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Memo

To: Blair Didway, Shapiro Didway Landscape Architecture

Date: 2 Feb 2009

Project: Redding School of the Arts

Re: Comparing the effectiveness of rock-lined versus vegetated swales

In an effort to put a adequate decision making document together for you and your client, I want to start from the beginning and make sure that everyone is on the same page with the understanding that they need to make an informed decision. I apologize if this document is longer than you expected, but making the comparison between rock-lined and vegetated facilities does require a certain amount of technical knowledge.

Water Quality & Runoff

Vehicular areas are the main source of pollutants in surface water. Any impervious areas where cars go are laden with pollutants that have been tracked in on the wheels or drip off the car itself. These pollutants hang out until a very small sized storm, called the "Water Quality Storm" comes along. Now, the "Water Quality Storm" might sound like a good thing, but it's not. It's the amount of rainfall that it takes to scour those pollutants from the impervious surfaces and carry them along downstream by either transporting the sediment itself where pollutants that won't dissolve attach themselves or by dissolving pollutants that will dissolve into the water. Remember, the water quality storm is quite small so it occurs pretty often on its own, but the first portion of all storms larger than it will also have the same scouring, polluting effect, *but only the first portion of all larger storms*. The rest of the large storm's runoff is clean because the scouring takes place at the beginning of the storm, and then the pavement is basically clean until a bunch of new cars with new pollutants drive onto the impervious surface.

Water Quality in Soil

Treatment of runoff by soil is achieved through infiltration into native, uncompacted soils. A common quote in this business is, "Some people treat soil like dirt" meaning that soil is a living system filled with microbes, worms, bugs, rocks, air pockets, and water pockets at the very least. As long as the soil isn't compacted, the living goodies can get the food, water, and air needed to survive. Some of the soil's tiniest living goodies, the microscopic microbes, think that polluted runoff tastes pretty good and they eat pollutants on settled sediments or that are dissolved in the infiltrated water. This digestive process takes those pollutants and turns them into harmless elements like hydrogen, nitrogen, and oxygen, which in turn provides nutrients and resources for other soil dwellers (and plants, if there are any).

But this only works if the runoff passes through at least 2' of uncompacted soil[1], which is a common engineering rule of thumb before it might be considered clean enough to enter the groundwater table without causing contamination. In Oregon, where I happen to have a lot of experience obtaining permits for infiltration facilities, the regulatory requirement for runoff from vehicular areas, the dirtiest and most detrimental kind of runoff remember, is much greater than that – there must be at least 10' separation between the bottom of an infiltration facility and the top of the groundwater table to prevent groundwater contamination!

[1] If the soil is compacted, voids where water and air used to be are lost as the particles are pressed together. Larger bugs get squished and die, and microbes lose their water and air and die. And, compaction like the sort that happens from construction vehicles driving over landscape areas can take soil and turn it into concrete, so no water at all can infiltrate into the soil, it just runs right off.

Design History & Logic

Originally, the rock-lined swales were only needed to convey runoff from the parking lots to a storage facility until it could be harvested for irrigation. A pre-treatment system of sumped catch basins would sufficiently remove large particulates and some pollutants from the stormwater runoff. Ultimately water quality treatment wasn't necessary for this system since irrigation water would enter the soil and get treated by microbes in the soil after storage.

However, as is common in the world of construction, things have changed. Runoff entering the rock-lined swales is going to be conveyed to a detention basin, never to be seen again on-site, but sure to be seen again in a surface-water near you.

Water Quality in a Vegetated System

In a vegetated swale, pollutants get an "assist" from the plants. Roots of the vegetation are good at soaking up runoff. They're thirsty, right? So, they pull the polluted water through their roots. They take the water in, but leave the pollutants on the surface. Microbes go where the food is so they concentrate and multiply on the surface of the roots-- the more roots, the more microbes, the more water quality. Retention time, the length of time that polluted water is held in a vegetated system, also plays a role – the longer the retention time, the higher the water quality coming out the downstream side.

Water Quality in a Rock-lined Swale

Water quality, sufficient for vehicular area runoff, could work in a rock-line swale, but only if there's enough soil that the runoff can infiltrate through. A perforated pipe at the bottom of 2' of planting soil with check dams as needed would've worked, but everything's installed now, so that's not a cost-effective option. Water quality could work in a rock-lined swale if the native soils themselves weren't essentially impervious due to the fragipan discussed in the geotechnical report.

But, honestly, the rocks won't do anything for water quality. The roughness might settle out some particulates, but there's no mechanism for treatment on the rocks since microbes don't live in the sun on the surface of rocks with insufficient water. Any particulates that do settle out will only be re-suspended during a large storm and carried efficiently downstream without treatment.

In our currently installed system with no underdrain, water that does enter the planting soil will be held by the soil until it's saturated and those pollutants will stay in the swale to be treated or at least retained[2]. The rest of the storm runoff though, having nowhere else to go, will pass right over the saturated planting soil with no opportunity for sufficient retention in the soil for water quality. And, even if there were "sufficient" retention of the water with check dams, there would be a fraction of the microbes in the non-vegetated area to provide water quality. All this would seem to indicate that simply passing the stormwater runoff over the rocks and soil will not be an effective water quality approach.

Literature Review

Initially, you asked me to provide percent removals or some sort of quantitative values that compare the water quality effectiveness of a rock-lined swale to a vegetated bioswale. In a literature review of a number of stormwater management manuals, websites, and the many on-line periodical articles available through the Multnomah County Library system, I have been unable to come up with a quantitative argument for the rock-lined swale because as vegetation density decreases (either from trees and shrubs to grass or by planting vegetation physically farther apart), water quality treatment decreases[3].

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[2] There are number of pollutants, including heavy metals, which can't be treated by mechanical or vegetated means. They are simply a result of our habit of driving and can't be eliminated or treated. The best we can hope for is that they 're held in the soil of the vegetated swale or in the vegetation itself on our site, right where the pollution is originating. This is the lesser of two evils when compared to sending those non-treatable pollutants to our surface waters to kill things.

[3] See page 187 of "Urban Stormwater Retrofit Practices, Version 1.0" which can downloaded from the Center for Watershed Protection website: http://www.cwp.org/formmaker/Download-Form_RedirectFormPage.html

I was able to find some info on vegetated swales though, and unfortunately, my literature review indicates that vegetated swales aren't effective enough to meet EPA water quality standards.[4] That's because water is flowing through them instead of being retained[5]. Ultimately, we need to retain the runoff in small basins where the plants and soil can treat it. There are a number of names for this, but both the University of New Hampshire and Center for Watershed Protection documents refer to them as "Bioretention"[6], and I'm going to add the word Basin to indicate that it's a small ponding area (with not more than 6" of water in at any given time).

Retrofit Recommendations

In light of my research and the factors that we discussed yesterday, namely:

- that the rock-lined swales are installed,
- the catch basins are probably already installed,
- the client wants to cleanse the stormwater leaving the site,
- the cost benefits of just putting a single water quality facility for each area draining to a catch basin (versus a series of vegetated swales with check dams in various intervals throughout the rock-lined swale),

I would recommend a biorention basin. These biorention basins are more effective than swales at removing the kinds of pollutants that the site will generate[7]:

Table 1: Range of Reported Removal Rates for Swales

Pollutant	Low End	Median	High End
Total Suspended Solids	70	80	90
Total Phosphorus	-15	25	45
Soluble Phosphorus	-95	-40	25
Total Nitrogen	40	55	75
Organic Carbon	55	70	85
Total Zinc	60	70	80
Total Copper	45	65	80
Bacteria	-65	0	25
Hydrocarbons	70	80	90
Chloride	0	0	0
Trash/Debris	0	0	50

See Appendix D for data sources and assumptions used to derive these removal rates
Low End and High End are the 25th and 75th quartiles

Table 1: Range of Reported Removal Rates for Bioretention Areas

Pollutant	Low End	Median	High End
Total Suspended Solids	15*	60*	75*
Total Phosphorus	-75	5	30
Soluble Phosphorus	-10	0	50
Total Nitrogen	40	45	55
Total Zinc	40	80	95
Total Copper	40	80	100
Bacteria	20	50	80
Hydrocarbons	80	90	95
Chloride	0	0	0
Trash/Debris	80*	90*	95*

* Adequate pretreatment must be provided to reduce sediment loads to bioretention areas or clogging and practice failure may result
See Appendix D for data sources and assumptions used to derive these removal rates
Low End and High End are the 25th and 75th quartiles

[4] See highlighted text on page 1of the attached University of New Hampshire cut sheet on Vegetated Swales
[5] See highlighted text on page 2 of the attached University of New Hampshire cut sheet on Vegetated Swales
[6] See page 171 of "Urban Stormwater Retrofit Practices, Version 1.0" which can downloaded from the Center for Watershed Protection website: http://www.cwp.org/formmaker/Download-Form_RedirectFormPage.html
[7] These tables were lifted from, yep, you guessed it, "Urban Stormwater Retrofit Practices, Version 1.0" which can downloaded from the Center for Watershed Protection website: http://www.cwp.org/formmaker/Download-Form_RedirectFormPage.html

If the client wants to adequately treat stormwater before it leaves the site then each catch basin should be retrofitted so that a bioretention basin is carved out around it, thus receiving surface runoff from the rock-lined swale. The water will be retained in the basin until it passes through the planting soil and into a perforated pipe connected to the catch basins or until it overflows the top of the catch basin (during large storms after the basin is filled and the water running off has already scoured all the pollutants.) Water quality facilities of this nature tend to be surprisingly small. I've drawn a little sketch of what might be required, although the size of each facility will vary depending on the amount of impervious area draining to it.

If the outlet pipe that overflows to the detention basin is deep enough, ideally we would want to have 2' of planting soil between the bottom of the bioretention basin and the top of the perforated pipe assembly. The depth of the standing water in the basin would be 6" max.

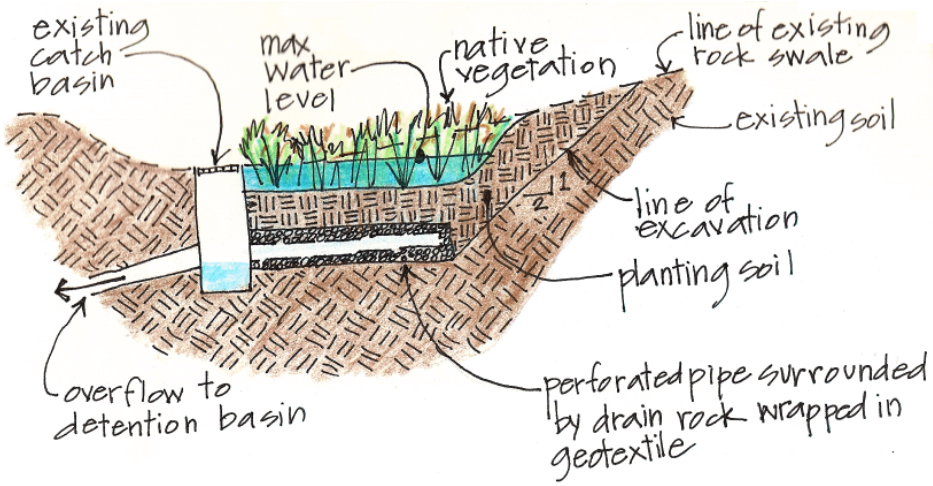

Figure 1. Basin retrofit recommendation for existing catch basins

Next Steps

I suggest distributing this memo to the school to find out if they're interested in considering the bioretention basins. If they are, we should hold a conference call with the you, me, the civil engineering project manager, and the school to tackle any constructability issues, especially since the system is in currently in construction! Only after that should we spend the time and money to look at what the boundaries and design of the biorention basins should be at each catch basin.