WRIA 9 Stormwater Retrofit BMP Design Assumptions

BMPs have been selected for evaluation using SUSTAIN to develop gross planning-level cost estimates of BMP treatment systems and associated design, permitting, materials, construction and maintenance and operation costs over a 30-year planning time frame (conceptually 2010 to 2040). Conceptually, two different BMP treatment scenarios will be evaluated. One scenario will consider only Natural Drainage Design or Low Impact Development (i.e.," Green") approaches to stormwater control (e.g., rain barrels, bioretention and porous pavement), while the second scenario will include downstream treatment using detention ponds[1] ("Gray" treatment approach) (see Figures 1 and 2).

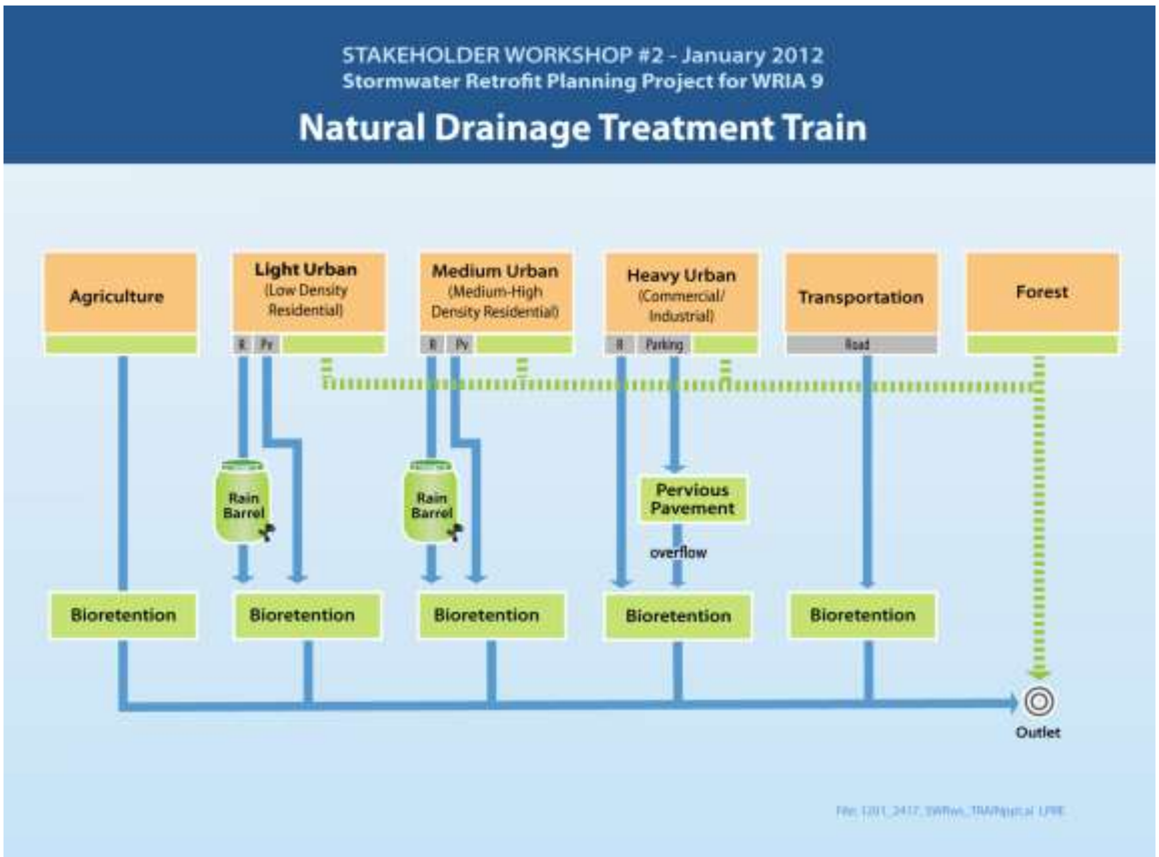

Figure 1. Natural Drainage Treatment Train

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[1] Detention ponds for this project are "stacked" ponds with a wet pond (standing water) with runoff storage available above the wet pond (often referred to as a dry pond). These types of ponds are used for water quantity and water quality treatment.

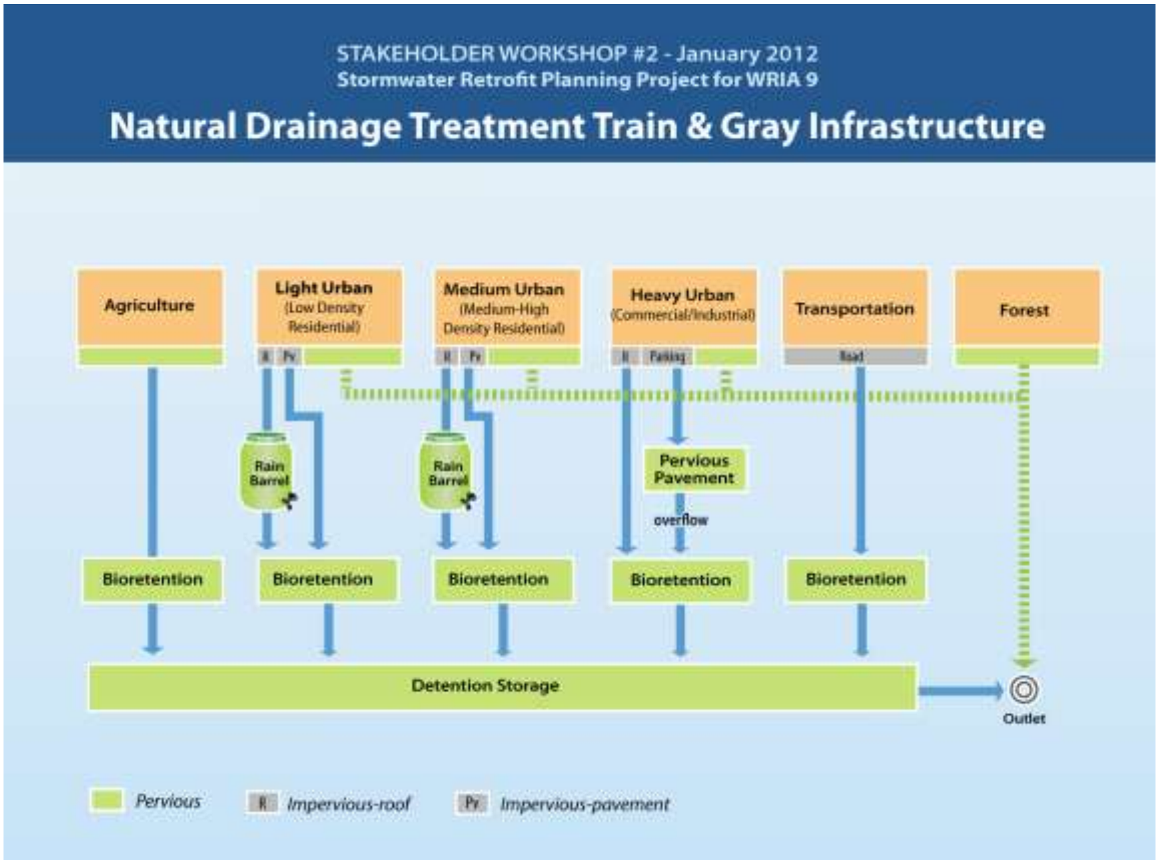

Figure 2 Natural Drainage & Gray Infrastructure Treatment Train

Stormwater BMP designs and associated unit costs for use in SUSTAIN were developed by a technical workgroup formed for this purpose.[2] Unit BMP costs proposed by the technical workgroup are described in a separate document.

Designs were tailored to provide inputs to the SUSTAIN model and as with many modeling exercises require simplification of as-built designs to match the complexity of the model. The design goals and general concepts are described for each BMP type below. The detailed SUTAIN model inputs required to implement these designs are provided in Table 1.

Residential On-site Detention Facilities

Two types of residential on-site detention BMPs were designed for use in SUSTAIN modeling scenarios. Conceptually, these BMPs will detain residential rooftop runoff, but will provide no water quality benefit. One design represents a standard 55 gallon rain barrel. The second design represents a much

[2] The technical workgroup consisted of King County staff (Jeff Burkey, Curtis DeGasperi, Mark Wilgus), Dr. Rich Horner (University of Washington) and Ben Parrish (City of Covington) and the workgroup was facilitated by Tamie Kellog (Kellog Consulting).

larger receptacle that might be described as a custom on-site detention facility or cistern, although the design for use in SUSTAIN does not include any indoor water use; rather the stored water is drained for outdoor use.

The residential rain barrel design is cylinder that is 1.9 ft in diameter and 2.6 ft in height ((1.9/2)^2 x PI x 2.6 = 7.37 ft^3; 7.37 x 7.48052 = 55.1 gal). Overflow to the rain garden occurs over a rectangular weir with a weir crest width of 5 ft so overflow from the barrel is not limited by the weir. The orifice is at the bottom of the barrel and has a diameter of 5/8" (0.625 in) to represent a standard hose fitting. The number of dry days required before water is released through the orifice is 1 day (i.e., 24 hours without any inflow to the barrel. The first-order pollutant decay rate will be set to zero so no TSS removal will occur in the barrel.

The custom on-site detention BMP is 10 ft in diameter and 5 ft in height ((10/2)^2 x PI x 5 = 392.7 ft^3; 392.7 x 7.48052 = 2,937.6 gal). Overflow to the rain garden occurs over a rectangular weir with a weir crest width of 5 ft so overflow from the facility is not limited by the weir. The orifice is at the bottom of the custom detention facility and has a diameter of 0.1 in. The number of dry days required before water is released through the orifice is 1 day. The first-order pollutant decay rate will be set to zero so no TSS removal will occur in the barrel.

Bioretention Facilities

Two types of bioretention facilities will be considered in this study. One type will represent a residential BMP that would be characterized as a rain garden. The second type of facility will represent a bioretention BMP that treats runoff from public roads. Depending on the underlying soil type, either facility may or may not have an underdrain. In areas underlain by very poorly drained soils (Type D soils), the facility will include an underdrain that will capture all of the infiltrated water. In all other areas, no underdrain will be included in the design.

A unit of bioretention will be represented by a 100-ft^2 area with a 1.5-ft layer of bioretention soil with a porosity of 0.4 (40%) and a 1-ft ponding depth[3]. Infiltration rates to native till and outwash soils (no underdrain) will be set to 0.5 and 2.0 in/hr, respectively, to represent long-term percolation rates in these soils. In areas with very poorly drained Type D soils, bioretention facilities will include an underdrain (i.e., no infiltration to native soils) that will release water to the outlet of the catchment or to the detention pond in the Green + Gray BMP scenario.

First-order TSS decay rates to simulate TSS removal in BMPs were selected based on analyses conducted by Herrera in their development of SUSTAIN models to evaluate cost-effective pollutant treatment approaches in an urbanized basin in Federal Way, WA. A 1st order TSS decay rate of 0.6/hr was chosen to simulateTSS removal in the bioretention cell. When an underdrain is present, a removal fraction of 0.08 will be used.

[3] The maximum ponding depth of 1 foot is based on expected revisions to the King County Surface Water Drainage Manual, which will require a Vb/Vr ratio of 3 (The ratio of the facility storage volume Vb to the volume of runoff from the mean annual storm Vr, where Vr = mean annual storm depth x runoff coefficient).

Porous Pavement

Porous pavement (consisting of concrete or asphalt) will be considered in this study and will represent replacement of impervious surfaces on private property, including parking lots and driveways with porous pavement. Depending on the underlying soil type, the porous pavement may or may not have an underdrain. In areas underlain by very poorly drained soils (Type D soils), the porous pavement will include an underdrain that will capture all of the infiltrated water. In all other areas, no underdrain will be included in the design.

A unit of porous pavement will be represented by a 100-ft^2 area with a 1.6-ft layer of porous surfacing material and engineered subsurface aggregate layers with an average porosity of 0.3 (40) and a 0.01-in depression storage depth. Infiltration rates to native till and outwash soils (no underdrain) will be set to 0.5 and 2.0 in/hr, respectively, to represent long-term percolation rates in these soils. In areas with very poorly drained Type D soils, porous pavement will include an underdrain (i.e., no infiltration to native soils) that will release water to the outlet of the catchment or to the detention pond in the Green + Gray BMP scenario before release to the assessment point.

First-order TSS decay rates to simulate TSS removal in BMPs were selected based on analyses conducted by Herrera in their development of SUSTAIN models to evaluate cost-effective pollutant treatment approaches in an urbanized basin in Federal Way, WA. A 1^{st} order TSS decay rate of 0.03/hr was chosen to simulateTSS removal by porous pavement. When an underdrain is present, a removal fraction of 0.08 will be used.

Detention Pond

Public stormwater detention facilities will be considered in this study to represent “gray” as opposed to the “green” or Low Impact Development (LID) BMPs addressed above. Detention ponds were designed using version 3.0 of the Western Washington Hydrology Model (WWHM3). Three separate pond designs were developed for treatment of 1-acre of runoff from three levels of development identified in the 2007 Land Use/Land Cover data used in the HSPF model set up for this project. These development categories in HSPF are described as 1) Commercial/Industrial, 2) Medium Density Residential and 3) Low Density Residential. Conceptually, these ponds are sealed and no infiltration to native soils occurs.

For the treatment of runoff from Commercial/Industrial land, the unit pond length and width are 105 and 35 ft, respectively. The rectangular overflow weir is 5.2 ft above the pond bottom with a width of 4.4 ft and the 0.542-in diameter orifice is 1.2 ft above the pond bottom.

For the treatment of runoff from Medium Density Residential development, the unit pond length and width are 85 and 28 ft, respectively. The rectangular overflow weir is 5.4 ft above the pond bottom with a width of 4.4 ft and the 0.537-in diameter orifice is 1.4 ft above the pond bottom.

For the treatment of runoff from Low Density Residential development, the unit pond length and width are 71 and 24 ft, respectively. The rectangular overflow weir is 5.1 ft above the pond bottom with a width of 4.4 ft and the 0.547-in diameter orifice is 1.1 ft above the pond bottom.

First-order TSS decay rates to simulate TSS removal in BMPs were selected based on analyses conducted by Herrera in their development of SUSTAIN models to evaluate cost-effective pollutant treatment approaches in an urbanized basin in Federal Way, WA. A 1st order TSS decay rate of 0.02/hr was chosen to simulateTSS removal.

Table 1 SUSTAIN BMP Design Details

	Residential On-site Detention Facility		Bioretention		Porous Pavement		Detention Pond
	Rain Barrel	Custom design	Outwash / Till	D Soils	Outwash / Till	D Soils	(e.g., Urban High)
Design Unit Size	7.37 ft^3 (55 gal)	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2	19,110 ft^3
Design Drainage Area a	0.01 ac	0.04 ac	0.0215 ac	0.0215 ac	100 ft^2	100 ft^2	1 acre
Infiltration Model (Green-Ampt, Horton, Holtan) [INFILTM]	NA	NA	2 (Holtan)	2 (Holtan)	2 (Holtan)	2 (Holtan)	NA
Pollutant Removal Method (1st Order Decay, K-C' method – Kadlec and Knight Method) [POLREMM]	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)	0 (1st Order Decay)
Pollutant Routing Method (Completely Mixed, CSTRs in series) [POLROTM]	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)	1 (Completely Mixed)
Dimensions Tab							
Number of Units	Optimize	Optimize	Optimize	Optimize	Optimize	Optimize	Optimize
Diameter/Length (ft) **[LENGTH]**	1.9	10	10	10	10	10	105
Width (ft) **[WIDTH]**	NA	NA	10	10	???	???	35
Exit Type **[EXITTYPE]**	1	1	1	1	NA	NA	1
Orifice Diamter (in) **[DIAM]**	0.625	0.1	0	0	NA	NA	0.542
Orifice Height (Ho, ft) **[OHEIGHT]**	0	0	0	0	NA	NA	1.2
Release Type **[RELEASETYPE]**	2	2	NA	NA	NA	NA	3

	Residential On-site Detention Facility		Bioretention		Porous Pavement		Detention Pond
	Rain Barrel	**Custom design**	**Outwash / Till**	**D Soils**	**Outwash / Till**	**D Soils**	**(e.g., Urban High)**
Design Unit Size	7.37 ft^3 (55 gal)	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2	19,110 ft^3
Number of dry days **[DDAYS]**	1	1	NA	NA	NA	NA	NA
Number of People **[PEOPLE]**	NA	NA	NA	NA	NA	NA	NA
Weir Type **[WEIRTYPE]**	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)	1 (rectangular)
Weir Height (Hw, ft) **[WEIRH]**	2.6	5	1.0	1.0	0.01	0.01	5.2
Rectangular Weir Crest Width (B, ft) **[WEIRW]**	5	5	10	10	10	10	4.4
Triangular Weir Angle (theta, deg) **[THETA]**	NA	NA	NA	NA	NA	NA	NA
Substrate Properties Tab							
Depth of Soil (Ds, ft) **[SDEPTH]**	NA	NA	1.5	1.5	1.6	1.6	NA
Soil Porosity (0-1) **[POROSITY]**	NA	NA	0.4	0.4	0.3	0.3	NA
Soil Field Capacity **[FCAPACITY]**	NA	NA	0.244	0.244	NA	NA	NA
Soil Wilting Point **[WPOINT]**	NA	NA	0.136	0.136	NA	NA	NA
Initial Surface Water Depth (ft) **[WATDEP_I]**	NA	NA	0	0	0	0	NA
Initial Moisture Content (0-1) **[THETA_I]**	NA	NA	0	0	0	0	NA
Saturated Soil Infiltration (in/hr) **[FINFILT]**	NA	NA	2.0 / 0.5	0	2.0 / 0.5	0	NA
ET Multiplier **[ET_MULT]**	NA	NA	1.0	1.0	1.0	1.0	NA
Route Infiltration to Aquifer	NA	NA	Yes	NA	Yes	NA	NA
Consider Underdrain Structure **[UNDSWITCH]**	NA	NA	0 (No)	1 (Yes)	0 (No)	1 (Yes)	0 (No)
Storage Depth (Du, ft)	NA	NA	NA	0.5	NA	0.25	NA

	Residential On-site Detention Facility		Bioretention		Porous Pavement		Detention Pond
	Rain Barrel	Custom design	Outwash / Till	D Soils	Outwash / Till	D Soils	(e.g., Urban High)
Design Unit Size	7.37 ft^3 (55 gal)	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2	19,110 ft^3
[UNDDEPTH]							
Media Void Fraction (0-1) **[UNDVOID]**	NA	NA	NA	0.5	NA	0.35	Na
Background Infiltration (in/hr) **[UNDINFILT]**	NA	NA	NA	0	NA	0	Na
Route Underdrain/Outlet to:	Bioretention	Bioretention	NA	Outlet/Pond	NA	Outlet/Pond	Outlet
Infiltration Parameters Tab							
Green-Amp Infiltration Parameters	NA	NA	NA	NA	NA	NA	NA
Suction Head (in) **[SUCTION]**	NA	NA	NA	NA	NA	NA	NA
Initial Deficit (fraction) **[IMDMAX]**	NA	NA	NA	NA	NA	NA	NA
Horton Infiltration Parameters							
Maximum Infiltration (in/hr) **[MAXINFILT]**	NA	NA	NA	NA	NA	NA	NA
Decay Constant (1/hr) **[DECAYCONS]**	NA	NA	NA	NA	NA	NA	NA
Drying Time (day) **[DRYTIME]**	NA	NA	NA	NA	NA	NA	NA
Maximum Volume (in) **[MAXVOLUME]**	NA	NA	NA	NA	NA	NA	NA
Holtan Infiltration Parameters							
Vegetative Parameter A **[AVEG]**	NA	NA			1	1	Na

	Residential On-site Detention Facility		Bioretention		Porous Pavement		Detention Pond
	Rain Barrel	**Custom design**	**Outwash / Till**	**D Soils**	**Outwash / Till**	**D Soils**	**(e.g., Urban High)**
Design Unit Size	7.37 ft^3 (55 gal)	393 ft^3 (2,938 gal)	100 ft^2	100 ft^2	100 ft^2	100 ft^2	19,110 ft^3
Monthly Growth Index **[GIi]**	NA	NA	1	1	1	1	NA
Water Quality Parameters Tab (for TSS)							
Decay factor (1/hr) **[QUALDECAY1]**	0	0	0.6	0.6	0.03	0.03	0.02
K (ft/yr) **[QUALK1]**	NA	NA	NA	NA	NA	NA	NA
C* (mg/L) **[QUALC*1]**	NA	NA	NA	NA	NA	NA	NA
Underdrain Removal Rate (fraction, 0-1) **[QUALPCTREM1]**	NA	NA	NA	0.08	NA	0.08	NA

NA = Not applicable.

a The design drainage area is a conceptual starting point used to estimate an upper limit on the number of each BMP type to use in cost-effectiveness optimization model runs. Initial optimization model results can then be used to refine the range and number of intervals to use in final cost-effectiveness optimization runs.