SPRING STREET RAIN GARDEN

Evaluation

Supplemental

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Spring Street Rain Garden Evaluation

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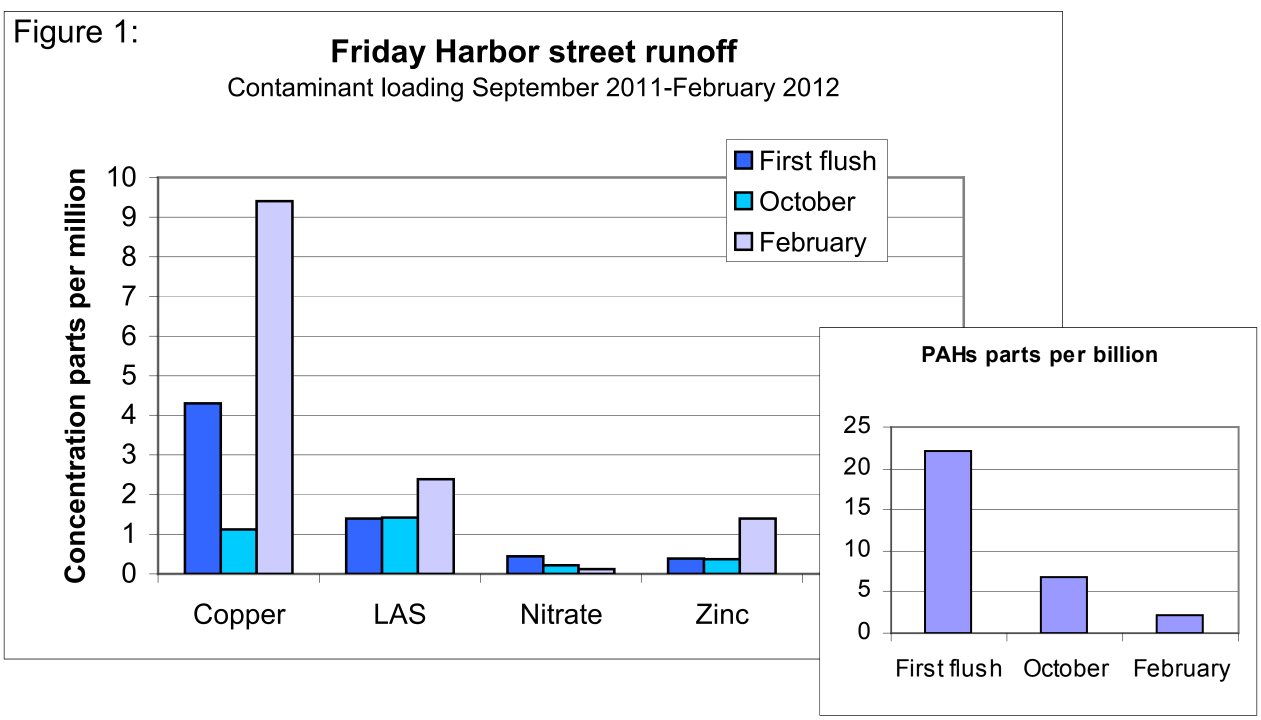
The following report summarizes the results of three rounds of testing of influent and effluent collected from the rain garden constructed at Spring Street and First Street, Friday Harbor, in May 2011. It should be borne in mind that the biological components of the installation—vascular plants and associated microbial communities—have barely had time to begin to establish. Most of the functioning observed in fall and winter must be attributed to physical filtration by the substrate.[1] Functioning will change, and should improve over the next 1-2 years.

Project sponsors requested pre- and post-treatment testing of eight contaminants: total dissolved and suspended solids, total dissolved hydrocarbons, nitrates, copper, zinc, anionic surfactants, and polycyclic aromatic hydrocarbons (PAHs). Water samples were drawn from grated traps installed at the upstream and downstream ends of the rain garden following the first significant precipitation of the winter (26 September 2011), the second significant precipitation (30 October 2011), and then in mid-winter after more than a foot of rain had fallen (11 February 2012).

Analytical methods are set out fully in our initial report.

Contaminant loading

Figure 1 summarizes the contaminant loading of runoff entering the rain garden in September, October, and February.



[1] Details on the composition of the substrate are contained in our December 2011 report.

Copper was the most concentrated constituent measured in this study, with levels from 1.1 to 9.4 parts per million. Copper loads of 1 ppm or more are considered toxic to fish. Anionic surfactants (LAS) took second place, with loads between 1.4 and 2.4 parts per million that are several times the current Washington State maximum discharge level. Zinc was also measured at levels that raise concerns, since this metal is also highly toxic to fish. PAHs were lowest in concentration (inset), but these carcinogens can be toxic at part-per-billion levels. The maximum PAH load we observed was 22 parts per billion.

Although levels of nitrates and PAHs in runoff decreased between the first flush and mid-winter, copper, zinc, and surfactants increased markedly. It is important to learn what caused this pattern. PAHs are mainly associated with internal combustion engines, lubricants, tires and fuels. PAHs accumulate in dry weather adsorbed to particles of silt, tire and brake dust that wash off roadways when the rains begin—as observed on Spring Street. The main source of copper, zinc and surfactants must be different. One possible source is moss-control products designed to protect roofing: most such products contain copper and/or zinc in a surfactant emulsion.

Bulk functioning

In terms of mass and volume, most of the rain garden is unconsolidated sand and gravel ("aggregate"), which can function as a sieve trapping particles and the compounds typically adsorbed to those particles, such as PAHs. Trapping partly decomposed organic matter (such as leaves and animal waste) can also remove a significant source of nitrates, lignins, tannins, and other dissolved solids from runoff water.

Figure 2: **Total Suspended Solids (Turbidity)**

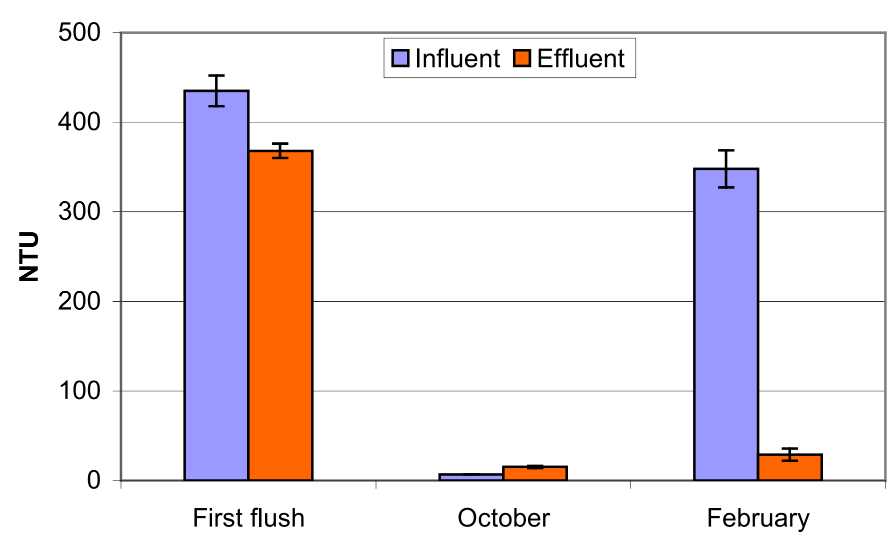
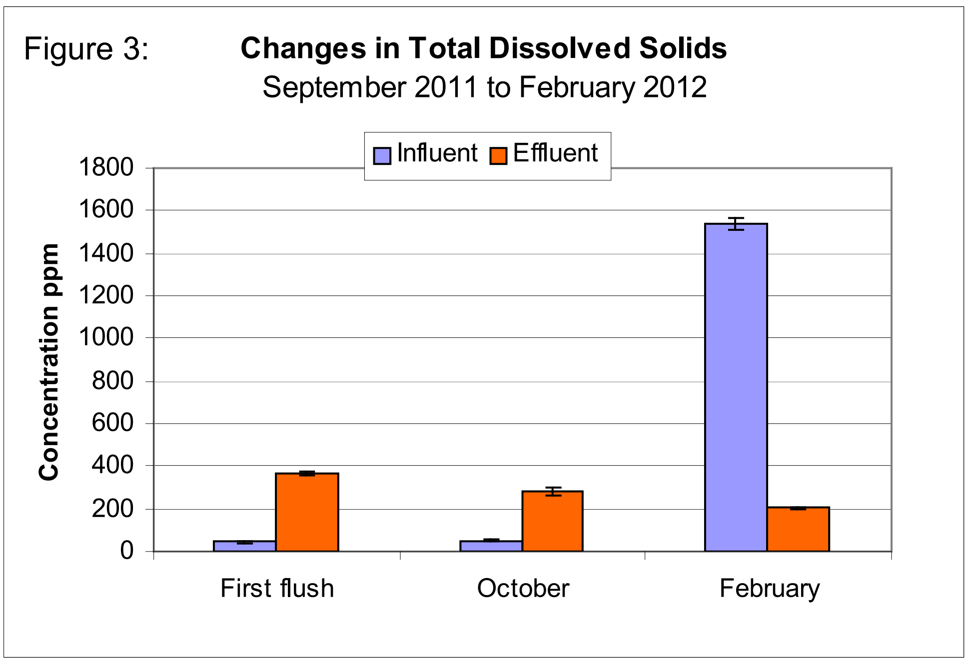


Figure 2 shows results of testing for suspended solids (expressed in Nephelometer Turbidity Units). There was some measurable filtration of solids from the first flush—on the order of 15 percent apparent remediation. By October there was little silt or organic matter left on Spring Street, but runoff water picked up a small amount of turbidity as it passed through the rain garden. By February, heavy storms had swept more detritus into the street, and it appeared as if the rain garden removed more than 90 percent of it.

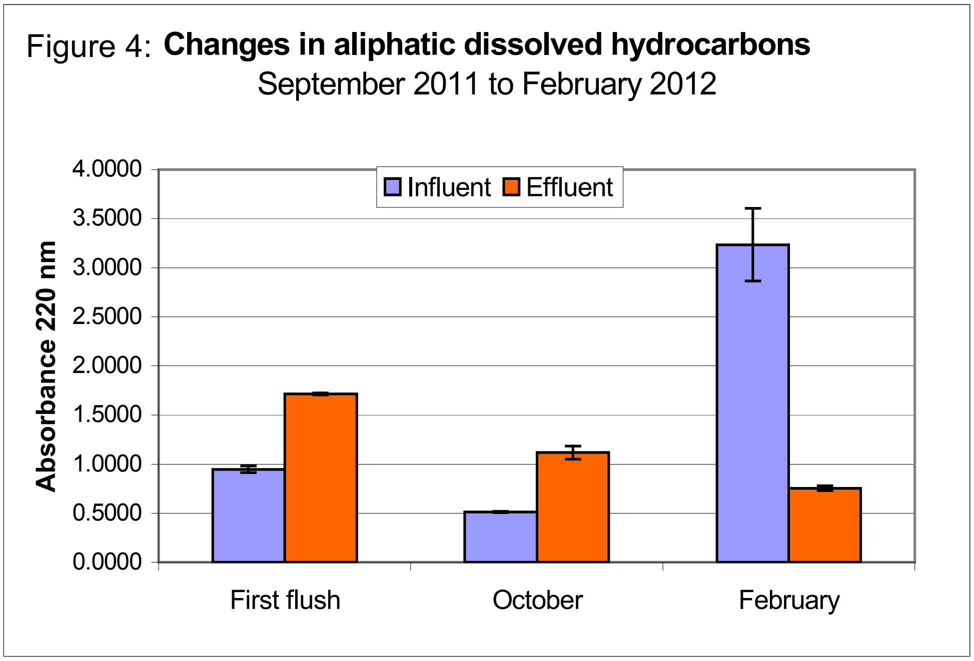
Unfortunately, the apparent remediation may be an artifact of a build-up of sludge in the influent trap. When sampled in February, the influent trap was nearly filled with a thick black sludge consisting mainly of decaying plant material. The sludge was over six centimeters deep and the water above it was yellow. Influent samples were centrifuged at 2000 rpm for five minutes to remove larger debris, and still measured over 300 NTU. As long as the rain garden continues to back up and flood the street during storms, it will not be possible to say with confidence whether influent samples are representative of through put water. Judging from Figures 2 and 3, it is likely that the influent trap is accumulating contamination from street runoff. Influent samples probably overstate the contamination of street runoff, and consequently overstate the efficiency of the rain garden.

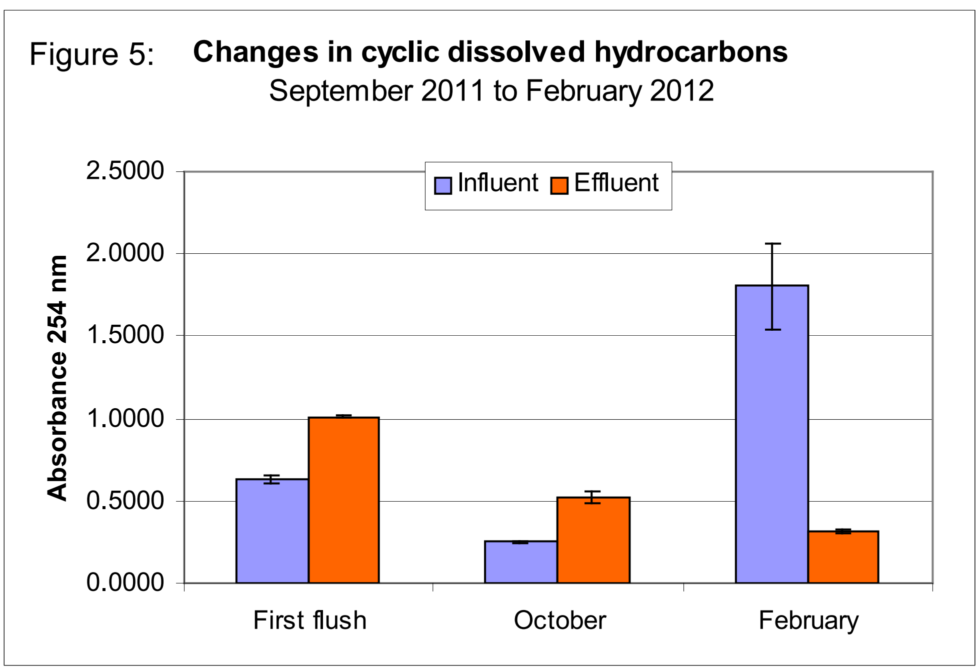


Data for total dissolved solids (TDS) in Figure 3 raise the same concern. Last fall the rain garden was actually increasing dissolved solids, presumably from decomposition of organic material in its fill. Effluent TDS has declined gradually since the first flush in September, but influent TDS was forty times greater in February than it was the previous September or October. This suggests that the influent trap has become compromised, not that the rain garden has changed from the net addition of dissolved solids to more than 80 percent effective at removing dissolved solids in three months.

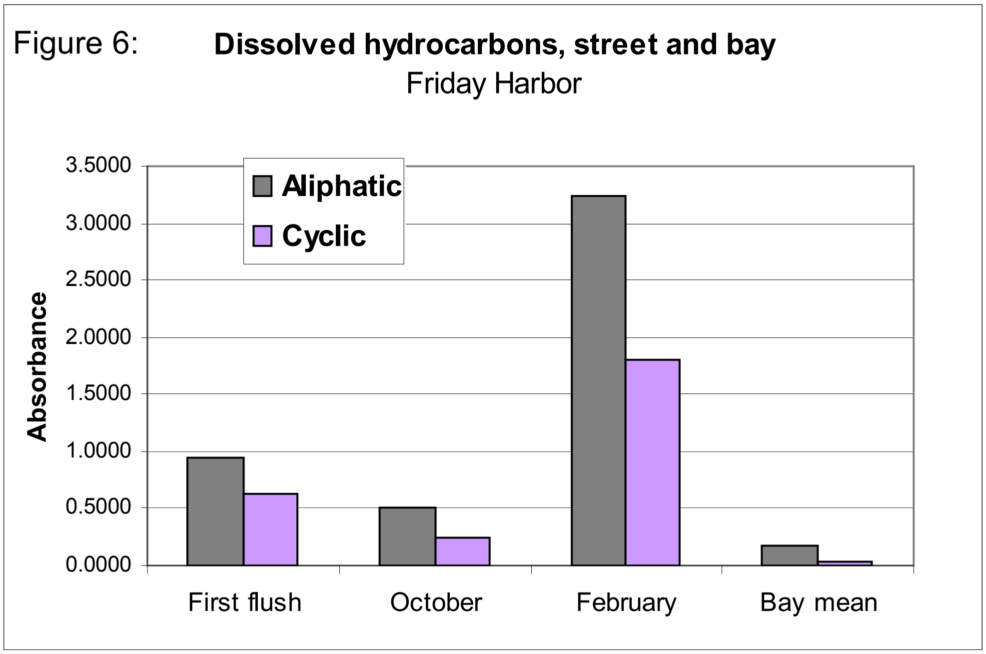
If there is a problem with accumulating trapped organic matter, then TDS should be mainly dissolved hydrocarbons from plants, such as tannins and lignins. Figures 4 and 5 show that the input/output pattern for dissolved hydrocarbons is the same as the pattern for dissolved solids as a whole. Effluent levels were greater than influent levels in fall—the rain garden was adding hydrocarbons to runoff—but this pattern reversed sharply in

February. Looking at effluent loads alone, both classes of dissolved hydrocarbons fell gradually from September to February, suggesting that two processes were at work here: gradual leaching of organic matter in the rain garden fill into effluent, and rapid failure of the influent trap several months into the winter season.



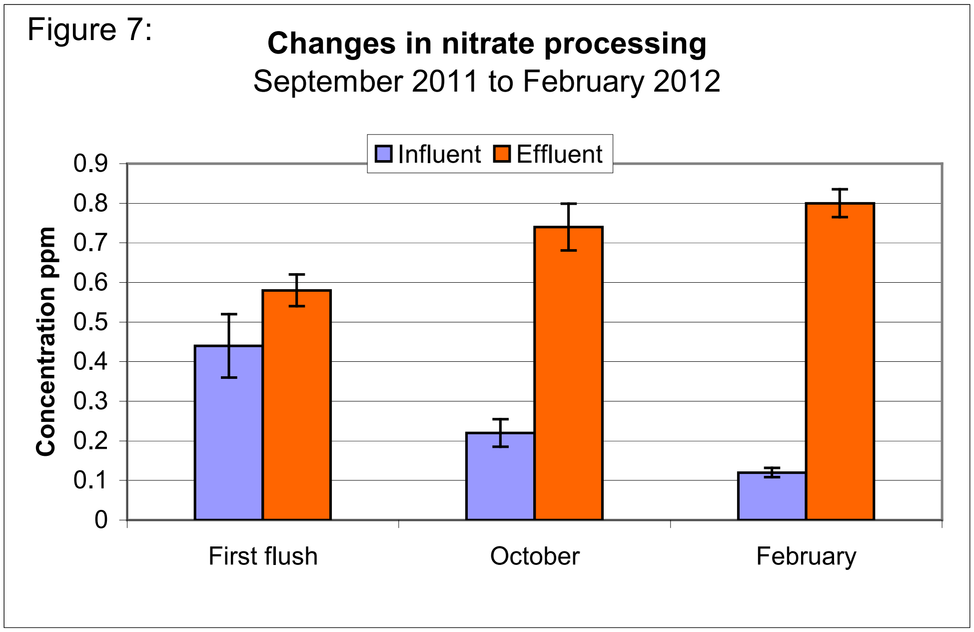


To place these data in context Figure 6 compares dissolved hydrocarbons from the rain garden inflow trap with mean monthly dissolved hydrocarbons in the bay, measured at the surface from six floats in the Port of Friday Harbor marina, February to December 2011.[2] Hydrocarbon loading of February street runoff was considerably greater than the loads we observed the previous fall. Loading of the bay was understandably much lower, presumably due to dilution.



[2] Friday Harbor Marine Health Observatory, Second Annual Review (February 8, 2012).

Processing of nutrients



Although nitrate loading of street runoff has been declining, nitrate loading of rain garden effluent is still increasing (Figure 7). Decomposing rain garden fill is liberating nitrate faster than rain garden plants can utilize it. The nitrate data is also consistent with our inference that the sharp February increase in influent TDS is a result of accumulating sludge and back-ups: the ratio of nitrate to hydrocarbons in influent has declined sharply, indicating that the nature or source of influent TDS changed from fall to winter.

Nitrate leaching from the compost in the rain garden fill should eventually decline and, as plants grow, they will consume more nitrates. The nitrate loading of effluent will then decrease, and the net effect of the rain garden on nitrate loading of the bay will shift from addition to remediation. This may take one or two more growing seasons.

Processing toxic metals

As noted above two of the most conspicuous contaminants in Spring Street runoff are copper and zinc, both of which are highly toxic to fish. Metal ions adsorb to clay and decaying organic matter. Vascular plants and associated fungi and bacteria utilize metals and sometimes hyperaccumulate them. A thickly vegetated rain garden should be able to reduce copper and zinc loads significantly.

In September and October, the rain garden was an increased copper and zinc loads in storm water runoff (Figures 8 and 9). Once again, this was probably due to leaching of the compost-and-aggregate fill, which could include wood waste from construction sites.[3] In February, after repeated heavy winter storms, influent metal loads soared and the rain

[3] In our initial report, we reviewed the certification standards applicable to the fill used, and discussed the risk of contamination of wood waste and food waste in commercial compost products.

garden appeared to be having some remedial activity. At a minimum, the rain garden is no longer leaching zinc, and copper loading of effluent has fallen below 1 part per million for the first time. If influent sampling has indeed been compromised by back-ups and the accumulation of sludge, we cannot say to what extent the rain garden is removing metals from influent, as opposed to no longer adding metals from the fill.

Figure 8:

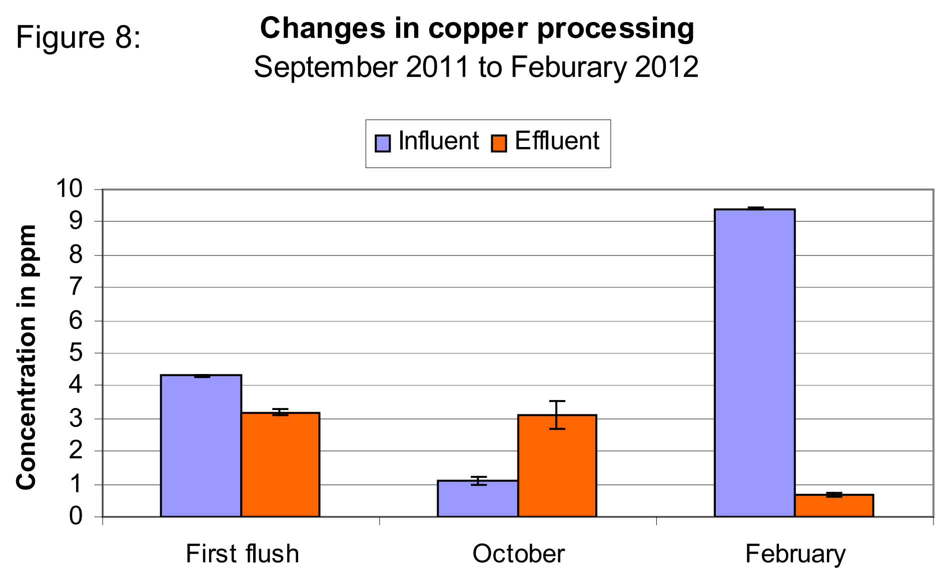
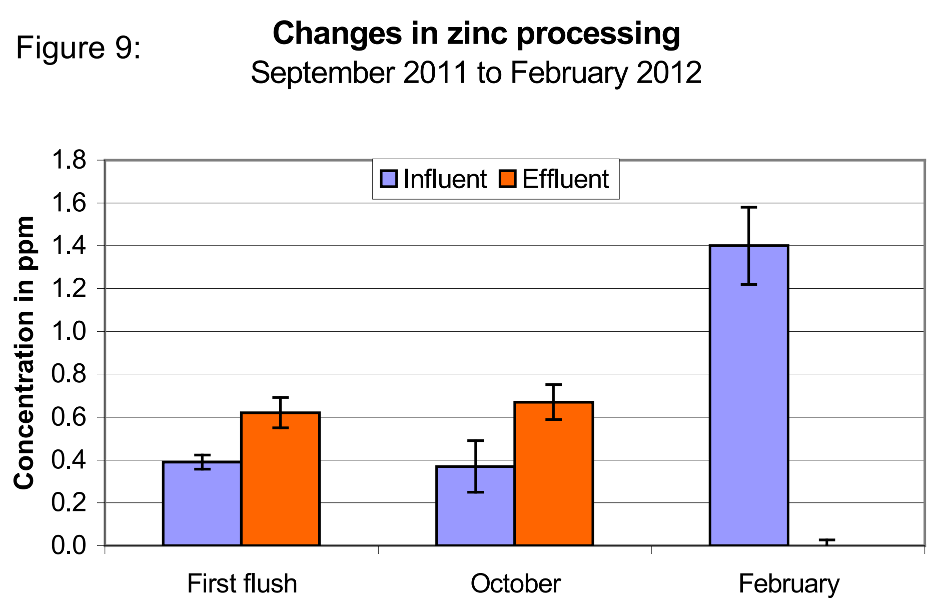


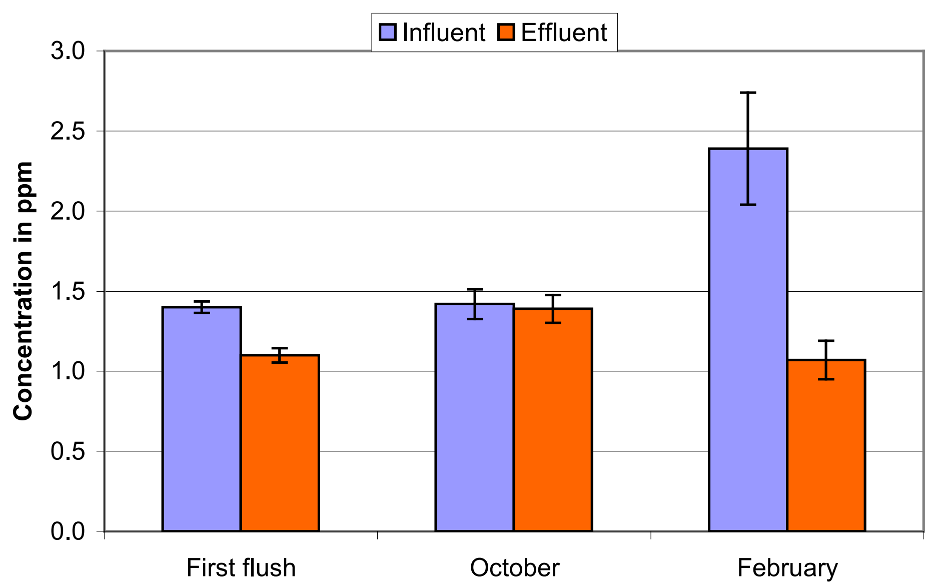
Figure 9:



Processing surfactants

Surfactants are added to so many cleaning products and biocides as de-greasers or emulsifiers that high concentrations of surfactants in Spring Street runoff should probably not be surprising. We used a modified MBAS (Methylene Blue) method that is a reliable measure of linear alkyl sulfonates (LAS) and other synthetic anionic surfactants that have been in widespread use for decades, and still comprise nearly half of the surfactants made and used in North America. MBAS is not a reliable measure of the non-ionic surfactants such as alkyl phenyl ethoxylates (APEOs) that are increasingly found in shampoos, body washes, cosmetics, biocides, and motor vehicle fluids.[4]

Figure 10: **Change in processing anionic surfactants**



The evidence for surfactant processing is mixed. During the first flush, there was evidence of a modest 21 percent reduction in anionic surfactants (T-test $p<0.01$). There was no reduction in October. In February, there is an apparent 58 percent reduction, but this assumes that the sample drawn from the influent trap was representative of the water that actually passed through the rain garden. Surfactant loads over 2 parts per million are quite high; indeed, the samples foamed when shaken. What must be considered carefully is the similarity in the three effluent measurements (1.1, 1.4, and 1.1 ppm respectively). They are suspiciously close. This suggests, again, that the toxic loading of the February influent is inflated by back-ups and sludge accumulation.

Anionic surfactants are highly soluble and relatively stable in the environment. A modest remedial efficiency is reasonable.

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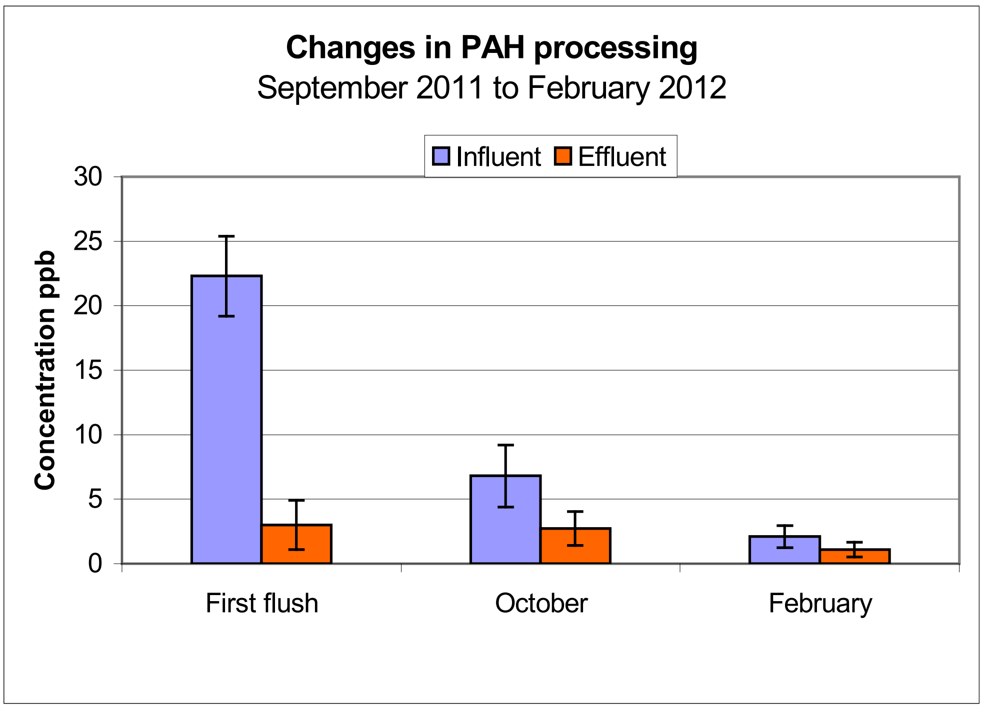
[4] APEOs can be determined by mass spectrometry or an ELISA immunoassay. Funding for this evaluation was inadequate for use of these methods.

Processing of PAHs

Figure 11 shows a pattern that is more like what I would expect, with declining loading of influent, and a limit to remedial effect



Maintenance

Runoff water has been backing up, pooling, and overflowing around the upstream entry to the rain garden complex. Sand is accumulating where there is pooling above and inside the rain garden, and for about two meters downstream along Spring Street. Grains are coarser than the silt that we have found mixed with tars and oils on the street surface, and match the coarse sand in the aggregate used to fill the rain garden. The influent trap has filled with a mixture of oily sludge and decaying vegetation, which is compromising its function, and must be corrected before any further testing.

Summary of findings

Rain garden effluent has grown cleaner since the fall, with two exceptions: nitrate loading of effluent continued to rise, and there was no significant difference in surfactant loading of effluent. February nitrate and surfactant loads in effluent were approximately one part per million, which could have adverse impacts on the bay ecosystem.

There has been a gradual and relatively constant rate of decrease in total dissolved solids (TDS), including dissolved aliphatic and cyclic hydrocarbons, suggesting that the underlying process is leaching of tannins and other organic compounds from rain garden compost, rather than improving filtration of influent.

PAH levels in effluent also fell gradually from September to February, although it is more likely that this represents decreasing concentrations of PAHs on the street, rather than leaching from rain garden fill. In our December report we noted that we had tested a sample of rain garden fill in the summer, before there was any input from the street, and found no measurable PAHs (LOD≈1 ppb).

Copper and zinc were enriched by the rain garden in fall, but effluent loads fell by February. Zinc loading fell below the limit of detection (0.1 ppm), although copper loads remain close to one part per million, which is problematic.

The most dramatic apparent improvement in rain garden efficacy was in turbidity, with a 92 percent difference between influent and effluent samples in February. But this kind of result should have been possible with a simple physical filtration system—such as a sand pile—and does not necessarily evidence any biological functioning.

Realistically, a rain garden cannot become a significant bioreactor until plants and associated microbial communities have grown, a process that may take several years. At this stage of its development, the Spring Street rain garden is chiefly acting as a physical filter (for solids and highly lipophilic compounds such as PAHs), and is still leaching the nutrients and phytochemicals contained in its compost substrate.

Tabular summary of test results

		First flush	*October*	*February*
Turbidity – NTU				
	Influent	435	6.81	348
	Effluent	368	15.2	28.8
Total Dissolved Solids – ppm				
	Influent	43.5	49.8	1540
	Effluent	368	281	202
Dissolved aliphatics – ABS220				
	Influent	0.9463	0.5122	3.2331
	Effluent	1.7139	1.1178	0.7538
Dissolved cyclics – ABS254				
	Influent	0.6294	0.2517	1.8036
	Effluent	1.0121	0.5187	0.3179
Nitrate – ppm				
	Influent	0.44	0.22	0.12
	Effluent	0.58	0.74	0.80
Copper – ppm				
	Influent	4.3	1.1	9.4
	Effluent	3.2	3.1	0.67
Zinc – ppm				
	Influent	0.39	0.37	1.4
	Effluent	0.62	0.67	<LOD
Anionic surfactants – ppm				
	Influent	1.4	1.4	2.4
	Effluent	1.1	1.4	1.1
PAHs – ppb				
	Influent	22.3	6.80	2.62
	Effluent	3.00	2.73	1.38