Deliverable 4.5: Progress Report 5

Overview of Work Period: 6/7/21 – 12/14/21

		Water Quality		Toxicology		Stormwater	
Water Year	Event	Basic	Full	Zfish	Coho	Collection Date	Treatment Dates
7	41	x				6/7/21	6/7/21-6/8/21
	42	x	x	*		9/17/21	9/18/21-9/19/21
8	43	x				9/27/21	9/27/21-9/30/21
	44	x				10/5/21	10/5/21-10/6/21
	45	x				11/9/21	11/10/21-11/11/21
	46	x				11/15/21	11/16/21-11/17/21
	47	x				11/19/21	11/20/21-11/21/21
	48	x	x	*	x	11/30/21	12/1/21-12/2/21
9	49	x				12/8/21	12/8/21-12/9/21
	50	x				12/13/21	12/13/21-12/14/21

*Zebrafish molecular assays have not yet been completed for Events 42 or 48.

Report Summary

Work Progress Status

Project Tasks	% Completion
1. QAPP development	100
2. Prepare experimental columns	100
3. Condition experimental columns	100
4. Bioretention performance throughout accelerated aging	83
5. Outreach and communication	0

Discussions/decisions made since last report period

- Beginning in Event 40, influent stormwater flow exceeded the ponding capacity of some of the experimental columns, resulting in overflow down the sides of the columns. To control and capture this overflow, ports were installed within the top inch of each column. For each column, a port was installed by tapping a 1/2" hole into the PVC and attaching a nylon connector and silicone tubing. The tubing extends from the port to the stainless-steel effluent pot that drains each column. Untreated stormwater runoff that bypasses the treatment system (overflow) was considered a part of the total effluent volume for chemical and biological analyses.
- The incidence of clogging was preceded by low saturated hydraulic conductivity (K_{sat}) values in all treatments, suggesting that a similar mechanism (e.g., surface clogging) could be affecting infiltration in all runoff-treated columns. To alleviate clogging in these columns, a maintenance intervention plan was implemented prior to the Event ending WY9 (Event 54). The plan was based on recommendations for addressing excessive ponding or overflow from the SWMMWW, and included the following actions:
  - From each column, the top mulch layer was removed and placed in a gallon Ziploc bag.

    - Three undisturbed soil cores (Diameter = 1.25”; Height = 1”) were removed from the top inch of each column for porosity measurements.
    - From each column, the remaining top inch of BSM was removed and homogenized in a plastic gallon Ziploc bag.
    - Subsamples of BSM were collected from these bags for chemical analyses (PAH analysis by Analytical Resources Inc., and total metals (Cu, Zn, Cd, Pb, As, Ni) analysis by Spectra Laboratories). Remaining soil was aliquoted into 250-mL amber glass jars (stored in -20°C freezer) and 1.5-mL microcentrifuge tubes (-80°C freezer) for potential future tire marker and qPCR analyses, respectively.
    - The mulch layer was then replaced in each column. Prior to doing so, plastic bags containing the mulch were shaken to break up potential biofilm formation.
    - Saturated hydraulic conductivity (K_{sat}) of each bioretention treatment was measured following the maintenance intervention.

Summary of Events

Summary of Full Water Chemistry

Event 42 (Post WY7)

- Overflow was observed from columns: 6R1, 18R1, and 18R2.
- A net export of nitrates was observed for all treatment depths, with significantly higher effluent concentrations from the deeper than the shallower BSM depths.
- A net export of orthophosphate was observed for all treatment depths.

Event 48 (Post WY8)

- Overflow was observed from columns: 12R2, 18R1, and 18R2.
- A net export of nitrates was observed for all treatment depths.

Summary of Toxicology: Event 48 (Post WY8)

- Untreated highway runoff was acutely lethal to juvenile coho salmon (56.3% mortality).
- Treatment of runoff through the 18” treatment depth resulted in 19% coho mortality. Mortality in the 18” treatment depth can likely be attributed to overflow occurring due to clogging in two of the three 18R columns.
    - *Comment from SAM project manager: coho mortality was tested in the overflowing water (unfiltered) water combined with bioretention treated water; therefore, this result doesn’t necessarily indicate the loss of bioretention function preventing acute toxicity. For future mortality tests, treated water and overflowing water will be separated before any toxicity tests.*
- Treatment of runoff through the 6” and 12” treatment depths completely prevented juvenile coho mortality.

Summary of Maintenance intervention (pre-WY9)

- Removal of the top inch of BSM increased K_{sat} values for all runoff treatments.

Full Water Chemistry

Full water chemistry analysis was conducted for Events 42 (End of WY7) and 48 (End of WY8). Samples for water chemistry were collected and analyzed as previously (Deliverable 4.1: Progress Report 1).

Event 42 (End of WY7)

Metals

Table 1. Average concentrations of dissolved and total metals in $\mu g/L$ (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6”, 12”, 18”) plus the clean water control (C) for the event ending Water Year 7. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following ‘<’ are equal to the detection limit.

Compound	MDL	Clean Water	Influent Runoff	6R	12R	18R	18C
Dissolved As	0.05	<0.05	1	<0.05	<0.05	<0.05	<0.05
Dissolved Cd	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dissolved Cu	0.05	<0.05	23.5	11.9 (0.5)	8 (0.1)	10 (1)	2.1 (0.2)
Dissolved Pb	0.079	<0.079	<0.079	<0.079	<0.079	<0.079	<0.079
Dissolved Ni	0.2	<0.2	2.8	2.1 (0.1)	1.7 (0.7)	1.6 (0.3)	0.4 (0.1)
Dissolved Zn	0.19	<0.19	45.3	10 (5)	6.2 (0.6)	14 (4)	0.6 (0.3)
As	0.05	<0.05	1.2	<0.05	<0.05	<0.05	<0.05
Cd	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Cu	0.2	<0.2	42.5	14 (2)	8.93 (0.03)	11 (2)	3.7 (0.3)
Pb	0.079	<0.079	3	<0.079	<0.079	<0.079	<0.079
Ni	0.2	<0.2	4.4	2.2 (0.2)	2.2 (0.4)	2.2 (0.1)	0.8 (0.3)
Zn	0.19	<0.19	114	15 (7)	6.8 (0.3)	18 (6)	0.6 (0.3)

Nutrient & Conventional Water Chemistry

Table 2. Average water chemistry values (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6”, 12”, 18”) plus the clean water control (C) for the event ending Water Year 7. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following ‘<’ are equal to the detection limit. n.m. = not measured for this event.

Compound	Units	Clean Water	Influent Runoff	6R	12R	18R	18C
Dissolved Organic Carbon	mg/L	<0.08	14.3	16.5 (0.1)^{a}	15 (0.1)^{ab}	13.9 (0.7)^{b}	3.57 (0.03)
Total Suspended Solids	mg/L	0.6	45.6	3 (1)	0.8 (0.6)	5 (2)	2.1 (0.1)
Turbidity	NTU	0.54	51.4	7 (3)	3.2 (0.3)	9 (2)	3.4 (0.8)
Conductivity	µS/cm	1500	165.2	171 (2)	167.5 (0.4)	165 (2)	1514 (1)
pH	n.a.	7.68	7.465	7.26 (0.04)	7.12 (0.03)	7.15 (0.04)	7.43 (0.02)
Alkalinity	mg/L as $CaCO_3$	63.9	58.7	50 (3)	56 (6)	44 (1)	59 (1)
Temperature	°F	NA	37	41.8 (0.8)	36 (1)	37 (1)	37.8 (0.4)
Dissolved Calcium	mg/L	5.72	18.4	17.5 (0.1)^{a}	16.9 (0.3)^{ab}	15.3 (0.2)^{b}	7.3 (0.09)
Dissolved Magnesium	mg/L	19	0.816	1 (0.03)^{a}	0.936 (0.007)^{ab}	0.77 (0.04)^{b}	18.2 (0.1)
Dissolved Sodium	mg/L	224	12.9	11.53 (0.07)^{a}	12.3 (0.1)^{ab}	14 (0.5)^{b}	225.3 (0.9)
Nutrients							
Nitrate/Nitrite	mg/L	0.312	1.2	2.66 (0.02)^{a}	3.04 (0.09)^{ab}	3.3 (0.1)^{b}	1.24 (0.08)
Orthophosphate, as P	mg/L	0.01	0.01	0.037 (0.003)	0.053 (0.003)	0.053 (0.009)	0.18 (0.01)

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

PAHs

Table 3. Average polycyclic aromatic hydrocarbon (PAH) concentrations in μg/L (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6”, 12”, 18”) plus the clean water control (C) for the event ending Water Year 7. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following ‘<’ are equal to the detection limit.

PAHs	Clean Water	Influent Runoff	6R	12R	18R	18C
1-Methylnaphthalene	0.003	0.021	0.014 (9e-04)	0.015 (3e-04)	0.014 (9e-04)	0.002 (0)
2-Methylnaphthalene	0.006	0.014	0.004 (7e-04)	0.003 (3e-04)	0.004 (6e-04)	0.003 (3e-04)
Naphthalene	0.011	0.039	0.008 (0.002)	0.007 (0.001)	0.009 (9e-04)	0.006 (3e-04)
Acenaphthene	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Acenaphthylene	<0.002	0.004	0.001 (3e-04)	<0.002	<0.002	<0.002
Anthracene	<0.001	0.007	0.001 (5e-04)	<0.001	<0.001	<0.001
Carbazole	0.002	<0.001	<0.001	0.001 (2e-04)	0.002 (8e-04)	0.001 (2e-04)
Dibenzofuran	0.004	0.008	0.004 (0.002)	0.006 (0)	0.006 (3e-04)	0.003 (3e-04)
Fluorene	<0.002	<0.002	0.003 (0.002)	<0.002	<0.002	<0.002
Phenanthrene	0.003	0.034	0.003 (0.002)	0.002 (3e-04)	0.004 (0.002)	0.001 (2e-04)
Benz[a]anthracene	<8e-04	0.01	0.001 (5e-04)	<8e-04	0.001 (5e-04)	<8e-04
Chrysene	<9e-04	0.029	0.002 (0.001)	<9e-04	0.003 (0.001)	<9e-04
Fluoranthene	<0.002	0.049	0.003 (0.002)	<0.002	0.005 (0.002)	<0.002
Pyrene	<0.001	0.081	0.005 (0.003)	0.002 (3e-04)	0.009 (0.004)	<0.001
Benzo(a)pyrene	<0.002	0.014	<0.002	<0.002	<0.002	<0.002
Benzo(b)fluoranthene	<5e-04	0.018	0.001 (9e-04)	0 (1e-04)	0.002 (5e-04)	<5e-04
Benzo(j)fluoranthene	<0.002	0.005	<0.002	<0.002	<0.002	<0.002
Benzo(k)fluoranthene	<0.003	0.01	<0.003	<0.003	<0.003	<0.003
Dibenzo(a,h)anthracene	<0.001	0.002	<0.001	<0.001	<0.001	<0.001
Perylene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Benzo(ghi)perylene	<0.001	0.044	0.002 (0.002)	<0.001	0.004 (0.002)	<0.001
Indeno(1,2,2-cd)pyrene	<0.001	0.012	0.001 (5e-04)	<0.001	0.002 (5e-04)	<0.001
Total PAHs	0.044	0.407	0.062 (0.006)	0.05 (0.001)	0.075 (0.006)	0.03 (6e-04)
Sum High Molecular Weight (HMW)	0.011	0.277	0.022 (0.005)	0.012 (4e-04)	0.032 (0.005)	0.011 (0)
Sum Low Molecular Weight (LMW)	0.033	0.13	0.04 (0.004)	0.038 (0.001)	0.044 (0.002)	0.02 (6e-04)

Event 48 (End of WY8)

Metals

Table 4. Average concentrations of dissolved and total metals in µg/L (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 8. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit.

Compound	**MDL**	**Clean Water**	**Influent Runoff**	**6R**	**12R**	**18R**	**18C**
Dissolved As	0.05	4.48	<0.05	<0.05	<0.05	0.5 (0.4)	4.8 (0.4)
Dissolved Cd	0.05	<0.05	<0.05	<0.05	<0.05	<0.05	<0.05
Dissolved Cu	0.05	0.81	6.94	4.6 (0.3)	4.2 (0.5)	5 (1)	2.9 (0.1)
Dissolved Pb	0.079	<0.079	<0.079	<0.079	<0.079	<0.079	<0.079
Dissolved Ni	0.2	<0.2	1.32	1.01 (0.03)	1 (0.1)	1.02 (0.06)	0.7 (0.06)
Dissolved Zn	0.19	<0.19	15.6	3 (0.2)	4 (2)	9 (3)	<0.19
As	0.05	0.099	1.27	0.69 (0.01)	0.63 (0.02)	0.8 (0.1)	0.45 (0.02)
Cd	0.05	0.067	0.05	0.027 (0.002)	<0.05	0.04 (0.01)	<0.05
Cu	0.2	<0.2	18.1	6.3 (0.2)	5 (1)	9 (3)	2.5 (0.2)
Pb	0.079	<0.079	2.2	0.25 (0.009)	0.3 (0.1)	0.8 (0.4)	0.083 (0.005)
Ni	0.2	0.211	1.74	0.543 (0.006)	0.7 (0.2)	0.9 (0.2)	0.49 (0.02)
Zn	0.19	<0.19	51.9	4.4 (0.2)	7 (4)	19 (10)	<0.19

Nutrient & Conventional Water Chemistry

Table 5. Average water chemistry values (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 8. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit. n.m. = not measured for this event.

Compound	Units	Clean Water	Influent Runoff	6R	12R	18R	18C
Dissolved Organic Carbon	mg/L	<0.08	3.2	2.3 (0.06)	2.3 (0.2)	2.5 (0.2)	1.17 (0.03)
Total Suspended Solids	mg/L	<0.5	15.2	0.4 (0.1)	1.5 (0.9)	5 (2)	0.6 (0.2)
Turbidity	NTU	0.02	24.7	2.3 (0.1)	4 (2)	9 (4)	1.8 (0.3)
Conductivity	μS/cm	1499	123.3	114.4 (0.8)	110 (2)	112 (3)	1494 (5)
pH	n.a.	7.914	7.622	7.38 (0.01)	7.27 (0.03)	7.32 (0.09)	7.657 (0.005)
Alkalinity	mg/L as $CaCO_3$	72.2	56.1	48 (3)	50 (7)	44 (2)	77 (10)
Temperature	°F	NA	NA	37 (0.3)	35 (1)	36.2 (0.8)	35.6 (0.6)
Dissolved Calcium	mg/L	7.64	19.6	17.27 (0.09)	16.6 (0.5)	17.8 (0.8)	7.49 (0.06)
Dissolved Magnesium	mg/L	19.5	0.463	0.97 (0.03)[a]	0.9 (0.04)[ab]	0.67 (0.08)[b]	18.6 (0.3)
Dissolved Sodium	mg/L	244	4.87	4.06 (0.02)	3.89 (0.04)	4 (0.3)	239.7 (0.3)
Nutrients							
Nitrate/Nitrite	mg/L	0.22	0.36	0.533 (0.007)	0.583 (0.009)	0.58 (0.02)	0.337 (0.009)
Orthophosphate, as P	mg/L	<0.01	<0.01	0.037 (0.003)	0.043 (0.007)	0.04 (0.01)	0.133 (0.003)
Microbiology							
Fecal Coliform by MF	CFU/100 mL	1	1020	200 (0)	169 (30)	531 (200)	1 (0)

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

Table 6. Average polycyclic aromatic hydrocarbon (PAH) concentrations in μg/L (standard error) for influent waters (clean water and influent stormwater runoff) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C) for the event ending Water Year 8. One-half of the value of the detection limit was substituted for the value of non-detects in calculating means; used when the compound was detected in at least one replicate for the treatment. Values following '<' are equal to the detection limit.

PAHs	Clean Water	Influent Runoff	6R	12R	18R	18C
1-Methylnaphthalene	0.002	0.005	0.003 (0)	0.004 (3e-04)	0.004 (6e-04)	0.002 (0)
2-Methylnaphthalene	0.003	0.006	0.002 (0)	0.003 (6e-04)	0.004 (9e-04)	0.003 (0)
Naphthalene	0.006	0.011	0.005 (3e-04)	0.007 (0.002)	0.01 (0.002)	0.006 (6e-04)
Acenaphthene	<0.003	<0.003	<0.003	<0.003	<0.003	<0.003
Acenaphthylene	<0.002	0.002	<0.002	<0.002	<0.002	<0.002
Anthracene	<0.001	0.003	<0.001	<0.001	0.002 (5e-04)	<0.001
Carbazole	<0.001	0.007	<0.001	<0.001	0.002 (0.001)	<0.001
Dibenzofuran	<0.002	0.003	0.001 (3e-04)	0.002 (3e-04)	0.003 (3e-04)	<0.002
Fluorene	<0.002	0.005	<0.002	0.001 (3e-04)	0.002 (9e-04)	<0.002
Phenanthrene	0.003	0.017	0.002 (0)	0.003 (0.001)	0.007 (0.004)	0.002 (0)
Benz[a]anthracene	<8e-04	0.005	<8e-04	0.001 (5e-04)	0.002 (0.001)	<8e-04
Chrysene	0.002	0.014	0.002 (3e-04)	0.003 (0.001)	0.007 (0.003)	0.002 (0)
Fluoranthene	<0.002	0.026	<0.002	0.003 (0.002)	0.01 (0.005)	<0.002
Pyrene	0.001	0.043	0.002 (0)	0.006 (0.004)	0.017 (0.009)	0.002 (0)
Benzo(a)pyrene	<0.002	0.006	<0.002	<0.002	0.003 (9e-04)	<0.002
Benzo(b)fluoranthene	0.001	0.01	0.001 (2e-04)	0.001 (9e-04)	0.004 (0.002)	0.001 (3e-05)
Benzo(j)fluoranthene	<0.002	0.003	<0.002	<0.002	0.001 (3e-04)	<0.002
Benzo(k)fluoranthene	<0.003	0.004	<0.003	<0.003	<0.003	<0.003
Dibenzo(a,h)anthracene	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Perylene	<0.006	<0.006	<0.006	<0.006	<0.006	<0.006
Benzo(ghi)perylene	<0.001	0.021	<0.001	0.002 (0.002)	0.008 (0.004)	<0.001
Indeno(1,2,3-cd)pyrene	<0.001	0.005	<0.001	0.001 (5e-04)	0.002 (0.001)	<0.001
Total PAHs	0.033	0.201	0.031 (6e-04)	0.048 (0.006)	0.1 (0.01)	0.033 (6e-04)
Sum High Molecular Weight (HMW)	0.013	0.14	0.014 (4e-04)	0.024 (0.005)	0.06 (0.01)	0.014 (3e-05)
Sum Low Molecular Weight (LMW)	0.02	0.06	0.018 (5e-04)	0.024 (0.003)	0.037 (0.005)	0.018 (6e-04)

Basic Water Chemistry: Events 41; 43-47; 49-50

Basic chemistry events were used to age the experimental columns. Influent water (stormwater runoff and clean lab water) and effluent waters (filtered through experimental columns) were not sub-sampled for chemistry or toxicology during these events. Temperature, pH, conductivity, and turbidity of influent and effluents waters were recorded (Table 4). Differences among the three 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.

Table 7. Mean (standard error) of conventional parameters in influent waters (clean water and stormwater runoff; SW) and triplicate effluent waters from each of the three runoff treatment (R) depths (6", 12", 18") plus the clean water control (C).

Compound	Units	Clean Water	Influent Runoff	6R	12R	18R	18C
				Event 41			
Conductivity	µS/cm	1497	52.2	62 (4)	60.9 (0.8)	66 (2)	1509 (1)
pH	n.a.	7.478	7.441	7.39 (0.07)	7.179 (0.006)	7.23 (0.03)	7.26 (0.03)
Temperature	°F	NA	NA	NA	NA	NA	NA
Turbidity	NTU	0.12	55.3	6 (4)	1.5 (0.1)	17 (7)	1.5 (0.3)
				Event 43			
Conductivity	µS/cm	1523	60.9	101 (5)[a]	135 (1)[ab]	146 (2)[b]	1528 (6)
pH	n.a.	7.779	7.28	6.9 (0.04)	7.08 (0.05)	7.05 (0.02)	7.36 (0.03)
Temperature	°F	NA	NA	42.3 (0.9)	38.8 (0.6)	39.7 (0.3)	39.8 (0.4)
Turbidity	NTU	0.02	27	7 (3)	4 (0.1)	10 (3)	3.9 (0.3)
				Event 44			
Conductivity	µS/cm	1494	104.3	107 (2)	105.9 (0.06)	112 (4)	1538 (3)
pH	n.a.	7.919	7.523	7.42 (0.06)	7.22 (0.01)	7.4 (0.09)	7.553 (0.009)
Temperature	°F	NA	39.7	42.6 (0.6)	39.1 (0.5)	39.8 (0.6)	39.6 (0.5)
Turbidity	NTU	0.05	59.6	13 (8)	3.7 (0.6)	20 (9)	3.4 (0.4)
				Event 45			
Conductivity	µS/cm	1508	73.9	89 (2)	94 (1)	96 (2)	1506 (6)
pH	n.a.	7.99	7.414	7.352 (0.007)[a]	7.23 (0.01)[ab]	7.12 (0.02)[b]	7.59 (0.01)
Temperature	°F	NA	NA	NA	NA	NA	NA
Turbidity	NTU	0.07	28.3	1.8 (0.3)	1.5 (0.1)	1.7 (0.1)	5 (0.3)
				Event 46			
Conductivity	µS/cm	1514	62	63.2 (0.7)	62.4 (0.8)	62.3 (0.6)	1525 (3)
pH	n.a.	7.864	7.329	7.26 (0.01)[a]	7.172 (0.009)[ab]	7.15 (0.02)[b]	7.604 (0.009)
Temperature	°F	NA	44	44.33 (0.07)	44 (0.1)	44.2 (0.2)	44.7 (0.2)
Turbidity	NTU	0.04	27.9	1.42 (0.08)	1.8 (0.3)	2 (0.4)	2.63 (0.09)

				Event 47			
Conductivity	µS/cm	1470	64.7	66.4 (0.9)	64 (1)	65 (1)	1477 (6)
pH	n.a.	7.852	7.264	7.25 (0.02)	7.17 (0.03)	7.22 (0.04)	7.596 (0.007)
Temperature	°F	NA	NA	NA	NA	NA	NA
Turbidity	NTU	0.05	18.51	1.27 (0.06)	2 (1)	6 (2)	1.5 (0.1)
				Event 49			
Conductivity	µS/cm	1485	119.4	155 (1)	166 (6)	175 (1)	1485 (4)
pH	n.a.	7.964	7.673	7.53 (0.03)	7.47 (0.08)	7.49 (0.05)	7.66 (0.02)
Temperature	°F	NA	NA	39.9 (0.3)	39.7 (0.5)	40.4 (0.1)	40.6 (0.2)
Turbidity	NTU	0.06	18.9	2 (1)	4 (3)	6 (3)	1.8 (0.1)
				Event 50			
Conductivity	µS/cm	1515	104.6	108 (2)	105 (3)	107 (3)	1501 (3)
pH	n.a.	7.344	7.638	7.47 (0.04)	7.34 (0.09)	7.41 (0.08)	7.58 (0.02)
Temperature	°F	NA	NA	45.4 (0.2)	43.7 (0.3)	43.9 (0.3)	43.4 (0.2)
Turbidity	NTU	0.07	NA	2 (1)	3 (2)	6 (2)	1.8 (0.2)

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

Toxicology – Event 48 (End of WY8)

Toxicity Testing – Salmon

Toxicity testing using juvenile coho salmon was conducted on the event ending WY8 (event 48), similar to previously reported (Deliverable 4.1: Progress Report 1). Untreated highway runoff was acutely lethal to juvenile coho salmon. At the end of the 24 h exposure, 56.3% mortality was observed. Mortality was also observed in juvenile coho salmon exposed to runoff filtered through the 18R BSM treatment (mortality = 19%). Treatment of runoff through the 6R and 12R BSM treatments completely prevented mortality.

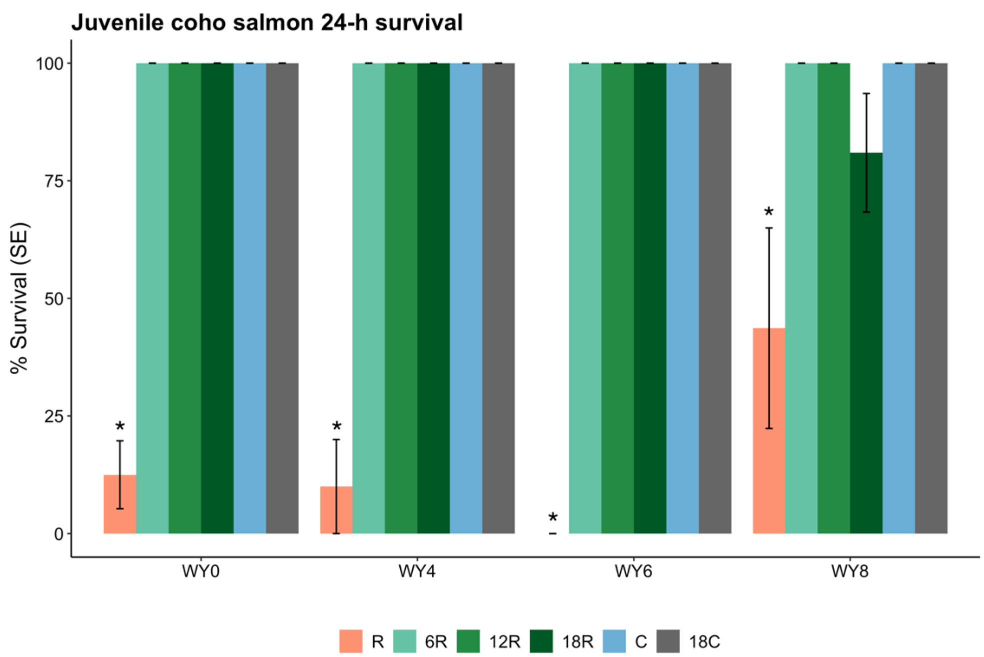

Figure 1. Survival of juvenile coho salmon following 24-h exposures to influent and effluent waters for three sampling Events: 1 (WY0), 24 (post-WY4), 36 (post-WY6), and 48 (post-WY8). Coho were exposed to influent stormwater (R), control water (C), and bioretention-treated runoff pooled across triplicates (WY0, WY6, and WY8) or duplicates (WY4) of each bioretention treatment depth (6”, 12”, 18”).
* indicates an exposure that significantly affected survival relative to controls.

Saturated Hydraulic Conductivity

Saturated hydraulic conductivity (K_{sat}) of each bioretention treatment was measured following Events 42 (WY7) and 48 (WY8) using the falling head method (Klute and Dirksen 1986). Table 8 additionally includes all previous tests.

Table 8. Average (standard deviation) saturated hydraulic conductivity (Ksat; cm/hr) for each treatment for each test. 6R, 12R, and 18R refer to the 6", 12", and 18" treatment depths; 18C refers to the 18" clean water control columns.

Test	6R	12R	18R	18C	Average
WY0	423 (127)	525 (150)	391 (27)	431 (94)	442 (107)
WY1	391 (50)	280 (94)[1]	200 (70)	164 (4)[1]	259 (106)
WY2	415 (31)	279 (65)[1]	243 (56)	204 (30)[1]	285 (93)
WY3	345 (48)	235 (67)[1]	194 (8)	208 (31)[1]	245 (72)
WY4	125 (140)	149 (89)[1]	141 (55)	216 (96)[1]	158 (92)
WY5	416 (87)	362 (8)[1]	324 (81)	368 (72)	368 (68)
WY6	174 (36)	146 (37)	95 (15)[1]	268 (115)	171 (85)
WY7	74 (59)	61 (19)	53 (72)	255 (81)	111 (102)
WY8	55 (42)	72 (47)[1]	81 (52)	274 (72)	120 (104)
Pre-WY9	283 (20)	147 (90)	199 (36)	353 (88)[1]	246 (100)

[1]Leaking from one replicate. Measurement from leaking column was substituted with duplicate measurement from a different replicate.

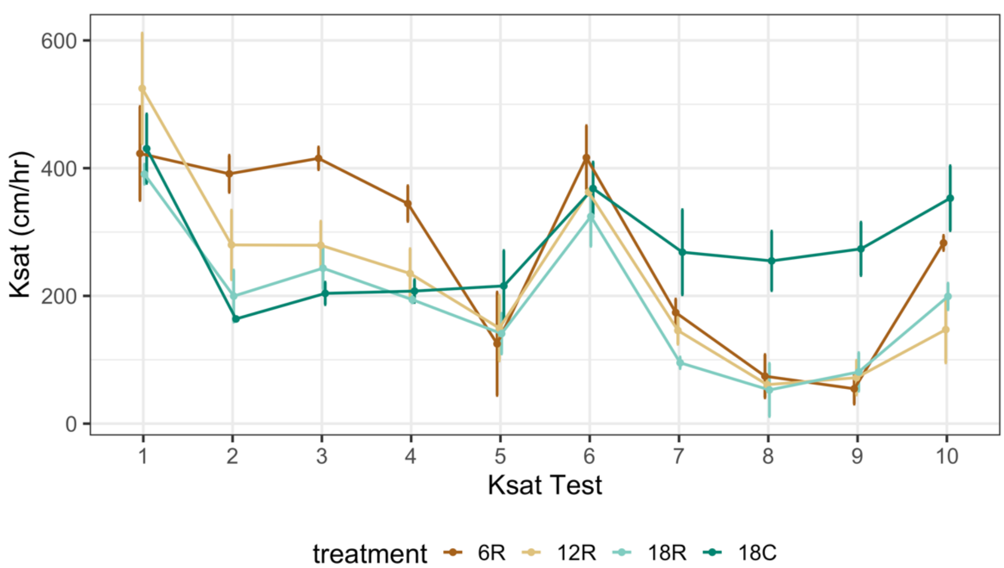

Figure 2. Average (standard error) saturated hydraulic conductivity (K_{sat}) for each treatment for each test.

Porosity

The porosity of the top inch of BSM from each bioretention column was measured prior to the Event ending WY9. For porosity measurements, triplicate soil cores were taken from each column using polypropylene tubes (diameter = 1.25”). A piece of 400-micron mesh was secured to the base of each core using a rubber band to retain soil particles. Soils were then saturated by placing the cores in a plastic tub that was gradually filled with water from the bottom until the water level was even with that of the soil. The cores were allowed to soak for a minute and then individually transferred to tin weigh boats and the weight of each saturated core recorded. Soil cores were then placed in a drying oven at 105°C for 24 hours. After drying, the weight of the cores was measured again. The difference in weight before and after drying is equal to the volume of water lost, which is assumed equal to the volume of pores. Porosity (%) is then calculated as:

$$(((\text{saturated core weight} - \text{oven-dry core weight}) * \text{density of water})/\text{total volume of core}) * 100 = (\text{pore volume}/\text{total volume}) * 100.$$

Figure 3. Polypropylene soil corers were used to take cores from the top inch of each column.

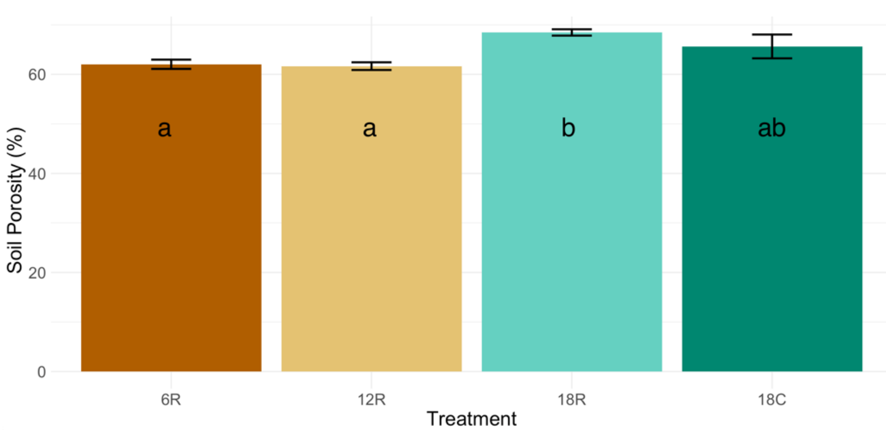

Figure 4. Average (standard error) soil porosity (%) for the top inch of BSM from each treatment. Porosity values for the 18R treatment were significantly greater than for the 6R and 12R treatments, according to a Kruskal-Wallis with post-hoc Dunn’s test (p = 0.001), and as indicated by the group labels (a, b).