APPENDIX K

Filter Panel Assessment

TECHNICAL MEMORANDUM

Date: August 3, 2018

To: John Rotondo, Rich Rotondo, Rotondo Environmental Solutions, LLC

Copy to: John Lenth, Herrera Environmental Consultants, Inc

From: Dylan Ahearn, Herrera Environmental Consultants, Inc

Subject: Rotondo StormGarden Filter Panel Assessment

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Introduction

In June 2016, Rotondo Environmental Solutions, LLC (Rotondo) initiated the formal certification process for the StormGarden® Biofilter (StormGarden) through the Technology Assessment Protocol–Ecology (TAPE) program that is administered by the Washington State Department of Ecology (Ecology). This program requires field testing of emerging stormwater treatment technologies to certify their performance relative to specific goals for different treatment categories. In April 2017, field testing of a StormGarden began at the Ship Canal Test Facility (SCTF) in Seattle, Washington. As part of this field testing, Rotondo looked to investigate the characteristics of their filter panel technology. This memorandum reports the results from the assessment of water quality and quantity associated with the filter panel.

Technology Description

The StormGarden is a biofiltration system design to treat stormwater via filtration through a planted media bed. Water enters through a curb cut, filters vertically through the treatment media and then egresses through a slotted underdrain pipe (Figure 1). As with most underdrains in vault systems, the underdrain pipe is encased in a drainage gravel layer and does not rest on the floor of the vault. This results in a dead storage zone beneath the underdrain. In order to drain the water from this storage zone, the StormGarden is designed with a permeable paver section installed flush with the floor of the vault. Under typical conditions water infiltrates into the native soil through this paver and after storm events the water beneath the underdrain exfiltrates out of the unit and into the native soil, thus eliminating the dead storage.

Rotondo designed the filter panel for two reasons: 1) to obtain additional treatment by infiltrating stormwater (and pollutants) that might otherwise be discharged from the system to the downgradient storm drain, and 2) to improve performance by draining the dead storage zone. It is assumed that water in the dead storage zone becomes elevated in pollutants with time and then subsequent events push those pollutants out through the underdrain, thus reducing performance.

To verify the benefits of the filter panel, the StormGarden installed at the SCTF for testing was retrofitted with a cover over the filter panel and a valve attached to the outside of the panel (Figures 1 and 2). The valve remained closed during normal operation and was only opened during discrete testing periods.

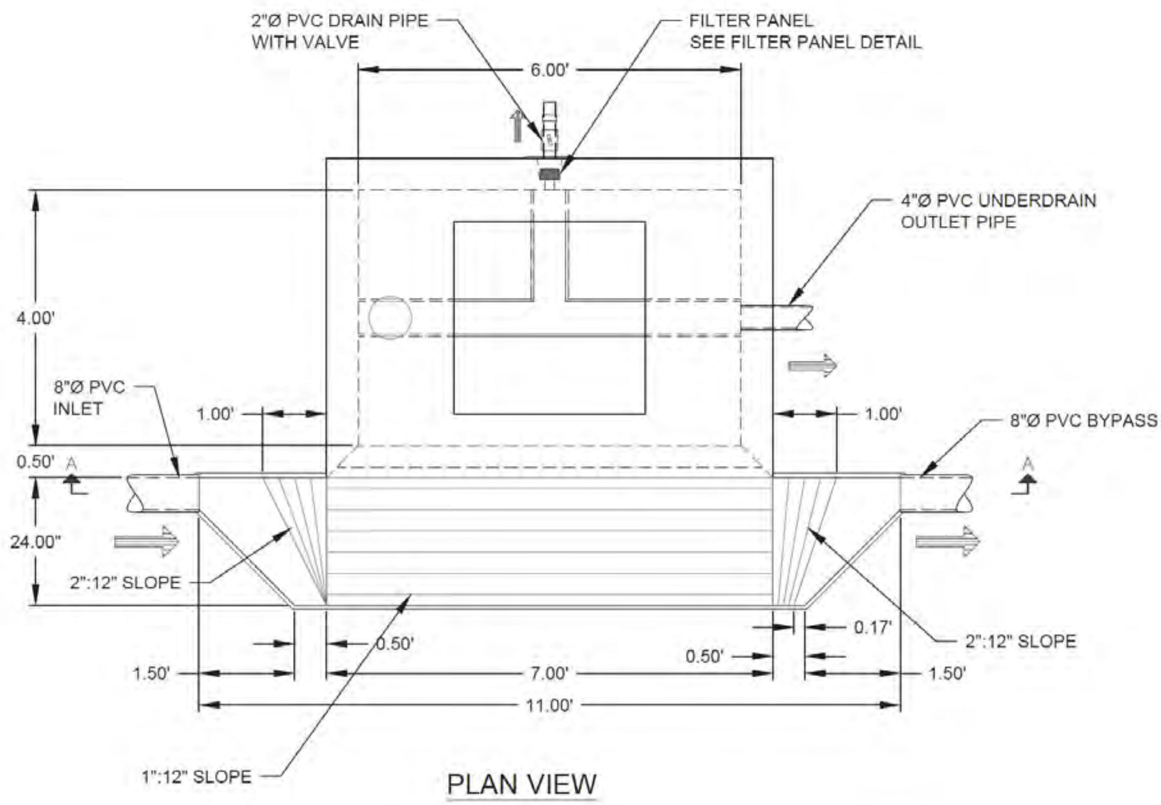

Figure 1. Plan View of the StormGarden Unit.

Figure 2. Photos of StormGarden Test System with Filter Panel Valve on the Right Bottom Wall.

FIELD SAMPLING

On May 10, 2017, and May 19, 2017 (dry days with preceding dry periods), the valve on the filter panel was opened and a sample of the dead storage zone water was collected. The samples were analyzed for total suspended solids, total phosphorus, ortho-phosphorus, and total and dissolved copper and zinc. The results of these analyses are presented in Table 1.

Table 1. Chemistry Results from Filter Panel Testing.

Parameter	Units	5/10/2017 Sampling Event	5/19/2017 Sampling Event	Mean Filter Panel Concentration	Mean Underdrain Concentration
Suspended Solids	mg/L	156	76.9	116.4	4.3
Total Phosphorus	mg/L	0.256	0.164	0.210	0.050
Orthophosphorus	mg/L	0.039	0.080	0.060	0.010
Total Copper	ug/L	7.6	9.6	8.6	12.6
Total Zinc	ug/L	34.6	19.2	26.9	24.6
Dissolved Copper	ug/L	4.2	5.2	4.6	8.7
Dissolved Zinc	ug/L	4	5.3	4.7	17.3

The May 10, 2017, sample was preceded by 7 days with no flow into the test system; whereas the May 19, 2017, sample was preceded by only 3 days with no flow. Consequently, the water sampled from the filter panel on May 10, 2017, was stored in the dead storage zone for 4 more days than the water sampled on May 19, 2017. Table 1 indicates that the May 10, 2017, sample had higher concentrations of total suspended solids, total phosphorus, and total zinc relative to the May 19, 2017, event. However, the May 19, 2017, event had higher concentrations of orthophosphorus, total and dissolved copper, and dissolved zinc. Additional samples would be required to determine if there is a relationship between antecedent dry period and dead storage zone chemistry.

To compare the filter panel chemistry to the underdrain chemistry, Table 1 also presents the mean concentration from the underdrain based on data from 21 flow weighted composite samples that were collected during storm events from May 2017 to February 2018. Concentrations of metals from the underdrain are either similar to or slightly lower than concentrations from the filter panel samples. Total suspended solids, total phosphorus, and orthophosphorus are all elevated in the filter panel samples by factors of 29, 4, and 6 for total suspended solids, total phosphorus, and orthophosphorus, respectively. These data indicate that sediment and nutrients tend to concentrate in the dead storage zone between storms; hence, infiltration of this water via the filter panel would effectively remove these pollutants before they could be flushed from the system during the next storm event.

FLOW TESTING

On April 20, 2017, a flow test of the StormGarden installed at the SCTF for testing was conducted to determine the infiltration rate of water at the surface of the media as well as the contribution of the filter panel to the total flow rate of water exiting the system. The results of this testing are presented in Attachment 1. These results show the flow rate of water exiting the StormGarden via the underdrain was 51 gallons per minute (gpm) with a constant 7 inches of driving head on the mulch surface of the media. When the filter panel valve was opened, the flow rate had to be increased to 62 gpm in order to maintain the same 7 inches of driving head above the media. Thus, it can be inferred that the filter panel increased the treated flow rate by 11 gpm or approximately a 21.6 percent increase (11/51 = 0.216). This means that under peak flow conditions, the filter panel will remove approximately 17.7 percent (11/62 = 0.177) of the influent flow from the downstream storm drain and discharge that volume to the ground via infiltration given the native soil does not limit the infiltration. A pollutant load reduction would occur commensurate with this volume reduction.

CONCLUSIONS

The results from the testing described herein indicate the use of a filter panel in the StormGarden to manage water trapped in the dead storage zone is likely improving system performance relative to total suspended solids and phosphorus removal. The study design did not allow for the quantification of the pollutant load removed via this design feature, but it did provide evidence that it exists. In addition, under peak flow conditions, the flow from the filter panel accounted for approximately 17.7 percent of the total flow exiting the test system. Given relatively permeable native soils, infiltration of this water would also result in a pollutant load reduction to the downstream storm drain, which would also improve performance of the system. These data indicate the filter panel provides a net benefit to system performance and should be used in applications where infiltration to the ground is allowed.

ATTACHMENT A

StormGarden Infiltration Testing at the Ship Canal Testing Facility

HERRERA

TECHNICAL MEMORANDUM

Date: May 1, 2017

To: John Rotondo, Rich Rotondo, Rotondo Environmental Solutions, LLC

Copy to: John Lenth, Herrera Environmental Consultants, Inc.

From: Dylan Ahearn, Herrera Environmental Consultants, Inc.

Subject: StormGarden Infiltration Testing at the Ship Canal Testing Facility

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On April 20, 2017, Herrera Environmental Consultants, Inc. (Herrera) conducted infiltration testing on a 4- by 6-foot (internal dimensions) StormGarden Stormwater Filtration System (StormGarden) installed at the Ship Canal Testing Facility (SCTF) in Seattle, Washington (Figure 1). In order to determine the maximum flow rate that the system could infiltrate without bypassing, a firehose with Master Meter™ fire hydrant meter (flow meter) was used to discharge potable water into the system. The flow rate of the flow meter was verified with a calibrated 30-gallon bucket and timer prior to testing, and it was determined that the error was less than 5 percent. Figure 2 provides images of both the flow meter and the graduated bucket.

The water quality design infiltration rate of the StormGarden is 140 inches per hour (in/hr), which for a 4- by 6-foot unit equates to a flow rate of 34.9 gallons per minute (gpm). It was anticipated that the maximum infiltration rate would exceed the design infiltration rate so that the system would have capacity to progressively clog during operation without the flow rate falling below the design rate. Water was discharged into the unit in four runs with approximately 5 to 15 minutes of no flow separating each run. During each run, the water level above the mulch was measured along with the flow rate. Table 1 summarizes the results. The initial run was used to wet the media and only 12.5 gpm (50 in/hr) was discharged into the unit. No standing water above the mulch was observed. In the second run the flow rate was brought up to 54.3 gpm or 218 in/hr. At this flow rate the water level was 7 inches above the mulch and equal to the bypass invert; however, the water level was rising slightly so it was assumed that the steady state infiltration rate was slightly below this level. During the third run, the water level held steady at the bypass and the measured flow was 51 gpm or 213 in/hr. This value was used as the final maximum infiltration rate for the StormGarden (Table 1).

The StormGarden is configured with a 4-inch underdrain as well as a 6- by 4-inch permeable paver filter panel that is designed to drain the water beneath the underdrain perforated pipe between storm events. The filter panel also provides some infiltration benefit. During the final run, a valve sealed over the filter panel (Figure 3) was opened and one final infiltration test was run to determine the maximum infiltration rate with both the underdrain and filter panel exporting filtered stormwater. The result was an increased maximum infiltration rate from 213 in/hr to 249 in/hr (Table 1).

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In summary, these results indicate that the StormGarden system installed at the SCTF exhibits a maximum infiltration rate of 213 in/hr with the filter panel sealed and 249 in/hr when the filter panel is allowed to drain free. It should be noted that when installed in the field the infiltration rate of the native soil may control the flow rate from the filter panel so the maximum infiltration rate of 249 in/hr may not be achievable under all field conditions.

Table 1. Infiltration Test Results.

Run	Date/Time	Head Above Mulch (in)	Flow Meter Flow Rate (gpm)	Equivalent Infiltration Rate (in/hr)	Notes
1	4/20/17 13:40	0	12.5	50	Low flow test to wet media
2	4/20/17 13:55	7	54.3	218	Water level at bypass but rising slightly
3	4/20/17 14:23	7	51	205	Water level steady at bypass invert
4	4/20/17 14:40	7	62	249	Filter panel underdrain valve open, estimated at 8 to 11 gpm. Water level steady at bypass
Estimated max infiltration rate with no filter panel			**51**	**213**	
Estimated max infiltration rate with filter panel			**62**	**249**	

in = inch

in/hr = inches per hour

gpm = gallons per minute

Bold values = final results

Figure 1. Image of the StormGarden System Tested at the SCTF.

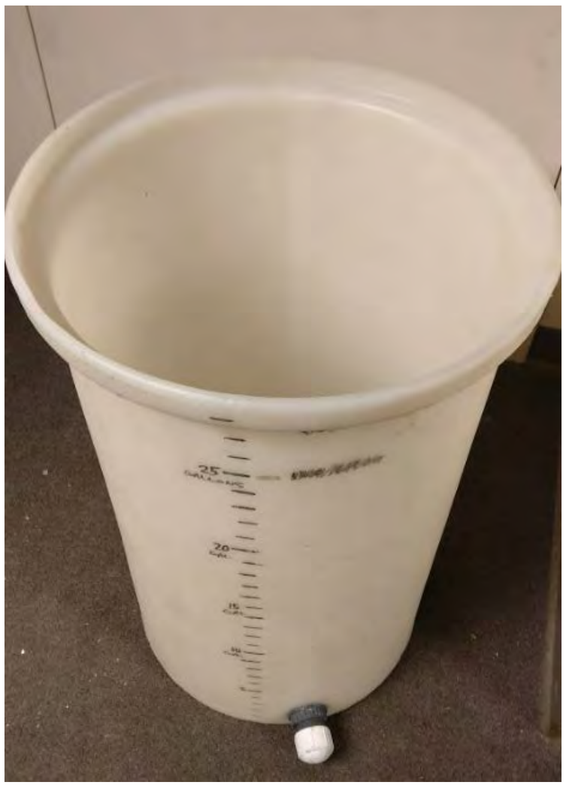

Figure 2. Images of the Rotameter and Graduated Bucket used During the Infiltration Testing.

Figure 3. Filter Panel Valve.