# Stormwater Action Monitoring - Effectiveness Studies

# Progress Report #3

## Evaluation of Hydraulic Control Approaches for Bioretention Systems

Prepared For:


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# Project Status Summary

**General Information**

| | |
|---|---|
| *Contract / Grant Agreement Number:* | IAA No. C2000041 |
| *Project Title:* | **Evaluation of Hydraulic Control Approaches for Bioretention Systems** |
| *Organization:* | Washington State University |
| *Project Managers:* | Anand Jayakaran, Washington State University<br>Myles Gray, Geosyntec Consultants |
| *Reporting Period:* | May 1, 2021 to October 31, 2021 |

**Brief description of Tasks and Achievements for current report period.**

**Task 1: Project Planning and QAPP Development**

| | |
|---|---|
| Percent Complete, Project Phase 1: | 100% |
| Percent Complete, Full Project: | 100% |
| All deliverables to be completed: | Deliverables 1.1 to 1.3 |
| Deliverables completed in **previous** reporting periods: | Deliverables 1.1 to 1.3 |
| Deliverables completed in **this** reporting period: | None |
| Description of Achievements: | Deliverable 1.1: Meeting notes from TAC Kickoff Call<br>Deliverable 1.2. Draft QAPP<br>Deliverable 1.3: Final QAPP |
| Challenges faced during **this** monitoring period: | None to report |

**Task 2: Installation and Startup**

| | |
|---|---|
| Percent Complete, Project Phase 1: | 100% |
| Percent Complete, Full Project: | 100% |
| All deliverables to be completed: | Deliverables 2.1 to 2.3 |
| Deliverables completed in **previous** reporting periods: | Deliverables 2.1 to 2.3 |
| Deliverables completed in **this** reporting period: | None |
| Description of Achievements: | Deliverable 2.1: Tables of equipment purchases<br>Deliverable 2.2: Installation photolog<br>Deliverable 2.3: Installation and Startup Report |
| Challenges faced during **this** monitoring period: | None to report |

**Task 3: Monitoring and Study Implementation**

| | |
|---|---|
| Percent Complete, Project Phase 1: | 100% |
| Percent Complete, Full Project: | 50% |
| All deliverables to be completed: | Deliverables 3.1 to 3.3 during Phase 1 |
| Deliverables completed in **previous** reporting periods: | Deliverable 3.1 and 3.2 |
| Deliverables completed in **this** reporting period: | Deliverable 3.3 |
| Description of Achievements: | Deliverable 3.1: Progress Report #1<br>Deliverable 3.2: Progress Report #2<br>Deliverable 3.3: Progress Report #3 |
| Challenges faced during **this** monitoring period: | Significant rain event caused damage to power supply system for entire WSU campus (blown fuses), resulting in data gaps for certain continuous monitoring data. Outage dates 10/1/21 to 10/11/21. |

**Task 4: Modeling Study**

| | |
|---|---|
| Percent Complete, Project Phase 1: | NA: No effort planned in Phase 1 |
| Percent Complete, Full Project: | 0% |
| All deliverables to be completed: | None during Phase 1 |
| Deliverables completed in **previous** reporting periods: | None |
| Deliverables completed in **this** reporting period: | None |
| Description of Achievements: | None to report |
| Challenges faced during **this** monitoring period: | None |

**Task 5: Reporting and Communication of Findings**

| | |
|---|---|
| Percent Complete, Project Phase 1: | 0% |
| Percent Complete, Full Project: | 0% |
| All deliverables to be completed: | Deliverable 5.1 during Phase 1 |
| Deliverables completed in **previous** reporting periods: | None |
| Deliverables completed in **this** reporting period: | None |
| Description of Achievements: | None to report |
| Challenges faced during **this** monitoring period: | None |

# 1 Introduction

This progress report documents the third monitoring period of the Stormwater Action Monitoring (SAM) Effectiveness Studies project Evaluation of Hydraulic Control Approaches for Bioretention Systems (Project). Progress Report #3 covers monitoring activities completed between May 1, 2021, and October 31, 2021. This period will be referred to as Monitoring Period #3. All monitoring activities were completed according to the Quality Assurance Project Plan (QAPP) dated August 20, 2020, with some noted modifications.

This report fulfills deliverable 3.3 of the Interagency Agreement effective September 9, 2019.

# 2 Continuous Monitoring Data

Continuous monitoring data were collected throughout Monitoring Period #3. Table 1 presents a summary of continuous monitoring data and data gaps. These data will be presented in more detail and analyzed as part of the Interim Presentation and the Final Report.

**Table 1. Continuous data collected during the monitoring period**

| Data Stream | Logging Interval | Data Gaps |
|---|---|---|
| Precipitation | 5-minute | 10/1/21 to 10/11/21- Power outage |
| Cistern Water Level | 5-minute | 10/1/21 to 10/11/21- Power outage |
| Mesocosm Inlet Flow | 5-minute | 10/1/21 to 10/11/21- Power outage<br>4/21/21 to 6/15/21 Inadvertent valve closure (MS 42 only) |
| Mesocosm Outlet Flow | 5-minute | 10/1/21 to 10/11/21- Power outage<br>4/21/21 to 6/15/21 Inadvertent valve closure (MS 42 only) |
| Ponding Depth | 5-minute | 7/27/21 to 8/30/21- Faulty sensor (MS 45 only) |
| Soil Moisture[1] | 5-minute | None |

[1] Soil moisture data are only collected for the six fully instrumented mesocosms

# 3 Water Quality Event #3

## *3.1 Sampling Overview*

Water quality event #3 was completed on October 25, 2021. During this event, dosed stormwater runoff was routed to the six fully instrumented mesocosms and to the influent monitoring point. During water quality event #1, monitoring data indicated that influent pollutant concentrations were substantially lower than the high pollutant dosing targets from the QAPP for TSS, copper, and zinc. Following water quality event #1, the research team agreed that precise pollutant concentration targets would be challenging to achieve due to variability in stormwater quality from the facility catchment and due to variable settling of pollutants in the two cisterns. To limit influent water quality variability from storm to storm, the research team agreed to use the same dosing approach for all future storms while also modifying the mixing approach in the cistern to

limit particulate settling. Accordingly, cistern dosing was conducted using the same dosing that was used during water quality event #1.

Based on observations during water quality event #1, modifications were made during water quality event #3 to limit settling of Sil-co-Sil 106. Specifically, an additional mixing pump was added to the bottom of the cistern and ran continuously throughout the duration of the event. This approach reduced Sil-co-Sil 106 settling, was used in water quality events #2 and #3, and will be used in all future water quality events.

Water was routed to the mesocosms and inlet point for four hours to represent a high intensity storm as presented in Table 9 of the QAPP. Flow-weighted composite samples were collected for the duration of the four-hour event and then overnight until the following morning. Each sample aliquot was 350 mL and was pumped into 20 L glass composite sampling containers. Following the completion of sampling, on the morning of October 26, 2021 the composite samples were delivered to ARI Labs where samples were mixed, split using a churn-splitter, and then analyzed for parameters listed in Table 11 of the QAPP.

## *3.2 Water Quality Data*

Laboratory analytical results are summarized in Table 2 and full results will be submitted as part of the Final Report. Analytical results for total and dissolved zinc were low in effluent from some of the mesocosms, with a total of five values below detection limits and another three between the detection limit and the reporting limit.

**Table 2. Water quality results for TSS and metals**

| **Location** | **TSS** | **Total Kjeldahl Nitrogen** | **Nitrate-Nitrite** | **Total Phosphorus** | **Orthophosphorous** | **Copper, total** | **Copper, dissolved** | **Zinc, total** | **Zinc, dissolved** |
|---|---|---|---|---|---|---|---|---|---|
| Units | mg/L | mg/L | mg/L | mg/L | mg/L | µg/L | µg/L | µg/L | µg/L |
| Influent Target[1] | 120 | 3[2] | | 0.4 | NA | 40 | NA | 150 | NA |
| Influent | 76 | 1.0 | 2.59 | 0.66 | 0.375 | 30.9 | 7.92 | 117 | 54.1 |
| 12: Standard BSM, outlet controlled | 36 | 4.8 | 1.47 | 0.66 | 0.248 | 19.1 | 13 | 8.96 | 3.23 |
| 33: Standard BSM, media controlled | 111 | 3.6 | 2 | 0.68 | 0.383 | 30.9 | 11.8 | 26.2 | 4.05 |
| 22: Mature BSM, outlet controlled | 8 | 2.4 | 1.78 | 0.092 | 0.037 | 14.1 | 12.1 | 3.50[4] | < 6[3] |
| 13: Mature BSM, media controlled | 7 | 1.0 | 2.29 | 0.12 | 0.075 | 4.68 | 3.94 | < 6[3] | < 6[3] |
| 15: Alternative BSM, outlet controlled | 12 | 1.1 | 1.65 | 0.193 | 0.137 | 5.89 | 3.50 | 4.04[4] | < 6[3] |
| 34: Alternative BSM, media controlled | 10 | 1.4 | 1.93 | 0.228 | 0.191 | 5.72 | 4.35 | 5.99[4] | < 6[3] |

[1] Influent target values are from the QAPP for high pollutant.
[2] The QAPP presented an influent target of 3 mg/L for total nitrogen which is the sum of nitrate-nitrite and total Kjeldahl nitrogen.
[3] Values were below the detection limit of 6 µg/L
[4] Values were between the detection limit and the reporting limit.

# 4 Special Testing Event #2

## *4.1 Testing Overview*

Special testing event #2 was completed on October 27, 2021, following the completion of water quality event #3. This consisted of hydraulic residence time monitoring followed by hydraulic conductivity testing.

## *4.2 Hydraulic Residence Time Testing*

Hydraulic residence time testing was completed according to the approach presented in the QAPP, with some minor modifications. To limit the potential for ion interference, the research team used bromide instead of $MgCl_2$ as the conservative tracer. The weir box for each of the fully instrumented mesocosms and the influent sampling point was dosed with 4 L of a solution with 2,500 mg/L bromide. The transfer pump in the cistern was configured to convey water at a rate of 28 L/minute instead of 19 L/minute which was proposed in the QAPP. This higher flow rate was used to induce hydraulic differences between outlet-controlled and media-controlled mesocosms which are more apparent at higher flow rates. Flow was conveyed to each mesocosm for approximately 75 minutes before and then for 180 minutes after the dose was applied. Electrical conductivity in mesocosm effluent was recorded on a 1-minute logging frequency using Oakton PC450 handheld electrical conductivity meters.

Conductivity data from this testing are presented in Figure 1. Further analysis and discussion of these data will be presented in the Final Report.

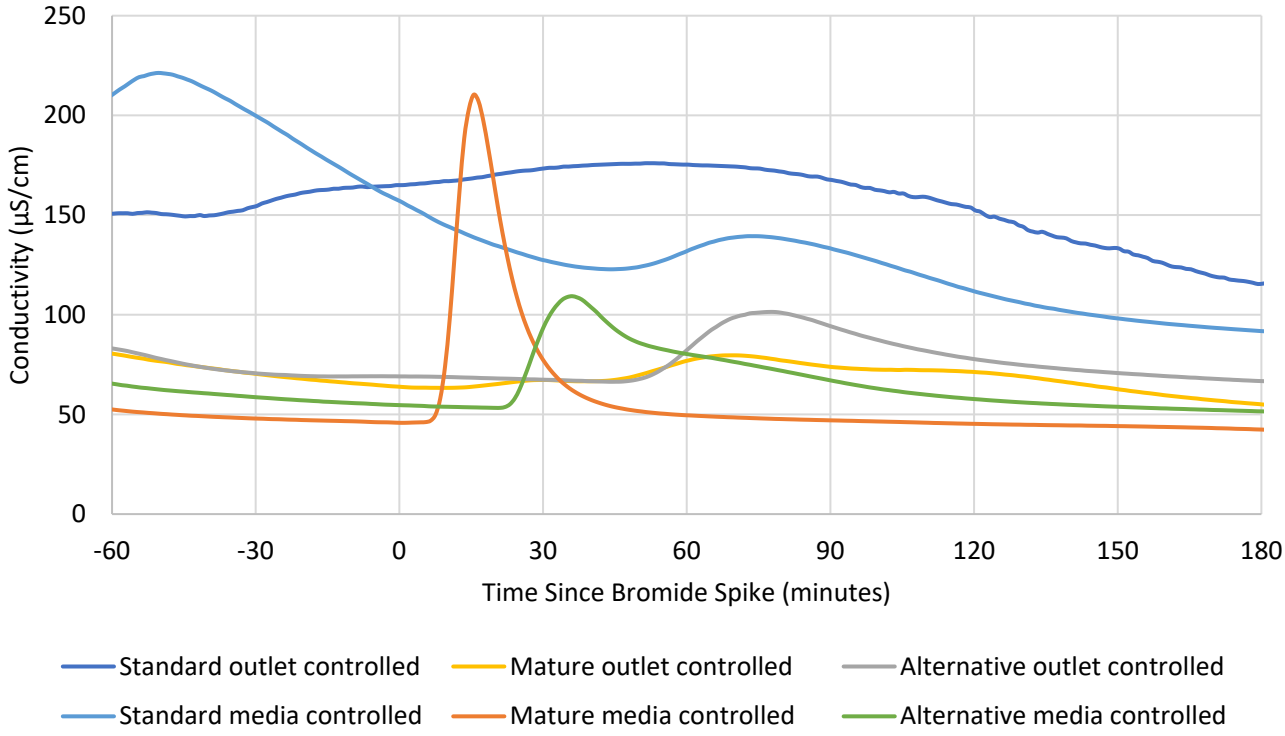


**Figure 1. Hydraulic residence time testing results**

### *4.3 Hydraulic Conductivity Testing*

Hydraulic conductivity testing was completed in accordance with the method presented in the QAPP, with some minor modifications. Briefly, the outlet valve from each mesocosm was closed and then water was conveyed to each mesocosm until it was at least nine inches deep. The QAPP proposed filling each mesocosm to brim full, however, to save time and water, filling to nine inches of ponding depth was deemed adequate to initiate testing. This testing was completed immediately after finishing residence time testing, so some of the mesocosms still had shallow ponding at the start of hydraulic conductivity testing. The inlet valve to each mesocosm was then closed, and then outlet valves were adjusted to that all mesocosms discharged under media-controlled conditions. Surface ponding data was continuously measured using the HYDROS 21 sensor in each mesocosm. Surface ponding measurements were collected every 5 minutes instead of every 1 minute as specified in the QAPP because the shortest possible logging interval for the Meter sensors is 5 minutes.

Results from hydraulic conductivity testing are presented in Figure 2. Sensor drawdown data were analyzed to determine drawdown rate values by dividing the drawdown depth by the elapsed time for the portion of the drawdown curve with the steepest slope. Calculated drawdown rate values from Special Testing Event #3 are presented in Table 3 along with values from Special Testing Event #1. These values do not represent hydraulic conductivity values which account for several other factors. Hydraulic conductivity values will be calculated and presented in the Final Report.

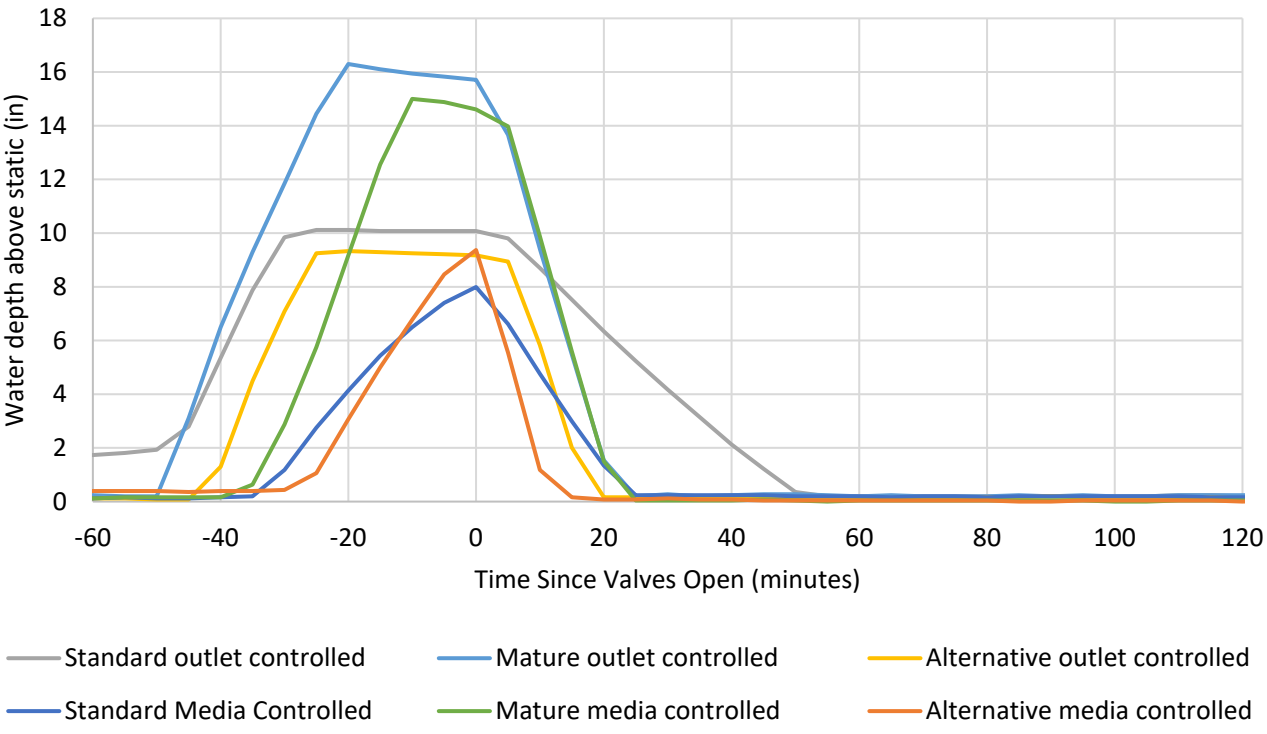


**Figure 2. Hydraulic conductivity testing results**

**Table 3. Hydraulic conductivity analysis data**

| Mesocosm | Special Event #3 | | | Special Event #1 |
|---|---|---|---|---|
| | Analysis Period (minutes) | Drawdown Depth (inches) | Infiltration Rate (inches/hour) | Infiltration Rate (inches/hour) |
| 12: Standard BSM, outlet controlled | 40 | 8.6 | 12.9 | 4.9 |
| 33: Standard BSM, media controlled | 15 | 5.3 | 21.1 | 5.8 |
| 22: Mature BSM, outlet controlled | 15 | 12.1 | 48.5 | 40.7 |
| 13: Mature BSM, media controlled | 15 | 12.5 | 49.9 | 44.3 |
| 15: Alternative BSM, outlet controlled | 10 | 6.9 | 41.6 | 41.3 |
| 34: Alternative BSM, media controlled | 5 | 4.4 | 52.4 | 31.8 |

# 5 Vegetation Monitoring

Vegetation monitoring measurements were taken on June 18, 2021 and September 16, 2021. During these vegetation monitoring events, each of the plants in all fourteen mesocosms was measured for height, base circumference, and ascribed a qualitative health and vigor rating from 1 to 5.

Based on past observations with the mesocosm system, it was determined that the plants would need supplementary irrigation during the dry summer months to prevent mortality. The mesocosms were irrigated through a timed irrigation system that added water directly into the weir box and through the distribution system to each mesocosm. Supplementary irrigation was applied weekly during the summer.

# 6 Operations and Maintenance Monitoring

Operations and maintenance (O&M) monitoring consisted of system operation checks including:

- Monthly desiccant changes to all sensitive electronic equipment
- Monthly cleaning and level checks on tipping bucket flow meters
- Monthly cleaning and height checks on influent weir boxes
- Monthly cleaning and level checks on weather station rain gauges
- Monthly inspection of outlet control orifices
- Weekly power and connection checks on data logging and monitoring equipment