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MEMO

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CC: Bill Taylor, MS CPSM, Raedeke Associates, Inc.; Joe Brascher, CCS

FROM: Doug Beyerlein, PE

SUBJECT: Bioretention Modeling Methods

This memo summarizes the bioretention modeling methods used in the design of the bioretention facilities for which infiltration tests were conducted. The information compiled in this memo was collected by reviewing the bioretention modeling methods described in the drainage reports for each of the bioretention cells studied.

Original drainage reports, previously collected by the AESI team, were reviewed for bioretention modeling information. Drainage reports from a total of 54 sites were reviewed; 28 of the 54 had useful bioretention modeling information.

All of the drainage reports, except for two, were produced prior to 2012 when Ecology's new stormwater manual for Western Washington first included bioretention modeling specific information to assist in the design of bioretention facilities. Prior to that date stormwater design engineers had little or no guidance in the modeling and design of bioretention cells. This is evident in the different modeling software that they used.

Of the 28 sites for which information is available, 11 used WWHM3 or its predecessor WWHM2 to model and size the bioretention cell. WWHM3 did not include a bioretention element so the modelers used either the pond element or the gravel trench element to represent the bioretention facility. The modelers for three of the sites used WWHM3 PRO or WWHM4, both of which did have the bioretention element that was later added to WWHM2012. This was the most accurate way to model bioretention facilities, but note that both WWHM3 PRO and WWHM4 were proprietary software which had to be purchased from Clear Creek Solutions while, in contrast, WWHM3 was free.

Five sites were modeled and designed using MGS Flood, which does not have the bioretention algorithms required by Ecology for bioretention modeling. Two of the sites used KCRTS (King County Runoff Time Series); six used single-event models (Waterworks and SBUH); and one used the Pierce County LID Sizing Tool. None of these modeling methods is appropriate for bioretention modeling, but considering the lack of guidance at the time from Ecology it is not surprising that they were used.

An attempt was made to compute the ratio of the bioretention surface ponding area to the contributing drainage area. The contributing drainage area value was taken from the drainage report where it was possible to identify the specific cell in the drainage report corresponding to the information in the AESI-provided infiltration test summary spreadsheet. The bioretention surface ponding area was taken from the measurements made by AESI of the final ponded area during the infiltration testing.

Of the 28 sites which had drainage reports, a total of 11 had sufficient information to compute the ratio of the bioretention surface ponding area to the contributing drainage area in terms of a percentage value. The general recommendation is that the size of the bioretention surface ponding area be at least 5 percent of the size of the contributing drainage area. Of the 11 sites for which there are numbers, only one (Thornton and Maureen, Ferndale) exceeded that recommendation with a percentage of 6.1. All of the other ten sites had values that were considerably smaller.

Seven of the sites had bioretention surface ponding area to the contributing drainage area ratios of less than 1 percent. Without further investigation one would automatically assume that these sites would fail in large storm events, as they would not be able to successfully infiltrate all or most of the stormwater flowing into the bioretention cell. However, a review of the measured infiltration rates for each of these apparently under-sized facilities indicates otherwise.

As shown in Table 1 below, the small ratio bioretention cells have very large infiltration rates.

Table 1. Ratio of Cell Area to Drainage Area for Cell Ratios of Less than 1 Percent

Bioretention Cell	Cell Area to Drainage Area Ratio	Measured Infiltration Rate (in/hr)
Tyee Middle School	0.1%	62.7
Central Park Pad 3	0.2%	18.4
Issaquah High School Cell 1	0.9%	80.6
Rainier Blvd	0.1%	35.8
Decatur Raingarden	0.1%	65.0
185th Swale 3	0.5%	66.5
Spanaway Park Area B	0.2%	103.3

The high measured infiltration rates offset the low cell area to drainage area ratios and make these facilities viable stormwater solutions. However, using today's WWHM2012 bioretention software it is unlikely that any of these facilities would meet either Ecology's Minimum Requirement #5 (LID Flow Duration) or Minimum Requirement #6 (Water Quality).

Three sites have ratios between 1 and 5 percent. As might be expected, these three sites also have relatively high infiltration rates, ranging from 5.3 inches per hour to 99.8 inches per hour.

It should also be noted that the current Ecology bioretention soil mix standard is for a soil mix with an infiltration rate of 12 inches per hour. For sites with higher native soil infiltration rates, as those noted above, the bioretention soil mix infiltration rate should be limiting the site's actual measured infiltration rate. In these early bioretention facilities that is obviously not the case.

Summary

Drainage reports from a total of 54 sites were reviewed; 28 of the 54 had useful bioretention modeling information.

Eleven of the sites used WWHM3 or its predecessor WWHM2 to model and size the bioretention cell. Three of the sites used WWHM3 PRO or WWHM4. The remainder used a variety of other methods (none of which are recommended).

Eleven sites had sufficient information to compute the ratio of the bioretention surface ponding area to the contributing drainage area. The majority of these 11 sites had ratios of less than 1 percent. The low ratios should indicate facility failure during large storm events. However, each bioretention facility had a very high infiltration rate to apparently offset the small bioretention surface ponding area. Today these designs would be unlikely to comply with either Ecology's Minimum Requirement #5 (LID Flow Duration) or Minimum Requirement #6 (Water Quality).

All of the compiled modeling information on the 54 sites is included in Appendix A.

Bioretention Modeling Methods

APPENDIX A

Site Name	Site ID	Design Software	Model Date	Model Method	Contributing Drainage Area	Measured Bioretention Ponding Area (sf)	Percent of Drainage Area	Measured Infiltration Rate (in/hr)
Airport Boulevard (51st Avenue) Cell 1 (South) Lot 2	AR51-S	N/A						
Airport Boulevard (51st Avenue) Cell 2 (North) Lot 10	AR51-N	N/A						
Pick Quick	AUPQ A	WWHM3	12/1/2010	gravel trench	0.9345 ac			
	AUPQ B	WWHM3	12/1/2010	gravel trench	1.0904 ac			
Bainbridge Island High School-Type 2 (Roof Cell)	BIHS-2	MGS Flood	11/12/2006	pond	2.25 ac for			
Bainbridge Island High School-Type 5 (Tennis Cell) (IT-1)	BIHS-5	MGS Flood	11/12/2006	pond	all 3 cells			
Bainbridge Island High School-Type 5 (Tennis Cell) (IT-2)	BIHS-5	MGS Flood	11/12/2006	pond	combined			
145th Pl RG#2	BV145	WWHM3 PRO	8/9/2010	bioretention	0.6 ac	294	1.1%	40.5
Cherry Crest Elementary-Rain Garden #1	BVCC-1	N/A						
Cherry Crest Elementary-Rain Garden #2	BVCC-2	N/A						
Bellevue High School (IT-1)	BVHS	WaterWorks	4/29/2010	pipe	??			
Bellevue High School (IT-2)	BVHS	WaterWorks	4/29/2010	pipe	??			
Spiritridge Elementary-Raingarden #1	BVSE-1	MGS Flood	6/2/2010	pond	??			
Spiritridge Elementary-Raingarden #2	BVSE-2	MGS Flood	6/2/2010	pond	??			
Tyee Middle School Bioretention Pond A	BVTM	WWHM3	2/17/2010	pond	5.092 ac	153	0.1%	62.7
Bellingham City Hall (IT-1)	BHCH	N/A						
Bellingham City Hall (IT-2)	BHCH	N/A						
Bloedel Donavan Park (IT-1)	BHBD	SBUH	N/A	N/A	??			
Bloedel Donavan Park (IT-2)	BHBD	SBUH	N/A	N/A	??			
Bloedel Donavan Park (IT-3)	BHBD	SBUH	N/A	N/A	??			
25th Avenue Site 7A	BO25	N/A						
35th and Grannism Raingarden #2	BO35G	N/A						
Brook Boulevard Site 2E	BOBB	N/A						
Thornton and Maureen	FDTM	SBUH	N/A	pond	0.34 ac	905	6.1%	6.0
Central Park Pad 3 Raingarden	ISCP	WWHM3	5/22/2014	pond	1.48 ac	129	0.2%	18.4
Issaquah High School-Cell #1	ISHS-1	KCRTS	1/29/2009	pond	0.34 ac	127	0.9%	80.6
Issaquah High School-Cell #24	ISHS-24	KCRTS	1/29/2009	pond	??			

Rainier Boulevard	ISRB	WWHM4	Jan 2014	bioretention	35420 sf	33.3	0.1%	35.8
Baron Residence Plat 2	MOBR	N/A						
Manry Residence Plat 3	MOMR	n/A						
David Brookings Rain Garden 1800 Continental Pl	MVDB	N/A						
Rosehill Community Center North Rain Garden	MKRH	WWHM3	3/23/2009	N/A	0.85 ac	979	2.6%	5.3
420 McPhee	OL420	N/A						
436 McPhee	OL436	N/A						
Decatur Raingarden	OLDE	WWHM2	7/6/2007	pond	11773 sf	13.5	0.1%	65.0
Yauger Park	OLYA	WWHM3 PRO	Dec 2011	bioretention	??			
Yelm Highway	OLYE	N/A						
Noll Road Roundabout Bioretention Cell	PUNR	WWHM3	5/13/2010	gravel trench	0.117 ac	143	2.8%	99.8
Viking Avenue Cell 4 (Lower)	PUVL	WWHM3	2/6/2009	pond	??			
Viking Avenue Cell 1 (Upper)	PUVU	WWHM3	2/6/2009	pond	??			
Waterfront Park Anderson Parkway	PUWA	WWHM3	11/13/2009	pond	??			
185th Bioretention Swale #3	RD185	WWHM3	2009	pond	0.95 ac	213	0.5%	66.5
Downtown Park	RDCC	N/A						
Creekside Elementary Rain Garden	SACR	N/A						
Ashworth Avenue-Cell 1 (18824)	SHAS-1	N/A						
Ashworth Avenue-Cell 2 (18834)	SHAS-2	N/A						
Ashworth Avenue-Cell 3 (18538)	SHAS-3	N/A						
Aurora Avenue Rain Garden Swale DR10-9	SHAU	N/A						
Spanaway Park Bioretention Area B	SPSP	Pierce Co LID Tool	12/19/2011	spreadsheet	3227 sf	6.1	0.2%	103.3
Central Maintenece Facility (IT-1)	SPCM	N/A						
Central Maintenece Facility (IT-2)	SPCM	N/A						
Dunn Residence	SMDR	N/A						
Woods at Golden Given (Cell 1)	TAWG-1	N/A						
Woods at Golden Given (Cell 7)	TAWG-7	N/A						

Total	54	
Design Software Total		28
Software: WWHM2/WWHM3		11
WWHM3 PRO/4		3
MGS Flood		5

KCRTS		2	
Waterworks/SBUH		6	
other		1	
Modeling Year			
	2006	3	
	2007	1	
	2008	0	
	2009	7	
	2010	9	
	2011	2	
	2012	0	
	2013	0	
	2014	2	
Model Method			
pond			15
bioretention			3
gravel trench			3
other			3