APPENDIX E

POST-GULD MONITORING REPORT

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POST-GULD MONITORING REPORT

TREEPOD™ BIOFILTER SYSTEM PERFORMANCE CERTIFICATION PROJECT

Prepared for
Oldcastle, Inc.

Prepared by
Herrera Environmental Consultants, Inc.

HERRERA

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POST-GULD MONITORING REPORT

TREEPOD™ BIOFILTER SYSTEM PERFORMANCE CERTIFICATION PROJECT

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June 27, 2018

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INTRODUCTION

The TreePod™ biofilter (TreePod™) (now known as the BioPod™) is a stormwater quality treatment system developed by Oldcastle, Inc. The Washington State Department of Ecology (Ecology) has established specific use level designations for emerging stormwater treatment technologies like the TreePod™ in accordance with guidelines that are identified by Ecology (2011) in the *Technical Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology* (*TAPE*). There are three use level designations: pilot, conditional, and general. Pilot and conditional use level designations allow limited application of emerging stormwater treatment technologies in Washington to facilitate field testing. If field testing shows that the treatment technology meets minimum treatment goals identified in the TAPE guidelines, Ecology may issue a general use level designation (GULD) for the treatment technology, permitting its widespread use in Washington.

Field testing of the TreePod™ was conducted over a 5-month period, from January 6, 2017, through May 15, 2017 at the Ship Canal Test Facility (SCTF) in Seattle, Washington. The results from this initial monitoring were summarized in a Technical Evaluation Report (TER) that was submitted to Ecology in August 2017 (Herrera 2018). The TreePod was subsequently issued a GULD for Basic Treatment and a Provisional GULD for phosphorus and enhanced treatment in April 2018 (Attachment 1). The conditions of the Provisional GULD held that four additional samples were required to be collected during storm events over one additional maintenance cycle to supplement the initial monitoring. These samples were collected from March 21, 2018, through April 28, 2018. Results from the initial and supplemental monitoring are summarized together in this report.

DATA SUMMARIES AND ANALYSIS

This section summarizes data collected during the initial and supplemental monitoring periods described above. The presentation of these data is organized under separate subsections for the hydrologic and water quality monitoring results, respectively. Quality assurance worksheets for the water quality data are presented in Attachment 2. Attachment 3 presents field notes for each event, while Attachment 4 provides the laboratory reports. Individual Storm Reports are provided in Attachment 5.

SYSTEM HYDRAULIC PERFORMANCE

The water budget for the TreePod™ test system was analyzed to determine influent volume, effluent volume, and bypass frequency and volume. Using this water budget, additional analyses were performed to meet the following objectives:

- Determine whether treatment goals for the test system were met based on the volume treated and bypassed
- Determine site specific maintenance frequency by examining bypass over the course of the study

Performance in Relation to Design Treatment Goal

Table 1 presents the hydraulic monitoring results for the TreePod™ test system for the 13 storm events that were sampled over the initial monitoring period (January 6, 2017, through May 15, 2017) and results for the 4 storm events that were sampled over the supplemental monitoring period (March 21, 2018, through April 28, 2018). Prior to the supplemental monitoring period, the TreePod test system at the SCTF was offline from May 15, 2017, until March 21, 2018, at which point the system was maintained (mulch replaced) and brought back online.

The water quality treatment goal for the TreePod™ test system was to capture and treat 91 percent of the average annual runoff volume. Due to rapid clogging of the TreePod™ test system at the SCTF, this goal was not met. Table 1 indicates the media was replaced during the initial testing on 3/28/17, after this point the media was exposed to 44.9 percent of a water year and required 2 mulch changes.

As is apparent from Table 1, the TreePod™ test system clogged prematurely when tested at the SCTF. However, two other stormwater treatment technologies were exhibiting similar premature clogging issues in adjacent bays. As noted in the TER that was produced after the initial monitoring period (Herrera 2018), the drainage basin that is the source of stormwater runoff for

the SCTF is dominated by highway land use. Based on these observations, it is likely that stormwater at the SCTF is not representative of the stormwater that the TreePod™ test system (or manufactured treatment devices, in general) will encounter given more typical urban land uses. Ecology indicated in the GULD that the approval could be updated once a year's worth of flow testing is conducted on a TreePod™ system installed under more typical land use conditions. This additional monitoring will be performed at another location in Western Washington within the next 2 years.

Table 1. Hydraulic Performance of the Sampled Events at the TreePod™ Test System.								
Media	**Media No.**	**Date**	**Average Sampled Flow (gpm)**	**Peak Inflow (gpm)**	**Peak Outflow (treated) (gpm)**	**Peak Bypass Flow (gpm)**	**Averaged Treated Flow During Bypass (gpm)**	**Cumulative Percent of a Water Year Treated by Media**
sand/AA	Media 2	3/3/2017	27.6	41.8	28.3	13.5	28	0.5
sand/AA	Media 2	3/7/2017	9.8	26.8	12.1	15.4	11	1.4
Media Replacement 3/28/17 – New Media and Mulch								
coarse sand/AA	Media 3	3/29/2017	33.4	63.2	36.1	27.2	36	0.2
coarse sand/AA	Media 3	4/4/2017	43	52.7	52.7	–	–	0.5
coarse sand/AA	Media 3	4/6/2017	8	10.2	10.2	–	–	0.7
coarse sand/AA	Media 3	4/10/2017	8.3	9.8	9.8	–	–	0.9
coarse sand/AA	Media 3	4/12/2017	18	23.1	23.1	–	–	2.2
coarse sand/AA	Media 3	4/19/2017	14.2	21.1	21.1	–	–	4.3
coarse sand/AA	Media 3	4/26/2017	6.7	20.1	20.1	–	–	4.6
coarse sand/AA	Media 3	5/2/2017	2.7	3.7	3.7	–	–	4.8
coarse sand/AA	Media 3	5/4/2017	17.5	30.2	28.4	2.7	25	6.3
Maintenance 5/10/17 – New Mulch								
coarse sand/AA	Media 3	5/11/2017	3.9	10.2	10.2	–	–	6.8
coarse sand/AA	Media 3	5/15/2017	17.3	23.3	23.3	–	–	11.5
Maintenance 3/21/18 – New Mulch								
coarse sand/AA	Media 3	4/4/18	32.7	39.7	35.7	4.1	35.1	15.1
coarse sand/AA	Media 3	4/7/18	11.2	20.7	20.7	–	–	20.1
coarse sand/AA	Media 3	4/11/18	24.5	30.4	30.4	–	–	26.9
coarse sand/AA	Media 3	4/28/18	10.2	11.5	11.2	3.0	9.8	44.9
Mean			17.0	25.8	22.2	11.0	24.2	NA

gpm = gallons per minute

AA = activated alumina

WATER QUALITY DATA

This section summarizes water quality data collected during the initial and supplemental monitoring period. Per Ecology's request, the datasets were combined to provide more data for assessing overall performance and performance as a function of influent flow rate. Overall performance is also assessed as a function of time through the two monitoring periods. Monitoring results for each parameter are summarized and discussed in separate sections.

Comparison of Data to TAPE Guidelines

The TAPE guidelines identify criteria for determining data acceptability based on the characteristics of sampled storm events and the collected samples. The data collected through this monitoring effort are evaluated relative to these criteria in the following subsections.

Storm Event Guidelines

During the initial and supplemental monitoring periods, 17 storm events were sampled to characterize the water quality treatment performance of the TreePod™ test system. Precipitation data from the sampled storm events in this period were compared to the following criteria from the TAPE guidelines for determining their acceptability:

- **Minimum precipitation depth**: 0.15 inch
- **Minimum antecedent dry period**: 6 hours with less than 0.04 inch of rain
- **Minimum storm duration**: 1 hour
- **Minimum average storm intensity**: 0.03 inch per hour for at least half the sampled storms

Summary data related to these criteria are presented in Table 2 for each of the 17 sampled storm events. These data show the criterion for minimum precipitation depth (0.15 inch) was met during all storm events. The minimum, median, and maximum precipitation depths across these storm events were 0.19, 0.43, and 0.82 inch, respectively. The criterion for minimum antecedent dry period (6 hours) and storm duration criterion (1 hour) were also met for all 17 storm events. Antecedent dry periods during the sampled storm events ranged from 9 to 268 hours, with a median value of 41 hours. Storm durations ranged 2.0 to 24.8 hours, with a median value of 12.8 hours (Table 2).

The criterion for minimum average storm intensity (0.03 inch per hour) was met for 90 percent of the sampled storm events (Table 2). The TAPE guidelines recommend this threshold be met for at least half of the sampled storms; consequently, this criterion was also met.

Table 2. Comparison of Precipitation Data from Sampled Storm Events at the TreePod™ Test System to Storm Event Guidelines in the TAPE.				
Storm Start Date and Time	**Storm Precipitation Depth (inches)**	**Storm Antecedent Dry Period (hours)**	**Storm Precipitation Duration (hours)**	**Average Storm Intensity (inches/hour)[b]**
3/3/2017 7:20[a]	0.32	12	10.3	0.03
3/7/2017 2:50	0.43	48	13.7	0.03
3/29/2017 0:15[a]	0.53	51	10.0	0.05
4/4/2017 21:25[a]	0.62	67	24.8	0.03
4/6/2017 5:25	0.19	10	4.8	0.04
4/10/2017 1:25	0.24	51	2.0	0.12
4/12/2017 20:00	0.26	9	6.3	0.04
4/19/2017 8:45	0.43	14	15.4	0.03
4/26/2017 13:25	0.22	69	12.7	0.02
5/2/2017 19:15	0.47	32	12.8	0.04
5/4/2017 16:15	0.6	36	16.9	0.04
5/11/2017 3:30	0.25	122	15.5	0.02
5/15/2017 14:00	0.73	41	20.8	0.04
4/4/2018 2:25	0.33	54	13.0	0.03
4/7/2018 3:20	0.7	33	10.2	0.07
4/11/2018 11:35	0.82	26	15.2	0.05
4/28/2018 3:55	0.43	268	5.9	0.07
Criteria	≥0.15	≤6	≥1	Range[b]
Minimum	0.19	9	2.0	0.02
Median	0.43	41	12.8	0.04
Maximum	0.82	268	24.8	0.12

Values in **bold** do not meet storm event guidelines recommended in the TAPE (Ecology 2011).

[a] All sampled events were flow-weighted composite sampled except these events, which consisted of discrete grab samples collected above a high flow rate threshold.

[b] Majority of events exceeded the 0.03 inch per hour rainfall intensity criteria.

Sample Collection Guidelines

As described in the TER (Herrera 2018), automated samplers were programmed with the goal of meeting the following criteria for acceptable composite samples that are identified in the TAPE guidelines:

- A minimum of 10 aliquots were collected for each event.
- Sampling was targeted to capture at least 75 percent of the hydrograph.
- Due to sample holding time considerations, the maximum duration of automated sample collection at all stations was 36 hours.

The criterion for minimum number of sample aliquots (10) was met for all of the flow-weighted composite sample events (see Table 3). It should be noted that 3 of the 17 sampled events were peak flow sample events, not flow weighted composite sample events. The TAPE guidelines indicate that samples must represent a wide range of treated flows including the system's design flow rate; to obtain representative samples at this threshold, discrete peak flow sampling is required.

The criterion for minimum portion of storm volume covered by sampling (75 percent) was met for all events except the three peak flow sample events (see Table 3). Finally, the sampling duration did not exceed 36 hours for any of the 17 events.

Table 3. Comparison of Sampling Data from Storm Events at the TreePod™ Test System to Sample Event Guidelines in the TAPE.

Storm Start Date and Time	Sample Aliquots (#)		Storm Coverage (percent)		Sampling Duration (hour)	
	OC-IN	OC-OUT	OC-IN	OC-OUT	OC-IN	OC-OUT
3/3/2017 7:20[a]	40	63	**23.3**	**20.2**	0.4	0.4
3/7/2017 2:50	23	19	95.6	94.6	9.2	9.7
3/29/2017 0:15[a]	20	15	77.3	**73.0**	0.6	0.6
4/4/2017 21:25[a]	**3**	**3**	**13.6**	**13.6**	0.1	0.1
4/6/2017 5:25	10	10	85.6	90.1	4.0	4.4
4/10/2017 1:25	11	10	94.8	87.7	2.7	2.5
4/12/2017 20:00	100	100	85.6	85.5	7.3	7.3
4/19/2017 8:45	100	100	80.6	80.9	13.6	13.1
4/26/2017 13:25	28	27	90.9	86.9	16.3	16.0
5/2/2017 19:15	24	23	89.0	85.7	13.0	12.7
5/4/2017 16:15	47	46	77.8	75.8	13.0	12.1
5/11/2017 3:30	43	42	85.8	84.6	18.2	18.0
5/15/2017 14:00	99	98	97.8	97.2	22.8	22.2
4/4/2018 2:25	42	40	85.8	84.4	2.3	3.4
4/7/2018 3:20	24	23	96.6	94.4	10.7	10.6
4/11/2018 11:35	100	100	92.9	92.5	14.5	7.6
4/28/2018 3:55	65	63	86.2	86.1	10.8	10.7
Criteria	≥10		≥75		≤36	
Minimum	3	3	13.6	13.6	0.1	0.1
Median	28	27	85.6	85.5	9.2	9.7
Maximum	100	100	97.8	97.2	22.8	22.2

Values in **bold** do not meet storm event guidelines recommended in the TAPE (Ecology 2011)

NA = not applicable

[a] All sampled events were flow-weighted composite sampled except these events, which consisted of samples collected above a high flow rate threshold. These events are not required to meet sampling guidelines.

PERFORMANCE EVALUATION

This section evaluates water quality data from the initial and supplemental monitoring relative to treatment goals identified in the TAPE guidelines. Included are data from sampling that occurred during 17 sampling events. Note that one of these events was a peak flow sample event that occurred on April 4, 2017, when the influent flow rate was approximately 42 gpm or 125 percent of the design flow rate. Per the TAPE guidelines, the data from this event were excluded in all analyses herein because there is no expectation the system will be able to meet the associated performance goals at flows this high. The one exception was that this data point was included in the percent reduction versus sampled flow rate analysis because it provided a useful point above the design flow rate for the required regression model (see description below). Consequently, the n-value of the final data set was 16 for all analyses except the percent reduction versus sampled flow rate where it was 17.

BASIC TREATMENT

The basic treatment goal identified in the TAPE guidelines indicates the bootstrapped 95 percent lower confidence interval (LCL95) for the mean total suspended solids (TSS) removal must be greater than or equal to 80 percent for influent concentrations ranging from 100 to 200 milligrams per liter (mg/L). For influent TSS concentrations less than or equal to 100 mg/L but greater than 20 mg/L, the upper 95 percent confidence interval (UCL95) for the mean effluent concentration must be less than or equal to 20 mg/L. There is no specified criterion for influent TSS concentrations less than 20 mg/L; consequently, those sample pairs (influent and effluent) are generally not used for assessment of TSS removal performance. For influent concentrations that exceed 200 mg/L, the treatment goal is an LCL95 of greater than an 80 percent reduction using an influent concentration capped at 200 mg/L in the associated calculation of this value. Finally, pollutant removals that meet the TAPE goals must be shown for sample pairs across a range of treated flow rates up to and including the design flow rate. This section describes the sampling results in relation to these criteria based on data collected from the TreePod™ test system.

Out of the 16 paired influent and effluent samples collected during storm events from the TreePod™ test system (Table 4), 10 influent samples had concentrations between 20 and 100 mg/L, and one influent sample had a concentration below 20 mg/L. Normally, these 11 samples would be excluded from a percent removal analysis for TSS because systems are not expected to achieve the 80 percent removal goal when influent concentrations are below 100 mg/L. Despite this consideration, these samples were included in this analysis to increase the n-value; the resultant LCL95 for the mean TSS removal was 84 percent, which still achieves this goal (Table 4).

An alternate analysis of performance involves a comparison of effluent TSS concentrations to the goal of less than 20 mg/L when influent concentrations are between 20 and 100 mg/L. Again, the n-value for this assessment would not be high enough without including the 5 influent samples with concentrations greater than 100 mg/L; hence, data from all 16 events were used in this analysis even though there is no expectation that the effluent TSS concentration goal can be achieved for the samples with the higher influent concentrations. The resultant UCL95 for the mean effluent concentration was 8.2 mg/L, well below the 20 mg/L goal. It should be noted that the first sampled storm event during the supplemental monitoring period had an influent TSS concentration of 666 mg/L; per Ecology guidance, this value was capped at 200 mg/L in subsequent percent reduction calculations. We believe the influent TSS concentration for this event was abnormally high because the upstream valve had been closed for 10 months prior to testing and sediment was flushing from the upstream drainage.

To evaluate how TSS treatment efficiency may vary as a function of influent flow rate, analyses were performed to determine the flow rate at the point when each aliquot for a flow-weighted composite sample was collected. These values were then averaged to determine the "sampled treated flow rate" for an entire event. As described above, peak flow sampling was also performed during three events (March 3, March 29, and April 4, 2017) to obtain results that reflect TSS treatment efficiency at or above the design flow rate. Figure 1 displays percent removal versus the treated flow rate for all 17 qualifying events. For reference, the open blue squares on the figure are sample pairs collected with Media 2, the open blue circles represent sample pairs collected with Media 3 prior to the GULD, and the solid blue circles represent the four supplemental Media 3 sample pairs. The TER (Herrera 2018) that was produced at the end of the initial monitoring period provides a more detailed description of the differences between Medias 2 and 3 and the justification for including both in the analysis.

The TAPE guidelines indicate a regression analysis should be conducted to evaluate whether treatment efficiency for TSS varies as a function of treated flow rate. The results of the regression analysis indicated there is no significant relationship between treatment efficiency and treated flow rate ($p = 0.280$). As is apparent from Figure 1, the system removed greater than 80 percent of the influent TSS at and above the design flow rate of 33.2 gpm.

Taken together, the above analyses indicate that the basic treatment criterion from the TAPE guidelines were met based on the data collected at the TreePod™ test system during the initial and supplemental monitoring periods.

Table 4. Water Quality Results and Comparison to TAPE Criteria.

Media	Media No.	Date	Total Suspended Solids (mg/L)			Total Phosphorus (mg/L)			Dissolved Copper (µg/L)			Dissolved Zinc (µg/L)			Sampled Flow (gpm)	Peak Treated Flow Rate (gpm)
			IN	OUT	Percent Reduction	IN	OUT	Percent Reduction	IN	OUT	Percent Reduction	IN	OUT	Percent Reduction		
Maintenance 3/2/2017 – New Media and Mulch																
sand/AA	Media 2	3/3/2017	89	20	78%	0.108	0.040	63%	15.5	6.1	61%	42.0	4.0	90%	27.6	28.3
sand/AA	Media 2	3/7/2017	35	6	83%	0.078	0.050	36%	12.8	6.7	48%	37.5	6.7	82%	9.8	12.1
Maintenance 3/28/2017 – New Media and Mulch																
coarse sand/AA	Media 3	3/29/2017	36	6	83%	0.086	0.038	56%	9.2	3.6	61%	26.1	5.5	79%	33.4	36.1
coarse sand/AA	**Media 3**	**4/4/2017**	**40**	**7**	**83%**	**0.104**	**0.060**	**42%**	**15.1**	**11.4**	**25%**	**37.6**	**14.2**	**62%**	**43.0**	**52.7**
coarse sand/AA	Media 3	4/6/2017	23	4	83%	0.076	0.028	63%	13.6	7.6	44%	32.4	8.5	74%	8.0	10.2
coarse sand/AA	Media 3	4/10/2017	17	4	76%	0.068	0.018	74%	9.0	4.0	56%	27.4	4.6	83%	8.3	9.8
coarse sand/AA	Media 3	4/12/2017	27	9	67%	0.064	0.028	56%	14.1	9.0	36%	30.5	7.8	74%	18.0	23.1
coarse sand/AA	Media 3	4/19/2017	53	2	96%	0.122	0.030	75%	11.5	7.0	39%	27.1	5.5	80%	14.2	21.1
coarse sand/AA	Media 3	4/26/2017	111	2	98%	0.184	0.028	85%	13.2	6.9	48%	33.8	6.3	81%	6.7	20.1
coarse sand/AA	Media 3	5/2/2017	41	2	95%	0.146	0.030	79%	21.1	9.0	55%[a]	35.8	5.9	84%	2.7	3.7
coarse sand/AA	Media 3	5/4/2017	130	4	97%	0.184	0.052	72%	16.3	10.6	35%	29.8	9.9	67%	17.5	28.4
Maintenance 5/10/2017 – Mulch Change																
coarse sand/AA	Media 3	5/11/2017	136	3	98%	0.354	0.05	86%	14.4	12.8	11%	36.6	9.7	74%	3.9	10.2
coarse sand/AA	Media 3	5/15/2017	34	4	88%	0.082	0.016	80%	13.8	9.4	32%	31.0	12.7	59%	17.3	23.3
Maintenance 3/21/2018 – Mulch Change																
coarse sand/AA	Media 3	4/4/2018	666	19.0	91%	1.56	0.06	88%[b]	11.0	6.8	38%	28.4	10.6	63%	32.7	35.8
coarse sand/AA	Media 3	4/7/2018	85.5	0.5	99%	0.13	0.022	83%	12.0	8.32	31%	33.0	9.28	72%	11.2	20.7
coarse sand/AA	Media 3	4/11/2018	114	6.0	95%	0.78	0.036	93%[c]	9.17	6.64	28%	27.6	9.2	67%	24.5	30.5
coarse sand/AA	Media 3	4/28/2018	30	4.4	85%	0.126	0.046	63%	18.8	13.0	31%	43.3	15.2	65%	10.2	11.2
Mean			98.1	6.1	88%	0.250	0.037	70%	13.1	8.2	40%	32.9	8.6	74%	17	22.2
LCL95 of the mean percent reduction					84%			64%			35%			71%		
UCL95 of the mean effluent concentration				8.2												

Note: design flow rate = 33.2 gpm or 153 in/hr. **Bold** values are at 125 percent of the design flow rate and results are not used in performance calculations.

[a] 5/2/17 event had influent dissolved Cu value of 21.1 µg/L. This value was reduced to 20 mg/L for percent reduction calculations per TAPE.

[b] 4/4/18 event had influent total phosphorus value of 1.56 mg/L. This value was reduced to 0.5 mg/L for percent reduction calculations per TAPE.

[c] 4/11/18 event had influent total phosphorus value of 0.78 mg/L. This value was reduced to 0.5 mg/L for percent reduction calculations per TAPE.

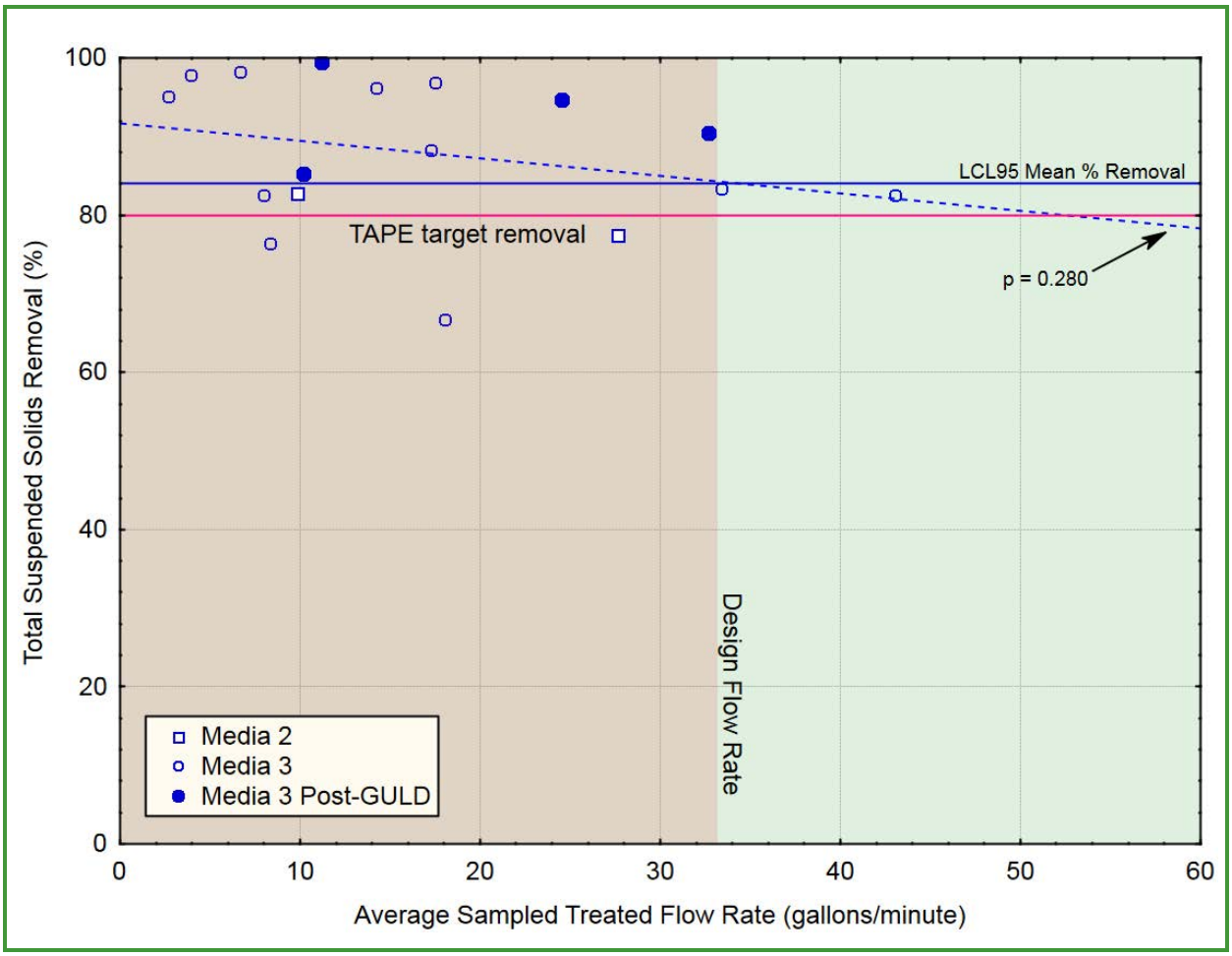

Figure 1. Total Suspended Solids Removal (percent) as a Function of Average Sampled Treated Flow Rate.

PHOSPHORUS TREATMENT

The phosphorus treatment goal identified in the TAPE guidelines indicates that the LCL95 of the mean removal must be greater than or equal to 50 percent for influent total phosphorus (TP) concentrations ranging from 0.1 to 0.5 mg/L. In addition, pollutant removals that meet the TAPE goals must be shown for sample pairs across a range of treated flow rates up to and including the design flow rate. This section describes the sampling results in relation to this criterion based on data collected from the TreePod™ test site.

Of the 16 paired influent and effluent samples collected during storm events from the TreePod™ test system (Table 4), 6 influent samples had TP concentrations below the minimum threshold of 0.1 mg/L specified in the TAPE guidelines for assessing performance. Normally, these six samples would be excluded from a percent removal analysis for TP because systems are not expected to achieve the 50 percent removal goal when influent concentrations are below this threshold. Despite this consideration, these samples were included in this analysis to increase

the n-value. In addition, two influent samples from the supplemental monitoring period had concentrations greater than 0.5 mg/L (Table 4). Before any percent reduction analyses were performed, these influent concentrations were capped at 0.5 mg/L per Ecology's guidance. The LCL95 for the mean percent reduction from the 16 sample pairs was 64 percent (Table 4), which is above the goal of ≥50 percent. Consequently, these samples also show the phosphorus treatment criteria from the TAPE guidelines was met.

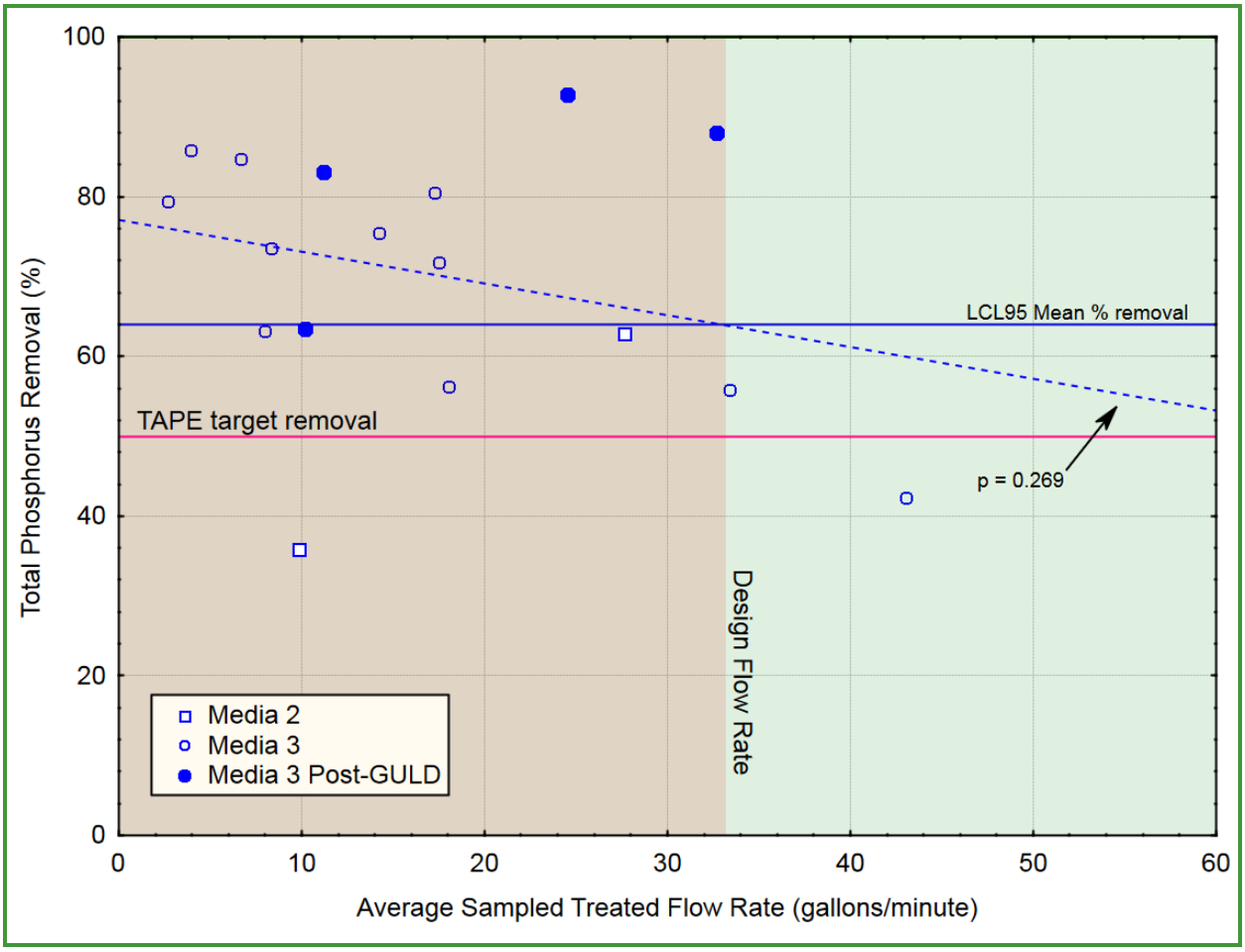

Figure 2. Total Phosphorus Removal (percent) as a Function of Average Sampled Treated Flow Rate.

To evaluate how TP treatment efficiency may vary as a function of influent flow rate, analyses were performed to determine the treated flow rate for each event as described above in the results section for TSS. Figure 2 displays percent removal versus treated flow rate for all 16 sample pairs described above, plus samples from the April 4, 2017, event when influent flows approached 125 percent of the design flow rate. As is apparent, the regression line is not significant ($p = 0.269$) and the system is able to remove greater than 50 percent total phosphorus at and above the design flow rate of 33.2 gpm.

Taken together, the above analyses indicate that the phosphorus treatment criterion from the TAPE guidelines were met based on the data collected at the TreePod™ test system during the initial and supplemental monitoring periods.

ENHANCED TREATMENT

The TAPE enhanced treatment criteria indicate that the LCL95 of the mean dissolved zinc removal must be greater than 60 percent for influent concentrations ranging from 20 to 300 µg/L. The LCL95 of the mean dissolved copper removal must be greater than 30 percent for influent concentrations ranging from 5 to 20 µg/L. Finally, pollutant removals that meet the TAPE goals must be shown for sample pairs across a range of treated flow rates up to and including the design flow rate. Separate subsections below describe the sampling results in relation to these criteria based on data from 16 events where influent concentrations were within the specified ranges for dissolved zinc and copper, respectively.

Dissolved Zinc Treatment

Of the 16 paired influent and effluent samples collected during storm events from the TreePod™ test system (Table 4), all the influent samples had dissolved zinc concentrations that met the TAPE guidelines for assessing performance. The calculated LCL95 for the mean percent removal from these samples was 71 percent (Table 4), which is above the goal of greater than 60 percent; consequently, these samples indicate the dissolved zinc removal criteria from the TAPE guidelines was met.

To evaluate how dissolved zinc treatment efficiency may vary as a function of influent flow rate, analyses were performed to determine the treated flow rate for each event as described above in the results section for TSS. Figure 3 displays percent removal versus treated flow rate for all 16 sample pairs described above, plus samples from the April 4, 2017, event when influent flows approached 125 percent of the design flow rate. As is apparent, only one data point fell below the 60 percent reduction threshold and the system generally removed greater than 60 percent of the influent dissolved zinc at and above the design flow rate of 33.2 gpm. The regression line was not significant ($p = 0.177$) so it was not used in the analysis.

Taken together, the above analyses indicate that the enhanced treatment criterion for dissolved zinc from the TAPE guidelines were met based on the data collected at the TreePod™ test system during the initial and supplemental monitoring periods.

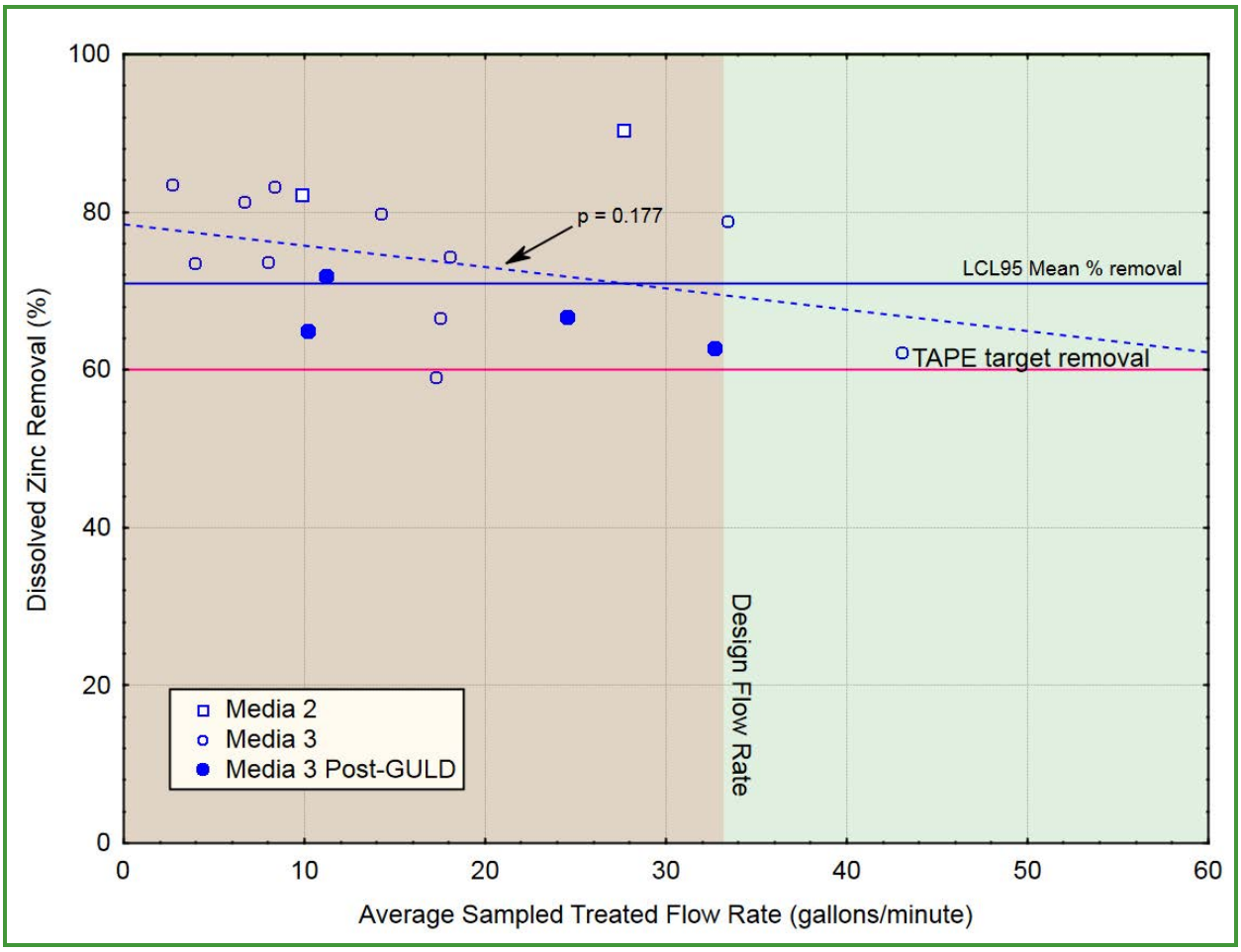

Figure 3. Dissolved Zinc Removal (percent) as a Function of Average Sampled Treated Flow Rate.

Dissolved Copper Treatment

Of the 16 paired influent and effluent samples collected during storm events from the TreePod™ test system (Table 4), 15 influent samples had dissolved copper concentrations that met the TAPE guidelines for assessing performance. The influent sample from the March 2, 2017, event had a concentration of 21.1 µg/L; per Ecology guidance, this value was capped at 20 µg/L in subsequent percent reduction calculations. The calculated LCL95 for the mean percent removal from these samples was 35 percent (Table 4), which is above the goal of greater than 30 percent; consequently, these samples indicate the dissolved copper removal criteria from the TAPE guidelines was met.

To evaluate how dissolved copper treatment efficiency may vary as a function of treated flow rate, analyses were performed to determine the treated flow rate for each event as described above in the results section for TSS. Figure 4 displays percent removal versus treated flow rate for all 16 sample pairs described above, plus samples from the April 4, 2017, event when influent flows approached 125 percent of the design flow rate. As is apparent, only three data points fell

below the 30 percent reduction threshold and the system removed 30 percent of the influent dissolved copper up to the design flow rate of 33.2 gpm. The regression line was not significant ($p = 0.999$), so it was not used in the analysis.

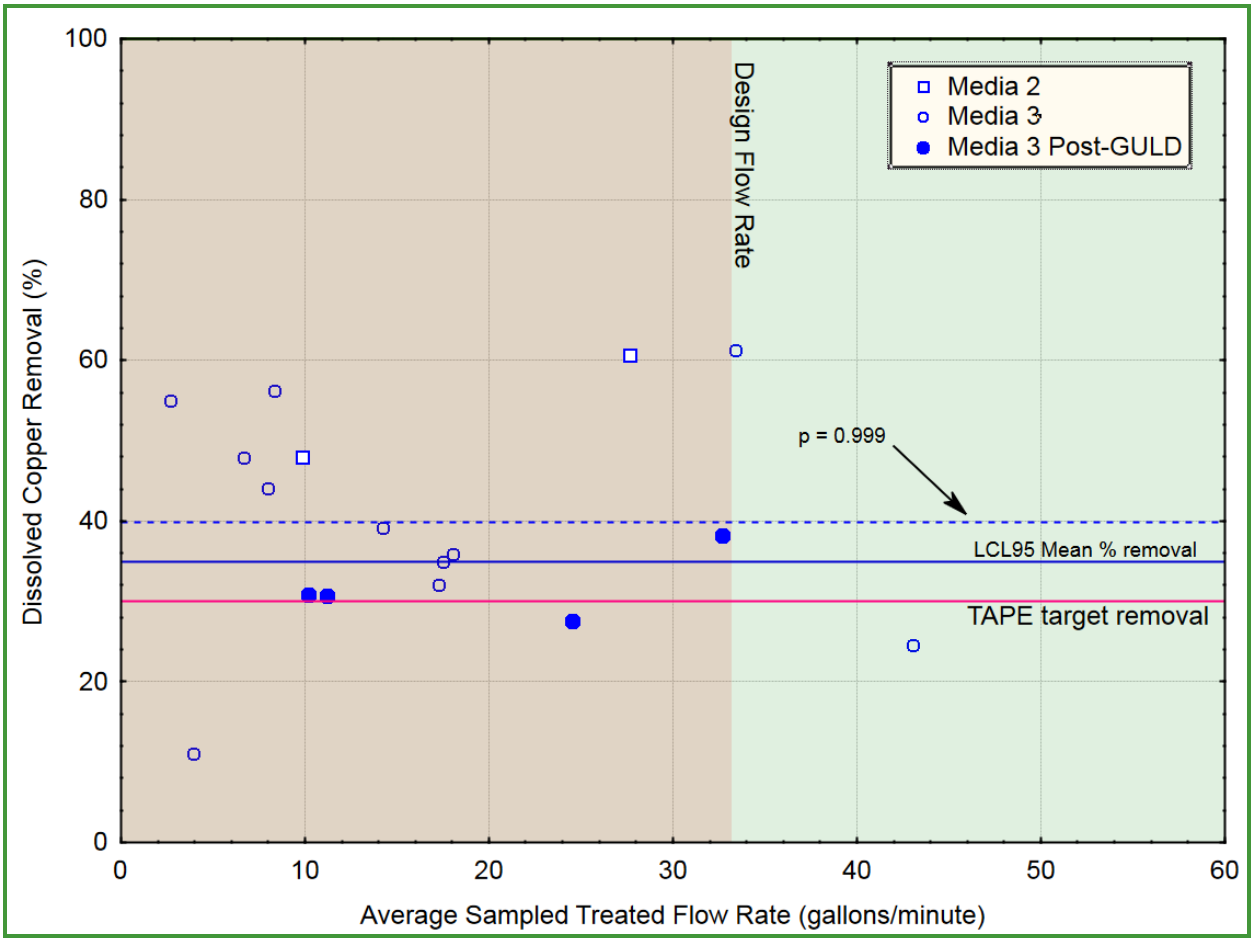

Figure 4. Dissolved Copper Removal (percent) as a Function of Average Sampled Treated Flow Rate.

Taken together, the above analyses indicate that the enhanced treatment criterion for dissolved copper from the TAPE guidelines were met based on the data collected at the TreePod™ test system during the initial and supplemental monitoring periods.

TEMPORAL PATTERNS

One of the objectives for conducting the supplemental monitoring was to provide additional data for assessing whether the performance of the TreePod™ test system was degrading with time due to media break-through (i.e., exhaustion of ion exchange sites). This concern was raised by the Board of External Reviewers (BER) in comments provided on the TER (Herrera 2018) that was prepared following the initial monitoring period. Figure 5 shows dissolved copper, dissolved zinc, and total phosphorus percent removal data as a function of time. Trend

lines are provided on the figure for reference. Flow rate and influent concentrations have a strong influence on percent removal, so these factors must be considered in this analysis. If media exhaustion is occurring, the associated trend may be masked by variability in the percent reduction data induced by influent concentrations and flow rates.

Total phosphorus percent removal appeared to increase slightly with time; however, this trend was not significant ($p = 0.055$). The increase may have related to elevated influent concentrations after the system was put back online in March of 2018 (Table 4).

Dissolved zinc removal did exhibit a ($p = 0.037$) negative trend driven by very high percent reductions with the first few samples collected. However, none of the samples collected during the supplemental monitoring period exhibited percent reductions below the 60 percent threshold; hence, the system is still exhibiting performance that meets the goals identified in the TAPE guidelines at the conclusion of the supplemental monitoring period.

Dissolved copper removal also decreased slightly with time; however, the trend was not significant ($p = 0.117$). Average dissolved copper removal during the supplemental monitoring period was 32 percent, which is above the 30 percent goal in the TAPE guidelines.

Overall, the system does not appear to be exhibiting a substantial decrease in performance with time. Although dissolved metals removal has decreased slightly, the system is still meeting the performance goals from the TAPE guidelines.

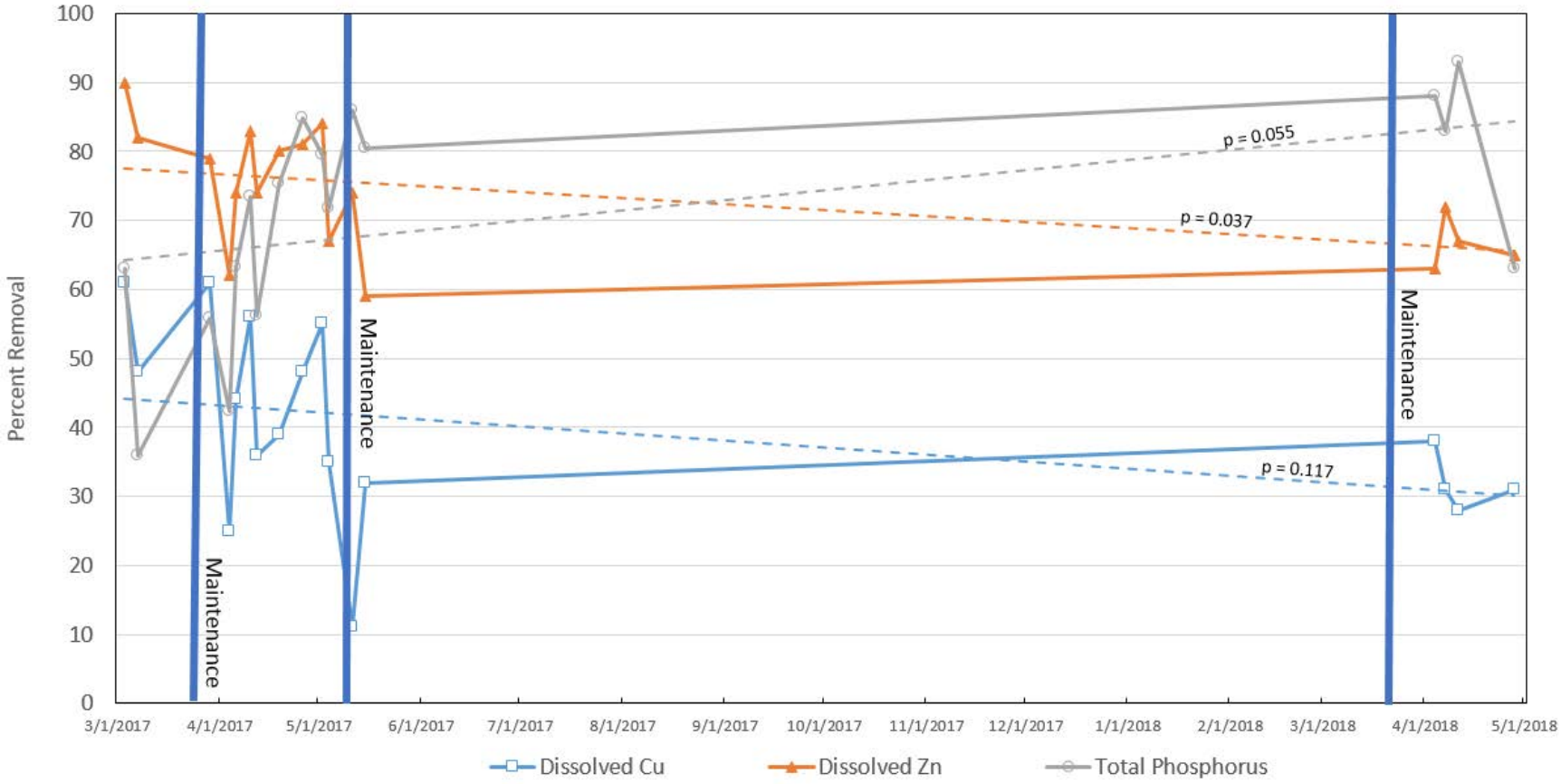

Figure 5. Percent Removal Versus Time for Dissolved Copper, Dissolved Zinc, and Total Phosphorus.

CONCLUSIONS

To obtain performance data to support the issuance of a GULD for the TreePod™, hydrologic and water quality monitoring was conducted at a test system located at the SCTF in Seattle, Washington from January 6, 2017, through May 15, 2017. During this initial monitoring period, 13 separate storm events were sampled. These data were submitted in a TER and the system was issued a GULD for basic treatment and a Provisional GULD for phosphorus and enhanced treatment. The GULD indicates that the "provisional" label would be reassessed after the proponent submits data from supplemental monitoring performed over an additional maintenance cycle. This supplemental monitoring involved the collection of samples during four additional storm events.

Based on the combined results from the initial and supplemental monitoring periods, the LCL95 for the mean percent removal of the TreePod™ test system was 84, 64, 35, and 71 percent for TSS, TP, dissolved copper, and dissolved zinc, respectively. These results indicate that the system is consistently meeting the performance goals identified in the TAPE guidelines. A temporal analysis of these data also indicates that the TreePod™ test system is not exhibiting a substantial decrease in performance with time and was still meeting the performance goals from the TAPE guidelines at the end of the monitoring period. Based on these considerations, we request that Ecology consider the contents of this report and remove the "provisional" designation from the phosphorus and enhanced TreePod™ GULD.

REFERENCES

Ecology. 2011. Technical Guidance for Evaluating Emerging Stormwater Treatment Technologies: Technology Assessment Protocol – Ecology (Tape). Publication No. 11-10-061, Washington State Department of Ecology, Olympia, Washington.

Herrera. 2018. Technical Evaluation Report, TreePod™ Biofilter System Performance Certification Project. Prepared for Oldcastle, Inc., Stockton, California, by Herrera Environmental Consultants, Inc., Seattle, Washington. February 7.