

# Seattle Public Utilities Green Stormwater Infrastructure: O&M Program



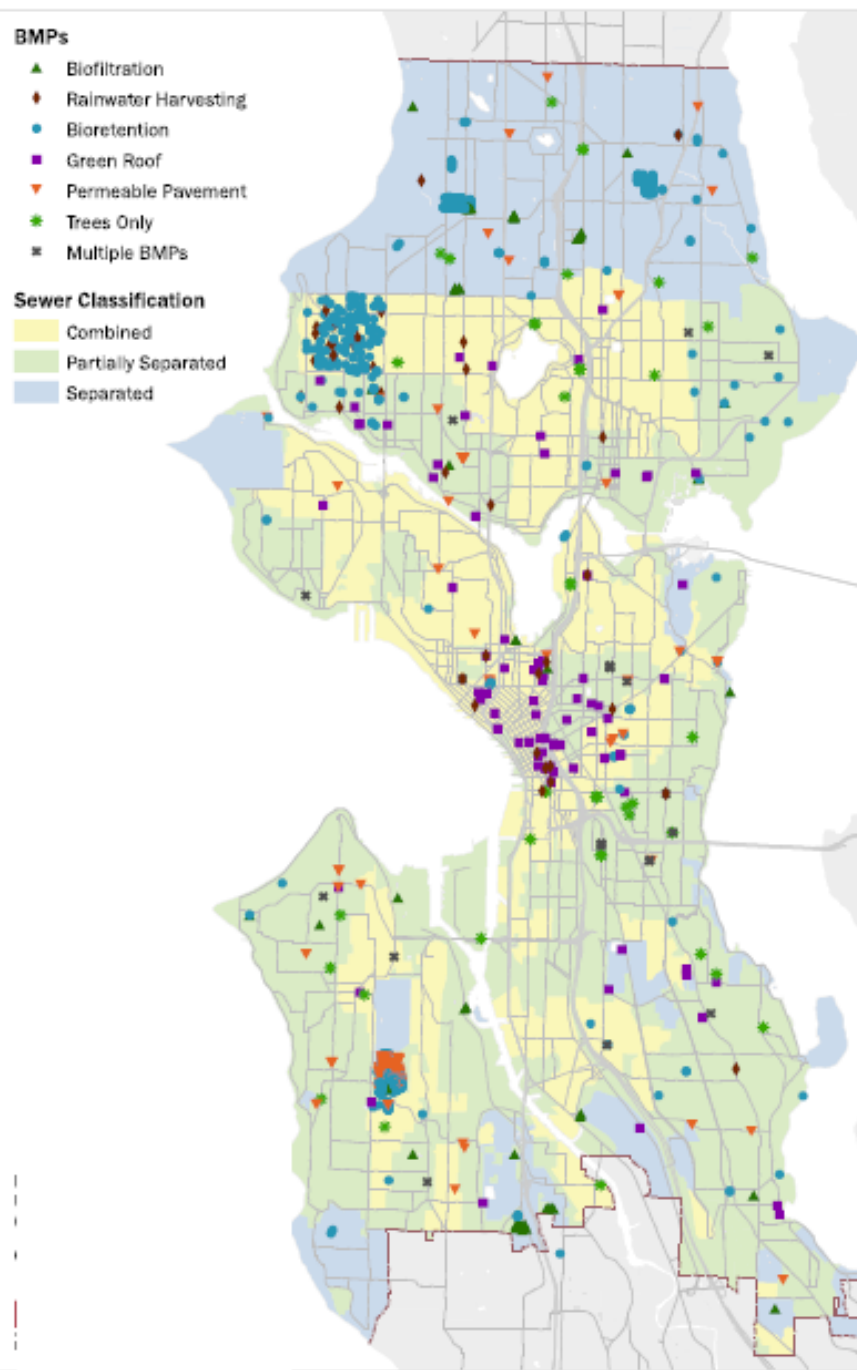


### BMPs

- ▲ Biofiltration
- ◆ Rainwater Harvesting
- Bioretention
- Green Roof
- ▼ Permeable Pavement
- ★ Trees Only
- ✱ Multiple BMPs

### Sewer Classification

- Combined
- Partially Separated
- Separated



# Operations and Maintenance

- O&M Maintenance Took Kit
  1. Landscape Maintenance Manual
  2. GSI/LID Maintenance Manual for ROW
  3. Identifiable and detailed levels of service
  4. Porous Pavement
  5. O&M Facility Checklists
  6. Key Performance Indicators
- Life Cycle Costs
- Maintenance Costs
- Additional Tools
- Risks/Lessons Learned

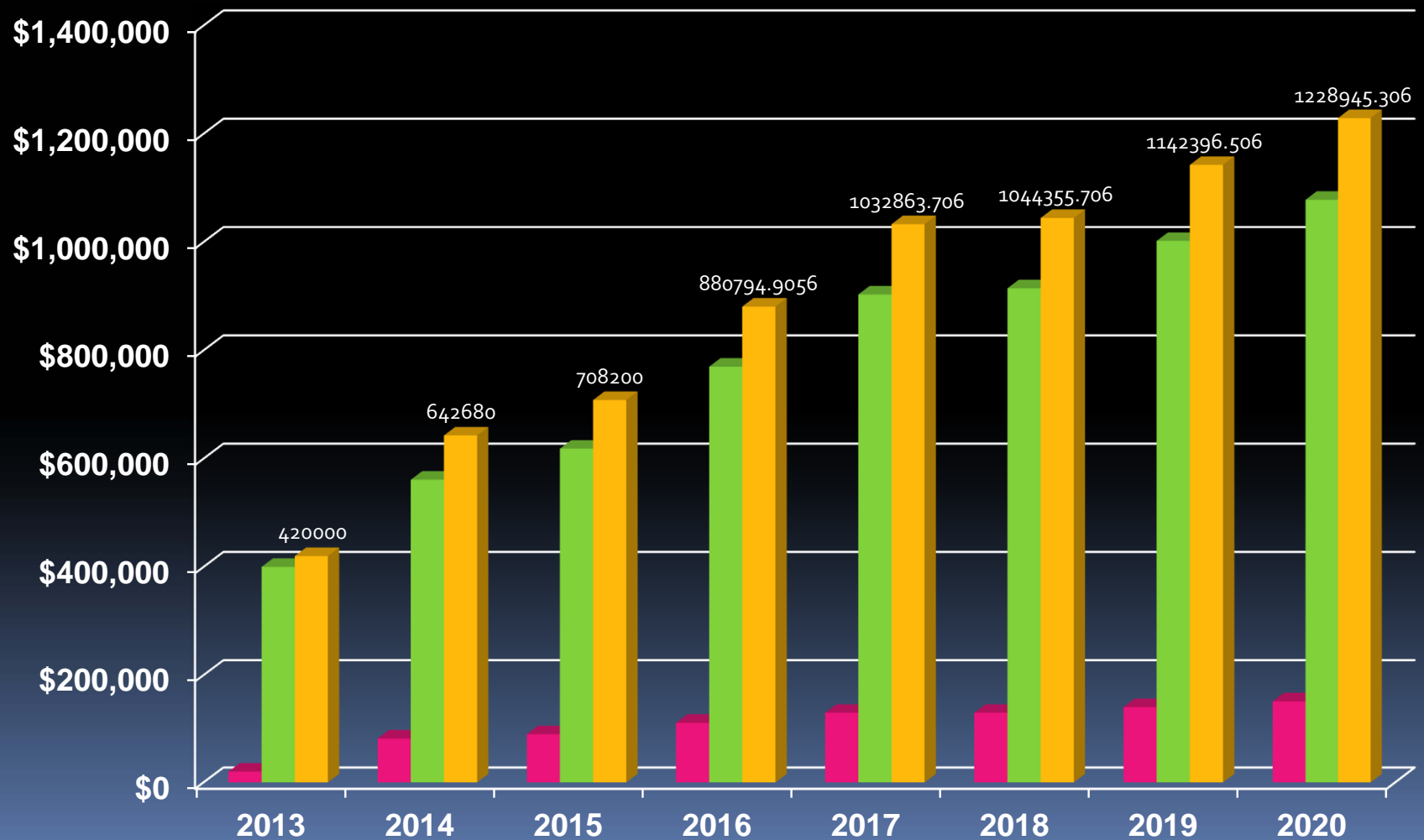
# Current and Forecasted Bioretention



- **Current (2000-14)**
- 180K sq ft
- \$500K budget
- **2014-2020**
- SPU: 42 acres
- SDOT: +/- 2.5 acres
- King County: 442 acres
- \$1.3M O&M budget



# Strategic Business Plan - O&M Baseline Budget



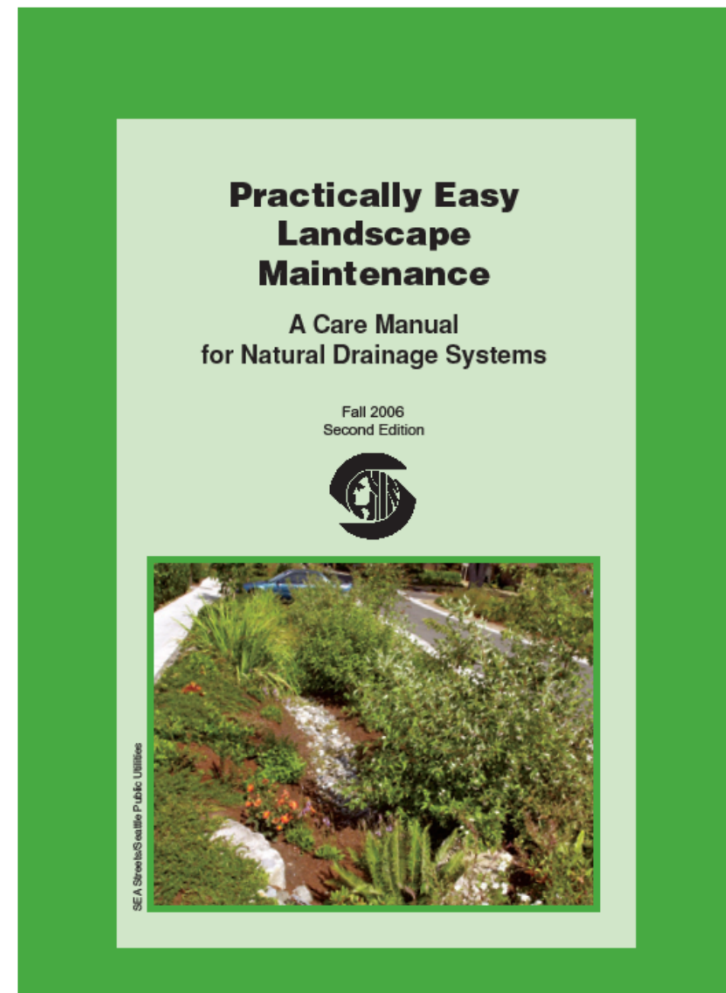
# SPU Tools





# Homeowners Landscape Manual

- Landscape Maintenance Manual
- Maintenance personnel
- Homeowners living adjacent to systems





# Restoration and Repair Manual

- ~ 10 Swales retrofitted
- ~ 4 possible failures 3-11
- ~ 2 possible infiltration failure 3-13





# Maintenance Management

## Two crews

- Hardscape: city crew
- Landscape: contractor through 2020

## Scheduled by LOS –*not frequency!*

## Semi annual inspections

- pre fall
- pre spring





# GSI Manual Sections

## Inspection/Checklist and Maintenance Activities

1. Vegetation and Landscaping
2. System Functionality
3. Hardscape and Infra-Structure
4. Infiltration Failure – Swale  
Ponding
5. Recommended Maintenance  
for Other Elements
6. Safety, Mobility, and  
Accessibility





# Maintenance Manual

- Summary
  - Routine maintenance activities
  - Non-routine maintenance activities
  - Inspection/checklist
  - Scheduling and performing maintenance activities in the ROW
  - Images and descriptions



# Program is currently designed

- Levels of Service
- LOS A – D
- Changing to meets NPDES requirements
- LOS to Acceptable/Unacceptable





# SPU Practice Changes

- Asset management tracking
  - Equipment #'s (EQ#'s) assigned and noted on CD level drawings
- Design for major program maintenance
  - Improve standard design and specifications
  - GSI Design Phase Asset checklist
    - Non-standard elements require approval early in design process
    - Identifies in design potential long term cost issues of non standard elements

# Changes and Improvements

- Third party inspection
  - Engineer of record
  - Landscape Architect of record
  - Geotechnical Engineer of record
- Clarity on acceptable maintenance
  - Compliance with NPDES
  - Communicating standard maintenance for function



# Updated GSI O&M Manual for ROW


## Summary of Topics

- Transition from construction and establishment
- Operations: Defining parameters and resources
- Bioretention surface maintenance
- Structures and subsurface maintenance
- Deep infiltration maintenance
- Permeable pavement maintenance
- Outsourcing and stewardship
- Storm events
- Inspection
- Public engagement
- Maintenance agreements




# Maintenance Guidelines-Update

- Identify asset categories
- Tie to Washington State Ecology
- Priority for function and safety
- Key observation items
- Maintenance activity
- Frequency
- Performance standard
- Adaptable for *Maximo*
- Adaptable for Work Order contracting



**King County**  
Department of  
Natural Resources and Parks  
Wastewater Treatment  
Division



**Seattle Public Utilities**  
SIGN COMPANY

## ROUTINE MAINTENANCE GUIDELINES FOR ESTABLISHED (1-3 YEARS AFTER INSTALLATION)




**INTERNAL WORKING DRAFT 4-30-2014** **This draft Bioretention Only**

**Notes:**

- The following table for SPU/MTD GSI program for bioretention (in City ROW) is based on the "Guidance Document: Western Washington Low Impact Development (LID) On Site".
- Click on the photos to link to an enlarged image and description. Click on the enlarged image to return to the table.

**\* Frequency Code**

R = Routine Visits (March, July, September and October - Adjust fall visits to follow tree leaf drop) M=Monthly  
 A = Annual visit in September (unless otherwise noted) W= Weekly  
 B = Biannual visits in March and September (unless otherwise noted)

GSI Facility Asset / Component		Priority for Function or Safety	INSPECTION	C O D E	Frequency	Est. Crew Hrs	Maintenance Activity (Crew)	C O D E
			Observation or Troubleshooting (Note 1. See also Long Term Table)					
◆ ◆ ◆ Major Storm or Weather Events ◆ ◆ ◆								
	Curb Cuts, Catch Basins (CB), and Weirs	HIGH PRIORITY	<input type="checkbox"/> Blockage	—	<input type="checkbox"/> Before Storm/ Notification of Storm Event <input type="checkbox"/> After Storm Event <input type="checkbox"/> After CSO Notification		<input type="checkbox"/> Remove at a minimum blockages/leaves from drain curb cuts at presetting zones, from the curb cut at the first cell after presetting and from the curb cut at the low point or corner. Remove blockages from all curb cuts if time allows. <input type="checkbox"/> Remove blockages from weirs and last CB	—
	Street Surface	HIGH PRIORITY	<input type="checkbox"/> Sand or salt	—	<input type="checkbox"/> After snow storm		<input type="checkbox"/> Sweep if sand or salt is used during a snow event and the City does not sweep	—
	Extreme drought/ Water Restrictions	HIGH PRIORITY	<input type="checkbox"/> Extreme Drought <input type="checkbox"/> Water restrictions	—	<input type="checkbox"/> Water restrictions		<input type="checkbox"/> Water facility bottom area vegetation first. <input type="checkbox"/> Limit water to remaining planted areas.	—
▲ ▲ ▲ A. Facility Footprint ▲ ▲ ▲								
A1	Soils	  	<input type="checkbox"/> Soil protection during maintenance	—	—		<input type="checkbox"/> When possible, perform maintenance work when soils are dry to prevent compaction and damage to soil structure.	—
			<input type="checkbox"/> Erosion and washouts	B	March September		<input type="checkbox"/> Fill in erosion gullies and clean up washouts <input type="checkbox"/> Install temporary erosion control measures until permanent repairs are made <input type="checkbox"/> Identify and remedy what is causing erosion and/or washouts <input type="checkbox"/> Place cobbles or other erosion protection measure where concentrated water flows	R
			<input type="checkbox"/> Settlement	B	March September		<input type="checkbox"/> Add mulch when settlement is less than 4 inches	R
			<input type="checkbox"/> Vegetative cover	B	March September		<input type="checkbox"/> Observe and report if plant coverage is less than 75% at bottom zone	B
			<input type="checkbox"/> Water is not draining <sup>1</sup> <input type="checkbox"/> Sediment accumulation	B	March September		<input type="checkbox"/> Report non-draining swales <input type="checkbox"/> Remove sediment <input type="checkbox"/> Attempt to identify and remedy source of sediment	R
A2	Check Dams		<input type="checkbox"/> Blockage <input type="checkbox"/> Backed up water <input type="checkbox"/> Undercutting <sup>1</sup>	A	September		<input type="checkbox"/> Remove surface blockages, debris, sediment & fall leaf litter.	R
A3	Weirs	HIGH PRIORITY	<input type="checkbox"/> Blockage <input type="checkbox"/> Backed up water <input type="checkbox"/> Undercutting <sup>1</sup>	B	March September		<input type="checkbox"/> Remove surface blockages, debris, sediment & fall leaf litter	R



# Focus on Acceptable

## ACCEPTABLE MAINTENANCE



Mostly healthy vegetation with good appearance



Appearance is good



Occasional weedy species (5-10%)



Some erosion and bare spots (0-5%)

## UNACCEPTABLE MAINTENANCE



Debris buildup



Appearance is poor



Weedy



Overgrown

<http://www.kingcounty.gov/environment/wtd/Construction/Seattle/BartonCSO-GSI/LandscapeMaint.aspx>

# 1-Vegetation and Landscape Maintenance

- **Inspection/checklist**
- Vegetation is mostly healthy
- Good appearance
- Small quantities of weeds
- Edges are loosely defined
- Grass encroaching on the swale (or vice versa)

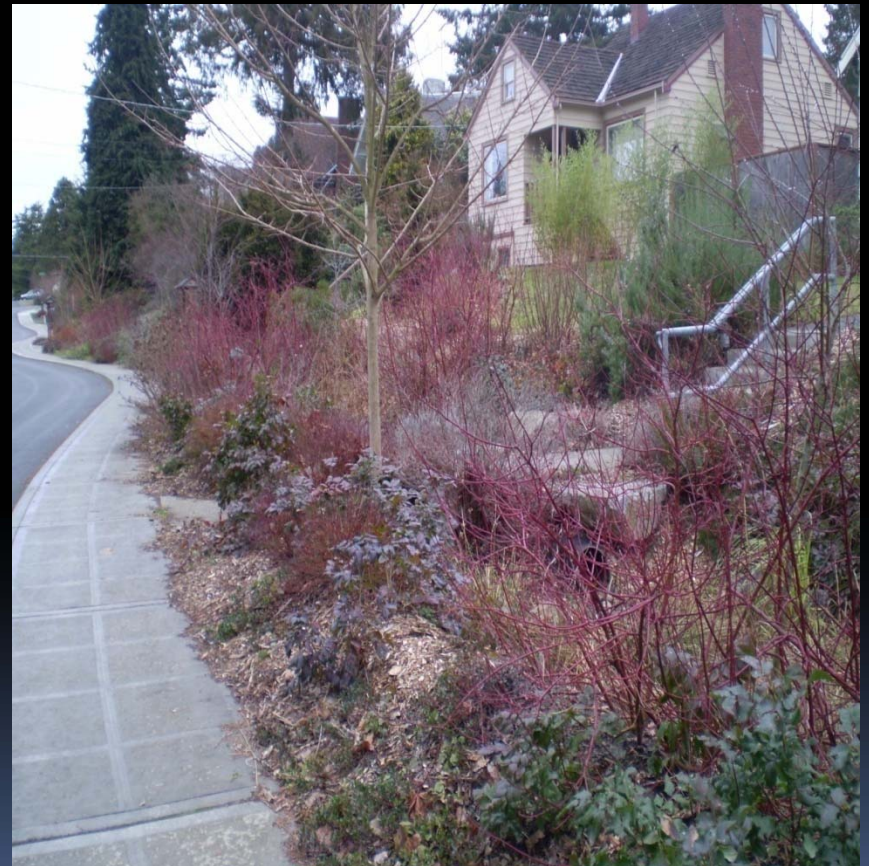


Levels of Service B - Good



# Levels of Service B - Good

- **Inspection/checklist**
- Plants growing onto the street or sidewalk
- Mulch is present with occasional bare spots
- Erosion is likely unless maintenance is improved
- Some shoulder compaction adjacent to the swale
- Plant palette is mostly working for the facility



# Noxious and Nuisance Weeds

- Special considerations need to be identified
- Provide link to jurisdiction's web site
- Photos
- Identification key
- Reporting requirements – *if applicable*

*Spotted Knapweed*

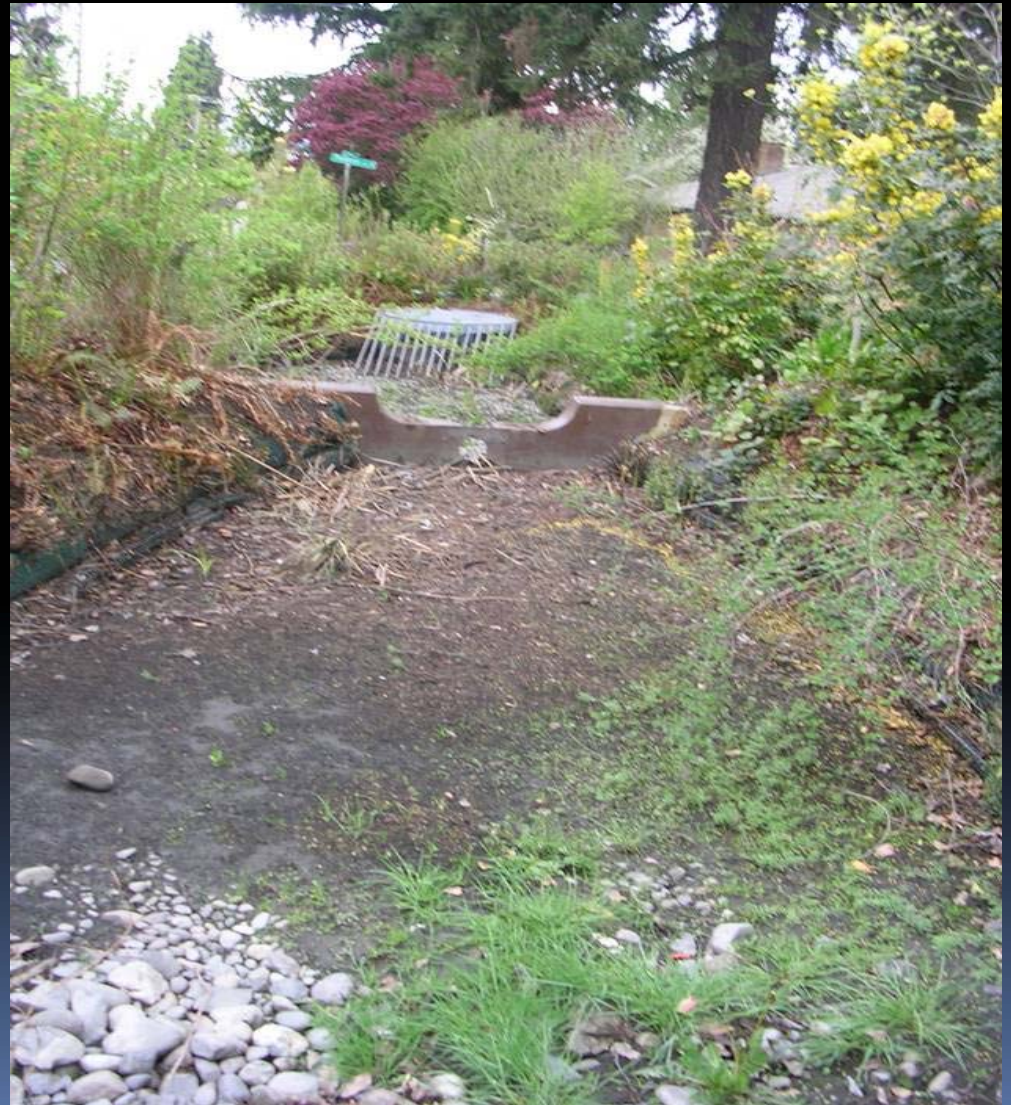




# 2-System Functionality

- Bioretention
- Biofiltration
- Bioretention and biofiltration
- Vegetation, soils, and substrate

*Level of Service D*





# Inspection/checklist LOS C

- Bioretention and or biofiltration
  - ▣ for vegetation, soils and substrate
- 40% to 60% bottom covered
- Healthy vegetation
- Uniformed fine-stemmed at least 18 to 24 inches high





# Continued...

- Soil is compacted
- Evidence of vehicle compaction
- Ponded water takes at least 72 hours to drain
- Many bare spots
- Significant level of sediment and debris accumulation



# 3-Hardscape and Infra-Structure

- Debris and sediment removal
- Clearing and cleaning





# Hardscape and Infra-Structure

## – Long Term Maintenance

- Every fifteen years
- Remove and replace top two inches of sediment
- Prevent swale clogging
- Maintains infiltration rates









# All Levels of Service-Meet permit requirements

- Stormwater sedimentation structures are less than  $\frac{1}{2}$  full or in accordance with NPDES requirements



## 4-Infiltration Failure

- Evidence of a cell holding water for more than 24 hours needs to be reported
- Operations and Maintenance Asset Manager
- Monitor swale for ponding water
- Retrofit swale





# 5-Recommended Maintenance for Other Elements

- Pest control
- Spill prevention and response
- Permeable pavements
- Irrigation systems





# Section 6: Safety

Accessibility

ADA

Right plant for right  
place

Simplified plant pallet

Maintenance access





# Checklists

- Condensed version of manual
- Developed for each section of the manual
- Reduce maintenance activities to a summary
- Eliminate photos
- Identify key performance indicators
  - monitoring and reporting



# Key Performance Indicators (KPI's)

- Data includes
  - Project location
  - Drainage area
  - Maintenance target
  - Reporting of maintenance LOS achieved
- Provides
  - Accountability
  - Reporting method
- Excellent asset management tool for management

NDS KPI Reporting Form  
USM Urban Watersheds

Date: \_\_\_\_\_

Project Location	Drainage area (sq ft)	Hardscape Maintained to:		Land-scaped area (sq ft)	Vegetation Maintained to:		Infiltration Failure	
		Target	Actual		Target	Actual	Yes/No	Cells retrofitted (Urban Ecosystems)
Carkeek Cascade at NW 110th	4,730	B		17,130	B			
Comments								
Project Achievement								
Broadview Green Grid - Carkeek Cascades at NW107th	8,240	B		29,330	B			
Comments								
Project Achievement								
Pinehurst Green Grid	19,160	B		69,650	B			
19th Avenue NE	3,170	B		9,850	B			
20th Avenue NE	5,390	B		27,370	B			
23rd Avenue NE	5,710	B		18,160	B			
NE 117th Street	2,240	B		8,400	B			
NE 113th Street	2,320	B		7,870	B			
25th Ave NE	330	B		??	B			
Comments								
Project Achievement								
High Point		B			B			
Comments								
Project Achievement								
Broadview Green Grid - SEA Streets	9,470	B		63,640	D			
Phinney Ave N SEA Street	2,000	B		15,700	D			
Palatine Ave N SEA Street	2,840	B		19,080	D			
1 <sup>st</sup> Ave NW SEA Street	2,060	B		12,130	D			
2 <sup>nd</sup> Ave NW SEA Street	2,570	B		16,730	D			



# Life Cycle Costs




# Life Cycle Costs - Pinehurst

- Present value of O&M + construction costs
- LCC for Pinehurst (47,290 ft<sup>2</sup>)
  - \$1.2M + \$5.2M = \$6.4M
- Initial estimates
  - \$4.8 million construction cost
- Comparable project to retrofit \$8.9 million
- Total project cost 453K for 660 ft blk
  - Includes all design, project management, const. cost
- Present value of O&M costs compared to traditional systems is significantly less





# Construction Costs

- \$280,000 for 660' block
  - 42% Stormwater elements (including soil)
  - 45% Street improvements (road, curb, sidewalk)
  - 13% Landscaping
- 

# Maintenance Costs





# Total Maintenance Cost

- Total \$\$ = Vegetation + Hardscape
- Initial Vegetation – 3 years
  - SPU cost: \$2.21
  - Watering method and frequency increase cost up to 4X
- Established Vegetation – 4 plus
  - SPU cost: \$1.66
  - 25% reduction
- Replacement costs - \$0.50 per sq. ft.
- Hardscape - \$0.31 per sq. ft.

# Additional tools and resources





# Example: Design Phase GSI ROW Checklist for O&M Asset Management to ensure consistency in approach as the program grows.

- A. Facility Footprint
- B. Inlets/Outlets/Pipes – Surface
- C. Inlets/Outlets/Pipes – Subsurface
- D. Vegetation
- E. Mulch
- F. Watering
- G. Deep Infiltration (over 6 feet)
- H. Permeable Pavement Facility
- I. Hardscape/ Specialty Elements

FOR INTERNAL DISCUSSION PURPOSES

SPU/WTG GSI Program Management SPU #C12-004  
DRAFT Preliminary ROW GSI Components Checklist for O Assets  
Date: May 5, 2014  
SVR #12034

King County Department of Natural Resources and Parks  
Seattle Public Utilities  
SVR DESIGN COMPANY

**RIGHT OF WAY BASED GSI COMPONENT CHECKLIST FOR O&M ASSET MANAGEMENT**  
WORKING DRAFT 5-3-2014 This draft Bioretention focus -placeholders for others

Notes:

GSI Facility Asset / Component		CHECK			Asset or EQ# If available	NEW Type Tool, design, location, material etc	ADDITIONAL INFO Reason for adding a new asset	APPROVED FOR USE		
		Is it defined in GSI Manual Vol V-O&M? If no then go to NEW type column.	Meets SPU Standard?	Meets WTD Standard?				Agency PM	O&M Mgr	Title?
▲▲▲ A. Facility Footprint ▲▲▲										
A1	Soils	COS Bioretention Mix								
		ECY Bioretention Mix								
		COS Mineral Aggregate Type 26								
		COS Mineral Aggregate Type 24								
		COS Mineral Aggregate Type 6 - sand								
A2	Check Dams	Rock								
A3	Weirs	Concrete								
		Wood or Composite								
		Boulder/stone								
		Segmental								
A4	Vertical Walls	Concrete								

\\bz-sr\project\1212034 SPU GSI PM\Task 3-Tech Analysis\Support\GSI Manual\Vol V - O&M & Inspection\O&M Tables\_Checklist\SPU\_WTD\_GSI\_O&M Table DRAFT\_Rev5ecrpt.xls

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# Porous Pavement

- SPU porous pavement spec
- Inspector and installer checklists
- BMP's
- Levels of services
- Frequency schedule & method
- Standardized infiltration testing
- Recommended maintenance activities
- Technical Report -available





# Client Assistance Memo's

- Mostly for Private Facilities
- Post Construction Soil Management
- Bioretention Cells (Rain Gardens)
- Permeable Pavement Surfaces and Facilities
- Tree Planting
- Green Roofs
- Bioretention Planters

# Private Property O&M

## D.9 Operation and Maintenance Requirements for NDS Stormwater Facilities

### D.9.1 Bioretention (Swales and Planters): Inspection and Maintenance Requirements

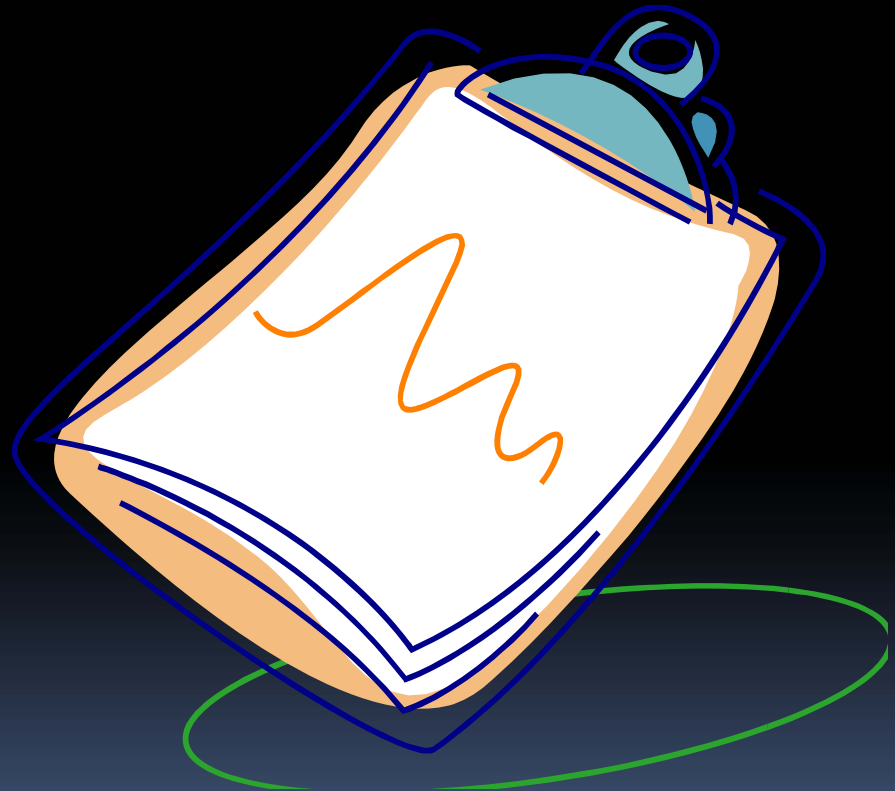
#### Inspection and Maintenance Requirements for Bioretention (Swales and Planters)

Components	Inspection Frequency <sup>1</sup>	Condition when Maintenance Required	Action Required	Satisfactory	Unsatisfactory	Comments
<b>Ponding Area (address applicable components)</b>						
Concrete planter reservoir	Biannually	Rot, cracks or failure in planter structure.	Repair/replace			
Earthen reservoir (embankments, dikes, berms, and side slopes)	Biannually (S)	Erosion (gullies/rills) greater than 2 inches around inlets, outlet, and along side slopes.	Eliminate source of erosion and stabilize damaged area (regrade, rock, vegetation, erosion control blanket)			
	Annually (W,S)	Settlement greater than 4 inches (relative to undisturbed sections of berm)	Restore to design height			
	Annually (S)	Downstream face of berm or embankment wet, seeps or leaks evident	Plug holes. Contact geotechnical engineer ASAP.			
	Annually	Any evidence of rodent holes or water piping around holes if facility acts as dam or berm	Eradicate rodents/repair holes (fill and compact)			
Sediment or debris accumulation	Quarterly	Sediment or debris accumulates.	Remove excess sediment or debris. Identify and control the sediment source (if feasible).			
Rockery reservoir or walls	Annually	Rock walls are insecure.	Stabilize walls			
Basin inlet via surface flow	Biannually (S)	Soil is exposed or signs of erosion are visible.	Repair and control erosion sources			
Basin inlet via concentrated flow (e.g., curb cuts)	Biannually (S)	Sediment, vegetation, or debris partially or fully blocking inlet structure.	Clear the blockage. Identify the source of the blockage and take actions to prevent future blockages.			



# ROW Facilities - documentation

- Construction and installation checklist
- Plan review checklist for bioretention
- Plan review checklist for permeable pavements
- GSI Restoration and Repair Manual



# SPU Specifications:

- Bioretention infiltration testing
- Porous pavement infiltration testing
- Bioretention soil
- Permeable/porous pavement
- Weir installation





A photograph of a stormwater runoff area. In the upper center, a black pipe outlet is visible, surrounded by grey rocks. The area is filled with dense green bushes and tall, dry, brown grasses. In the background, a paved road with several parked cars (a white car, a dark SUV, and a red car) is visible. The text "Risks" and "Lessons Learned" is overlaid in large red font in the center of the image.

# **Risks**

# **Lessons Learned**



# Inspection Processes and Protocols

















# Successful liner installation





# Evolving Systems

- Work, work, work with field or contracting crews
- Update photos to continue refining doc.

Document  
learned

- Include BMP's











## Minimal maintenance – Functioning system

- Erosion control during plant establishment (3yr)
- Tree canopy (leaf litter)
- Plant pallet (bushes shade swale bottom)





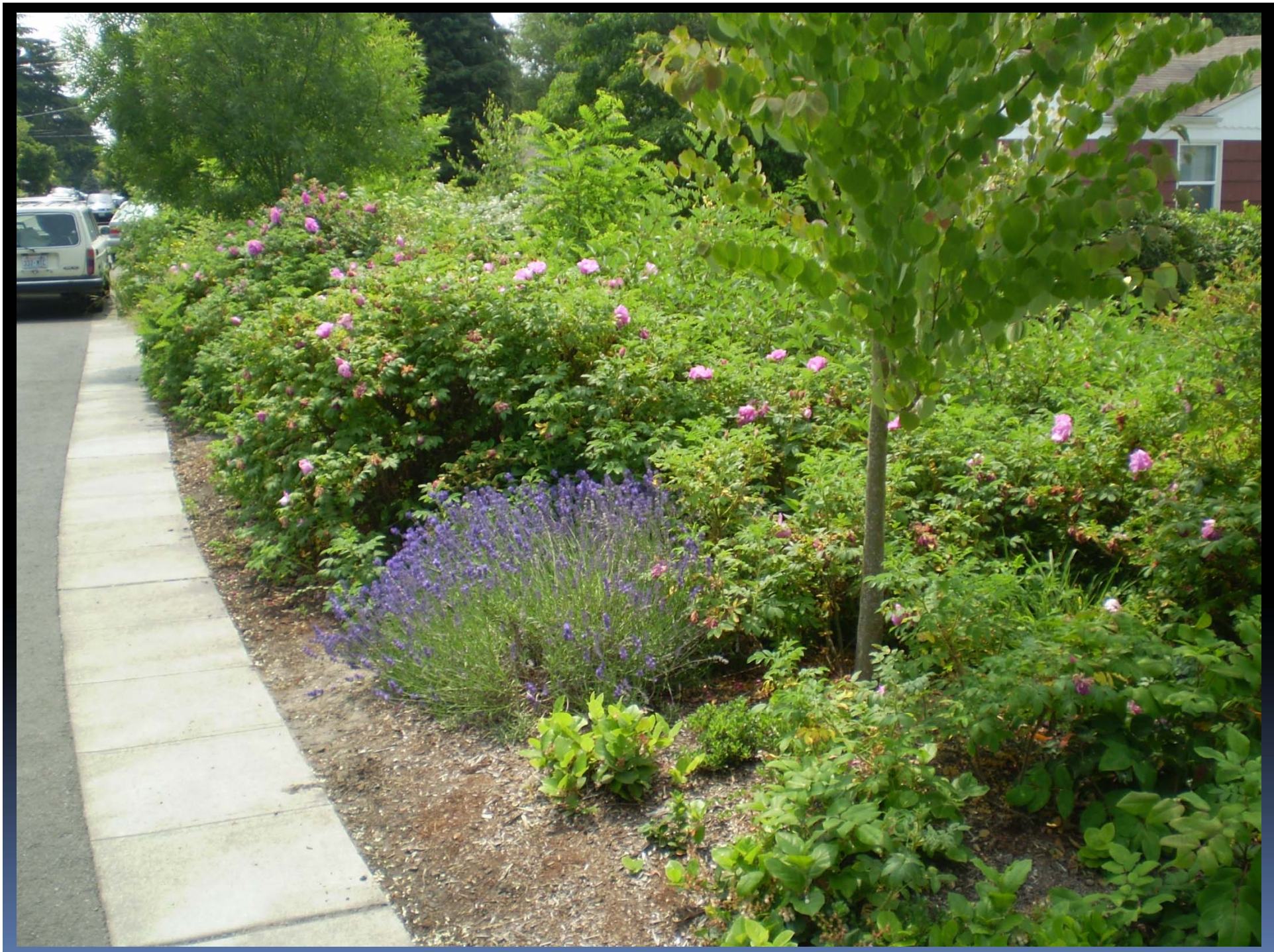
- Planting season
- Plants available
- Interim?





**Maintenance can be overwhelming**













**Acceptable? Still functions**



- 
- **Invasives**
  - **Aesthetically unpleasing**
  - **Neighborhood nuisance**
  - **Still functions**



Street edge parking?  
Erosion  
Compaction







- Street Edge
- Parking
- Access to vehicle
- Erosion control
- Vegetation/bushes



- Rock?
- Vegetation/ground cover?
  - sheet flow
- Mulch?













[www.seattle.gov/util/naturalsystems](http://www.seattle.gov/util/naturalsystems)