

RSMP Project: Testing the effectiveness of bioretention at reducing the toxicity of urban stormwater to coho salmon

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Deliverable 1: Bioretention cell construction and preparation

In October 2013 the research team constructed a portable bioretention treatment system for pilot work treating runoff for adult salmon exposures at Grover's Creek Salmon Hatchery (Poulsbo, WA). Four new 55-gallon polyethylene drums were fitted with a slotted underdrain. The underdrain was constructed from a 2" PVC pipe capped on one end and the other end attached to a bulkhead fitting near the base of the drum (Figures 1, 3). Slots in the underdrain were cut following guidance in Section 6.1.2 of the 2012 Low Impact Development Technical Guidance Manual for Puget Sound (Publication No. PSP 2012-3). On the exterior of each drum, a 2" PVC ball valve was attached to the bulkhead fitting.

In September 2014, the bioretention system was emptied of treatment media used in 2013. The new drainage layer (12") was a Seattle Type 26 mixed gravel aggregate obtained from CalPortland in DuPont, WA (product #8495). The bioretention soil media (BSM) was a mixture of 60% sand and 40% Cedar Grove compost mixed in 2011 and stored at Washington State University in Puyallup (WSU-P). The BSM was tamped down every 6" to reduce settling during conditioning to a total depth of 24". The BSM was topped with 2" of bark mulch created by Barri Hermann at WSU-P (Crop & Soil Sciences). One sample of BSM was taken from the center of each drum during construction for analysis of metals. Chilled samples were taken to ARI Laboratories in Tukwila, WA for analysis.

After transporting the bioretention system to Grover's Creek Salmon Hatchery, the bioretention media were conditioned in preparation for use in the coho study. Over two days, a total of 660 L of well water was passed through each bioretention cell at a rate of 2 L/min, equivalent to 2 months of summer rainfall on a contributing area 20x that of the treatment area (i.e., the treatment area is 5% of the contributing area – within recommended guidelines for the use of bioretention for treatment of runoff). Influent and effluent well water samples were collected on October 15, 2014 and transported on ice to Am-Test Laboratories in Kirkland, WA for analysis of metals and conventional water chemistry. Samples for PAH analysis were preserved with 10% methylene chloride and transported on ice to NOAA-Northwest Fisheries Science Center (NWFSC) for analysis.

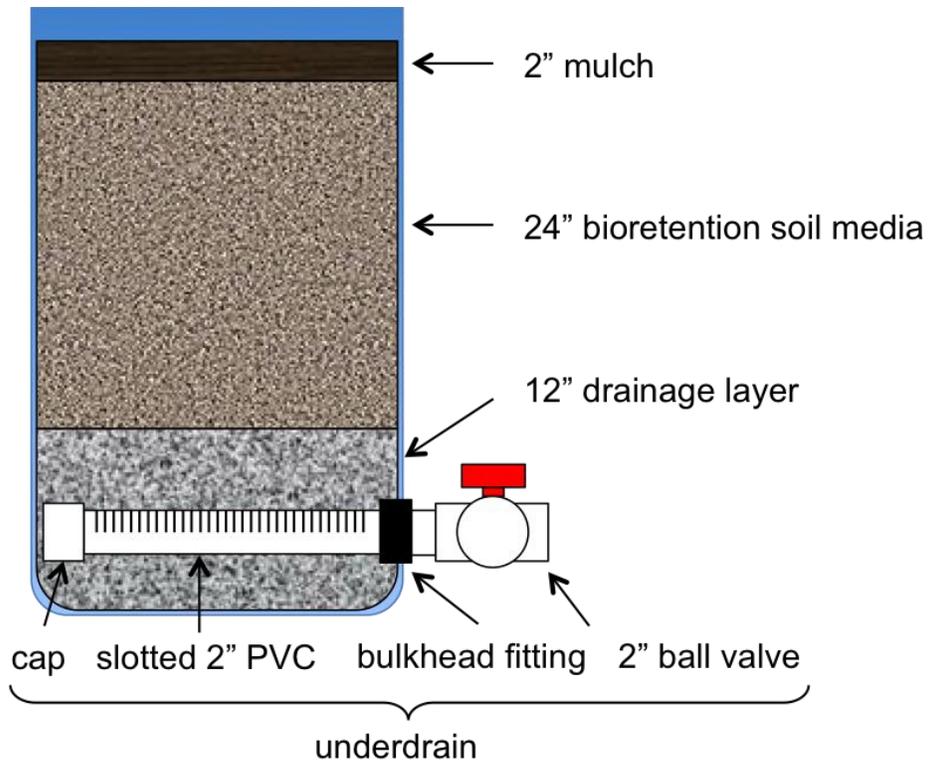


Figure 1. Diagram of bioretention unit using 55-gallon drum

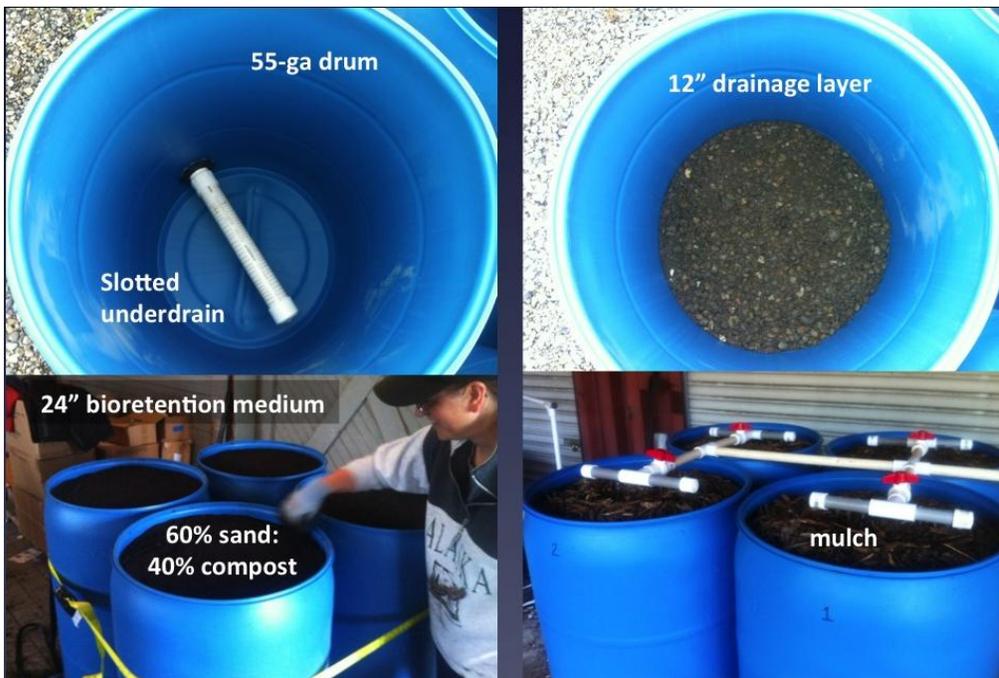


Figure 2. Images of the construction of the bioretention treatment system.



Figure 3. Image of the exterior of one treatment unit and effluent from conditioning.

Deliverable 2.1: Metal concentrations of BSM used in bioretention cells

The most abundant metal in the BSM was Zn. Metal abundance was in the order Zn>Ni>Cr=Cu>Pb>As>Cd. Silver (Ag) was below the 0.2 mg/kg limit of quantitation in all BSM samples.

Table 1. Metal concentrations in the bioretention soil medium from each bioretention cell.

mg/kg dry	LOQ ^a	Cell 1	Cell 2	Cell 3	Cell 4	Mean	SE
As	0.2	2	2	1.9	2.2	2.0	0.1
Cd	0.09	0.11	0.12	0.1	0.1	0.11	0.0
Cr	2	28	28	26	25	27	1
Cu	0.5	21.4	21.1	21.5	22.3	21.6	0.3
Pb	0.09	6.97	7.17	6.6	7.5	7.06	0.19
Ni	0.5	35.9	38.2	38	33.8	36.5	1.0
Ag	0.2	<LOQ	<LOQ	<LOQ	<LOQ	<LOQ	0.0
Zn	4	50	51	49	52	51	1

^a LOQ = limit of quantitation

Deliverable 2.2: Water chemistry of effluent from conditioned cells

Following conditioning of bioretention cells, well water leached significant ($p < 0.01$) concentrations of most water chemistry parameters from the cells including bacteria, solids, organic matter, nitrogen, total P, and metals. There was a slight but significant loss of minerals (Ca, Mg), and total Ag from well water to the bioretention cells. The only parameter not significantly changed by passing through the bioretention cells was dissolved P ($p = 0.77$). Neither total nor dissolved Cd was above the detection limit for well water either before or after filtration through the conditioned bioretention cells.

Dissolved metals in the effluent from bioretention cell conditioning were in the order Zn>Cu>As>Ni>Cr, with undetectable levels of Cd, Pb, and Ag. Based on the concentrations native to the BSM (Table 1), we conclude that As in the BSM was relatively mobile and Cr was relatively immobile.

Table 2. Water chemistry of effluent from conditioned cells on Oct 15, 2014. Values are the mean and standard error of the mean of triplicate samples.

Category	Parameter	D.L.	Units	Well Water	Filtered Well Water
Microbiological	Fecal Coliform	5	CFU/100 mL	< D.L.	307 (63)
	E. coli	5	CFU/100 mL	< D.L.	287 (56)
Conventionals	pH	0.1	-	7.7 (0.1)	7.3 (0.0)
	TSS	1	mg/L	29 (1)	18 (6)
	SSC	0.2	mg/L	< D.L.	25.3 (0.3)
Demand	TOC	0.5	mg/L	0.5 (0)	32.7 (0.3)
	COD	10	mg/L	< D.L.	89 (6)
	DOC	0.5	mg/L	< D.L.	30.3 (1.2)
Minerals	Alkalinity	1	mg CaCO ₃ /L	85 (1)	110 (0)
	Hardness	0.05	mg CaCO ₃ /L	74.00 (1.00)	56.33 (0.33)
	Ca	0.05	mg/L	18.33 (0.33)	14.00 (0.00)
	Mg	0.01	mg/L	6.83 (0.03)	5.17 (0.07)
Nutrients	Ammonia	0.01	mg/L	0.29 (0.02)	1.47 (0.00)
	Total N	0.1	mg/L	0.5 (0.0)	4.7 (0.9)
	Nitrate	0.025	mg/L	< D.L.	2.893 (0.009)
	Ortho-P	0.005	mg/L	0.223 (0.006)	0.205 (0.059)
	Total P	0.005	mg/L	0.251 (0.002)	0.571 (0.014)
Total Metals	As	0.02	ug/L	0.25 (0.00)	7.18 (0.15)
	Cd	0.025	ug/L	< D.L.	< D.L.
	Cr	0.05	ug/L	0.21 (0.00)	2.57 (0.03)
	Cu	0.1	ug/L	1.6 (0.1)	15.0 (0.4)
	Pb	0.05	ug/L	0.06 (0.01)	0.7 (0.07)
	Ni	0.05	ug/L	0.49 (0.01)	8.58 (1.66)

	Ag	0.05	ug/L	0.15 (0.01)	< D.L.
	Zn	0.05	ug/L	4.70 (0.58)	36.53 (3.25)
Dissolved Metals	As	0.02	ug/L	0.14 (0.01)	6.72 (0.04)
	Cd	0.025	ug/L	< D.L.	< D.L.
	Cr	0.05	ug/L	< D.L.	2.07 (0.09)
	Cu	0.1	ug/L	0.8 (0.1)	12.6 (0.1)
	Pb	0.05	ug/L	0.05 (0.00)	< D.L.
	Ni	0.05	ug/L	0.11 (0.00)	4.82 (0.21)
	Ag	0.05	ug/L	< D.L.	< D.L.
	Zn	0.05	ug/L	1.55 (0.04)	23.37 (1.66)

Deliverable 3.1: Effects of treated effluent on adult coho salmon

During the 2013 spawning season (Sep-Dec), we tested the ability of bioretention to prevent pre-spawn mortality in adult coho at the end of the run (November) for highway runoff during one 4-h and one 24-h exposure for two separate storms. During the 2014 spawning season (Oct-Dec), we completed three exposures, focusing on the early part of the run (October). All exposures were 24 h duration with an observation period at 4 h. Additionally, in 2014 an exposure was run comparing well water exposure with well water passed through the bioretention cells.

Healthy adult coho returning to the Suquamish Tribal Hatchery on Grovers Creek were randomly selected and placed in individual PVC holding tubes. Only fish exhibiting normal behavior and with no obvious signs of trauma, disease, or poor condition were included. Four fish per treatment were placed in 440L of experimental water. Each holding tube was equipped with a hose to pump water flow (4L/min) across the fish's head and each treatment tank was aerated to maintain dissolved oxygen at optimum levels for adult coho health during exposures.

In both years, all of the coho exposed to the unfiltered runoff were dead at the end of the exposure period, whereas all of the coho exposed to the filtered runoff or to well water were still alive at the end of the exposure period. All fish exposed to well water or filtered well water were alive and behaving normally at 24 h. During 2014, nearly all (11/12) coho exposed to unfiltered runoff were dead within 4 h of exposure. By the end of the 24 h trials, not only was there 0% mortality in the filtered runoff exposure, we did not observe any of the overt symptoms of 'pre-spawn mortality' that were observed in coho exposed to unfiltered runoff prior to death.

Table 3. Mortality of adult coho exposed to well water, or highway runoff that was unfiltered or filtered through the bioretention cells during 2013 or 2014. N = 4 spawners were used in each treatment for each trial.

Exposure Trial		Adult Coho Mortality		
Date	Duration (h)	Well Water	Unfiltered Runoff	Filtered Runoff
11/8/2013	4	0% (0/4)	100% (4/4)	0% (0/4)
11/18/2013	24	0% (0/4)	100% (4/4)	0% (0/4)
10/20/2014	24	0% (0/4)	100% (4/4)	0% (0/4)
10/22/2014	24	0% (0/4)	100% (4/4)	0% (0/4)
10/27/2014	24	0% (0/4)	100% (4/4)	0% (0/4)