Deliverable 4.2: Progress Report 2

Overview of Work Period: 3/6/20 – 6/13/20

		Water Quality		Toxicology		Stormwater	
Water Year	**Event**	**Basic**	**Full**	**Zfish**	**Coho**	**Collection Date**	**Treatment Dates**
2	11	x				3/6/20	3/6/20-3/7/20
	12	x				3/13/20	3/14/20-3/15/20
	13		x	x		3/30/20	3/31/20 – 4/1/20
3	14	x				4/22/20	4/23/20-4/24/20
	15	x				5/2/20	5/2/20-5/3/20
	16	x				5/22/20	5/22/20-5/23/20
	17	x				5/26/20	5/27/20-5/28/20
	18	x				6/1/20	6/1/20-6/2/20
	19		x	x		6/6/20	6/7/20-6/8/20
4	20	x				6/13/20	6/13/20-6/14/20

Report Summary

Discussions/decisions since last report period

- The number of bioretention treatment depths was reduced from five to three prior to the WY3 water quality-sampling event (Event 19), per the project QAPP (Deliverable 1). The intermediate depths 15” and 9” were discontinued. The three BSM depths continuing in the study are: 18”, 12”, and 6”.
- We are finding that the zebrafish morphological assay is not sensitive to influent stormwater from this roadway site. For the two tested events (Event 13 and 19), influent stormwater did not cause detectable toxicity compared with clean water controls. As such, this assay is not useful for assessing treatment performance of the various BSM depths. We know from past research that stormwater that does not cause morphological changes in developing zebrafish can still be acutely lethal to coho salmon, so we have proposed two amendments to the project. 1) Increasing the frequency of acute toxicity testing using coho salmon from 3 to 5 events and 2) replacing the zebrafish morphological assay with a molecular assay. The molecular assay will quantify exposure to metals and aromatic hydrocarbons via upregulation of the genes *mt2* and *cyp1a*, respectively.

Summary of Events

Deliverable 4.1 (Progress Report 1; summary of Events 1-10) was missing some water quality results for Event 6 (metals, nutrients, and conventional water quality) because the results had not yet been received. Deliverable 4.2 includes these results, as well as results from Events 11-20.

Summary of Full Water Chemistry

Event 6 (Post-WY1)

- Dissolved zinc was the most concentrated of the measured dissolved metals in effluent stormwater. This differs from Event 1, in which copper was detected at the highest concentrations in effluent waters.
- All BSM depths showed a net export of dissolved copper, as opposed to net removal during Event 1.
- For several water quality parameters, significantly higher concentrations were observed in effluent from the deeper compared with the shallower BSM. These were of total arsenic, dissolved copper and arsenic, orthophosphate and DOC. Differences among depths for these parameters were not observed during Event 1.
- Mean concentrations of total copper and zinc generally decreased with increasing BSM depth. The is contrary to Event 1, during which significantly higher concentrations of these two metals (as well as total nickel) were observed in effluent from the deeper compared to the shallower BSM, likely as a result of leaching of these metals from the BSM.
- Analysis of the clean water influent and effluent from the 18” clean water control showed that bioretention media continued to be a source of total As, Cu, Ni, and Zn and dissolved As, Cu, and Ni to effluent water.

Event 13 (Post-WY2)

- Removal of arsenic occurred for the first time at the shallower BSM treatments, but there was still net export from the deeper BSM treatments
- Removal of nickel occurred for nearly all replicates of all treatment depths. Prior to WY2, removal of nickel was only observed for a few replicates from a few depths.
- There was a net export of dissolved nickel from the 9”, 12”, and 15” depths and for dissolved arsenic from the 15” and 18” depths. Previously, net export of these metals was observed for all depths.
- Removal of DOC occurred for the first time at the shallower BSM treatments, but there was still some net export from the two deepest BSM treatments.
- Influent stormwater concentrations of TPAHs, total metals, and nitrates were less for Event 13 than the previous measured Events. This is likely a reflection of reduced traffic during the ‘Stay-at-Home’ order issued in Washington State in response to the COVID-19 pandemic.

Event 19 (Post-WY3)

- Total and dissolved copper concentrations were significantly higher in effluent from the shallower than the deeper BSM treatments.
- Event 19 was the first water-sampling event for which there was no net export of arsenic. Nickel also showed complete removal from all treatment depths, with the exception one replicate of the 12” depth.

- A net reduction of nitrates was observed for all treatment depths. Previously, nitrates were exported from all depths.
- Removal of DOC occurred for the deepest BSM treatment for the first time, but there was some net export for the shallower BSM treatments.

Summary of Toxicology

Event 13 (Post WY2)

- Zebrafish (*Danio rerio*) embryos exposed to effluent from the 18" clean water control treatment were slightly larger than the embryos exposed to influent control water. Pericardial area was also slightly larger. Neither influent nor effluent stormwater impacted embryo morphometrics compared with influent controls.

Event 19 (Post WY3)

- Zebrafish (*Danio rerio*) embryos exposed to influent stormwater and effluent stormwater from the 18" and 12" treatments were significantly larger than embryos exposed to influent control water. Additionally, the eye area of embryos exposed to stormwater effluent from the 18" treatment was significantly greater than that of embryos exposed to influent control water.

Summary of Saturated Hydraulic Conductivity

- K_{sat} values for the 6" treatment group were significantly greater than for the 18" treatment group. Previously there were no significant differences among the depths.

Detailed Report of Full Water Chemistry Events

Full water chemistry analyses are reported for Events 6 (End of WY1), 13 (End of WY2), and 19 (End of WY3). Samples for water chemistry were collected and analyzed as previously reported (Deliverable 4.1: Progress Report 1). Note: PAH results for Event 6 were previously reported in Deliverable 4.1.

Differences among the treatment depths for concentrations of each measured parameter in effluent were assessed by a Kruskal-Wallis test, followed by a post-hoc Dunn's test.

Event 6 (End of WY1)

Metals

Total metals in the influent stormwater were concentrated in the order of Zn>Cu>Pb>Ni>As (Table 1). Cadmium was not detected in influent stormwater. Concentrations measured in effluent from the clean water control columns (18" CWC) indicated that the bioretention media continued to be a source of As, Cu, Ni, and Zn. Statistically significant differences existed for concentrations of total arsenic ($\chi^2(4) = 11.84$, p=0.0186), with significantly higher concentrations in effluent from the 18" depths compared to the 6" depths (p = 0.0159). Although mean concentrations of total copper and zinc generally decreased with increasing BSM depth, differences between the depths were not statistically significant (Table 1).

Dissolved metals in the influent stormwater were concentrated in the order of Zn>Cu=As. Dissolved cadmium, lead, and nickel were not detected in influent stormwater. In effluent, dissolved metals were detected at concentrations of Cu>Zn>As>Ni. Dissolved lead and cadmium were not detected in effluent stormwater. Concentrations measured in effluent from the clean water control columns (18" CWC) indicated that the bioretention media continued to be a source of dissolved As, Cu, and Ni. Statistically significant differences among treatment depths existed for concentrations of dissolved copper ($\chi^2(4)$ = 10.56, p = 0.0320) and dissolved arsenic ($\chi^2(4)$ = 11.05, p = 0.026), with significantly higher concentrations of dissolved copper (p = 0.046) and arsenic (p = 0.0172) in effluent from the 18" depth compared with the 6" depth.

Table 1. Mean (standard error) of total metals in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC). One-half of the value of the detection limit (DL) was substituted for the value of non-detects in calculating means unless all replicates were below the detection limit (BDL). Statistical results are reported for SW effluent from the five treatment depths, where treatments sharing a superscript (a, b, c) are not significantly different at ? = 0.05 (Kruskal-Wallis with post-hoc Dunn Test).

Metal	DL	Influent Water (µg/L)		Effluent Water (µg/L)					
		Clean	SW	6"	9"	12"	15"	18"	18" CWC
Total	0.05	BDL	0.80	2.1	2.5	2.9	3.0	3.8 (0.1)^b	1.2

Arsenic				(0.2)^{a}	(0.2)^{ab}	(0.1)^{ab}	(0.2)^{ab}		(0.1)
Total Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Copper	0.2	0.10	17.7	11 (3)	9 (2)	7.1 (0.2)	7.23 (0.03)	7.8 (0.3)	1.37 (0.07)
Total Lead	0.079	BDL	3.80	0.8 (0.5)	0.4 (0.4)	BDL	0.2 (0.2)	0.4 (0.2)	BDL
Total Nickel	0.2	BDL	1.6	1.9 (0.5)	3 (2)	2.7 (0.9)	2.00 (0.06)	2.2 (0.1)	0.80 (0.06)
Total Zinc	0.19	BDL	88.1	15 (7)	15 (4)	8.73 (0.03)	8.9 (0.8)	8.7 (0.3)	0.9 (0.8)
Dissolved Arsenic	0.05	BDL	0.5	1.8 (0.2)^{a}	2.13 (0.09)^{ab}	2.2 (0.2)^{ab}	2.5 (0.2)^{ab}	3.5 (0.3)^{b}	1.03 (0.03)
Dissolved Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved Copper	0.05	BDL	0.50	5.9 (0.4)^{a}	5.7 (0.1)^{ab}	6.9 (0.2)^{ab}	7.1 (0.3)^{ab}	7.6 (0.2)^{b}	1.13 (0.09)
Dissolved Lead	0.079	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved Nickel	0.2	BDL	BDL	1.1 (0.3)	2 (1)	2.4 (0.9)	1.6 (0.1)	2.0 (0.1)	0.60 (0.06)
Dissolved Zinc	0.19	BDL	10.3	3.1 (0.8)	2.43 (0.09)	2.7 (0.1)	4 (1)	3.53 (0.09)	BDL

BDL = Below Detection Limit (DL)

Nutrient & Conventional Water Chemistry

A net export of nitrates and orthophosphate from the bioretention columns was observed for all treatment depths (Table 2). Several of the measured parameters had significantly higher concentrations in effluent from the deeper compared to the shallower BSM depths, including orthophosphate, DOC, alkalinity, and dissolved calcium, magnesium, and sodium. Concentrations of other parameters were significantly decreased in effluent from the deeper BSM depths, including alkalinity and dissolved calcium.

Table 2. Mean (standard error) of nutrients and conventional parameters in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC) for Event 6. Statistical results are reported for SW effluent from the five treatment depths, where treatments sharing a superscript (a, b, c) are not significantly different at $\alpha = 0.05$ (Kruskal-Wallis with post-hoc Dunn Test).

Measurement	Detection Limit	Influent Water		Effluent Water					
		Lab	**SW**	**6”**	**9”**	**12”**	**15”**	**18”**	**18” CWC**
Nitrates (mg/L)	0.003	0.15	0.13	0.30 (0.06)	0.25 (0.09)	0.5 (0.1)	0.5 (0.2)	0.84 (0.02)	0.22 (0.07)
Orthophosphate (mg/L)+	0.01	BDL	BDL	0.67 (0.01)^{a}	0.97 (0.09)^{ab}	1.42 (0.03)^{ab}	1.42 (0.03)^{ab}	1.94 (0.05)^{b}	0.67 (0.01)
DOC (mg/L)	0.08	0.5	0.5	5.0	5.4	7.2	7.2	8.5	3.10

				(0.4)[a]	(0.1)[a]	(0.4)[ab]	(0.2)[ab]	(0.4)[b]	(0.05)
Alkalinity (as $CaCO_3$)	0.3	48.3	40.3	51 (2)[a]	54 (1)[a]	60 (2)[ab]	60 (1)[ab]	64.7 (0.2)[b]	51 (2)
TSS (mg/L)	0.5	0.5	62.0	5.9 (0.5)	6.9 (0.9)	11 (0.00)	11 (1)	12 (1)	1.6 (0.2)
Fecal Coliform (CFU/100 mL)	n.a.	1.00	80.0	100***	80 (10)**	90 (20)**	230***	CG*	CG*
Dissolved Calcium (mg/L)	3.4	6.91	7.66	3.3 (0.1)[a]	3.5 (0.6)[a]	5.5 (0.5)[ab]	6.6 (0.3)[ab]	7.6 (0.2)[b]	19.0 (0.5)
Dissolved Magnesium (mg/L)	1.9	19.4	0.18	0.35 (0.02)[a]	0.39 (0.05)[a]	0.63 (0.05)[ab]	0.78 (0.04)[ab]	0.917 (0.004)[b]	15.7 (0.2)
Dissolved Sodium (mg/L)	27	196	6.45	120 (1)[a]	126 (9)[a]	166 (10)[ab]	189.7 (0.7)[ab]	213 (6)[b]	193.3 (0.9)

BDL = Below Detection Limit
NTU = Nephelometric Turbidity Units
*CG = Confluent Growth (reported for all replicates of a treatment)
**Confluent growth reported for one of the three replicates
***Confluent growth reported for two of the three replicates
+Orthophosphate analyzed by Spectra Laboratories – Kitsap.

Event 13 (Event of WY2)

Metals

Total metals in the influent stormwater were concentrated in the order of Zn>Cu>Pb>Ni>As (Table 3). Cadmium was not detected in influent stormwater. In effluent stormwater, total metals were detected at concentrations of Zn>Cu>Ni>As>Pb. Concentrations measured in effluent from the clean water control columns (18” CWC) indicate that the bioretention media continued to be a source of As, Cu, and Zn. Concentrations of total metal in effluent did not vary by treatment depth.

Of the measured dissolved metals, only dissolved copper and zinc were detected in the influent stormwater. In effluent, dissolved metals were detected at concentrations of Zn>Cu>Ni>As. Dissolved cadmium and lead were not detected in effluent. Concentrations of dissolved metal in effluent did not vary by treatment depth.

Table 3. Mean (standard error) of total metals in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC). One-half of the value of the detection limit (DL) was substituted for the value of non-detects in calculating means unless all replicates were below the detection limit (BDL).

Metal	DL	Influent Water (µg/L)		Effluent Water (µg/L)					
		Clean	SW	6”	9”	12”	15”	18”	18” CWC
Total Arsenic	0.05	BDL	0.40	0.3 (0.2)	BDL	BDL	0.43 (0.03)	0.47 (0.09)	0.6 (0.1)
Total Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Total Copper	0.2	0.7	15.5	3.53 (0.03)	3.37 (0.09)	3.5 (0.5)	3.4 (0.3)	3.3 (0.1)	2.6 (0.9)
Total Lead	0.079	BDL	1.9	BDL	BDL	BDL	BDL	BDL	BDL
Total Nickel	0.2	BDL	1.2	BDL	2 (2)	0.9 (0.8)	0.3 (0.2)	0.3 (0.2)	BDL
Total Zinc	0.19	1.3	58.2	4.90 (0.06)	4.1 (0.3)	3.8 (0.5)	4.2 (0.6)	3.8 (0.2)	4 (3)
Dissolved Arsenic	0.05	BDL	BDL	BDL	BDL	BDL	0.2 (0.1)	0.2 (0.1)	0.50 (0.06)
Dissolved Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved Copper	0.05	0.30	4.4	2.43 (0.03)	2.8 (0.1)	2.8 (0.2)	2.6 (0.5)	1.2 (0.4)	1.6 (0.1)
Dissolved Lead	0.079	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved Nickel	0.2	BDL	BDL	BDL	1 (1)	0.7 (0.6)	0.2 (0.1)	BDL	BDL
Dissolved Zinc	0.19	0.5	8.8	1.83 (0.03)	2.1 (0.2)	1.6 (0.6)	1.6 (0.6)	0.2 (0.1)	0.2 (0.1)

BDL = Below Detection Limit (DL)

Note: Treatments with different superscript group labels (a, b, c) are significantly different at = 0.05 (Kruskal-Wallis with post-hoc Dunn Test).

PAHs

Total PAHs (TPAH) in influent stormwater were less for Event 13 (TPAH = 0.315 µg/L) than for either Event 1 (TPAH=0.474) or Event 6 (TPAH=0.789) (Table 5). This may reflect reduced traffic during the 'Stay-at-Home' order issued by Washington State in response to the COVID-19 pandemic. Effluents contained low levels of PAHs (TPAH = 0.012-0.014 µg/L), with no differences among treatment depths ($\chi^2 = 5.816$, df = 4, p = 0.213) (Table 4). PAHs in stormwater runoff for Event 13 were predominately high molecular weight PAHs, dominated by pyrene. In bioretention-treated effluent waters, PAHs were predominantly low molecular weight PAHs, dominated by naphthalene. A complete table of concentrations of each PAH congeners are in Appendix A.

Table 4. Mean (standard error) of TPAHs in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC), and removal efficiencies for the five treatment depths. PAH congeners below the method detection limit were assigned a value of zero.

Treatment	TPAH (µg/L)
SW influent	0.315
6"	0.0133 (0.0007)
9"	0.0123 (0.0007)
12"	0.016 (0.001)
15"	0.014 (0.002)
18"	0.012 (0.002)
Clean water influent	0.005
18" CWC	0.01 (0.01)

Nutrient & Conventional Water Chemistry

A net export of nitrates and orthophosphate was observed for all treatment depths (Table 5). Several of the measured parameters had significantly higher concentrations in effluent from the deeper compared to the shallower BSM depths, including: nitrates, orthophosphate, DOC, and dissolved sodium. Concentrations of other parameters were significantly decreased in effluent from the deeper BSM depths, including alkalinity and dissolved calcium.

Table 5. Mean (standard error) of nutrients and conventional parameters in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC).

Measurement	Detection Limit	Influent Water		Effluent Water					
		Lab	**SW**	**6”**	**9”**	**12”**	**15”**	**18”**	**18” CWC**
Nitrates (mg/L)	0.003	0.08	0.07	0.2 (0.0)^{a}	0.26 (0.02)^{ab}	0.28 (0.02)^{ab}	0.32 (0.01)^{ab}	0.39 (0.04)^{b}	0.37 (0.01)
Orthophosphate (mg/L)	0.01	0.04	0.04	0.067 (0.003)^{a}	0.087 (0.007)^{ab}	0.120 (0.006)^{ab}	0.15 (0.01)^{ab}	0.21 (0.01)^{b}	0.213 (0.009)
DOC (mg/L)**	0.08	1.0	4.2	3.0 (0.3)^{ab}	2.8 (0.1)^{a}	3.3 (0.1)^{ab}	4.0 (0.3)^{ab}	4.53 (0.09)^{b}	2.9 (0.1)
Temperature (°F)		-	33.2	36.0 (0.3)^{a}	34.6 (0.3)^{ab}	33.5 (0.7)^{ab}	32.7 (0.4)^{b}	34.3 (0.4)^{ab}	35.5 (0.4)
pH	n.a.	7.55	7.67	7.49 (0.03)	7.37 (0.02)	7.26 (0.02)	7.24 (0.02)	7.26 (0.03)	7.288 (0.006)
Conductivity ($\mu S/cm$)		1486	111.7	108 (2)	105 (1)	102.4 (0.8)	102.2 (0.7)	105.3 (0.4)	1493 (2)
Turbidity (NTU)	n.a.	0.09	53.7	7.7 (0.5)	12.4 (0.9)	14.2 (0.3)	16 (1)	17 (1)	3.0 (0.3)
Alkalinity (as $CaCO_3$)	0.3	24.7	38.0	31.8 (0.6)^{a}	27 (3)^{ab}	21.5 (0.9)^{ab}	22.5 (0.4)^{ab}	20.3 (0.8)^{b}	25.1 (0.2)
TSS (mg/L)	0.5	0.5	47.0	1.2 (0.4)	1.7 (0.6)	1.47 (0.07)	1.9 (0.2)	1.5 (0.3)	0.63 (0.09)
Fecal Coliform (CFU/100 mL)	n.a.	1500	BDL	953 (490)	560 (304)	387 (59)	493 (203)	347 (109)	BDL
Dissolved Calcium (mg/L)	3.4	6.93	12.3	4.0 (0.2)^{a}	1.1 (0.7)^{ab}	0.21 (0.09)^{ab}	0.057 (0.006)^{ab}	0.039 (0.003)^{b}	20.8 (0.3)
Dissolved Magnesium (mg/L)	1.9	18.1	0.386	0.77 (0.05)	0.3 (0.2)	0.08 (0.02)	0.051 (0.004)	0.047 (0.004)	19.1 (0.1)
Dissolved Sodium (mg/L)	27	236	6.49	14.1 (0.5)^{a}	19 (2)^{ab}	20.7 (0.7)^{ab}	21.8 (0.1)^{ab}	21.9 (0.3)^{b}	228.0 (0.0)

Note: Treatments with different superscript group labels (a, b, c) show significance at ⍰ = 0.05 (Kruskal-Wallis with post-hoc Dunn Test).
BDL = Below Detection Limit

Event 19 (End of WY3)

Metals

Influent and effluent stormwater were most concentrated in total Zn>Cu>Pb=Ni>As (Table 6). Cadmium was not detected in either influent or effluent stormwater. Lead was not detected in effluent stormwater. Effluent from the clean water control columns (18” CWC) indicated that the bioretention media was still a source of copper. Differences existed for concentrations of total copper in effluent among depths ($\chi^2 = 6.01$, $p = 0.0496$), with significantly higher concentrations in effluent from the 6” depths compared to the 18” depths ($p = 0.0498$).

Dissolved metals in the influent stormwater were concentrated in the order of Zn>Cu>Ni>As. Dissolved metals in effluent water followed the same pattern. Dissolved cadmium and lead were not detected in influent or effluent stormwater. Effluent from the clean water control columns (18” CWC) indicated that the bioretention media was still a source of dissolved copper. Dissolved copper concentrations varied among the treatment depths ($\chi^2 = 6.01$, $p = 0.0496$), and were significantly greater in effluent from the 6” depths compared to the 18” depths ($p = 0.0498$).

Table 6. Mean (standard error) of total metals in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC). One-half of the value of the detection limit (DL) was substituted for the value of non-detects in calculating means unless all replicates were below the detection limit (BDL).

Metal	DL	Influent Water (µg/L)		Effluent Water (µg/L)			
		Clean	SW	6”	12”	18”	18” CWC
Arsenic	0.05	BDL	1.2	0.67 (0.03)	0.73 (0.07)	0.3 (0.2)	BDL
Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL
Copper	0.2	0.8	32.7	5.8 (0.2)[a]	4.0 (0.1)[ab]	3.77 (0.09)[b]	2.0 (0.0)
Lead	0.079	BDL	2.70	BDL	BDL	BDL	BDL
Nickel	0.2	BDL	2.9	BDL	0.8 (0.5)	BDL	BDL
Zinc	0.19	1.8	104.0	5.9 (0.2)	4.9 (0.1)	5.7 (0.2)	0.67 (0.09)
Dissolved Arsenic	0.05	BDL	0.7	0.2 (0.2)	0.2 (0.2)	BDL	BDL
Dissolved Cadmium	0.05	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved Copper	0.05	0.5	11.4	4.73 (0.03)[a]	3.4 (0.2)[ab]	3.2 (0.2)[b]	1.40 (0.06)
Dissolved Lead	0.079	BDL	BDL	BDL	BDL	BDL	BDL
Dissolved	0.2	BDL	0.8	BDL	0.5	BDL	BDL

Nickel					(0.4)		
Dissolved Zinc	0.19	1.3	19.5	4.1 (0.2)	4.4 (0.4)	4.0 (0.2)	0.57 (0.07)

BDL = Below Detection Limit (DL)

Note: Treatments with different superscript group labels (a, b, c) are significantly different at α = 0.05 (Kruskal-Wallis with post-hoc Dunn Test).

PAHs

TPAHs in stormwater influent were greater for Event 19 (TPAH = 0.498 µg/L) than the stormwater collection during 'Stay-at-Home' order (Event 13 TPAH = 0.315 µg/L). Stormwater effluent TPAH concentrations were 0.065 – 0.07 µg/L (Table 7). There were no statistically significant differences in effluent TPAHs between the three different depths ($\chi^2 = 0.20168$, df = 2, $p = 0.9041$). PAHs in stormwater runoff for Event 19 were predominantly high molecular weight, dominated by pyrene. PAHs in bioretention-treated effluent waters were predominantly low molecular weight, dominated by 1-methylnapthalene. A complete table of PAH concentrations by congener can be found in Appendix A (Table A1.2).

Table 7. Mean (standard error) of TPAHs in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC), and removal efficiencies for the five treatment depths. PAH congeners below the method detection limit (MDL) were assigned a value of zero.

Treatment	TPAH (µg/L)
SW influent	0.498
6”	0.070 (0.006)
12”	0.065 (0.006)
18”	0.067 (0.002)
Clean water influent	0.052
18” CWC	0.046 (0.001)

Nutrient & Conventional Water Chemistry

A net export of orthophosphate and a net reduction of nitrates were observed for all treatment depths (Table 8). Concentrations of these nutrients did not differ significantly between the three BSM depths. Mean concentrations of DOC generally decreased with increasing BSM depth, with a net reduction only for the deepest BSM depth. Conductivity, pH, and concentrations of dissolved calcium also decreased with increasing BSM depth and were significantly greater in effluent from the shallower BSM depths compared to the deeper depths.

Table 8. Mean (standard error) of nutrients and conventional parameters in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC).

Measurement	Detection Limit	Influent Water		Effluent Water			
		Lab	**SW**	**6”**	**12”**	**18”**	**18” CWC**
Nitrates (mg/L)	0.003	0.2	3.1	2.73 (0.09)	2.87 (0.03)	2.90 (0.06)	0.2 (0.00)
Orthophosphate (mg/L)	0.01	0.04	0.06	0.08 (0.01)	0.087 (0.003)	0.097 (0.003)	0.2 (0.00)
DOC (mg/L)**	0.08	1.0	9.8	11.33 (0.03)	10 (1)	8.97 (0.03)	1.0 (0.0)

Temperature (°F)		-	33.0	34.5 (0.9)	32.43 (0.07)	33.7 (0.3)	34.4 (0.4)
pH	n.a.	7.55	7.71	7.53 (0.03)^{a}	7.461 (0.003)^{ab}	7.32 (0.01)^{b}	7.417 (0.009)
Conductivity ($\mu S/cm$)		1553	163.7	157 (2)^{a}	153.2 (0.9)^{ab}	148.6 (0.9)^{b}	1566.3 (0.9)
Turbidity (NTU)	n.a.	0.03	59.4	2.8 (0.2)	2.1 (0.3)	3.4 (0.2)	1.9 (0.1)
Alkalinity (as $CaCO_3$)	0.3	31.0	39.0	41 (3)	39.0 (0.5)	35 (3)	29 (2)
TSS (mg/L)	0.5	0.8	58.4	0.7 (0.1)	0.53 (0.03)	1.1 (0.3)	0.8 (0.1)
Fecal Coliform (CFU/100 mL)	n.a.	BDL	200	1120 (942)	340 (230)	240 (181)	BDL
Dissolved Calcium (mg/L)	3.4	14.6	6.77	14.63 (0.03)^{a}	13.5 (0.1)^{ab}	12.4 (0.2)^{b}	7.6 (0.1)
Dissolved Magnesium (mg/L)	1.9	16.8	0.645	1.24 (0.03)	1.47 (0.04)	1.5 (0.1)	16.87 (0.09)

Detailed Toxicology – Zebrafish Morphometric Bioassay

Zebrafish (*Danio rerio*) embryos were used to evaluate the effectiveness of bioretention columns. Influent and effluent waters were tested for acute toxicity using wild type (AB) zebrafish embryos. Exposure began approximately 2.5-3 hours post fertilization (hpf). For each of the influent waters (stormwater and clean water controls) and effluent waters (from each of the five treatment depths plus the 18" clean water control), 32 embryos were placed in a glass-lined 96-well microplate containing 250 μL of test solution. A water change was performed at approximately 24 hpf and zebrafish were imaged at approximately 48 hpf. All tests were considered valid, with control survival (influent clean water) of at least 90%. Images were analyzed for morphometrics including embryo length, eye area, and heart-related metrics including pericardial area (PCA) and periventral area (PVA). A Kruskal-Wallis test was performed to compare medians of the treatment groups for each morphometric. For metrics with a significant difference among treatment groups, a post-hoc Dunnett's test was performed to determine which treatment groups differed from the control influent treatment.

Event 13 (End of WY2)

Embryo survival was high in all treatments, with values of 91% for influent stormwater, 97% for effluent from the 6", 9" and 12" depths, 94% for the 15" depth, and 100% for the 18" depth, as well as 100% for the clean water control influent and effluent (Table 9). Three outliers (one influent stormwater, one influent control, and one 6" effluent) were removed from the dataset due to extreme developmental abnormalities. Embryos exposed to influent stormwater were not significantly different than clean water controls (Figure 1). Comparing treated effluent to influent clean water controls, embryos exposed to effluent from the 18" CWC were significantly larger ($p = 0.0141$) and the PCA of embryos exposed to effluent from the 18" treatment was significantly greater ($p = 0.0275$). None of the treatment groups differed significantly from the control in eye area or PVA. Additionally, there were no differences in morphology between embryos exposed to 18" effluent stormwater and 18" CWC effluents, suggesting that some aspect of leachate from the BSM itself may have been responsible for increased growth.

Table 9. Summary of sublethal effects of influent and bioretention-treated effluent on zebrafish development at 48 hpf. Values presented are mean (standard error).

Treatment	Mortality Rate	PCA (mm^2)	PVA (mm^2)	Eye Area (mm^2)	Length (mm)
SW influent	9%	0.0216 (0.0008)	0.025 (0.0008)	0.0516 (0.0007)	3.13 (0.02)
6	3%	0.0216 (0.0006)	0.026 (0.001)	0.0537 (0.0006)	3.16 (0.01)
9	3%	0.0230 (0.0005)	0.0274 (0.0007)	0.0525 (0.0007)	3.18 (0.02)
12	3%	0.0228 (0.0004)	0.0274 (0.0007)	0.0524 (0.0006)	3.13 (0.02)
15	6%	0.0232 (0.0005)	0.0280 (0.0007)	0.0532 (0.0006)	3.15 (0.02)
18	0%	0.0244 (0.0006)*	0.030 (0.001)	0.0532 (0.0005)	3.18 (0.01)
Clean influent	0%	0.022 (0.0006)	0.027 (0.001)	0.0532 (0.0005)	3.13 (0.01)

18 CWC	0%	0.0236 (0.0006)	0.029 (0.001)	0.0555 (0.0008)	3.195 (0.009)*

*Significantly different from influent clean water controls (p < 0.05)

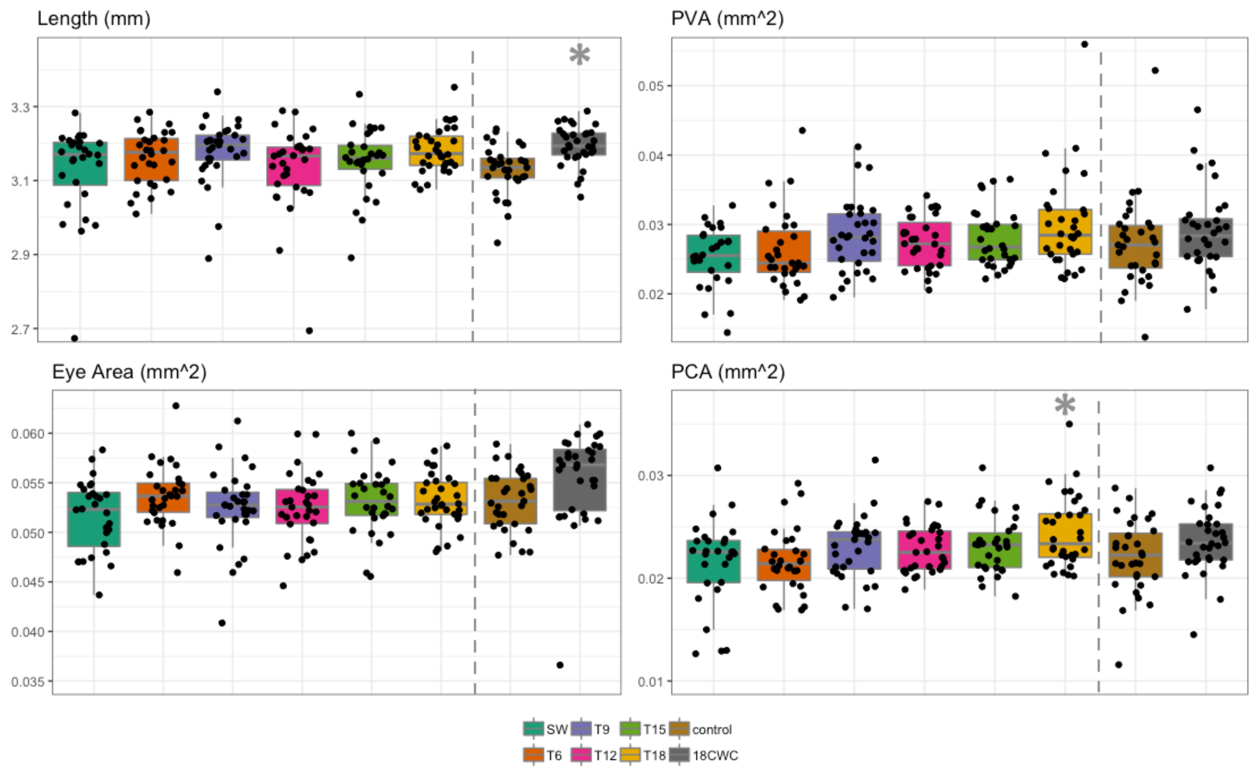

Figure 1. End of WY2. *Danio rerio* morphometrics for 48 h exposure to fish rearing water (control), stormwater runoff influent (SW), and bioretention-treated runoff pooled across triplicates of each bioretention treatment depth (6”, 9”, 12”, 15”, 18”, and 18” clean water control (CWC)). PVA = periventral area and PCA = pericardial area. * denotes significant difference from control.

Event 19 (End of WY3)

Embryo survival was 100% in all treatments (Table 10). Embryos exposed to influent stormwater were significantly larger than clean water controls (p = 0.0139; Figure 2). Comparing treated effluent to influent clean water controls, embryos exposed to the 18” (p = 0.0244) and 12” (p = 0.0021) treatments were significantly larger and the eye area of embryos exposed to the 18” treatment was significantly greater (p = 0.0212). There were no differences in morphology between embryos exposed to 18” effluent stormwater and 18” CWC effluents.

Table 10. Summary of sublethal effects of influent and bioretention-treated effluent on zebrafish development at 48 hpf. Values presented are mean (standard error).

Treatment	PCA (mm^2)	PVA (mm^2)	Eye Area (mm^2)	Length (mm)
SW influent	0.0206 (0.0004)	0.0226 (0.0005)	0.0443 (0.0004)	3.10 (0.01)*
6	0.0195 (0.0004)	0.0215 (0.0004)	0.0453 (0.0004)	3.10 (0.01)
12	0.0192 (0.0004)	0.0211 (0.0004)	0.0461 (0.0004)	3.11 (0.01)*
18	0.0201 (0.0004)	0.0221 (0.0004)	0.0467 (0.0003)*	3.102 (0.009)*
Clean influent	0.0200 (0.0004)	0.0222 (0.0005)	0.0452 (0.0004)	3.062 (0.009)
18 CWC	0.0203 (0.0004)	0.0223 (0.0005)	0.0465 (0.0004)	3.093 (0.009)

*Significantly different from clean water influent controls ($p < 0.05$)

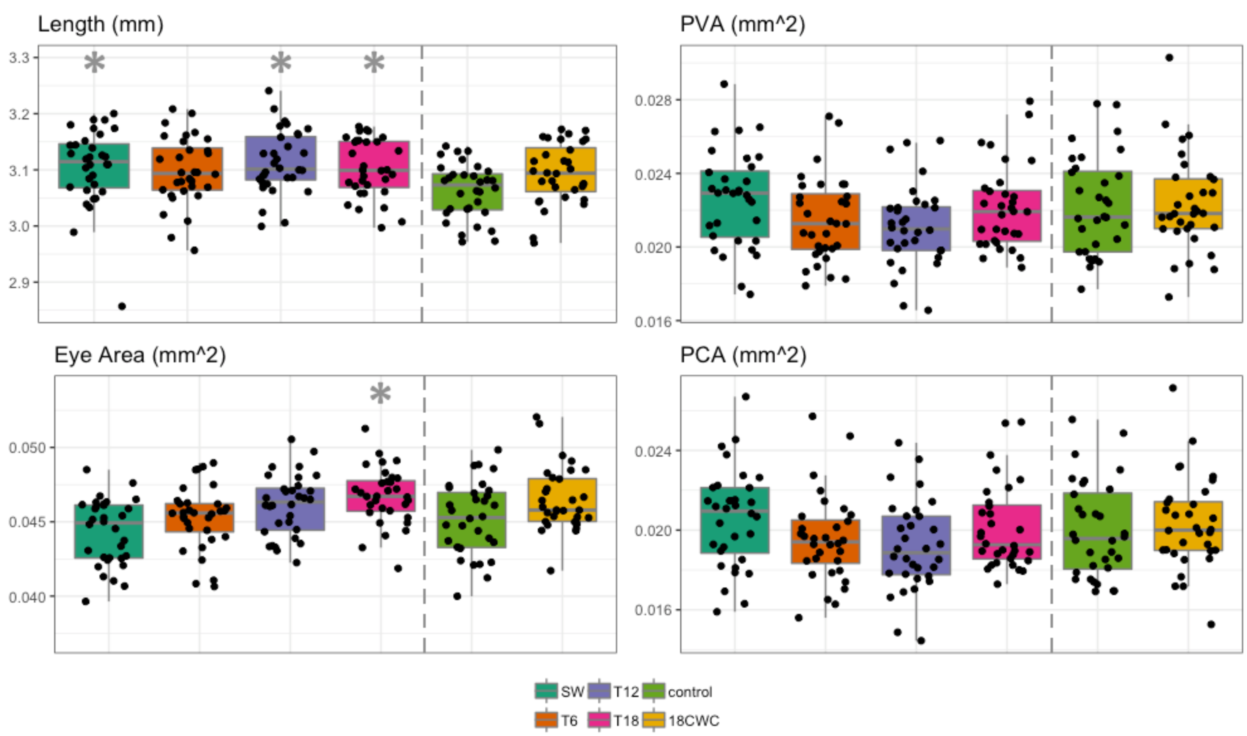

Figure 2. End WY3. *Danio rerio* morphometrics for 48 h exposure to fish rearing water (control), stormwater runoff influent (SW), and bioretention-treated runoff pooled across triplicates of each of three bioretention treatment depths (6”, 12”, 18”, and 18” clean water control (CWC)). PVA = periventral area and PCA = pericardial area. * denotes significant difference from influent control water.

Basic Water Chemistry: Events 11-12; 14-18; 20

Full water chemistry and toxicology were assessed only for the final event of each water year. For all intervening events, temperature, pH, conductivity, and turbidity of influent and effluents waters were recorded (Table 11). Differences among the five treatment depths for concentrations of each conventional parameter in effluent were assessed by a Kruskal-Wallis test, followed by a post-hoc Dunn's test. There continued to be differences between effluents of the various treatment depths in conductivity (Events 11, 12, 14), pH (Event 14), and turbidity (Event 15).

Table 11. Mean (standard error) of conventional parameters in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC).

Measurement	Influent Water		Effluent Water					
	Clean water	SW	6"	9"	12"	15"	18"	18" CWC
				Event 11				
Temperature (°F)	-	44.9	70.93 (0.07)	72.4 (0.3)	72.3 (0.3)	71.1 (0.3)	72.5 (0.3)	72.8 (0.3)
pH	7.69	7.67	7.66 (0.03)	7.65 (0.04)	7.72 (0.02)	7.80 (0.01)	7.82 (0.02)	7.46 (0.01)
Conductivity ($\mu S/cm$)	1544	92.9	100 (3)[a]	105.2 (0.9)[a]	117 (1)[ab]	127 (2)[ab]	150 (2)[b]	1581 (2)
Turbidity (NTU)	0.01	48.9	25 (1)	40.3 (0.2)	34 (5)	32 (4)	39 (2)	13 (1)
				Event 12				
Temperature (°F)	-	48.9	53.4 (0.1)	53.1 (0.2)	53.0 (0.1)	52.0 (0.2)	53.0 (0.1)	53.53 (0.07)
pH	7.60	7.61	7.51 (0.04)	7.45 (0.03)	7.49 (0.02)	7.44 (0.02)	7.46 (0.03)	7.39 (0.01)
Conductivity ($\mu S/cm$)	1535	99.8	96.4 (1.3)	97 (1)	101 (1)	104 (2)	111.1 (0.1)	1537.3 (0.7)
Turbidity (NTU)	0.08	37.6	12.2 (0.4)	17.3 (0.8)	19 (2)	22 (3)	22.3 (1)	6.6 (0.5)
				Event 14				
pH	7.72	7.28	7.59 (0.03)[a]	7.43 (0.04)[ab]	7.39 (0.02)[ab]	7.32 (0.03)[b]	7.28 (0.01)[b]	7.268 (0.007)
Conductivity ($\mu S/cm$)	1502	85.6	127 (1)[a]	139.0 (0.8)[ab]	148 (4)[ab]	156 (3)[ab]	160 (4)[b]	1532 (1)
Turbidity (NTU)	0.01	88.1	5.8 (0.2)	6.9 (0.6)	6.2 (0.7)	5.9 (0.4)	5.7 (0.4)	9.1 (0.6)
				Event 15				
Temperature (°F)	-	57.3	70.3 (0.9)	66.3 (0.2)	66.2 (0.5)	66.4 (0.5)	67.07 (0.09)	66.8 (0.3)

pH	7.48	7.306	7.35 (0.03)^{a}	7.31 (0.02)^{a}	7.24 (0.02)^{ab}	7.13 (0.05)^{ab}	7.04 (0.01)^{b}	7.267 (0.005)
Conductivity ($\mu S/cm$)	1524	109.1	103.4 (0.7)	106 (1)	103 (1)	105 (2)	104.7 (0.4)	1545.7 (0.3)
Turbidity (NTU)	0.04	92.5	4.9 (0.2)^{a}	6.2 (0.4)^{ab}	5.5 (0.3)^{ab}	6.0 (0.1)^{ab}	8.1 (0.3)^{b}	11 (1)
Event 16								
Temperature (°F)	-	52.5	56.3 (0.9)	53.7 (0.3)	52.7 (0.4)	52.2 (0.3)	52.4 (0.3)	52.4 (0.2)
pH	7.62	7.51	7.31 (0.04)	7.22 (0.04)	7.17 (0.02)	7.09 (0.05)	7.3 (0.3)	7.175 (0.008)
Conductivity ($\mu S/cm$)	1510	117.0	110.1 (0.4)	111.9 (0.6)	112 (2)	113 (1)	112 (1)	1527 (1)
Turbidity (NTU)	0.04	76.9	4.41 (0.08)^{a}	6.5 (0.5)^{ab}	5.6 (0.8)^{ab}	5.20 (0.05)^{ab}	7.2 (0.4)^{b}	7.2 (0.3)
Event 17								
Temperature (°F)	-	46.4	50.0 (0.6)^{a}	47.4 (0.7)^{ab}	45.5 (0.3)^{ab}	44.9 (0.1)^{b}	46.2 (0.3)^{ab}	45.9 (0.3)
pH	7.61	7.62	7.34 (0.02)	7.26 (0.02)	7.21 (0.02)	7.17 (0.06)	7.08 (0.02)	7.18 (0.01)
Conductivity ($\mu S/cm$)	1500	123.9	114 (1)^{a}	112 (1)^{ab}	109.6 (0.6)^{ab}	110 (1)^{ab}	106.7 (0.3)^{b}	1497.3 (0.3)
Turbidity (NTU)	0.03	69.4	2.5 (0.1)	3.2 (0.1)	2.4 (0.1)	2.47 (0.05)	4.3 (0.1)	3.4 (0.2)
Event 18								
Temperature (°F)	-	48.7	35.4 (0.7)^{a}	35.13 (0.07)^{ab}	33.0 (0.4)^{ab}	32.3 (0.4)^{b}	34.8 (0.5)^{ab}	34.9 (0.3)
pH	7.60	7.55	7.58 (0.01)^{a}	7.55 (0.02)^{ab}	7.50 (0.01)^{ab}	7.42 (0.03)^{ab}	7.38 (0.03)^{b}	7.402 (0.008)
Conductivity ($\mu S/cm$)	1560	106	92.1 (0.9)	91.4 (0.9)	89.7 (0.6)	90 (1)	89 (1)	1556.7 (0.3)
Turbidity (NTU)	0.01	256	2.4 (0.6)	1.99 (0.06)	1.6 (0.1)	1.8 (0.3)	2.0 (0.2)	2.0 (0.2)
Event 20								
Temperature (°F)	-	38.6	40.2 (0.5)		37.3 (0.6)		38.4 (0.4)	37.8 (0.1)
pH	7.71	7.798	7.63 (0.02)^{a}		7.54 (0.01)^{ab}		7.498 (0.006)^{b}	7.49 (0.01)
Conductivity ($\mu S/cm$)	1570	102	137 (3)		141 (13)		179 (9)	1552 (9)
Turbidity (NTU)	0.02	44.7	2.68 (0.04)		2.0 (0.1)		2.3 (0.2)	3.1 (0.5)

Note: Treatments with different superscript group labels (a, b, c) show significance at α = 0.05 (Kruskal-Wallis with post-hoc Dunn Test).
BDL = Below Detection Limit
NTU = Nephelometric Turbidity Units

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity (K_{sat}) of each bioretention treatment was measured following Event 19 (Post-WY3) using the falling head method (Klute and Dirksen 1986). Average K_{sat} values for each depth post-WY3 were similar to values determined following Event 13 (Post-WY2; Table 12). K_{sat} values were compared between the three remaining treatment depths (6”, 12”, and 18”) over four time-points (Pre-WY1, Post-WY1, Post-WY2, and Post-WY3) using a profile analysis. The profiles did not have equal levels, indicating a between-groups main effect of treatment depth (F-value = 10.37, df = 2, p = 0.0113). K_{sat} values for the 6” treatment group were significantly greater than for the 18” treatment group, according to a Kruskal-Wallis with post-hoc Dunn’s test (p = 0.005).

Table 12. Average (standard error) of saturated hydraulic conductivity (K_{sat}) measurements for each treatment depth prior to stormwater dosing in July 2019 (pre-WY1), at the end of the first way year in February 2020 (post-WY1), at the end of the second water year (post-WY2), and at the end of the third water year (post-WY3).

	Ksat (cm/hr)			
Treatment	**Pre-WY1**	**Post-WY1**	**Post-WY2**	**Post-WY3**
6”	423 (73)	391 (29)	415 (18)	345 (28)
9”	553 (148)	461 (172)	475 (171)	-
12”	525 (86)	280 (54)	279 (38)	235 (39)
15”	610 (18)	327 (81)	383 (75)	-
18”	391 (16)	200 (41)	243 (32)	194 (5)
18” CWC	431 (54)	164 (2)	204 (18)	208 (18)
Average	489 (33)	304 (38)	333 (36)	245 (21)

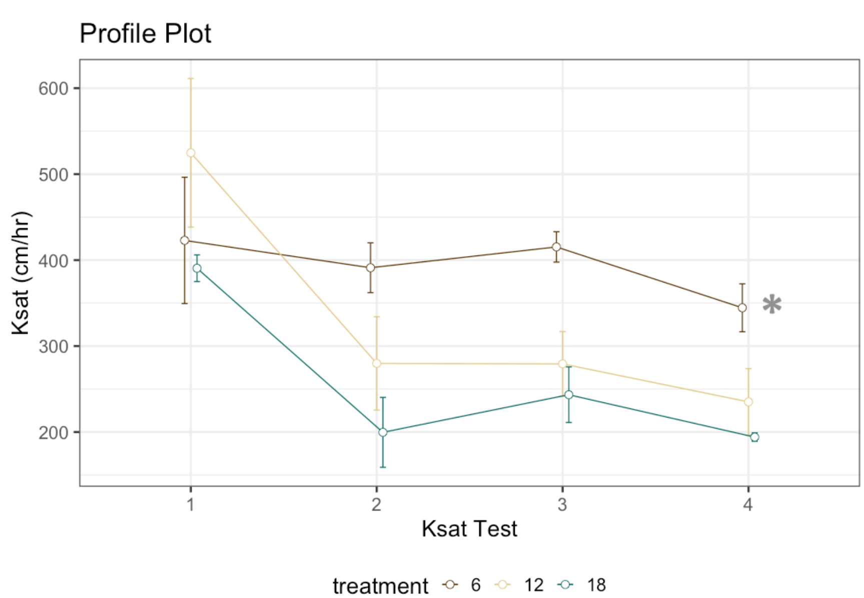

Figure 3. Average saturated hydraulic conductivity (K_{sat}) measurements across four sampling events and three BSM treatment depths (6”, 12”, and 18”). Error bars are one standard error of the mean.

References

Kreider, M. L., Panko, J. M., McAtee, B. L., Sweet, L. I., & Finley, B. L. (2010). Physical and chemical characterization of tire-related particles: Comparison of particles generated using different methodologies. *Science of the Total Environment*, *408*(3), 652-659.

Appendix A.

Table A1.1. Mean (standard error) of total PAHs in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the five treatment depths plus the clean water control (CWC) during Event 13. One-half of the value of the detection limit (DL) was substituted for the value of non-detects in calculating means unless all replicates were below the detection limit (BDL).

Compound	DL (µg/ L)	Influent Waters (µg/ L)		Bioretention-Treated Effluent Waters (µg/ L)					
		Clean water	SW	6”	9”	12”	15”	18”	18” CWC
Total PAHs		0.0247	0.321	0.0308 (0.0007)	0.0305 (0.0006)	0.0333 (0.0007)	0.0318 (0.0009)	0.0290 (0.0008)	0.034 (0.007)
Benzo(ghi)perylene	0.002	BDL	0.028	BDL	BDL	BDL	BDL	BDL	BDL
Indeno(1,2,3-cd)pyrene	0.001	BDL	0.01	BDL	BDL	BDL	BDL	BDL	BDL
Dibenzo(a,h)anthracene	0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Perylene	0.007	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzo(a)pyrene	0.003	BDL	0.009	BDL	BDL	BDL	BDL	BDL	BDL
Benzo(j)fluoranthene	0.002	BDL	0.004	BDL	BDL	BDL	BDL	BDL	BDL
Benzo(k)fluoranthene	0.004	BDL	0.007	BDL	BDL	BDL	BDL	BDL	BDL
Benzo(b)fluoranthene	0.0005	BDL	0.014	BDL	BDL	BDL	BDL	BDL	BDL
Chrysene	0.001	BDL	0.02	0.0007 (0.0002)	0.0007 (0.0002)	0.0013 (0.0003)	0.0012 (0.0004)	0.0012 (0.0004)	BDL
Benzo(a)anthracene	0.0008	BDL	0.009	BDL	BDL	BDL	BDL	BDL	BDL
Pyrene	0.001	BDL	0.066	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	BDL
Fluoranthene	0.002	BDL	0.059	0.0017 (0.0003)	BDL	0.0013 (0.0003)	0.0013 (0.0003)	BDL	BDL

Carbazole	0.001	BDL	0.013	BDL	BDL	BDL	BDL	BDL	BDL
Anthracene	0.001	BDL	0.005	BDL	BDL	BDL	BDL	BDL	BDL
Phenanthrene	0.001	0.002	0.041	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	0.002 (0.000)	BDL
Fluorene	0.002	BDL	0.005	BDL	BDL	BDL	BDL	BDL	BDL
Dibenzofuran	0.002	BDL	0.004	BDL	BDL	BDL	BDL	BDL	BDL
Acenaphthene	0.003	BDL	0.003	BDL	BDL	BDL	BDL	BDL	BDL
Acenaphthylene	0.002	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1-Methylnaphthalene	0.001	0.0005	0.003	0.003 (0.00)	0.003 (0.00)	0.0033 (0.0003)	0.0027 (0.0003)	0.0027 (0.0003)	0.004 (0.004)
2-Methylnaphthalene	0.001	BDL	0.005	0.0015 (0.0005)	0.0015 (0.0005)	0.0023 (0.0003)	0.002 (0.00)	0.0010 (0.0005)	0.006 (0.006)
Naphthalene	0.001	0.003	0.01	0.0033 (0.0003)	0.0037 (0.0003)	0.0043 (0.0003)	0.0040 (0.0003)	0.0033 (0.0003)	0.005 (0.002)
2-Chloronaphthalene	0.001	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Sum Low Molecular Weight (LMW)*		0.012	0.0905	0.0158 (0.0006)	0.0162 (0.0006)	0.0180 (0.0006)	0.0167 (0.0007)	0.0150 (0.0007)	0.022 (0.007)
Sum High Molecular Weight (HMW)**		0.0127	0.23	0.0150 (0.0004)	0.0143 (0.0002)	0.0153 (0.0005)	0.0152 (0.0006)	0.0148 (0.0004)	0.0127 (0.0000)

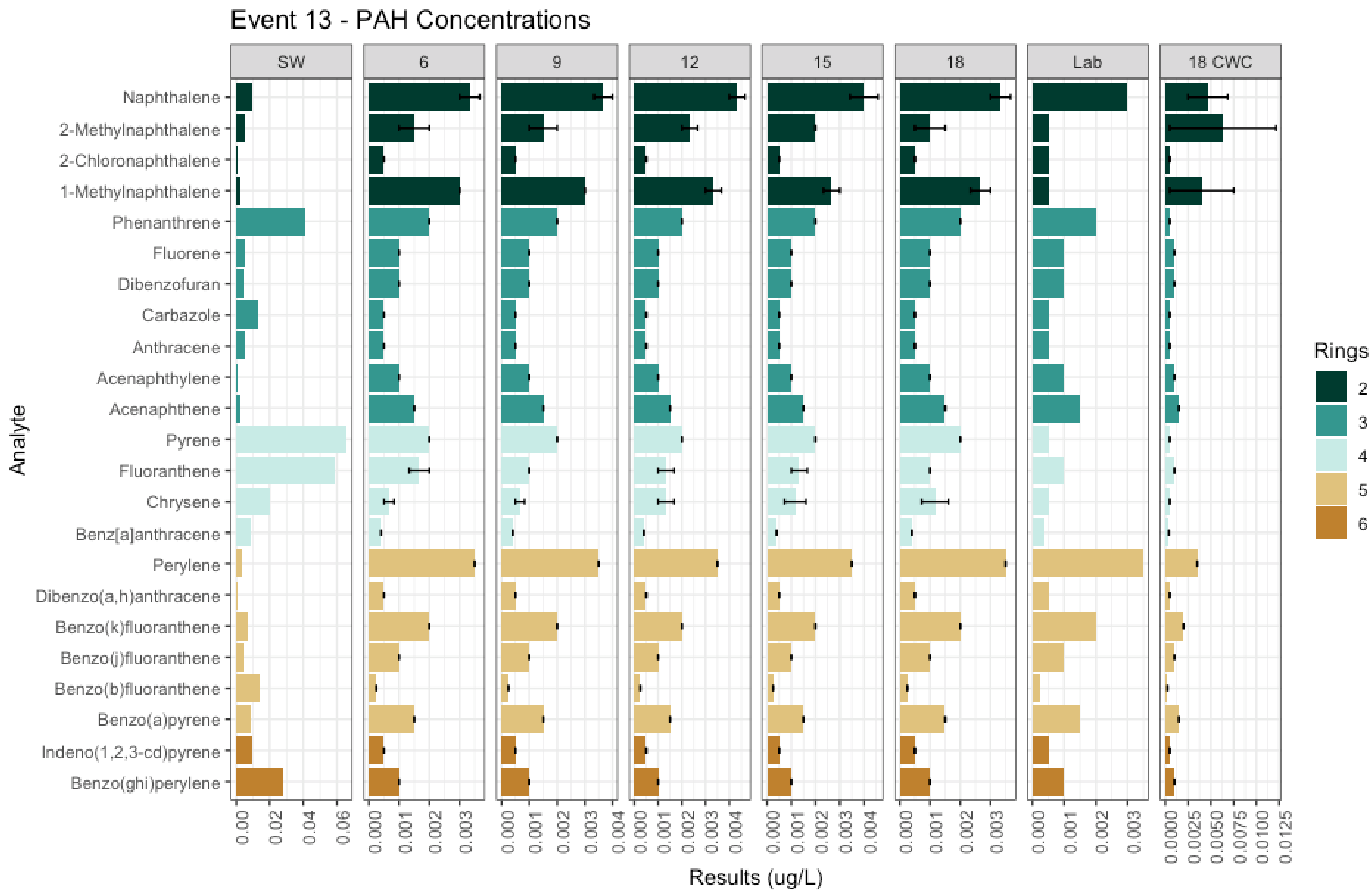

Figure A1.1. PAH concentrations in influent clean water (Lab), influent stormwater (SW), and triplicate samples of effluent from each of the five treatment depths (6", 9", 12", 15", 18") plus the clean water control (18" CWC) during Event 13. Error bars are one standard error of the mean. One-half of the value of the detection limit (DL) was substituted for the value of non-detects.

Table A1.2. Mean (standard error) of total PAHs in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the three treatment depths plus the clean water control (CWC) during Event 19. One-half of the value of the detection limit (DL) was substituted for the value of non-detects in calculating means unless all replicates were below the detection limit (BDL).

Compound	DL (µg/ L)	Influent Waters (µg/ L)		Bioretention-Treated Effluent Waters (µg/ L)			
		Clean water	SW	6”	12”	18”	18” CWC
Total PAHs		0.070	0.503	0.087 (0.003)	0.083 (0.003)	0.084 (0.001)	0.0655 (0.0007)
Benzo(ghi)perylene	0.002	BDL	0.066	BDL	BDL	BDL	BDL
Indeno(1,2,3-cd)pyrene	0.001	BDL	0.014	BDL	BDL	BDL	BDL
Dibenzo(a,h)anthracene	0.001	BDL	0.002	BDL	BDL	BDL	BDL
Perylene	0.007	BDL	BDL	BDL	BDL	BDL	BDL
Benzo(a)pyrene	0.003	BDL	0.013	BDL	BDL	BDL	BDL
Benzo(j)fluoranthene	0.002	BDL	0.007	BDL	BDL	BDL	BDL
Benzo(k)fluoranthene	0.004	BDL	0.007	BDL	BDL	BDL	BDL
Benzo(b)fluoranthene	0.0005	BDL	0.019	BDL	BDL	BDL	BDL
Chrysene	0.001	BDL	0.028	BDL	BDL	BDL	BDL
Benzo(a)anthracene	0.0008	BDL	0.009	BDL	BDL	BDL	BDL
Pyrene	0.001	BDL	0.098	0.002 (0.000)	BDL	BDL	BDL
Fluoranthene	0.002	BDL	0.074	BDL	BDL	BDL	BDL
Carbazole	0.001	0.002	0.007	BDL	BDL	BDL	BDL
Anthracene	0.001	BDL	0.006	BDL	BDL	BDL	BDL
Phenanthrene	0.001	0.002	0.041	0.0015 (0.0005)	0.0010 (0.0005)	BDL	BDL
Fluorene	0.002	BDL	0.015	0.011 (0.002)	0.010 (0.001)	0.0093 (0.0003)	BDL

Dibenzofuran	0.002	BDL	0.006	BDL	0.0013 (0.0003)	0.0017 (0.0003)	BDL
Acenaphthene	0.003	BDL	0.004	BDL	BDL	BDL	BDL
Acenaphthylene	0.002	BDL	BDL	BDL	BDL	BDL	BDL
1-Methylnaphthalene	0.001	0.013	0.02	0.022 (0.002)	0.022 (0.002)	0.0227 (0.0009)	0.0137 (0.0003)
2-Methylnaphthalene	0.001	0.022	0.026	0.021 (0.002)	0.0203 (0.0009)	0.0213 (0.0009)	0.0220 (0.0006)
Naphthalene	0.001	0.013	0.036	0.0117 (0.0009)	0.0113 (0.0009)	0.0120 (0.0006)	0.0107 (0.0003)
2-Chloronaphthalene	0.001	BDL	BDL	BDL	BDL	BDL	BDL
Sum Low Molecular Weight (LMW)*		0.0575	0.1625	0.073 (0.003)	0.070 (0.003)	0.072 (0.001)	0.0528 (0.0007)
Sum High Molecular Weight (HMW)**		0.0127	0.341	0.014 (0.000)	0.013 (0.000)	0.013 (0.000)	0.013 (0.00)

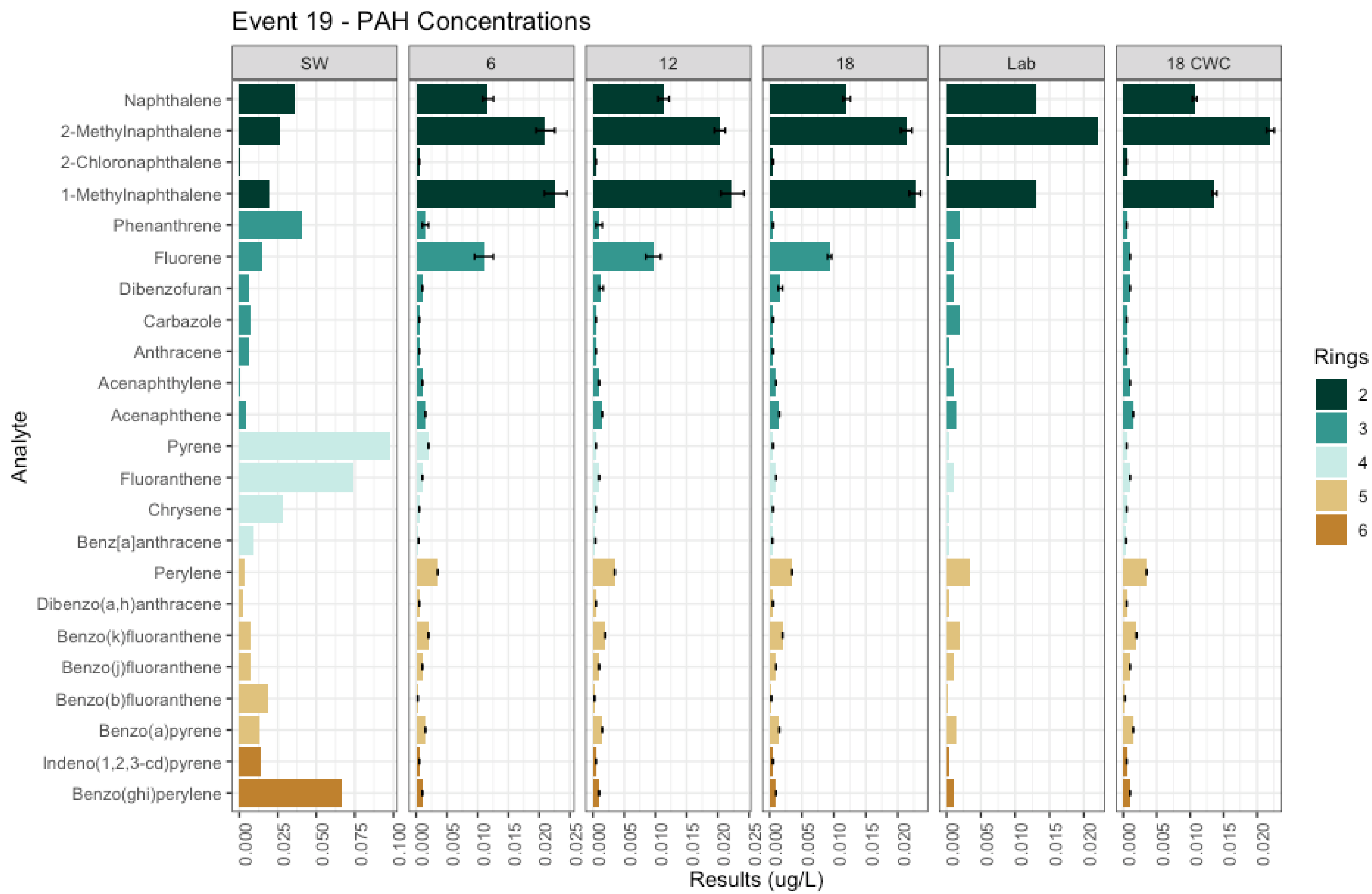

Figure A1.2. PAH concentrations in influent clean water (Lab), influent stormwater (SW), and triplicate samples of effluent from each of the three treatment depths (6”, 12”, 18”) plus the clean water control (18” CWC) during Event 19. Error bars are one standard error of the mean. One-half of the value of the detection limit (DL) was substituted for the value of non-detects.