individuals and Responsibilities

Name:	Title:	Responsibility:
James George III City of Spokane Wastewater Department 509.625.7908	Project Manager	Develop, implement, and maintain the SAP/QAPP. Verify the QAPP is followed and the project is producing data of known acceptable quality. Supervision of all monitoring and data collection activities. Validate and verify data collected, monitor and determine qualifying sampling events, deploy sampling team, data analysis and prepare reports. Overall management of the City's NPDES Phase II compliance activities.
Jeff Donovan City of Spokane RPWRF 509.625.4638	QA Manager	Oversee monitoring activities, including sampling data management and documented summaries are complete for reporting purposes. Review laboratory data against the study specific QA/QC requirements.
Jon Eckhart City of Spokane RPWRF 509.625.4641	Laboratory Manager	Supervise sampling team members and laboratory personnel involved in generating analytical data for the RPWRF Laboratory and sampling team members. Ensure all QA/QC procedures are completed as required and documentation is accurate and complete. Enforce and implement corrective action as necessary.
Angela Tagnani City of Spokane RPWRF 509.625.4620	Laboratory Pre-Treatment Program Manager	Supervise sampling team members and laboratory personnel involved in generating analytical data for the RPWRF Pre-Treatment Program and sampling team members. Enforce and implement corrective action as necessary.
Kyle Arrington RPWRF 509.625.4647	Laboratory QA Manager	Verify all aspects of QA/QC in the RPWRF laboratory. Validate and verify data before released from the laboratory.
Bruce Brurud RPWRF 509.625.4631	Flow Monitoring Manager	Supervise and ensure rain gauge equipment operation and maintenance. Enforce and implement corrective action as necessary.
Raylene Gennett Wastewater Department 509.625.7900	Collection System Manager	Supervise and ensure collection system operation and maintenance. Enforce and implement corrective action as necessary

5.2 Special Training and Certifications

Sampling team members have a wide range of experience sampling wastewater and stormwater throughout the City's collection system. The RPWRF laboratory is a Washington State accredited laboratory for analysis of each of the constituents per the methods in the table provided in Section 5.6 Sampling Constituents. Also, contracted laboratories are Washington State accredited laboratories for the constituents per the methods listed in the table provided in Section 5.6 Sampling Constituents.

Sampling team members installing or maintaining sampling equipment will be exposed to weather conditions, traffic hazards, confined spaces, biological hazards (e.g. stagnant water), vector (e.g. spiders, rats), fall hazards, hazardous materials, fast moving stormwater, and slippery conditions. Sampling team members may be required either to obtain or already process, necessary certifications such as Flagger Certification.

5.3 Study Schedule

Sample collection will occur on a long term basis starting after the finalization of this QAPP and Department of Ecology's (Water Quality Program) approval. There should be a minimum of at least five years' worth of sample and data collection. In addition, the Project Manager will determine if sampling beyond five years would be necessary. Also, the Project Manager will determine if adjustment(s) to the sampling frequency would be necessary. Furthermore, the Project Manager will also determine if a schedule for adaptive management would be needed. The following table summarizes the tentative schedule for this study. The schedule could be subject to change.

Table 2. Study Schedule

	When:	**Description:**
Prepare Study Design Proposal:	1st and 2nd Quarter 2017	Initial preparation of study design proposal
Final Design proposal Submittal:	June 30, 2017	Submitted to Ecology
Prepare QAPP:	6 months after Ecology's written approval of study design proposal	Initial preparation of QAPP
Ecology QAPP review:	3rd through 4th Quarter 2018	Ecology review and provide written comments to the City of Spokane
Final QAPP Submittal:	After Ecology's review and written comments were provided	Respond to comments and submit final QAPP to Ecology
Implement Monitoring:	6 months after Ecology's approval of QAPP	Conduct stormwater monitoring
Evaluate Results:	After sampling events	Review analytical results
Annual Reporting:	March 30th of the year of completion	Upon completion, the final report and dataset will be included with that year's annual report
Final Report:	6 months after the study is completed	Summarize monitoring efforts and recommend future actions

Enter Data into International BMP database:	6 months after the study is completed	Enter applicable data collected into the International BMP database

5.4 Study Schedule Limitations

Stormwater sampling is inherently unpredictable because it is weather dependent on the frequency and timing of stormwater sample collection is very difficult to predict. Therefore, the schedule will need to be adaptive. Weather should be monitored continuously and sampling team members should be ready to deploy with little notice. Due to funding limitations, sampling and laboratory analysis will be conducted during normal working days (Monday through Friday excluding holidays).

5.5 Sampling Collection Frequency Schedule

A reasonable attempt will be made to collect stormwater samples from all qualifying events during the calendar year, with a maximum of 12 samples collected for the calendar year. The following table summarizes the sample collection frequency schedule.

Table 3. Tentative Sample Collection Frequency Schedule

When:	Frequency:
1st Quarter (January – March):	All qualifying events
2nd Quarter (April – June):	All qualifying events
3rd Quarter (July – September):	All qualifying events
4th Quarter (October – December):	All qualifying events
Total Samples (per year):	**≤12**

Sampling events should meet the qualifying criteria(s) and occur during the normal work week (Monday through Friday excluding holidays) due to availability of sampling personnel. Sampling frequency and schedule is weather dependent.

5.6 Sampling Constituents

The constituents listed in the following table are in order of priority in the event there is not enough sample volume to analyze all constituents.

Table 4. Summary of Sampling Constituents

Constituent:	Matrix:	Analytical Method:	Preservative:	Sample Container:	Laboratory:	Reporting Limit:	Holding Time:	Comments
pH	Water	pH: SM 4500-H+B	N/A	500 mL HDPE	RPWRF	NA	N/A	
Total Suspended Solids (TSS)	Water	SM 2540-D	≤6°C	1L HDPE	RPWRF	2.5 mg/L	48hrs	
Total Metals (As, Cd, Cr, Cu, Pb, Zn)	Water	EPA 1638	HNO_3 to pH <2	250 mL HDPE	Eurofins Frontier Global Sciences	As (0.3 µg/L), Cd (0.02 µg/L), Cr, Cu (0.1 µg/L), Pb (0.04 µg/L), Zn (0.5 µg/L)	6 months	
Dissolved Metals (As, Cd, Cr, Cu, Pb, Zn)	Water	EPA 1638	HNO_3 to pH <2 after filtration	250 mL HDPE	Eurofins Frontier Global Sciences	As (0.3 µg/L), Cd (0.02 µg/L), Cr, Cu (0.1 µg/L), Pb (0.04 µg/L), Zn (0.5 µg/L)	6 months	Samples will be filtered in the lab using a 0.45 µm filter
Hardness	Water	SM 2340 B	HNO_3 to pH <2	500 mL HDPE	Eurofins Frontier Global Sciences	0.3 mg/L	6 months	
Total Phosphorus	Water	Low: EPA 365.3 High: SM 4500-PE	H_2SO_4 to pH <2, ≤6°C	1L HDPE	RPWRF	Low: 0.003 mg/L High: 0.059 mg/L	28 days	
Total petroleum hydrocarbons (NWTPH-Dx)	Water	Ecology 1997 (Pub. No. ECY 97-602)	HCl to pH <2, ≤6°C	8 fl. oz. Amber	Test America	0.25 mg/L	7 days	NWTPH-Dx will be collected using the Vortox sampler and noted in the lab report narrative

Constituent:	Matrix:	Analytical Method:	Preservative:	Sample Container:	Laboratory:	Reporting Limit:	Holding Time:	Comments
Nitrate-Nitrite-N	Water	SM 4500-NO3-E	H_2SO_4 to pH <2, ≤6°C	1L HDPE	RPWRF	0.5 mg/L	28 days	

Note: EPA: Environmental Protection Agency; RPWRF: Riverside Park Water Reclamation Facility; SM: Standard Method; °C: degrees Celsius; mg/L: milligrams per liter; µg/L: micrograms per liter; NWTPH-Dx: Northwest Total Petroleum Hydrocarbon; As: Arsenic; Cd: Cadmium; Cr: Chromium; Cu: Copper; Pb: Lead; Zn: Zinc

Equipment blank sampling will be included with sample collection activities. Equipment blank samples are to be collected once per calendar year for the duration of this project. Equipment blank samples will also be analyzed for the constituents identified in the above table. The Project Manager will determine if adjustments to the sampling frequency, and quantity, of equipment blank sample collection are needed.

If possible, replicate samples will also be included with sample collection. Replicate samples are to be collected once per calendar year for the duration of this project. Replicate samples will also be analyzed for the constituents identified in the above table. The Project Manager will determine if adjustments to the sampling frequency, and quantity, of replicate sample collection are needed.

5.7 Budget and Funding

Funding sources will be budgeted and funded by the utility rates specifically from Wastewater Management's departmental budget. Costs include the development of this SAP/QAPP, purchase of sampling equipment, laboratory analysis of samples, personnel completing tasks associated with this SAP/QAPP, data collection, data analysis, data evaluation, and reporting.

6.0 SAMPLING PROCESS DESIGN (STUDY DESIGN)

6.1 Design Area

Section 2.4 discusses the location of the study area, and Figure 2 illustrates the drainage area for this study. Autodesk® Storm and Sanitary Analysis software was utilize to model the hydrodynamics of the drainage area, and the modeled results are presented in Appendix B. The drainage area for this study is the west side of N. Belt St and the residential lots adjacent to the west side N. Belt St., as they bounded to the north by W. Walton Ave, and bounded to the south by W. Garland Ave. The areal extent of the drainage area is approximately 43,000 square feet, where the direction of stormwater flow is generally west-southwest. Runoff from the 'Belt' and 'Sub-1' basins, as identified in the Autodesk® model were calculated as 0.79 inches and 0.12 inches, respectively, for 1 inch of rain. The modeled data indicate that the storm garden exceeds the minimum design capacity for a bio-infiltration swale for drainage area of this study.

6.2 Field Measurements

Temperature and pH will be measured in the lab. These measurements will be obtained at the time the samples are collected at the end of each storm event and arrive at the lab. These measurements will be taken by portable meters. Meters will be calibrated prior to each sample event.

6.3 Storm Event Measurements

Rainfall measurements will be collected using an Isco rainfall logging system. These rain gauges use a tipping bucket method with precision sapphire bearings for accurate measurement. Gauges are connected with telemetry to allow nearly instantaneous data retrieval through the Flowlink Pro software.

Rain gages are illustrated in the following figure. Total rainfall for each sampling event would be calculated by triangulating the three nearest gauges to the Garland Storm garden Basin: Shadle, Joe Albi, and City Hall. In the event that one of these gauges fails, the next closest operational gauge will be used.

The Inverse power of Distance Weighted Interpolation (IDW) method is used to calculate total rainfall in the storm garden 1 drainage basin for each storm:

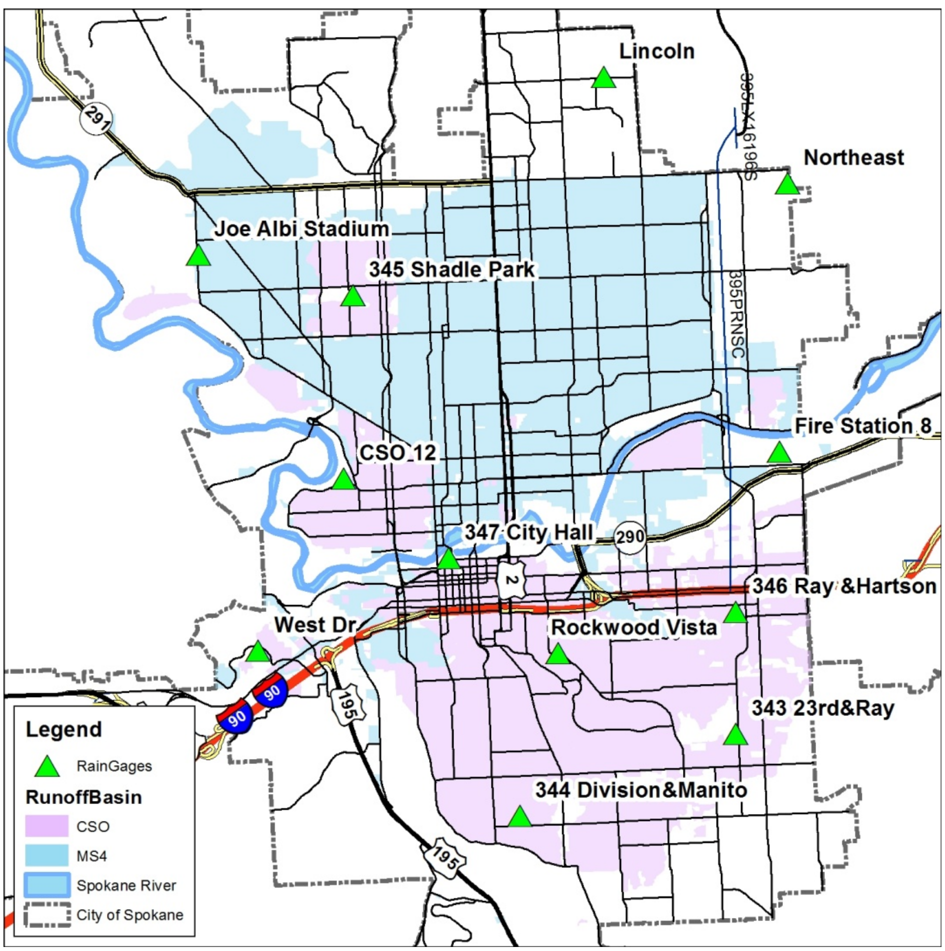
$$Po = \Sigma(P * W)/\Sigma W$$
$$W = 1/d^2$$

Where: P = precipitation

W = weighted distance

d = distance (Shadle = 0.39 miles; Joe Albi = 2.07 miles; City Hall = 2.47 miles to the basin centroid)

Figure 5. Rain Gauge Locations



6.4 Composite Stormwater Samples

Samples will be collected from both the influent and effluent sampling structures. Vortox Air Technology FS8A fluid samplers have an adjustable screw at the top of the ball valve that adjusts the rate at which liquid enters the sampler. The screw can be adjusted to let water in slowly, filling the sampler in as much as 20 minutes. This allows for a pseudo-composite sample collected the first 20 minutes of runoff. The Vortox fluid samplers input rate will be set to collect the first flush of stormwater from the study area until the entire volume of the sampler is collected.

Samples will be transported to the RPWRF laboratory in the Vortox sampler, and transferred to a carboy a poured off to proper aliquot per analyte for sample preparation for analytical analysis completed by the RPWRF laboratory. The RPWRF laboratory will prepare samples for shipment under chain-of-custody to contracted laboratories for analysis for constituents that cannot be analyzed at the RPWRF lab.

Sample sets will consist of laboratory-prepared bottles appropriate for each analysis. Sample bottles will be filled with stormwater samples and analyzed at the respective laboratory.

Sampling team members identified in section 5.1 Key Individuals and Responsibilities will complete collection activities.

6.5 Storm Events

Sampling should be attempted for storms that are predicted to meet the following qualifying criteria*. The National Oceanic and Atmospheric Administration's (NOAA) National Weather Service, Spokane forecast office website should be monitored for storm predictions (http://graphical.weather.gov/sectors/otx.php).

Qualifying wet season storm event goal (October 1 through April 30):

- Rainfall volume: 0.20" minimum, no fixed maximum
- Rainfall duration: No fixed minimum or maximum
- Antecedent dry period: Les than or equal to 0.05" rain in the previous 24 hours
- Inter-event dry period: 6 hours

Qualifying dry season storm event goal (May 1 through September 30):

- Rainfall volume: 0.20" minimum, no fixed maximum
- Rainfall duration: No fixed minimum or maximum
- Antecedent dry period: Less than or equal to 0.02" rain in the previous 48 hours
- Inter-event dry period: 6 hours

Storm Event Collection Goals

- Sample collected at the onset of runoff resulting from a qualifying storm
- The total volume of the sampler to full capacity needed to analyze all parameters is three liters

**The Western WA Phase II permit qualifying storm events are a minimum of 0.2 inches for both wet and dry seasons (Ecology, 2012). The Western WA Phase II permit qualifying storm event criteria are being adopted for this study.*

6.6 Observing Rainfall Predictions

- Monitor the NOAA National Weather Service Forecast Office for Spokane, WA website when storm events are predicted. http://forecase.weather.gov/mapclick.php
- Determine if predicted storm will meet qualifying event criteria.

6.7 Storm Event Staff Deployment

Sampling team members should be fully prepared to deploy when a qualifying storm event has been forecasted. Once deployed and onsite, powder-free gloves should be worn and clean techniques practiced. Upon site arrival, sampling team members should perform field checks to ensure proper operation of the sampling equipment.

7.0 DATA QUALITY OBJECTIVES

All data should meet precision, recovery, and accuracy requirements specified in the laboratory method used. Each laboratory used for this study should maintain internal quality assurance/quality control procedures as documented in its laboratory quality assurance manual. Data represent the field site and are of a known precision, bias, and accuracy; and, have sufficient analytical sensitivity to achieve study objectives for decision making.

The laboratory will use a combination of blanks; laboratory control spikes, surrogates, and duplicates to evaluate analytical results. Instruments used to measure parameters temperature and pH will be calibrated before each sample event to ensure data quality objectives are met.

7.1 Decision Quality Objectives (DQOs)

Decision Quality Objectives (DQOs) are used to select between two clear alternative conditions, or to determine compliance with a standard. The DQO for this study is to identify if stormwater treatment from run-off (effluent) samples meet state water quality criteria.

7.2 Measurement Quality Objectives (MQOs)

Measurement Quality Objectives (MQOs) specify how good the data must be in order to meet the objectives of the project. They are often obtained from the participating laboratories, and/or the analytical methods used. Data analyzed should meet the precision, recovery, and accuracy requirements specified in the laboratory method used. The laboratory maintains internal quality assurance/quality control procedures as documented in its laboratory quality assurance manual. The laboratory will use a combination of blanks, laboratory control spikes (LCS), surrogates, matrix spikes, matrix spike duplicates, and laboratory duplicates as appropriate for the method to evaluate the analytical results. The following tables detail the measurement quality objectives for this study.

Table 5. Laboratory Measurement Quality Objectives

Analyte:	Laboratory Blank:	CCV Recovery:	LCS Recovery (%):	Surrogate Recovery (%):	Laboratory Duplicate RPD:	Matrix Spike Recovery (%):	Matrix Spike Dup RPD:	Field Replicate
TSS	<2.5 mg/L	N/A	80-120	N/A	<30%	N/A	N/A	±30%
TPH NWTPH-Dx	<0.24 mg/L	N/A	50-150	50-150	N/A	N/A	N/A	±30%
Total Phosphorous	N/A	N/A	80-120	N/A	N/A	N/A	N/A	±30%
Nitrate-Nitrite-N	<0.1 mg/L	N/A	80-120	N/A	<30%	N/A	N/A	±30%
Arsenic, total	<0.3 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Cadmium, total	<0.020 µg/L	84-113	84-113	N/A	20%	84-113	<20%	±30%
Chromium, total	<0.1 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Copper, total	<0.1 µg/L	80-120	51-145	N/A	20%	51-145	<20%	±30%
Lead, total	<0.040 µg/L	91-109	72-143	N/A	20%	72-143	<20%	±30%
Zinc, total	<0.5 µg/L	79-121	46-146	N/A	20%	46-146	<20%	±30%
Arsenic, dissolved	<0.3 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Cadmium, dissolved	<0.020 µg/L	84-113	84-113	N/A	20%	84-113	<20%	±30%
Chromium, dissolved	<0.1 µg/L	85-115	85-115	N/A	20%	85-115	<20%	±30%
Copper, dissolved	<0.1 µg/L	80-120	51-145	N/A	20%	51-145	<20%	±30%
Lead, dissolved	<0.040 µg/L	91-109	72-143	N/A	20%	72-143	<20%	±30%
Zinc, dissolved	<0.5 µg/L	79-121	46-146	N/A	20%	46-146	<20%	±30%

Notes: mg/L: milligrams per liter equivalent to ppm; µg/L: micrograms per liter

Table 6. Equipment Blank QC Sample Quality Objectives

Analyte:	Equipment Blank
TSS	< 2.5 mg/L
Total Phosphorous	Low: <0.003 mg/L High: <0.059 mg/L
TPH NWTHP-Dx	< 0.25 mg/L
Nitrate-Nitrite-N	<0.5 mg/L
Arsenic, total	< 0.3 µg/L
Cadmium, total	< 0.02 µg/L
Chromium, total	< 0.1 µg/L
Copper, total	< 0.1 µg/L
Lead, total	< 0.04 µg/L
Zinc, total	< 1 µg/L
Arsenic, dissolved	< 0.3 µg/L
Cadmium, dissolved	< 0.02 µg/L
Chromium, dissolved	< 0.1 µg/L
Copper, dissolved	< 0.1 µg/L
Lead, dissolved	< 0.04 µg/L
Zinc, dissolved	< 1 µg/L
Hardness	< 0.201 mg/L

Note: Equipment blank samples with analytical results above the sample quality objective values identified in Table 6 will be repeated until the results are below the identified values.

Table 7. pH and Temperature Measurement Specification

Analyte:	Instrument:	Measurement Range:	Accuracy:	Resolution:
pH	Accumet	-1.99 to 19.99	±0.01	0.01
Temperature	Accumet	0 to 100°C	±0.3°C	0.1°C

7.3 Targets for Precision, Bias, and Sensitivity

7.3.1 Precision

Precision is a measure of the variability in the results of replicate measurements due to random error. Random error is imparted by the variation in concentrations of samples from the environment as well as other introduced sources of variation (e.g., field and laboratory procedures). Precision for laboratory duplicate samples will be expressed as relative percent difference (RPD). Precision for field replicate samples will be expressed as the relative standard deviation (RSD) for the group of duplicate pairs.

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

Where:

RPD =relative percent difference
C_1 =concentration of original sample
C_2 =concentration of duplicate
$\bar{x}$ =mean of samples

7.3.2 Bias

Bias is the difference between the population mean and the true value. Bias affecting laboratory measurement procedures can be inferred from the results of QC procedures. Bias in field measurements and samples will be minimized by strictly following measurement, sampling, and handling protocols. Field sampling precision bias will be addressed by submitting replicate samples.

FIELD BIAS

Bias from meters used in the field will be consistently evaluated using calibration methods. Sampling bias will be minimized by adhering to procedures outline in this SAP/QAPP.

LABORATORY BIAS

Laboratories use method blanks and matrix spikes to identify potential laboratory or sample matrix biases affecting results. Laboratory method blanks should not exceed the reporting limit. The targeted range for percent recovery of matrix spikes and matrix spike duplicates are presented in Table 5.

7.3.3 Sensitivity

Sensitivity is a measure of the capability of a method to detect a substance. It is commonly described as detection limit. In a regulatory sense, the method detection limit (MDL) is usually used to describe sensitivity. Targets for field and lab measurement sensitivity required for the study are listed in Tables 5 through 7.

7.4 Targets for Comparability, Representativeness, and Completeness

7.4.1 Representativeness

Representativeness ensures that the study includes samples that are representative of existing conditions. Samples should be collected during all seasons, representing a proportional amount of spring, summer, fall, and winter rainfall conditions.

7.4.2 Completeness

Completeness is a measure of the amount of valid data needed to be obtained from a measurement system. The goal for this study is to correctly collect and analyze all of the samples for each of the sites. However, problems occasionally arise during sample collection that cannot be controlled. Therefore, a completeness of 95% is acceptable.

8.0 SAMPLING (FIELD) PROCEDURES

This section describes field procedures that will be utilized to ensure that samples are collected in a consistent manner, are representative of the matrix being sampled, and that the data will be comparable to data collected by other existing and future monitoring programs.

The quality of data collected in an environmental study is critically dependent upon the quality and thoroughness of field sampling activities. General field operations, practices, and specific samples will be planned, implemented, and follow specific standard operating procedures (SOP) that support grab sampling. Stormwater sampling procedures are based on data collection methods adapted from Ecology's Standard Operating Procedures (SOP) for Collecting Grab Samples from Stormwater Discharges (Ecology, 2009).

8.1 Equipment Decontamination Procedures

8.1.1 Sample Bottles

The RPWRF and contracted laboratories will provide sample collection containers for collecting stormwater samples. Containers, jars, and lids will be pre-cleaned and certification information will be kept with the RPWRF laboratory information.

8.1.2 Composite Sampling Equipment

Prior to deployment, all sampling equipment will be cleaned by running the following solutions through the equipment:

- Hot soapy water (Liqui-Nox or equivalent)
- Hot water
- Reagent grade water

After decontamination, the sampling equipment will be wrapped in plastic bags until placed in the field. Equipment rinsate blanks will be performed by running enough reagent grade water through sampling equipment into a pre-cleaned container until sufficient volume is collected to run the analytes of interest. Rinse blank performance will determine if the decontamination procedures are sufficient for the project.

8.2 Sampling Handling and Custody

Sample handling and custody procedures ensure that uniquely identifiable samples are transported to the analytical laboratory with appropriate preservation within prescribed holding times and with proper documentation. Written documentation of sample custody from the time of sample collection through the generation of data by analysis of that sample is recognized as a vital aspect of an environmental study. All personnel involved with handling the samples will be wearing appropriate gear (e.g. powder free rubber gloves) through sample handling activities. The chain-of-custody of the physical sample and its corresponding documentation will be maintained through the handing of the sample by following the procedures outlined below.

8.2.1 Sample Identification

All samples will be clearly labeled with indelible ink. Each sample will be uniquely identified by a nomenclature system maintained and implemented by the RPWRF laboratory. The standard format is YY-NNNNN, where YY is the two digit year and NNNNN is the count of samples processed through the lab for that year, beginning at 00001. In addition, all sample containers will be labeled with date, time, sample number, sampling team initials, and sample analytes.

8.2.2 Sample Transportation

The sampling team will retrieve collected samples and will place samples on ice or cooling gel packs. Samples will be transported as soon as possible to the selected laboratory for analysis. For all samples shipped to laboratories, samples will be placed in coolers and placed on cooling gel packs. Copies of shipping papers will be taken prior to shipment and will be a component of documentation for this study.

8.2.3 Sample Preservation

Other than ice or cooling gel packs, sample preservation will not be required in the field. Chemical preservatives are provided in sampling containers and/or added to the samples for certain analyses to prolong the stability of the parameters during transport and storage. For composite sampling, no preservatives are added to the composite container because no single chemical preservative is suitable for all of the parameters to be analyzed. The laboratory must first divide the composite sample into the appropriate bottle for each analysis, and then add chemical preservatives (if not already provided in the sample container) as appropriate for each analysis.

8.2.4 Sample Processing

In general, all samples will be minimally processed in the field to prevent potential contamination from trace pollutants in the atmosphere. Samples will be transported to the analytical laboratory as soon as possible after sample collection.

8.2.5 Holding Times

Holding times are short for some parameters and long for others. Table 4 summarizes holding times for analyses. To minimize the risk of exceeding holding times, the QA Manager will coordinate with the analytical laboratory, and the sampling team, prior to each sampling event to ensure that the laboratory is prepared to begin processing samples, or begin prepping samples for submission to contracted laboratories, as soon as samples are received. In addition, samples will be delivered to the laboratory immediately after retrieval from field equipment.

8.2.6 Chain-of-Custody Forms

A chain-of-custody form will accompany each sample batch that is delivered to the laboratory. The purpose of chain-of-custody (COC) forms is to keep a record of the sample submittal information and to document the transfer of sample custody. The COC forms used in this study will include sample location identifier, analyses to be performed, and any special considerations, such as analyses priority order and sample filtration needs. At the time of sample collection, the sampling team will record the sample date and time, sample location, matrix, and analyses requested. The COC form must be signed by both the person relinquishing the samples and the person receiving the samples every time the samples change hands, thus documenting the chain-of-custody. During non-work hours, samples will be stored in a refrigerator at the RPWRF laboratory until custody officially changes hands.

For replicate and equipment blank samples, these samples will not be specifically identified on the COC (e.g. replicate sample or equipment blank sample) form that will be submitted to the laboratory analyzing the samples. But rather distinguished and documented in field sampling notes.

8.3 Sample Equipment Installation

All sampling equipment will be decontaminated prior to installation. Assemble the sampler. Set the intake adjusting screen to allow appropriate intake flow. Ensure the center port valve is in the closed position. Install the sampler by handing it below the cover or setting it on a pre-installed supportive structure located at the proper elevation to allow sample collection.

8.4 Sample Equipment Retrieval

At the end of the storm event, sampling team will retrieve sampling equipment. Upon arrival, inspect all components of the sampling system to ensure samples were properly collected. If any warranted conditions were found, note conditions in field notes. Visually inspect the components of the sample structure for damage and/or clogging.

Retrieve the sampler equipment from the sampling structure. Gently shake the sampler. Place sampler equipment in a cooler on ice until it is transported to the RPWRF laboratory for distribution into prepared sampling jars. Conduct field measurements using the equipment manufacturers' instructions. Calibrate the equipment prior to collecting field measurements. Use the center port valve located on the bottom of the sampler to transfer the sample to the laboratory prepared jars. Transport samples into sample storage area and/or laboratory.

9.0 MEASUREMENT PROCEDURES

The section describes the analytical methods to be used for each constituent, the reporting limits for each constituent, and the frequency of analysis, number of samples to be analyzed, needed sample volume, container type, holding time, and preservation. All laboratories analyzing constituents will be accredited by the Washington Department of Ecology Laboratory Accreditation Program for the constituents to be analyzed. The Project Manager will obtain and maintain current copies of laboratory certifications throughout the duration of this study.

9.1 Analytical Methods, Reporting Limits, and Containers

Section 5.6 Sampling Constituents details sample container type, holding time, preservative and reference for each constituent to be analyzed.

9.2 Sample Volume Requirements

A significant sampling design concern is the ability to obtain adequate sample volume to complete the selected analyses. This section discusses the selected parameters, the volumes required to analyze those parameters, and the priority order in which analyses will be completed. Section 5.6 Sampling Constituents summarizes the estimated volumes needed for stormwater analytical chemistry samples.

If volume of stormwater sample collected from a qualifying storm is insufficient to allow analysis for all parameters detailed in Section 5.6 Sampling Constituents, samples shall be analyzed for as many parameters as possible starting from top down in Table 4.

10.0 QUALITY CONTROL (QC) PROCEDURES

Samples will be analyzed using the designated EPA method or Standard Methods. Chain-of-custody procedures will be followed for samples submitted to the laboratory. The quality control procedures outlined in the RPWRF laboratory SOPs will be followed.

10.1 Field and Lab QC Required

Laboratory QC samples are described in Section 7.0 Data Quality Objectives. Field QC samples include equipment blanks and field replicate samples. Sampling equipment will not be cleaned in the field.

10.2 Corrective Action Processes

Each laboratory will provide a summary of all QA/QC results. The QA/QC summary will be reviewed by the laboratories own designated personnel and the QA Manager to assess the adequacy of the quality control checks and to identify any potential problems.

Any blank, duplicate or spike results that are out of acceptance ranges will be denoted with data qualifier flags. If method criteria are not met, the laboratory should take appropriate corrective action including re-extraction if necessary.

11.0 DATA MANAGEMENT PROCEDURES

11.1 Documents and Records

There will be different types of documentation that will be managed that includes:

- Field Operation Records
- Laboratory records
- Data handling records
- SAP/QAPP

11.2 Field Operation Records

Sample log sheets will be completed by the sample collection team members during sampling activities. The sheets will serve as a daily record of events and observation during sampling activities. All information pertinent to sampling activities will be recorded on the sample log sheet. Sample log sheets will be maintained by sampling staff at all times documenting activities and conditions. In addition, photographs of field and samples collection activities will also be completed for the project file. Copies of all sample log sheets and photographs will be made following each sampling event and maintained in the project file(s).

Entries on the sample log sheet will include:

- Name and location of project
- Field personnel
- Sequence of events
- Any changes or deviations from the SAP/QAPP
- Environmental conditions
- Date, time, location, ID, and description of each sample
- Field instrument calibration procedures
- Field measurement results
- Identity of QC samples collected
- Unusual circumstances that might affect interpretation of results

Field data will be recorded by field personnel during sampling activities and reviewed for accuracy and completeness. Data and field information will be checked by the QC Manager. Field data documentation and procedures includes the following criteria:

- Keep all field notes and/or field notebook notes on file.
- Keep all photos associated with the project on file.
- Be sure to save and back up any electronic notes/files/downloads collected in the field.
- It is recommended to enter the notes into an electronic data system, save and backup the files.
- Keep files available for at least 5 years.
- When using field data forms, create an original and field test the sheet for adaptation to the field procedure. This will help to avoid comprehensive updates. Use a finalized form and update every year.

11.3 Laboratory Records

Contracted laboratories shall submit electronic copies of analytical data and quality control data to the QA Manager, preferably in PDF or excel formats. The RPWRF laboratory will keep written and electronic records of sample analysis performed on site. In addition, the QA Manager will provide sample analysis reports to the Project Manager. Laboratory data will include measurement of each parameter as well as QA/QC documentation and explanation of any data qualifier flags assigned to sample results. The RPWRF laboratory will keep electronic copies of analytical data and quality control data in their files. In addition, sampling data and reports will be retained. Laboratory data will be entered into the laboratory database.

11.4 Laboratory Data Verification

The Laboratory QA Manager will be responsible for verification of laboratory-generated data, through the laboratory Standard Analytical Procedures for each method require some components of the verification to also be conducted at the bench level. Laboratory verification will include both contracted laboratories verification and the RPWRF Laboratory verification. Laboratory verification will include assessing that the procedures used to generate the data are consistent with the method requirements and that the QA/QC requirements for the method are met. Examples of method requirements include verifying the calibration and data reduction procedures. Once the data have been verified and approved by the laboratory, the QA manager shall document that verifications have been reviewed. The QA manager shall notify the Project Manager. Laboratory verification documentation should be included in reports.

12.0 AUDITS AND REPORTS

12.1 Audits

Each laboratory is accredited by the State of Washington for analysis of the respective analytes for this project. As part of the accreditation process, the State of Washington will perform on-site audits of the laboratories staff, facilities, and analytical capabilities. The laboratory's quality system, test methods, records, and reports will also be evaluated as part of the accreditation process. Each laboratory must participate in performance and system audits of their routine procedures. Results of these audits must be made available on request.

12.2 Deficiencies, Nonconformance, and Corrective Action

Deficiencies are defined as unauthorized deviation from procedures documented in this SAP/QAPP. Nonconformances are deficiencies that affect quality and render the data unacceptable or indeterminate. Field deficiencies and nonconformances will be documented and summarized in reports. Additional deficiencies and nonconformance may be found through the life of this study. Some examples of deficiencies and nonconformances include:

- Deficiencies
    - Chain-of-custody deviation such as incorrect sample time, resulting in holding time exceedances.
    - Not conducting field measurements such as temperature and pH.
    - Non-reporting of sampling equipment issues resulting in loss of sample collection.
- Nonconformance
    - Preservation of nitrogen samples with incorrect (nitric acid) preservative.

If laboratory deficiencies and nonconformances, and field sample collection deficiencies, occur throughout the course of this study, the Project Manager, Laboratory Manager, and Pre-treatment Program Manager, will collaborate to develop corrective actions to be implemented. The Laboratory Supervisor and Pre-treatment Program Supervisor are responsible for tracking field sample collection and RPWRF laboratory deficiencies and nonconformances. If deficiencies and nonconformances occur with other tasks associated with this study, the Project Manager will collaborate with the appropriate management team members to develop corrective actions to be implemented. The Project Manager is responsible for summarizing all deficiencies, field deficiencies, nonconformances, and corrective actions.

12.3 Reporting

The Project Manager will be responsible for writing reports related to this study. The Project Manager will rely on key individuals to assemble the necessary information to compile reports. Reports will be developed and available summarizing results with respect to pollutant removal efficiency. Reports will be distributed to internal staff and management for review. Annual reports will be developed summarizing yearly sampling activities and statistical analysis. A final report will be developed summarizing the project including sampling events, monitoring results, conclusions, and recommendations. Reports shall include the following:

12.3.1 Field Summary

The QA Manager will be responsible for summarizing field activities. The summary will include a case narrative for each sampling event including:

- Description of each sampling event including date, time
- Description of each sampling event including dates of deployment and retrieval
- Description of total volume sampling equipment captured
- Field observations
  - Observations and issues of sampling equipment structures
  - Observations of potential reasons for sample descriptions
- Deviation(s) from field procedures
- Other information needed for reporting purposes

12.3.2 Quality Assurance/Quality Control Summary

The QA Manager will be responsible for summarizing QA/QC. The summary will include a case narrative for each sampling event including:

- A narrative analysis of appropriate field quality control procedures, data quality indicator results, and of any associated issues and corrections made.
- A narrative analysis of appropriate laboratory quality control procedures with measurement quality objectives discusses, any associated issues and corrections made.
- Chain-of-custody procedures used, and explanation of any deviations from this SAP/QAPP procedures.
- Summary of the data quality assurance results from each sampling event (i.e. were data quality objectives met and, if not, why not).
- An overall assessment of the usability and representativeness of the data.
- A summary description of any planned changes or deviations from this SAP/QAPP to address problems encountered during QA/QC
- Other information needed for reporting purposes

12.3.3 Annual Report

Annual reports will be developed summarizing monitoring data collected during the previous year. Reports will also include statistical analysis data and other information the Project Manager deems necessary to include.

12.4.4 EIM/STORET data upload procedures

Data will be entered into the International BMP Database.

13.0 DATA VERIFICATION AND VALIDATION

Data verification is defined as a detailed examination of results to determine if the project's MQOs have been met. The intent is to ensure data of known and documented quality and quantity meet the use for which they are intended. The quality of the data is indicated by data qualifier codes, notations used by laboratories and data reviewers to briefly describe, or qualify, data and the systems producing data.

During data review, verification, and validation, results are either accepted or reported with data qualifiers or flags. Data that meet all QC acceptance limits are potentially usable and are not qualified. Data that fail one or more QC criteria are qualified as estimated (with the FA-flag). The distinction between estimated and rejected data resides in the degree of the QC failure and is highly dependent upon the reviewer's understanding of the objectives of the study.

13.1 Data Review, Verification, and Validation

For the purposes of this document, data verification is a systematic process for evaluating performance and compliance for a set of data to ascertain its completeness, correctness, and consistency using the methods and criteria defined in this SAP/QAPP. Validation means those processes taken independently of the data-generation processes to evaluate the technical usability of the verified data with respect to the planned objectives or intention of this project. Additionally, validation can provide a level of overall confidence in the reporting of the data based on the methods used.

All data obtained from field and laboratory measurements will be reviewed and verified for conformance to study requirements, and then validated against the measurement quality objectives, which are described in Section 7.0 Data Quality Objectives. Only those data that are supported by appropriate quality control data and meet the measurement performance specification defined for this project will be considered acceptable and used in this project.

13.2 Verification and Validation Methods

All data will be verified to ensure they are representative of the samples analyzed and locations where measurements were made, and that the data and associated quality control data conform to project specifications. The data verification procedures will generally include:

- Storm event verification (i.e. did the sampling event meet the established storm criteria).
- Sampling equipment verification (i.e. did the sampling equipment capture enough volume).
- Field QC (i.e. were samples collected at appropriate frequency and did they meet the established control limits).
- Laboratory QA/QC (i.e. did the lab meet method quality objectives).

14.0 DATA QUALITY (USABILITY) ASSESSMENT

The Project Manager will assess the quality of the data based on case narratives and data packages. Laboratory QC tests and field QC parameters will be examined to determine if the field staff and laboratory met the project's MQOs. Reporting limits will be examined to ensure that the contract-defined reporting limit was met. Data will either be accepted, accepted with additional qualification, or rejected and re-analysis considered depending on the severity of the infraction. During the data usability assessment, data that are believed to be completely unusable with a high degree of confidence (e.g. because of the gross failure of QC criteria) are qualified as rejected and would not normally be used to support decisions for an environmental study.

Usability is defined as a qualitative decision process whereby the decision-makers evaluate the achievement of measurement quality objectives and determine whether the data may be used for the intended purpose.

Data reduction is the process of converting raw data into results. Study-specific data reduction methods are designed to ensure that data are accurately and systematically reduced into a usable form.

Data Quality Assessment (DQA) is the scientific and statistical evaluation of data to determine if data obtained from environmental data operations are of the right type, quality, and quantity to support their intended use.

14.1 Data Usability Assessment

There are three categories of data quality that are used and are as followed:

- Accepted – Data conform to all requirements, all quality control criteria are met, methods were followed, and documentation is complete.
- Qualified – Data conform to most, but not all, requirements, critical QC criteria are met, methods were followed or had only minor deviations, and critical documentation complete.
- Rejected – Data do no conform to some or all requirements, critical QC criteria are not met, methods were not followed nor had significant deviations, or critical documentation is missing or incomplete. The results are unusable.

Data usability assessment is a more complex and comprehensive activity than data review or validation and is usually performed by the end user (rather than by the data reviewer) because the data user typically possesses a greater understanding of the project's DQOs (e.g. because of a more extensive knowledge of the study's history). Therefore, the end user must ultimately determine the acceptability of the data. However, this does not imply that the end user may apply qualified data in an indiscriminate fashion.

Ideally, estimated data (i.e. J-qualified) though presumed to be usable by the data reviewer, should be accepted by the end user only after the reasons for the data qualifications and their impact on the achievement of study DQOs have been examined.

The usability assessment includes assessment of potential outliers and confirmation that the data is comparable and representative.

14.2 Data Quality Assessment Metrics

The data quality assessment process determines whether the sampling and analytical program has fulfilled the project objectives, including the DQOs, and whether the data can be used to support project management decisions with the desired level of confidence. Data quality assessment is a professional judgement based on several lines of evidence:

- **Laboratory Data Validation Results**. This metric evaluates laboratory data quality, i.e. the extent to which MQOs for accuracy, precision, sensitivity, and bias have been met during laboratory analysis, as determined by the data validation process.
- **Field and Laboratory Completeness**. This metric evaluates data quantity, i.e. the extent to which the QAPP-specified number of valid field and laboratory measurements has been obtained and whether field and laboratory completeness goals have been achieved.
- **Sample Representativeness**. The degree to which the monitoring program provides a representative sample of the physical-chemical characteristics of stormwater in space and time will be evaluated. An assessment as to whether the data are suitably representative of the spatial characteristics of the drainage area (i.e. land use, gradient, ground cover, etc.).

14.3 Data Analysis Methods

Statistical analysis and trending will be completed using the laboratory analytical results. Summary statistics will be calculated each year for the current monitoring year as well as for the entire duration of the study. For each constituent analyzed, infiltration rates, and durability the following summary statistics will be calculated:

- Number of samples analyzed and infiltration rates.
- Number and percentages of samples with detected concentrations.
- Arithmetic mean concentration
- Standard deviation of the arithmetic mean
- Median concentration
- Percent coefficient of variation
- Minimum and maximum concentrations
- 95th percentile upper and lower confidence limits of the arithmetic mean and the median

Statistical analysis will also be performed on precipitation volumes the storm garden 1 drainage basin receives. As well as, influent and effluent sample analysis from the storm garden 1.

14.4 Treatment of Non-Detected Values

The analytical laboratory will be required to report estimated values for any detections between the Method Detection Limit (MDL) and the reporting limit (RL), and appropriate data qualifiers (e.g. J-flags). For general summary statistics, undetected values will be substituted at one-half the MDL.

15.0 REVISION HISTORY

This SAP/QAPP is a living document and revisions will be completed on an as needed basis. In the event that significant changes to this QAPP are required prior to the completion of the study, revisions will be documented and submitted to key individuals identified in section 5.0.

Revision:	Affected Page:	Revision Date:	Completed by:	Revision Details:
0	All		LMS/AP/JG	Developed, provided to Ecology for comment, addressed Ecology's comments, and finalized.

16.0 REFERENCES

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Appendix A

Biochar Specification

BIORETENTION SOIL MEDIA MIXES
EVALUATING THE STORMWATER TREATMENT PERFORMANCE FOR BIOCHAR AMENDMENTS

PROPOSED STORM GARDEN SOIL MIX

The proposed bioretention soil mix includes loamy sand top soil (per USDA texture triangle) amended with either Kentucky Bluegrass or Biochar Supreme Stormwater Mix with a mulch layer. The characteristics for the soil mix are provided at right with installation requirements described in the subsequent sections.

BIOCHAR

- Prior to installation, the biochar shall be prewashed with water (deionized, distilled, or tap). During rinsing a soil fabrics (150 mesh or smaller) should be used to retain the material. The volume of water used for rinsing should be a minimum of twice the biochar volume. *The Wood biochar has already been pre-washed by the supplier*.
- The portion of biochar defined for the mix is based on the dry weight determined using ASTM D1762-84. Based on recent testing the percent moisture of the biochars as provided by the supplier is 9% for Kentucky Bluegrass (prior to washing) and 45% for the Wood (after washing).
- The organic matter (OM) content is determined from the portion of organic carbon and a standard conversion factor. For this project the OM content listed will be achieved with either of the biochars specified for this project.

SOIL MEDIA MIX PLACEMENT

- Place the bioretention soil in 6" lifts.
- The base 6" shall include only loamy sand.
- Well mix 2/3 of the biochar into the top 12" of the bioretention soil media mix. The remaining 1/3 should be tilled into the top 3" of the soil.
- Compact each lift to a relative compaction of 85% by boot packing (per Volume 5 of the SMMWW). (Do not use heavy equipment in the bioretention cell). Maximum dry density shall be determined following ASTM D 1557 for loamy sand and the Simplified Method is recommended for biochar (Muszynski, M. 2006. Determination of Maximum and Minimum Densities of Poorly Graded Sands Using a Simplified Method. Geotechnial Testing Journal, Volume 29, No. 3).

NOTE: *This document is not intended to fully replace current bioretention soils guidelines; additional information needed to complete the installation of a bioretention cell should follow the requirements specified in the applicable stormwater manuals. In addition, this specification is specific to the biochar's under investigation in the research study specified on this document and it is not intended to serve as guidance for other biochar's.*

SOIL MIX SPECIFICATION

TOP SOIL -LOAMY SAND

APPROXIMATE GRADATION

3/8"	-	100%
#4	-	98%
#10	-	95%
#40	-	67%
#100	-	4-10%
#200	-	2-5%

PH
5.5-8

CEC (MEQ/100GRAMS)
>2 (TOP SOIL)
>19 (BIOCHAR)

INFILTRATION RATE
< 12 IN/HR

MAX COMPACTION
85%

SOIL DEPTH
18 INCHES

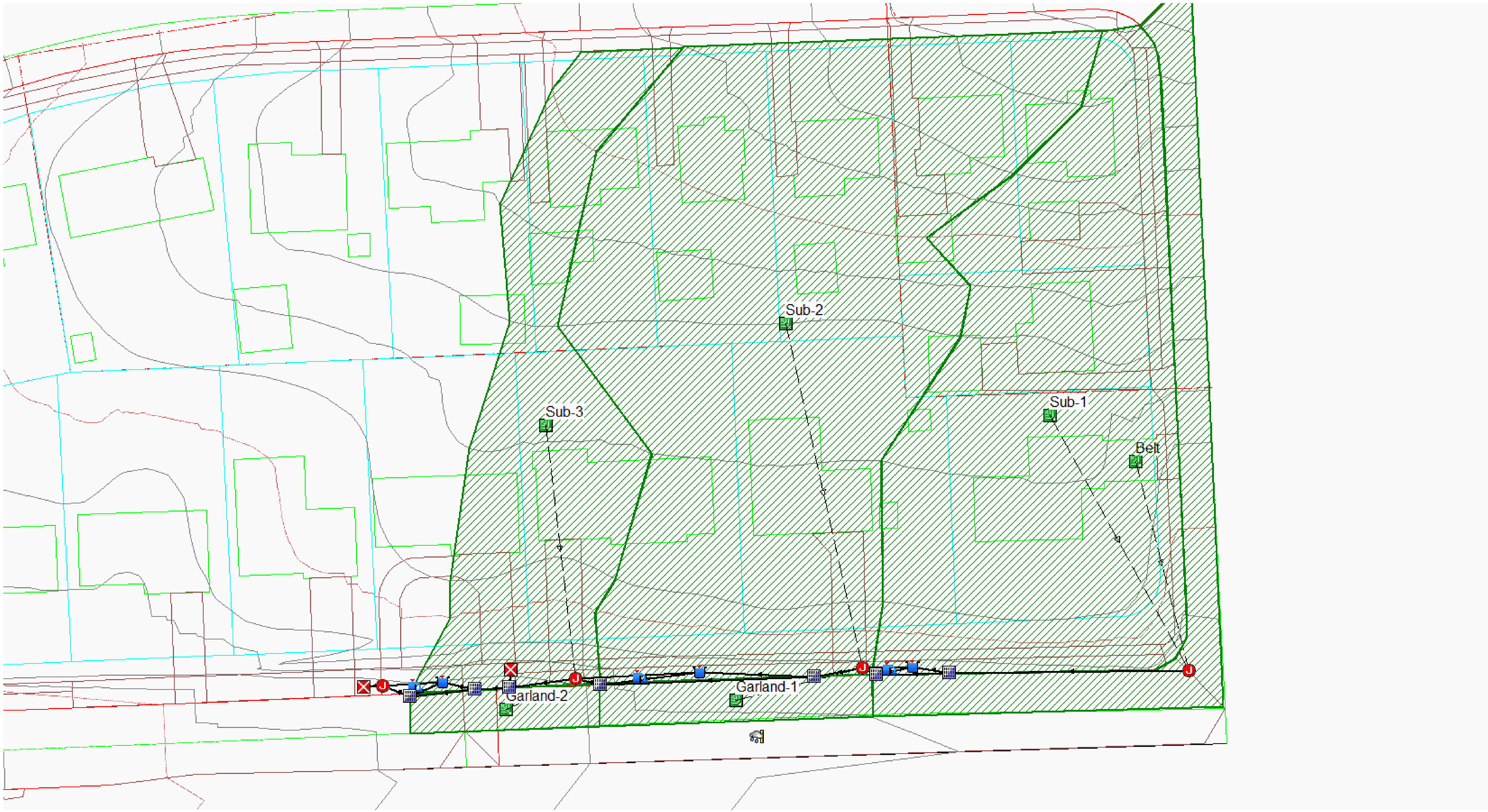
BIOCHAR PORTIONS
(IN TOP 12" OF SOIL)
30% ($V_{BIOCHAR}:V_{LS}$) DRY
2.6% ($W_{BIOCHAR}:W_{LS}$) DRY

ORGANIC MATTER
0.5%-1.0% (LOSS ON IGNITION)
2%-4.5% (ACTUAL ESTIMATED)

MULCH
1-1 ½ INCH SHREDDED BARK

Appendix B

Autodesk® Storm and Sanitary Analysis



Sub-2
Sub-3
Sub-1
Belt
Garland-2
Garland-1

Project Description

File Name .... 2013692_Calc_STRM_Drainage Model.SPF

Project Options

Flow Units .... CFS
Elevation Type .... Elevation
Hydrology Method .... SCS TR-55
Time of Concentration (TOC) Method .... Kirpich
Link Routing Method .... Steady Flow
Enable Overflow Ponding at Nodes .... YES
Skip Steady State Analysis Time Periods .... YES

Rainfall Details

SN	Rain Gage ID	Data Source	Data Source ID	Rainfall Type	Rain Units	State	County	Return Period (years)	Rainfall Depth (inches)	Rainfall Distribution
1	Rain Gage-01	Time Series	WQ TYPE 1A	Intensity	inches	Washington	Spokane	2	1.00	SCS Type IA 24-hr

Subbasin Hydrology

Subbasin : Belt

Input Data

Area (ac) 0.21
Weighted Curve Number 98.00
Average Slope (%) 3.4000
Flow Length (ft) 162.00
Rain Gage ID .... Rain Gage-01

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
PGIS-Road	0.21	-	98.00
Composite Area & Weighted CN	0.21		98.00

Time of Concentration

TOC Method : Kirpich

Sheet Flow Equation :

Tc = (0.0078 * ((Lf^0.77) * (Sf^-0.385)))

Where :

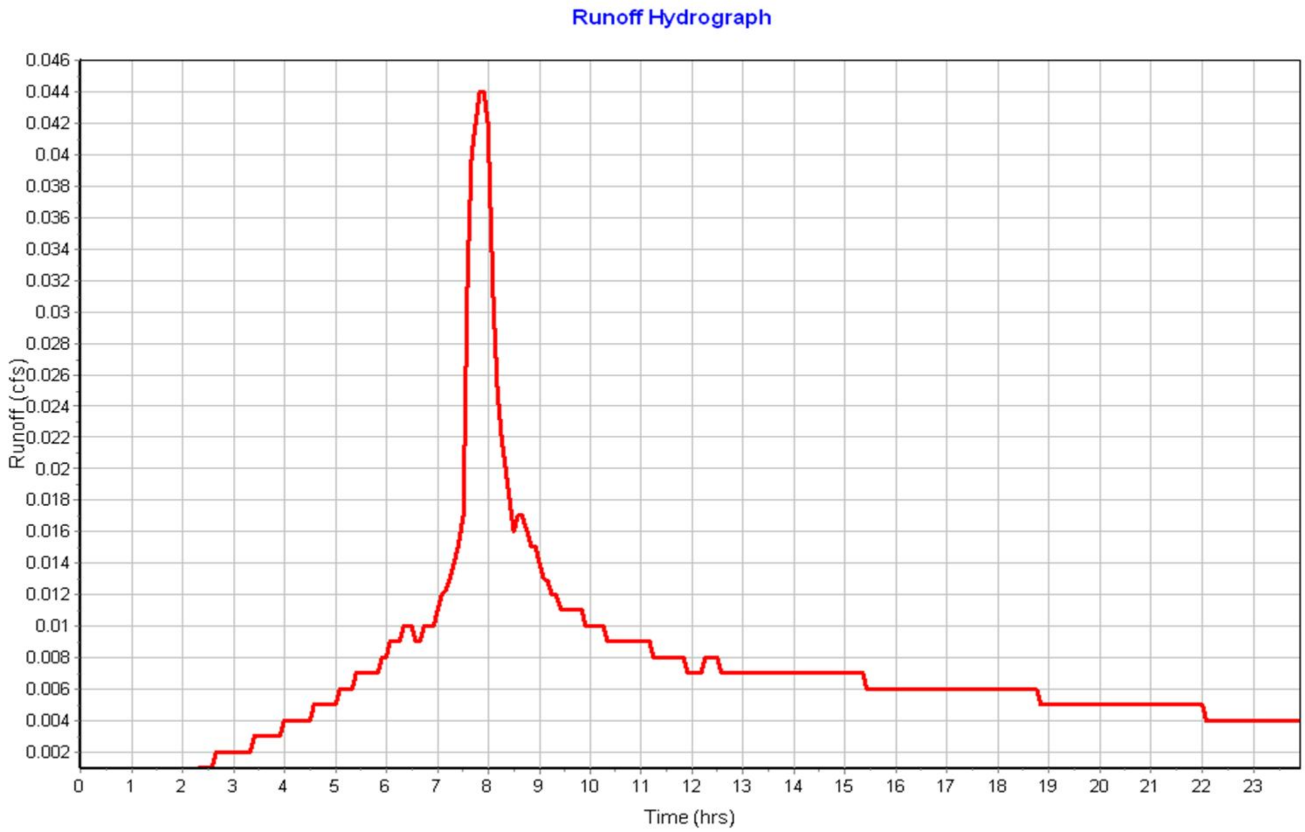
Tc = Time of Concentration (min)
Lf = Flow Length (ft)
Sf = Slope (ft/ft)

Flow Length (ft) 162.00
Slope (%) 3.4
Computed TOC (min) 1.44

Subbasin Runoff Results

Total Rainfall (in) 1.00
Total Runoff (in) 0.79
Peak Runoff (cfs) 0.04
Weighted Curve Number 98.00
Time of Concentration (days hh:mm:ss) 0 00:01:26

Subbasin : Belt



Subbasin : Sub-1

Input Data

Area (ac) 0.78
Weighted Curve Number 82.35
Average Slope (%) 2.9000
Flow Length (ft) 150.00
Rain Gage ID .... Rain Gage-01

Composite Curve Number

Soil/Surface Description	Area (acres)	Soil Group	Curve Number
> 75% grass cover, Good	0.51	C	74.00
PGIS-Roof/Drives	0.27	-	98.00
Composite Area & Weighted CN	0.78		82.35

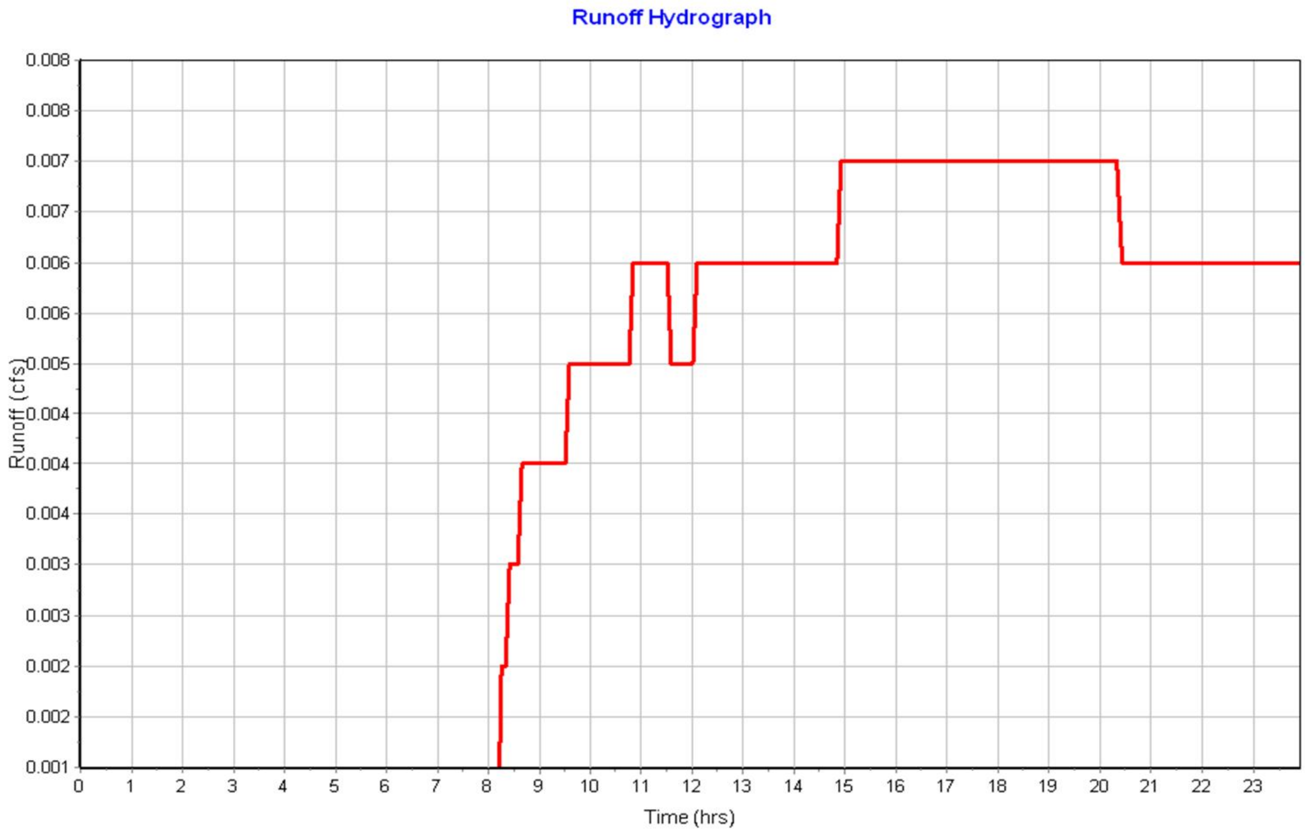
Time of Concentration

Flow Length (ft) 150.00
Slope (%) 2.9
Computed TOC (min) 1.44

Subbasin Runoff Results

Total Rainfall (in) 1.00
Total Runoff (in) 0.12
Peak Runoff (cfs) 0.01
Weighted Curve Number 82.35
Time of Concentration (days hh:mm:ss) 0 00:01:26

Subbasin : Sub-1



Storage Nodes

Storage Node : SWALE-01

Input Data

Invert Elevation (ft) 1972.91
Max (Rim) Elevation (ft) 1973.41
Max (Rim) Offset (ft) 0.50
Initial Water Elevation (ft) 0.00
Initial Water Depth (ft) .... -1972.91
Ponded Area (ft²) 0.00
Evaporation Loss 0.00

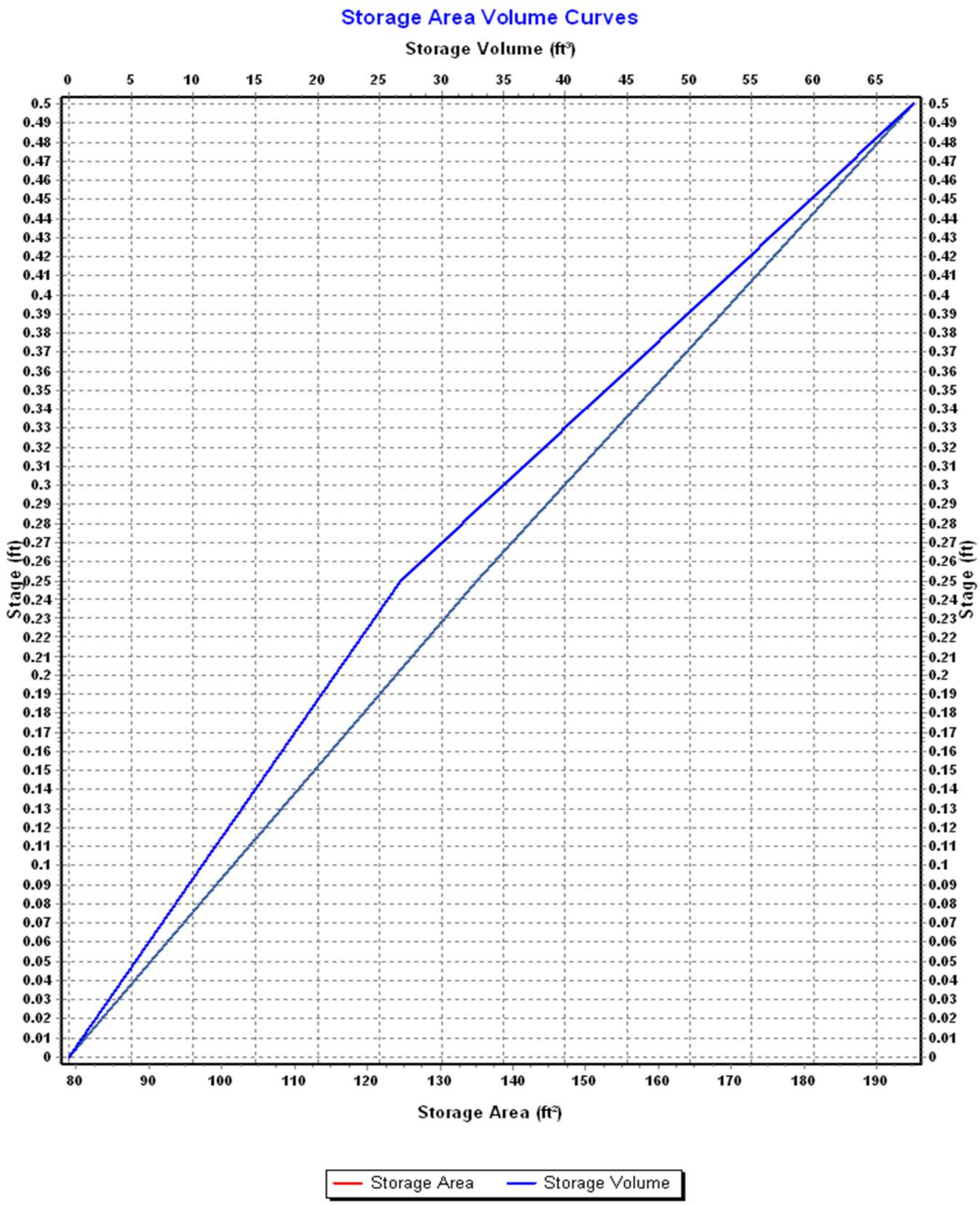
Infiltration/Exfiltration

Exfiltration Rate (in/hr) 2.4000

Storage Area Volume Curves

Storage Curve : Storage-03

Stage (ft)	Storage Area (ft²)	Storage Volume (ft³)
0	79	0.000
.25	135	26.75
.5	195	68.00


Storage Area Volume Curves
Storage Volume (ft³)
0
5
10
15
20
25
30
35
40
45
50
55
60
65
Stage (ft)
0.5
0.49
0.48
0.47
0.46
0.45
0.44
0.43
0.42
0.41
0.4
0.39
0.38
0.37
0.36
0.35
0.34
0.33
0.32
0.31
0.3
0.29
0.28
0.27
0.26
0.25
0.24
0.23
0.22
0.21
0.2
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
Storage Area (ft²)
80
90
100
110
120
130
140
150
160
170
180
190
Storage Area
Storage Volume

Storage Node : SWALE-01 (continued)

Output Summary Results

Peak Inflow (cfs) 0.04
Peak Lateral Inflow (cfs) 0.00
Peak Outflow (cfs) 0.03
Peak Exfiltration Flow Rate (cfm) 0.55
Max HGL Elevation Attained (ft) 1973.27
Max HGL Depth Attained (ft) 0.36
Average HGL Elevation Attained (ft) 1973.16
Average HGL Depth Attained (ft) 0.25
Time of Max HGL Occurrence (days hh:mm) 0 07:58
Total Exfiltration Volume (1000-ft³) 0.582
Total Flooded Volume (ac-in) 0
Total Time Flooded (min) 0
Total Retention Time (sec) 0.00