

Bioretention Hydrologic Modeling

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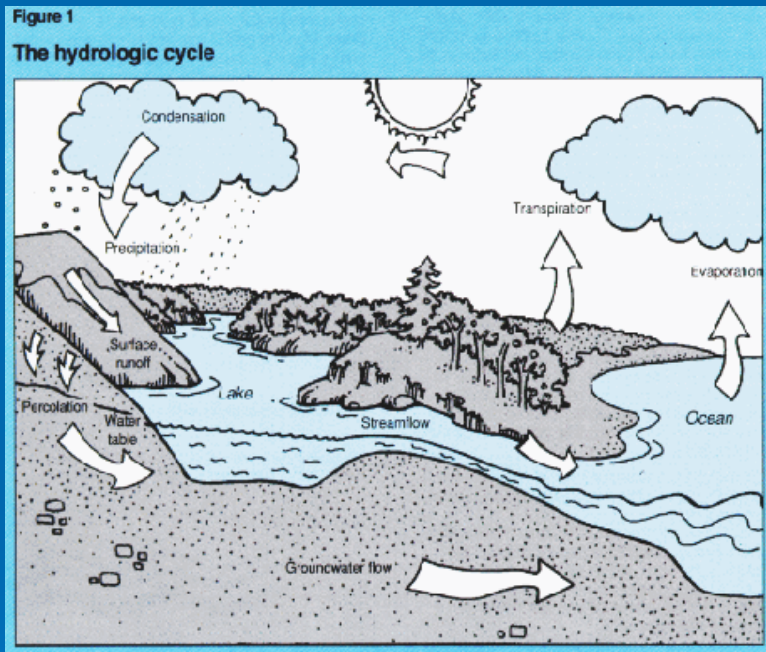
September 10, 2014

Presentation Overview

- Hydrologic Modeling
- Performance Standards
- Modeling Guidelines, Tools, Concepts
- Bioretention Types
- Applications
 - Flow Control
 - Water Quality Treatment
 - Combined Sewer Overflow Reduction
 - Wetland Protection



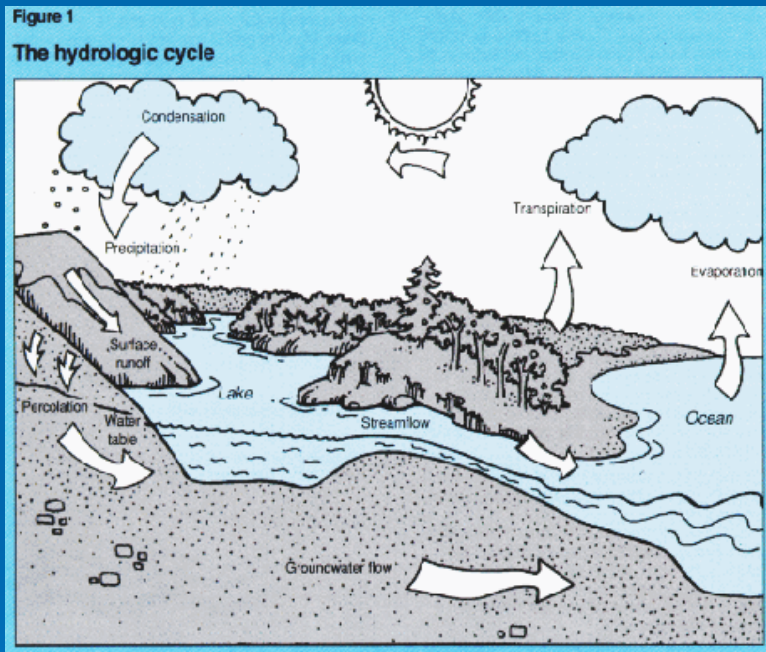
Hydrologic Modeling



Source: <http://www.und.nodak.edu/>

- Q: What is hydrologic modeling?
- A: Use of mathematical equations to estimate runoff based on:
 - weather patterns
 - landuse
 - soil
 - topography

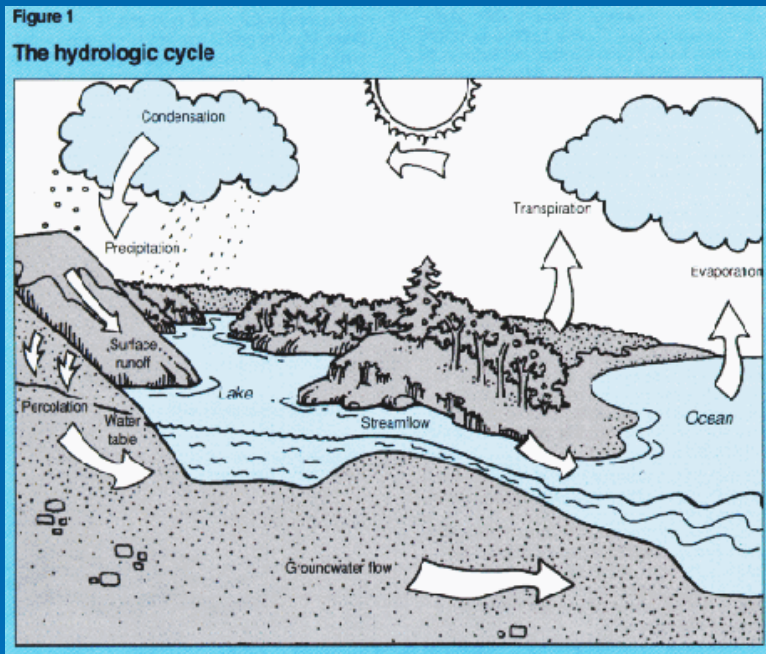
Hydrologic Modeling



Source: <http://www.und.nodak.edu/>

- Q: Why do we use hydrologic models?
- A1: Characterize hydrologic conditions
 - Predeveloped
 - Current
 - Post-project
- A2: Design mitigation
- A3: It's fun!

Hydrologic Modeling



Source: <http://www.und.nodak.edu/>

- Q: When does hydrologic modeling enter into your project?
- A: Start to finish
 - preliminary design (sizing)
 - final design (optimization)
 - demonstrate requirements met (permit submittals)

Performance Standards

- **On-site Stormwater Management (MR #5) (NEW 2012)**
 - Use BMP List (rain garden)
or
 - Meet LID Performance Standard (match flow durations to pre-developed condition from 8% to 50% of the 2-year peak flow)
- **Runoff Treatment (MR #6)**
 - Infiltrate 91 percent of the total runoff volume through soil meeting Ecology treatment criteria (for infiltration BMPs)
- **Flow Control (MR #7)**
 - Match flow durations to pre-developed condition from 50% of the 2-year to the 50-year peak flow
- **Other Flow Control Standards**
 - Combined Sewer or Capacity Constrained Basins (peak-based standards)

Hydrologic Modeling Methods

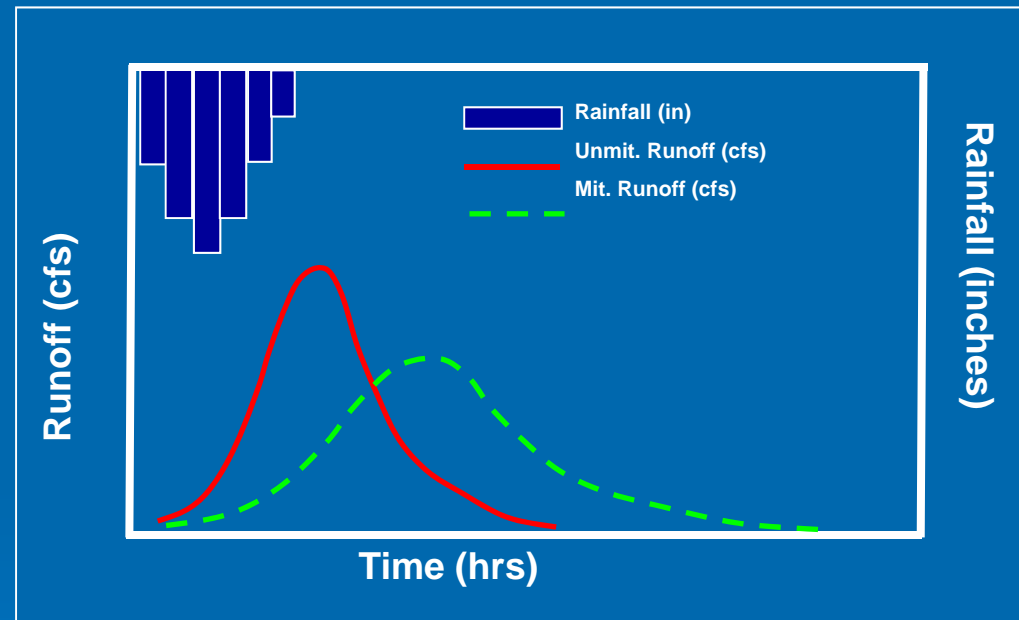
- Single-event models
 - May be appropriate for conveyance sizing
- Continuous models
 - Required for sizing flow control (MR7) and treatment (MR6) BMPs
- Simplified sizing tools
 - Will be covered in class exercise



Hydrologic Modeling

Single-Event Methods

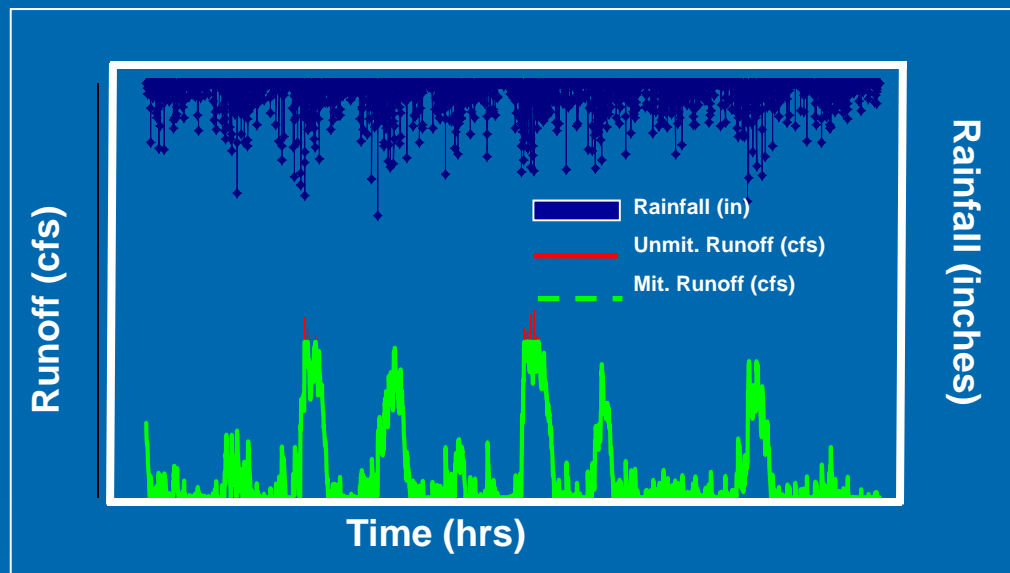
- Input single storm event
- Output peak flow rates
- Typical methods
 - SCS
 - SBUH
 - StormShed
 - SWMM
 - HEC-HMS



Hydrologic Modeling

Continuous Models

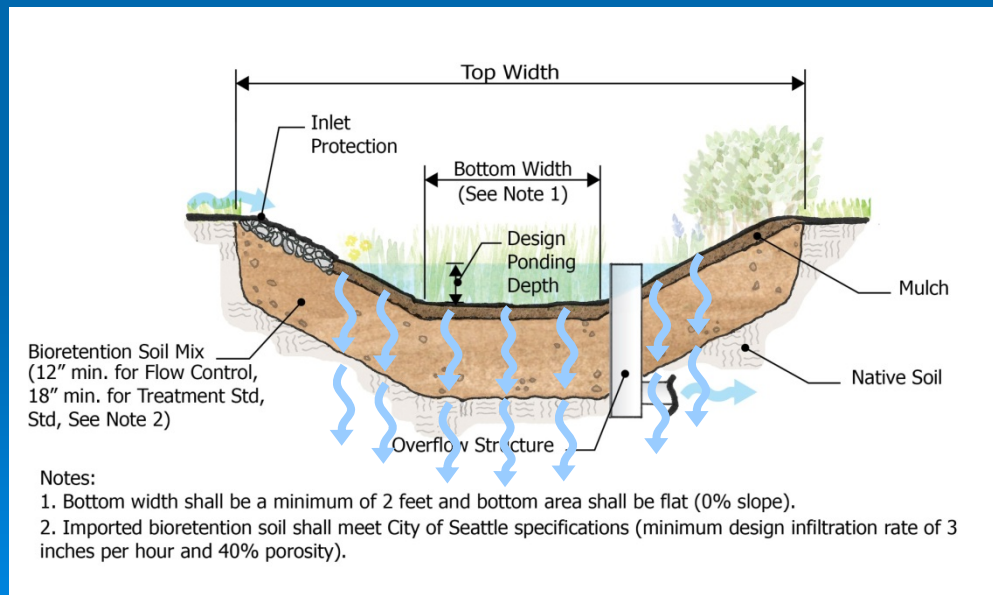
- Input long-term rain and evaporation
- Output continuous runoff, peak flow, & duration
- Typical programs
 - HSPF
 - WWHM
 - MGS Flood
 - KCRTS
 - SWMM
 - SUSTAIN
 - InfoWorks



Bioretention Types

Without Underdrain

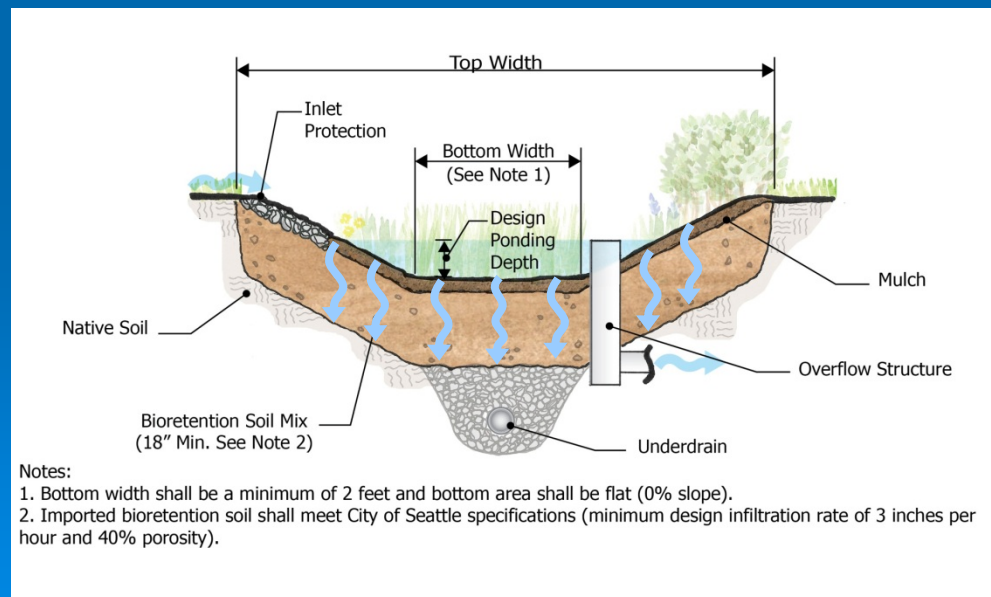
- Relies on infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- Can provide effective flow control and meet duration standard for many soil conditions



Bioretention Types

With Underdrain

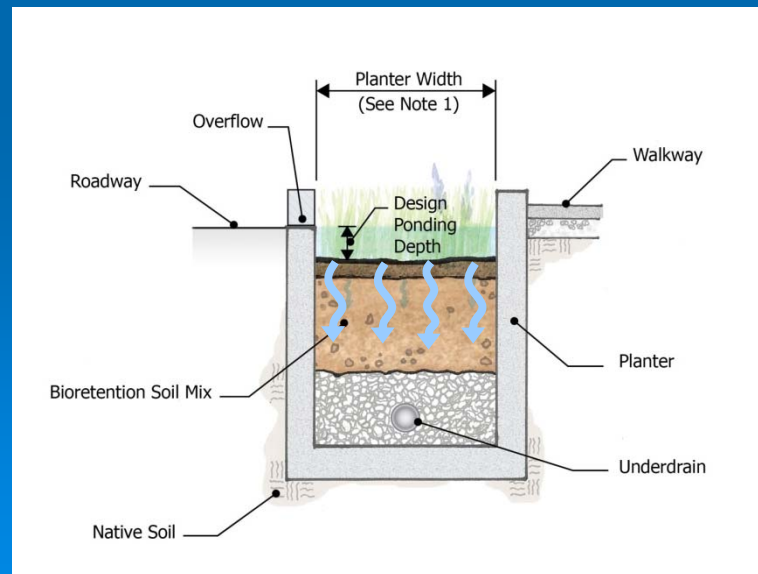
- Some infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- May not be able to meet duration standard alone, but can contribute as part of a system to achieve flow control goals (raised underdrain and orifice improve performance)



Bioretention Types

With Underdrain & Liner/Impermeable Container

- No infiltration to native soil
- Can meet on-site list requirement
- Can provide effective WQ treatment for some pollutants
- Cannot meet duration standard alone, but can contribute as part of a system to achieve flow control goals (orifice improves performance)



Current Modeling Guidelines

➤ Implicit Method (2005 LID Manual)

- Lump surface ponding and storage in BR soil
- Effective depth = ponding depth + BR soil depth x void ratio (%)
- MGS Flood and WWHM3
- Neglects movement of water through layers

➤ Explicit Method

- Explicitly represents:
 - Surface ponding
 - Infiltration into BR soil and native soil
 - Storage in BR soil
 - Overflow
 - Underdrain flow
- MGSFlood4, WWHM4, WWHM2012



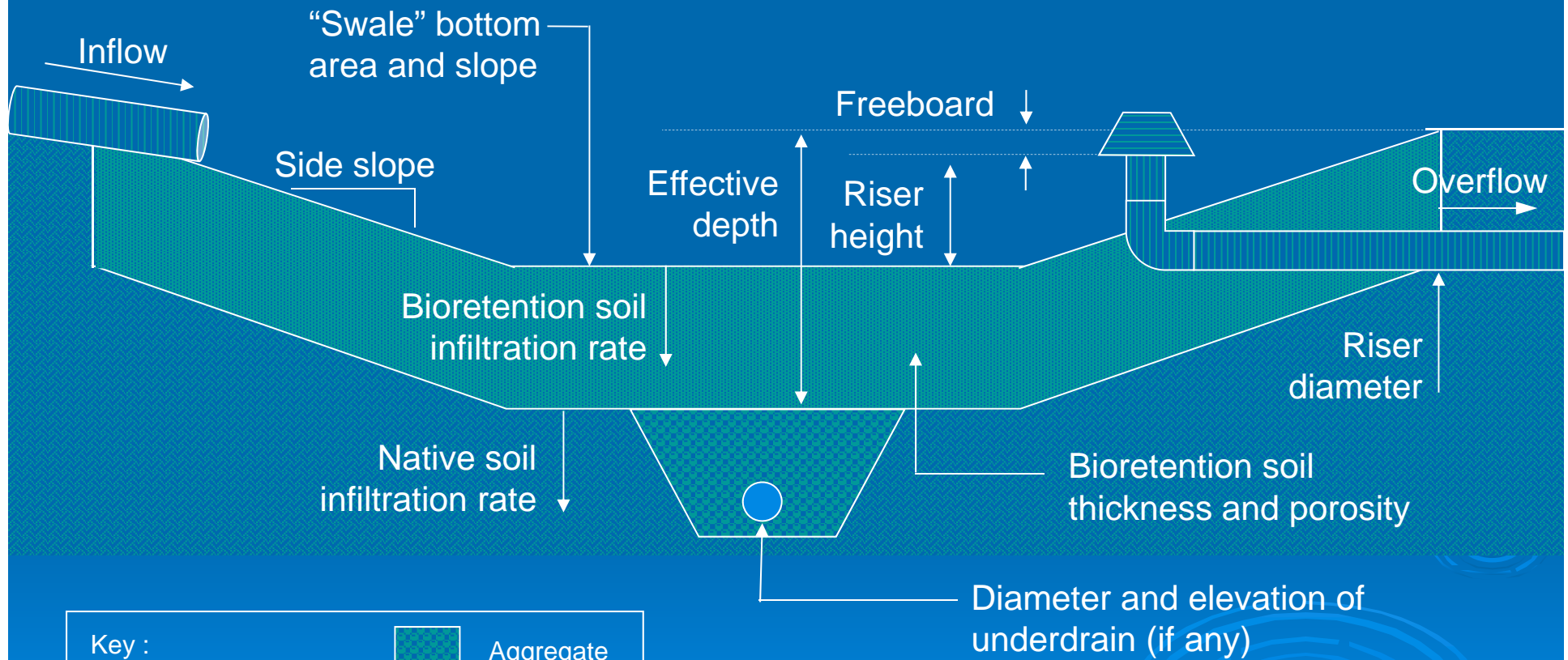
WWHM/MGSFlood Basics

Model Inputs

- Meteorological Data
 - Rainfall (5-min, 15-min, hourly)
 - Evaporation (daily)
- Land Cover Types
 - Impervious areas
 - Slope
 - Pervious areas
 - Vegetation
 - Soil type (A, B, C/D)
 - Slope
 - Regional calibrated parameters (Dinicola 1990)
- BMP Configurations

WWHM/MGSFlood Representation

Bioretention Module Parameters- Explicit

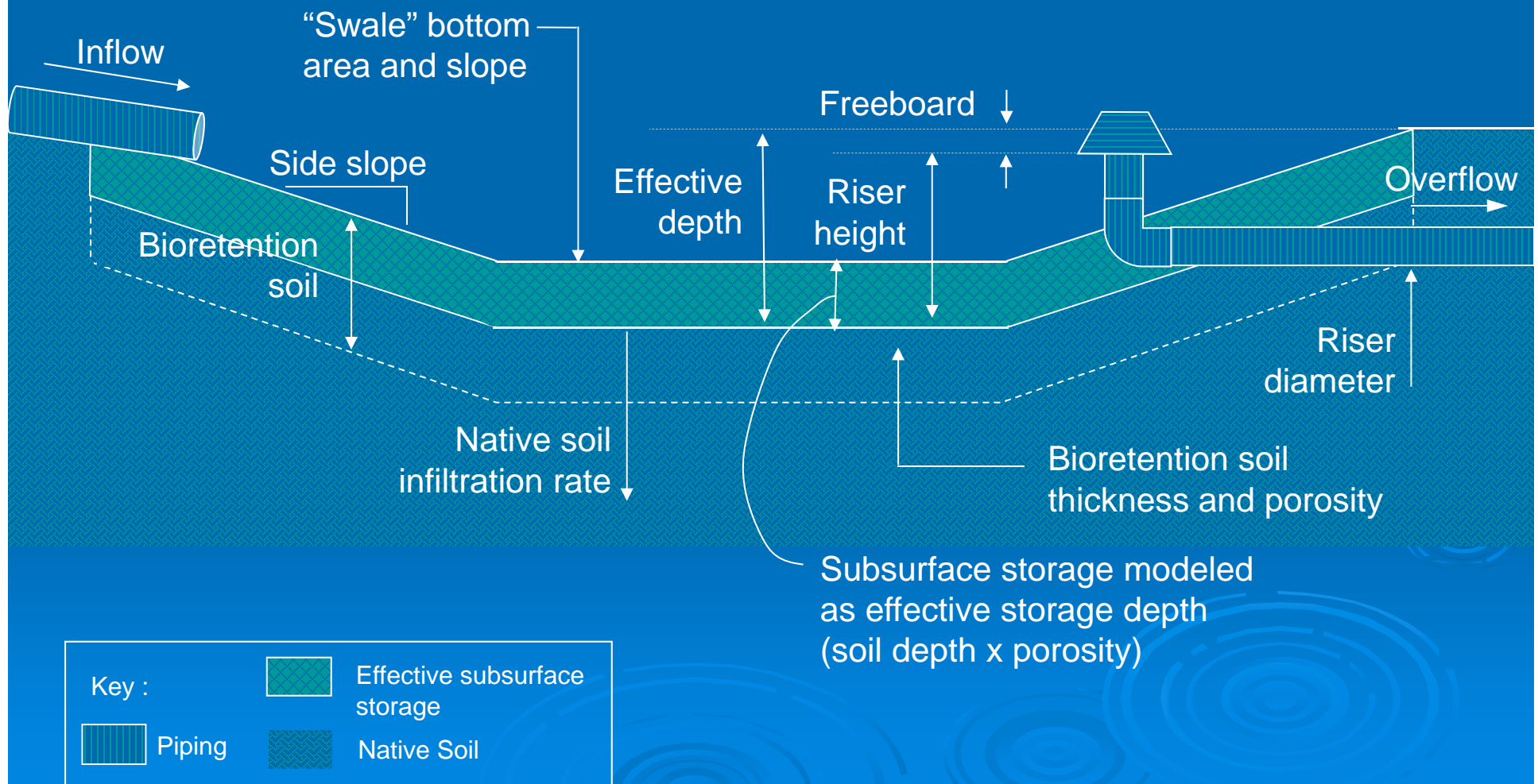


Key :		Aggregate
		Underdrain
		Subbase
Piping		
Bioretention Soil		

* Showing "riser outlet structure"
(alternative: "vertical orifice and overflow")

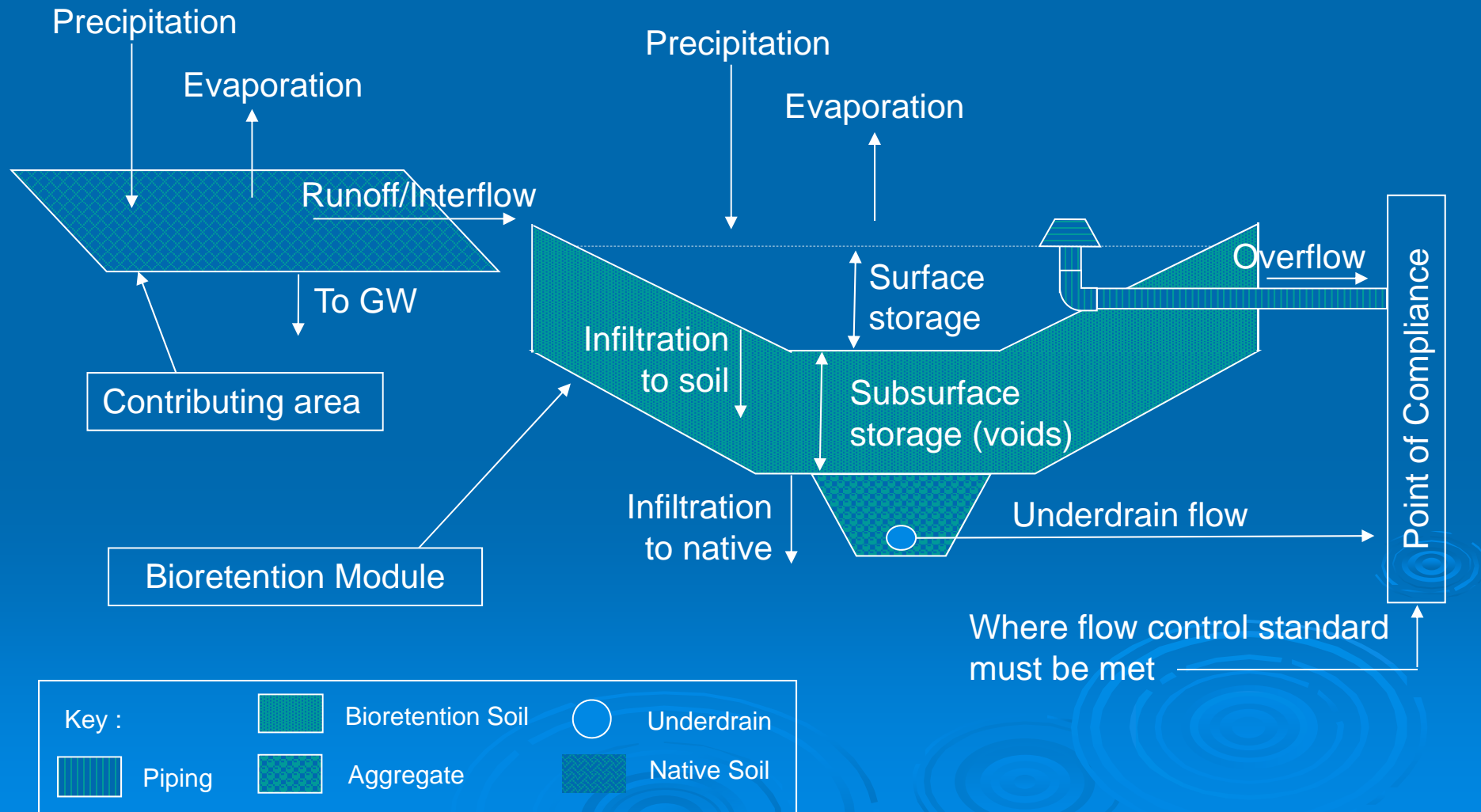
WWHM/MGSFlood Representation

Bioretention Module Parameters- Implicit



WWHM/MGSFlood Representation

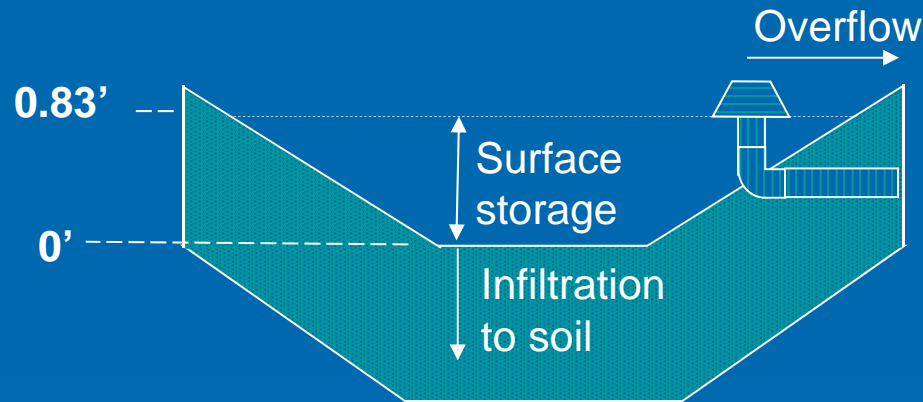
Model Configuration



WWHM/MGSFlood Representation

Bioretention Surface Routing- Explicit

Surface SSD Table



Stage (ft)	Area (sf)	Storage (cf)	Infilt. (cfs)	Overflow (cfs)
0.0	0	0	0	0
0.2	304	243	0.0035	0
0.4	328	253	0.0038	0
0.6	352	263	0.0041	0
0.8	376	273	0.0044	0
0.9	388	278	0.0045	0.8
1.0	400	283	0.0046	1.5

Bioretention Sizing Examples

- Flow Control in Creek Basins (WWHM)
- Water Quality Treatment (WWHM)
- Flow Control for CSO Reduction (SWMM)



Flow Control in Creek Basin

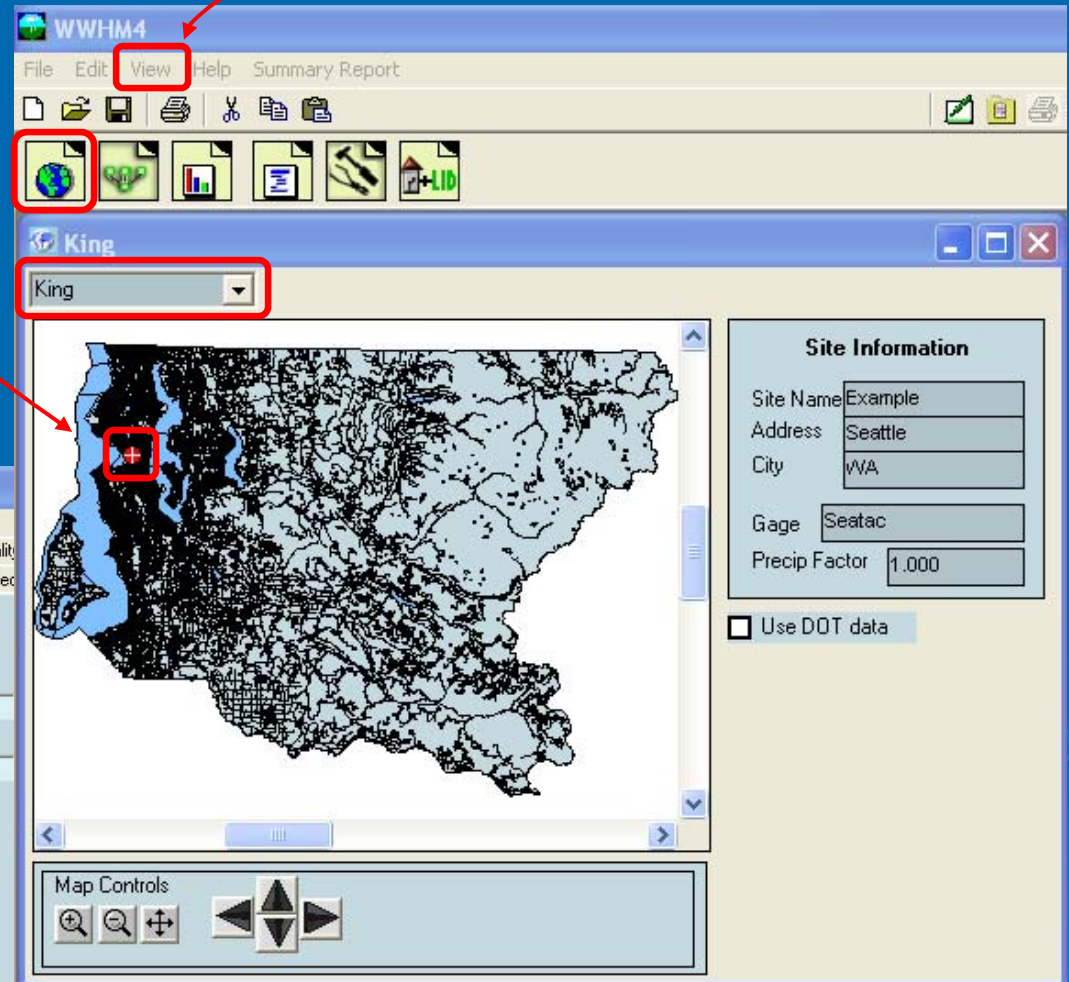
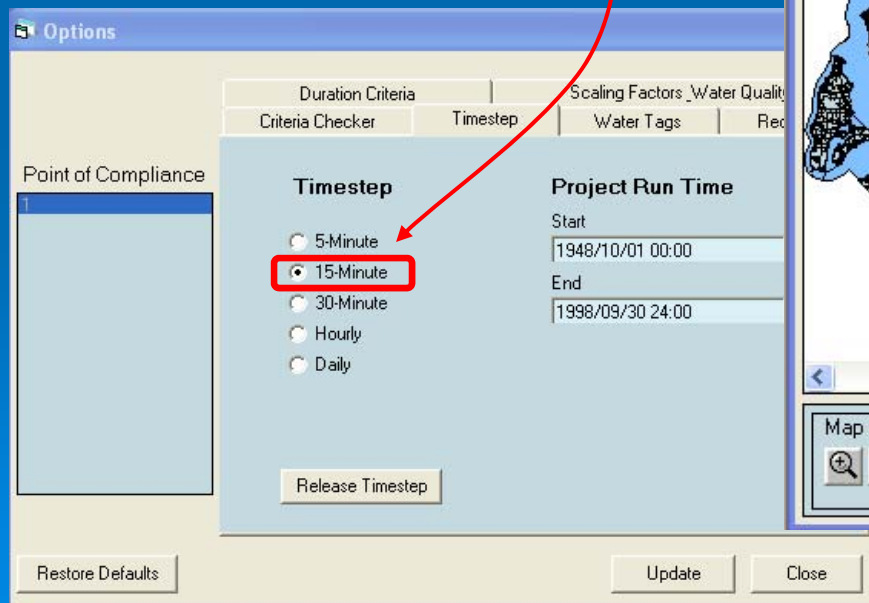
WWHM4 Example- Explicit Method

- Site in Seattle
- Size bioretention cell to meet creek protection goal (Ecology flow duration standard)
- Predeveloped condition = forest on till
- Native soil is till (0.25 inch/hour design infiltration rate)
- Bioretention cell (12" ponding depth, no underdrain)
- Receiving runoff from 2,000 sf of impervious area (0.046 acres)
- Using bioswale module in WWHM4
- 15 minute time-step

Sizing for Flow Control

- Precipitation/Evap. Data → Select county and location on map
- Computational Time Step → 15 minutes

Option Menu



Sizing for Flow Control

Predeveloped Basin → Select area, soil type, land cover and slope

WWHM4
File Edit View Help Summary Report

Schematic

SCENARIOS

- ☒ Predeveloped
- ☐ Mitigated

Run Scenario

Basic Elements

- ☒ Predeveloped Forest

Pro Elements

- ☐ SWMM
- ☐ Curb
- ☐ LID

LID Toolbox

Move Elements

Save x,y Load x,y

X: 20 Y: 12

Basin 1 Predeveloped

Subbasin Name: Predeveloped Forest

Flows To: Surface Interflow Groundwater

Area in Basin

Available Pervious	Acres
<input type="checkbox"/> A/B, Forest, Flat	0
<input type="checkbox"/> A/B, Forest, Mod	0
<input type="checkbox"/> A/B, Forest, Steep	0
<input type="checkbox"/> A/B, Pasture, Flat	0
<input type="checkbox"/> A/B, Pasture, Mod	0
<input type="checkbox"/> A/B, Pasture, Steep	0
<input type="checkbox"/> A/B, Lawn, Flat	0
<input type="checkbox"/> A/B, Lawn, Mod	0
<input type="checkbox"/> A/B, Lawn, Steep	0
<input type="checkbox"/> C, Forest, Flat	0
<input checked="" type="checkbox"/> C, Forest, Mod	0.046
<input type="checkbox"/> C, Forest, Steep	0
<input type="checkbox"/> C, Pasture, Flat	0
<input type="checkbox"/> C, Pasture, Mod	0
<input type="checkbox"/> C, Pasture, Steep	0
<input type="checkbox"/> C, Lawn, Flat	0
<input type="checkbox"/> C, Lawn, Mod	0
<input type="checkbox"/> C, Lawn, Steep	0
<input type="checkbox"/> SAT, Forest, Flat	0

☐ Show Only Selected

Available Impervious

Available Impervious	Acres
<input type="checkbox"/> ROADS/FLAT	0
<input type="checkbox"/> ROADS/MOD	0
<input type="checkbox"/> ROADS/STEEP	0
<input type="checkbox"/> ROOF TOPS/FLAT	0
<input type="checkbox"/> DRIVEWAYS/FLAT	0
<input type="checkbox"/> DRIVEWAYS/MOD	0
<input type="checkbox"/> DRIVEWAYS/STEEP	0
<input type="checkbox"/> SIDEWALKS/FLAT	0
<input type="checkbox"/> SIDEWALKS/MOD	0
<input type="checkbox"/> SIDEWALKS/STEEP	0
<input type="checkbox"/> PARKING/FLAT	0
<input type="checkbox"/> PARKING/MOD	0
<input type="checkbox"/> PARKING/STEEP	0
<input type="checkbox"/> POND	0
<input type="checkbox"/> Porous Pavement	0

Pervious Total: 0.046 Acres
Impervious Total: 0 Acres
Basin Total: 0.046 Acres

Deselect Zero Select By: GO

Sizing for Flow Control

Predeveloped Basin → Point of Compliance

The screenshot displays the WHM4 software interface. The main window shows a schematic grid with a green icon labeled '1' highlighted by a red square and a red arrow. The 'Basin 1 Predeveloped' dialog box is open, showing the 'Point Of Compliance' settings. The 'Subbasin Name' is 'Predeveloped Forest'. The 'Flows To' section has 'Surface', 'Interflow', and 'Groundwater' options. The 'POC Outlet' section has 'Surface Flow' and 'Interflow' checked, and 'Groundwater' unchecked. The 'Select POC' list shows '1'. The 'Connect' button is visible. The 'Move Elements' section shows 'Save x,y' and 'Load x,y' buttons. The status bar at the bottom indicates 'Thu 1:46p - default[1] - Finish Predeveloped'.

WHM4
File Edit View Help Summary Report

Schematic

SCENARIOS

- ☒ Predeveloped
- ☐ Mitigated

Run Scenario

Basic Elements

Pro Elements

LID Toolbox

Move Elements

Save x,y Load x,y

X: 20 Y: 0

Thu 1:46p - default[1] - Finish Predeveloped

Basin 1 Predeveloped

Subbasin Name: Predeveloped Forest

Flows To: Surface Interflow Groundwater

Point Of Compliance

Element: Predeveloped Forest

POC Outlet

- ☒ Surface Flow
- ☒ Interflow
- ☐ Groundwater

Select POC ADD

1

Connect

☐ C, Lawn, Flat 0

☐ C, Lawn, Mod 0

☐ C, Lawn, Steep 0

☐ SAT, Forest, Flat 0

Pervious Total 0.046 Acres

Impervious Total 0 Acres

Basin Total 0.046 Acres

Deselect Zero Select By: GO

Sizing for Flow Control

Developed Mitigated Basin → Impervious with same area and slope....

The screenshot displays the WHIM4 software interface, specifically the 'Basin 1 Mitigated' configuration window. The 'Subbasin Name' is set to 'Impervious Surface'. The 'Available Impervious' list on the right shows 'ROADS/MOD' selected with 0.046 acres. The 'Available Pervious' list on the left shows various land use types with 0 acres. The 'Basin Total' is 0.046 acres. The 'Basin 1 Mitigated' window is titled 'Basin 1 Mitigated' and has a 'Subbasin Name' field set to 'Impervious Surface'. Below this, there are sections for 'Flows To' (Surface, Interflow, Groundwater) and 'Area in Basin'. The 'Area in Basin' section is divided into 'Available Pervious' and 'Available Impervious' lists. The 'Available Pervious' list includes items like 'A/B, Forest, Flat', 'A/B, Forest, Mod', 'A/B, Forest, Steep', 'A/B, Pasture, Flat', 'A/B, Pasture, Mod', 'A/B, Pasture, Steep', 'A/B, Lawn, Flat', 'A/B, Lawn, Mod', 'A/B, Lawn, Steep', 'C, Forest, Flat', 'C, Forest, Mod', 'C, Forest, Steep', 'C, Pasture, Flat', 'C, Pasture, Mod', 'C, Pasture, Steep', 'C, Lawn, Flat', 'C, Lawn, Mod', 'C, Lawn, Steep', and 'SAT, Forest, Flat'. The 'Available Impervious' list includes items like 'ROADS/FLAT', 'ROADS/MOD', 'ROADS/STEEP', 'ROOF TOPS/FLAT', 'DRIVEWAYS/FLAT', 'DRIVEWAYS/MOD', 'DRIVEWAYS/STEEP', 'SIDEWALKS/FLAT', 'SIDEWALKS/MOD', 'SIDEWALKS/STEEP', 'PARKING/FLAT', 'PARKING/MOD', 'PARKING/STEEP', 'POND', and 'Porous Pavement'. The 'ROADS/MOD' item is selected in the 'Available Impervious' list, showing 0.046 acres. At the bottom, there are fields for 'Pervious Total' (0 Acres), 'Impervious Total' (0.046 Acres), and 'Basin Total' (0.046 Acres). There are also buttons for 'Deselect Zero' and 'Select By: GO'.

Available Pervious	Acres
A/B, Forest, Flat	0
A/B, Forest, Mod	0
A/B, Forest, Steep	0
A/B, Pasture, Flat	0
A/B, Pasture, Mod	0
A/B, Pasture, Steep	0
A/B, Lawn, Flat	0
A/B, Lawn, Mod	0
A/B, Lawn, Steep	0
C, Forest, Flat	0
C, Forest, Mod	0
C, Forest, Steep	0
C, Pasture, Flat	0
C, Pasture, Mod	0
C, Pasture, Steep	0
C, Lawn, Flat	0
C, Lawn, Mod	0
C, Lawn, Steep	0
SAT, Forest, Flat	0

Available Impervious	Acres
ROADS/FLAT	0
ROADS/MOD	0.046
ROADS/STEEP	0
ROOF TOPS/FLAT	0
DRIVEWAYS/FLAT	0
DRIVEWAYS/MOD	0
DRIVEWAYS/STEEP	0
SIDEWALKS/FLAT	0
SIDEWALKS/MOD	0
SIDEWALKS/STEEP	0
PARKING/FLAT	0
PARKING/MOD	0
PARKING/STEEP	0
POND	0
Porous Pavement	0

Pervious Total: 0 Acres
Impervious Total: 0.046 Acres
Basin Total: 0.046 Acres

Sizing for Flow Control

Developed Mitigated Basin Continued: Route to Bioswale Module

The screenshot displays the WHM4 software interface. The main window is titled 'Basin 1 Mitigated'. The 'Schematic' panel on the left shows a grid with a green square (representing a pervious surface) and a black square (representing a bioswale). A red box highlights the black square, and a red arrow points from it to the 'From Basin to conveyance' dialog box. The dialog box has a 'Flow From:' section with three options: 'Surface Flow' (checked), 'Interflow' (checked), and 'Groundwater' (unchecked). The 'OK' button is at the bottom. The 'Basin 1 Mitigated' panel on the right shows the 'Subbasin Name' as 'Impervious Surface'. The 'Flows To:' section has three tabs: 'Surface' (selected), 'Interflow', and 'Groundwater'. The 'Surface' tab shows 'Surface Swale 1'. The 'Area in Basin' section lists 'Available Pervious' and 'Available Impervious' areas. The 'Available Impervious' section lists various pervious types and their acreages.

Available Pervious	Acres	Available Impervious	Acres
A/B, Forest, Flat	0	ROADS/FLAT	0
A/B, Forest, Mod	0	ROADS/MOD	0.046
A/B, Forest, Steep	0	ROADS/STEEP	0
A/B, Pasture, Flat	0	ROOF TOPS/FLAT	0
A/B, Pasture, Mod	0	DRIVEWAYS/FLAT	0
		DRIVEWAYS/MOD	0
		DRIVEWAYS/STEEP	0
		SIDEWALKS/FLAT	0
		SIDEWALKS/MOD	0
		SIDEWALKS/STEEP	0
		PARKING/FLAT	0
		PARKING/MOD	0
		PARKING/STEEP	0
		POND	0
		Porous Pavement	0

Summary Totals:

Category	Value	Unit
Pervious Total	0	Acres
Impervious Total	0.046	Acres
Basin Total	0.046	Acres

Buttons: Deselect Zero, Select By: GO

Sizing for Flow Control

Developed Mitigated Basin Continued: Characterize Bioretention

WWHM4 WSU Example

File Edit View Help Summary Report

Schematic

SCENARIOS

☐ Predeveloped

☒ Mitigated

Run Scenario

Basic Elements

Pro Elements

LID Toolbox

Move Elements

Save x,y Load x,y

X 40 Y 0

Thu 4:55p - WSU Example - Finish Mitigated

Bio Swale 1 Mitigated

Facility Name Bio Swale 1

Outlet 1 Outlet 2 Outlet 3

Downstream Connection 0 0 0

Facility Type Bioretention Swale

☐ Use Simple Swale

☐ Underdrain Used

Swale Bottom Elevation (ft) 0

Swale Dimensions

Swale Length (ft) 20.000

Swale Bottom Width (ft) 10.500

Freeboard (ft) 0.500

Over-road Flooding (ft) 0.000

Effective Total Depth (ft) 2.5

Bottom slope of Swale (ft/ft) 0.000

Left Side Slope (H/V) 3.000

Right Side Slope (H/V) 3.000

Material Layers for Swale

	Layer 1	Layer 2	Layer 3
Depth (ft)	1.000	0.000	
Soil Layer 1	Amended 3.0 in/hr		
Soil Layer 2	GRAVEL		
Soil Layer 3	GRAVEL		

Edit Soil Types

Use Embankment Slope if this is a roadside embankment.

Embankment Slope (ft/ft) 0.000

Native Infiltration YES

Measured Infiltration Rate (in/hr) 0.5

Reduction Factor (infiltration factor) 0.5

Use Wetted Surface Area (sidewalls) YES

Facility Dimension Diagram

Outlet Structure Data

Riser Outlet Structure

Outlet Structure Data

Riser Height Above Swale surface (ft) 1

Riser Diameter (in) 12

Riser Type Flat

Orifice Number Diameter (in) Height (ft)

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Show Swale Table

Swale Volume at Riser Head (ac-ft) .003

	Total Volume Infiltrated (ac-ft)	Total Volume Through Riser (ac-ft)	Total Volume Through Facility (ac-ft)	Percent Infiltrated
	0	0	0	0

BRS

Infiltration to Native Soil

Outlet & Ponding Depth

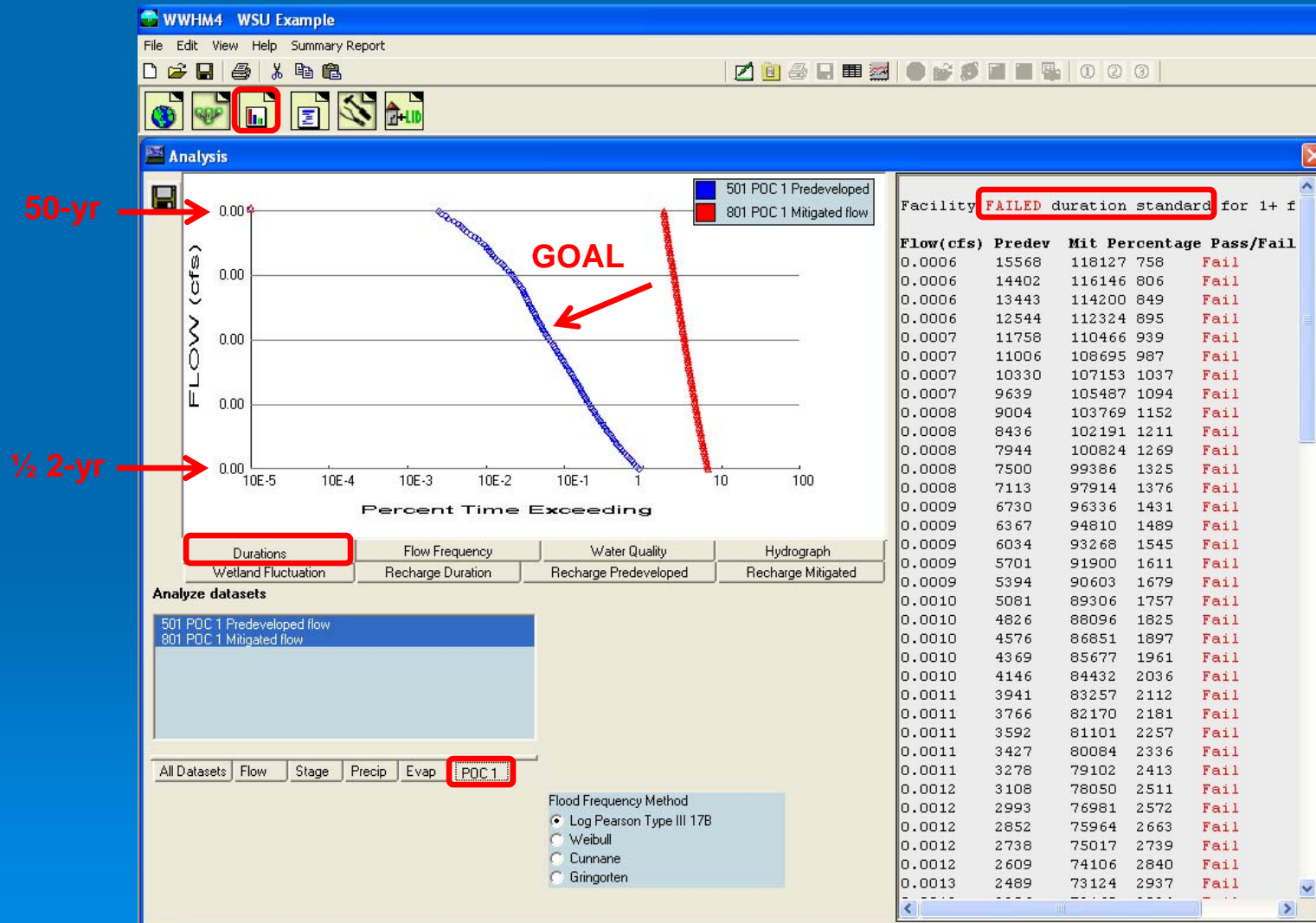
Sizing for Flow Control

Stage Storage Discharge Table

Bio Swale 1					
Stage (ft)	Area (acres)	Storage (acre-ft)	Dschrg (cfs)	Infiltration (cfs)	
Sub-surface Table				Native	
0.000000	0.008264	0.000000	0.000000	0.000000	
0.027473	0.008234	0.000059	0.000000	0.000000	
0.054945	0.008159	0.000120	0.000000	0.000000	
0.082418	0.008083	0.000181	0.000000	0.000000	
0.109890	0.008007	0.000243	0.000000	0.000000	
0.137363	0.007931	0.000305	0.000000	0.000000	
0.164835	0.007856	0.000369	0.000000	0.000000	
0.192308	0.007780	0.000433	0.000000	0.000000	
0.219780	0.007704	0.000498	0.000000	0.000000	
0.247253	0.007629	0.000564	0.000000	0.000000	
0.274725	0.007553	0.000631	0.000000	0.000000	
0.302198	0.007477	0.000698	0.000000	0.000000	
0.329670	0.007402	0.000767	0.000000	0.000000	
0.357143	0.007326	0.000836	0.000000	0.000000	
0.384615	0.007250	0.000906	0.000000	0.000000	
0.412088	0.007175	0.000977	0.000000	0.000000	
Surface Table				To Amended	Native(wetted surface)
1.000000	0.008264	0.002686	0.000000	0.016855	0.000714
1.027473	0.008340	0.002914	0.000000	0.016855	0.000714
1.054945	0.008416	0.003144	0.000000	0.017306	0.000733
1.082418	0.008492	0.003376	0.000000	0.017756	0.000752
1.109890	0.008567	0.003611	0.000000	0.018207	0.000771

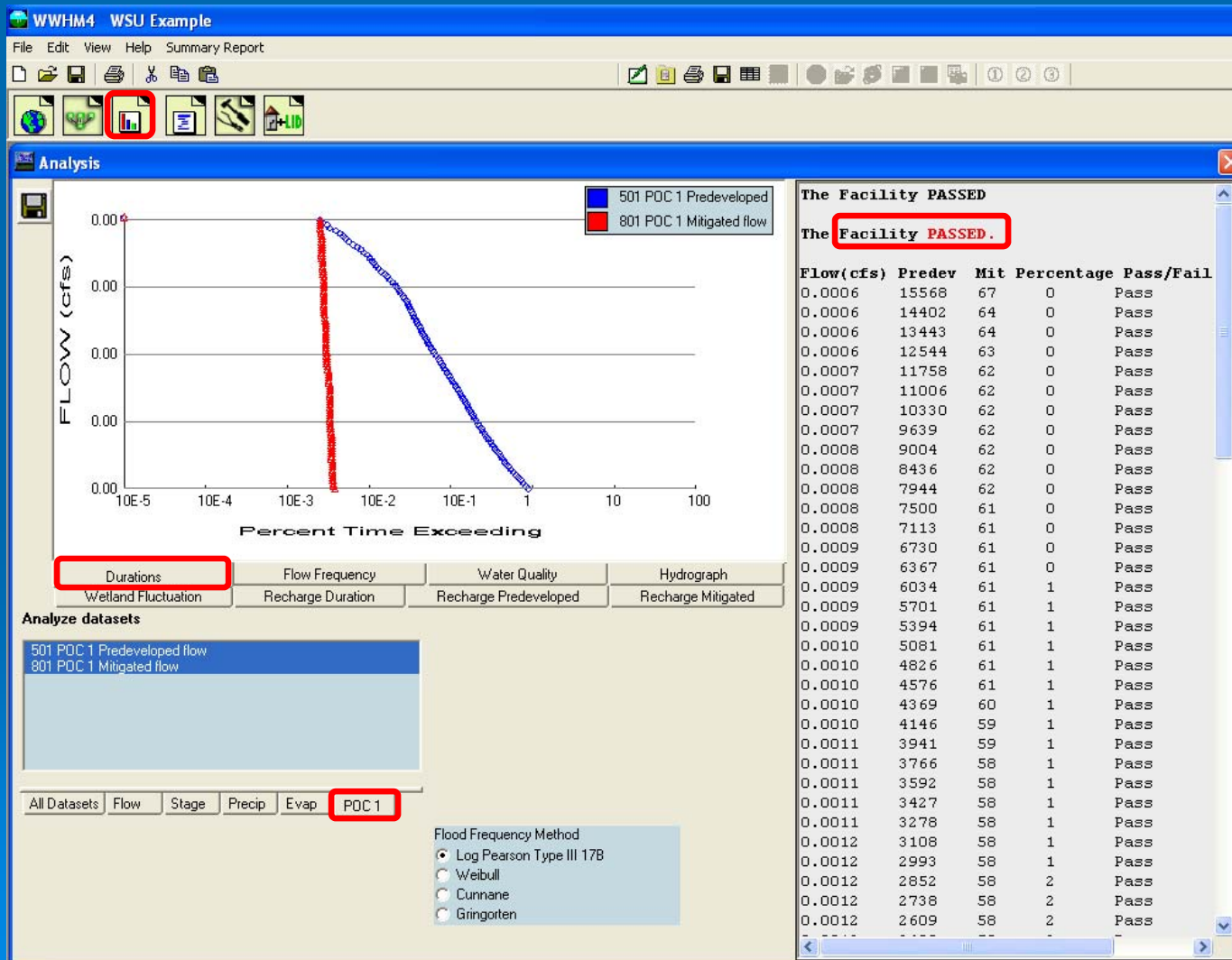
Sizing for Flow Control

Flow Duration Curve- Developed Unmitigated (Impervious)



Sizing for Flow Control

Flow Duration Curve- Developed Mitigated (Impervious to Bioretention)



Sizing for Flow Control

Iteratively Sized Bioretention Area to Meet Duration Standard

WWHM4 WSU Example

File Edit View Help Summary Report

Schematic

SCENARIOS

☐ Predeveloped

☒ Mitigated

Run Scenario

Basic Elements

Bio Swale 1 Mitigated

Facility Name: Bio Swale 1

Outlet 1: 0 Outlet 2: 0 Outlet 3: 0

Downstream Connection: 0

Facility Type: Bioretention Swale

☐ Use Simple Swale

☐ Underdrain Used

Swale Bottom Elevation (ft): 0

Swale Dimensions

Swale Length (ft): 20.000

Swale Bottom Width (ft): 10.500

Freeboard (ft): 0.500

Over-road Flooding (ft): 0.000

Effective Total Depth (ft): 2.5

Bottom slope of Swale (ft/ft): 0.000

Facility Dimension Diagram

Riser Outlet Structure

Outlet Structure Data

Soil Layer 2: GRAVEL

Soil Layer 3: GRAVEL

Edit Soil Types

Use Embankment Slope if this is a roadside embankment.

Embankment Slope (ft/ft): 0.000

Native Infiltration: YES

Measured Infiltration Rate (in/hr): 0.5

Reduction Factor (infiltration factor): 0.5

Use Wetted Surface Area (sidewalls): YES

Orifice Number

Orifice Diameter (in)

Orifice Height (ft)

1: 0 0

2: 0 0

3: 0 0

Show Swale Table

Open Table

Swale Volume at Riser Head (ac-ft): .003

Total Volume Infiltrated (ac-ft): 6.317

Total Volume Through Riser (ac-ft): 0.006

Total Volume Through Facility (ac-ft): 6.323

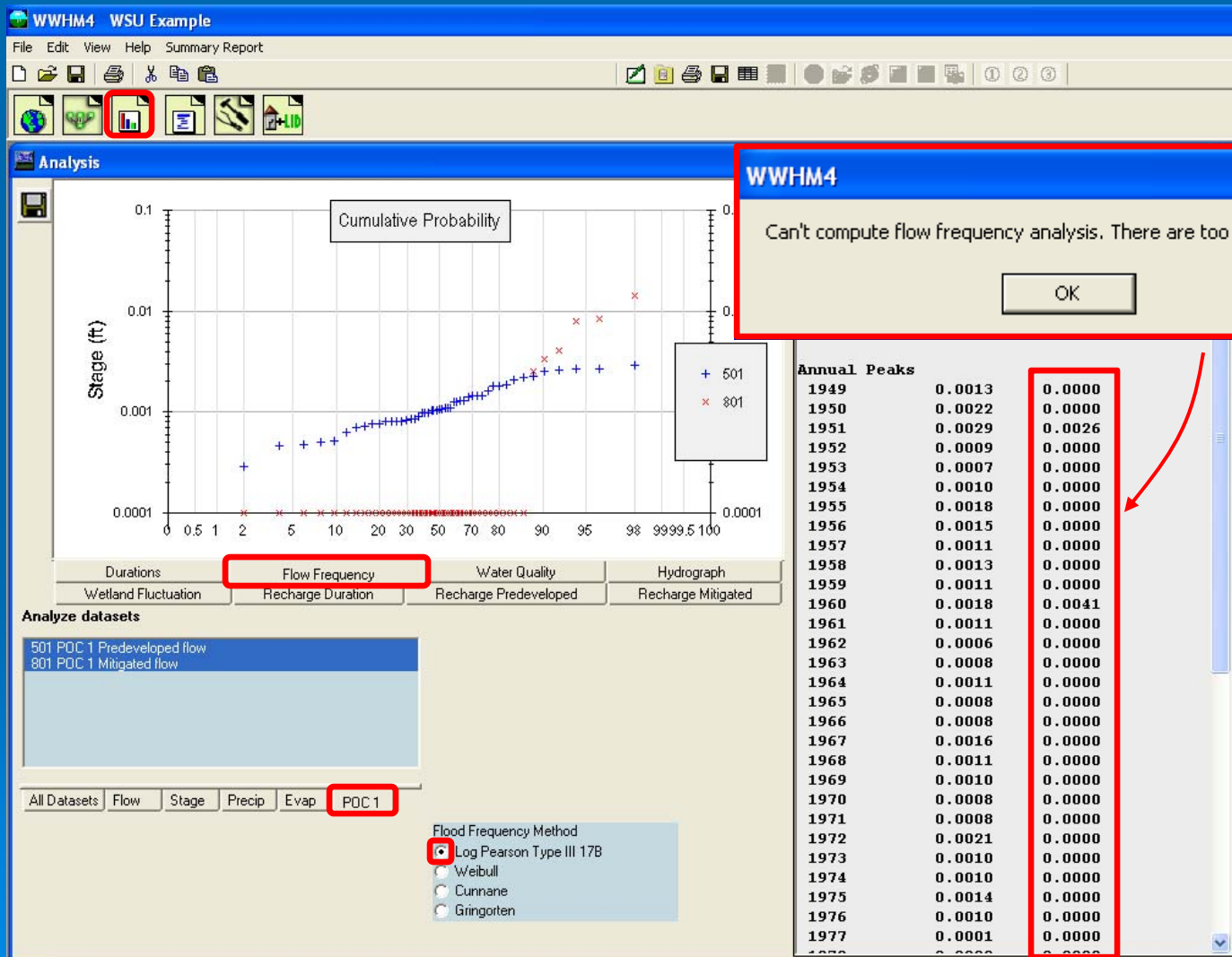
Percent Infiltrated: 99.91

Infiltrates almost 100% runoff

Thu 5:08p - WSU Example - Finish Mitigated

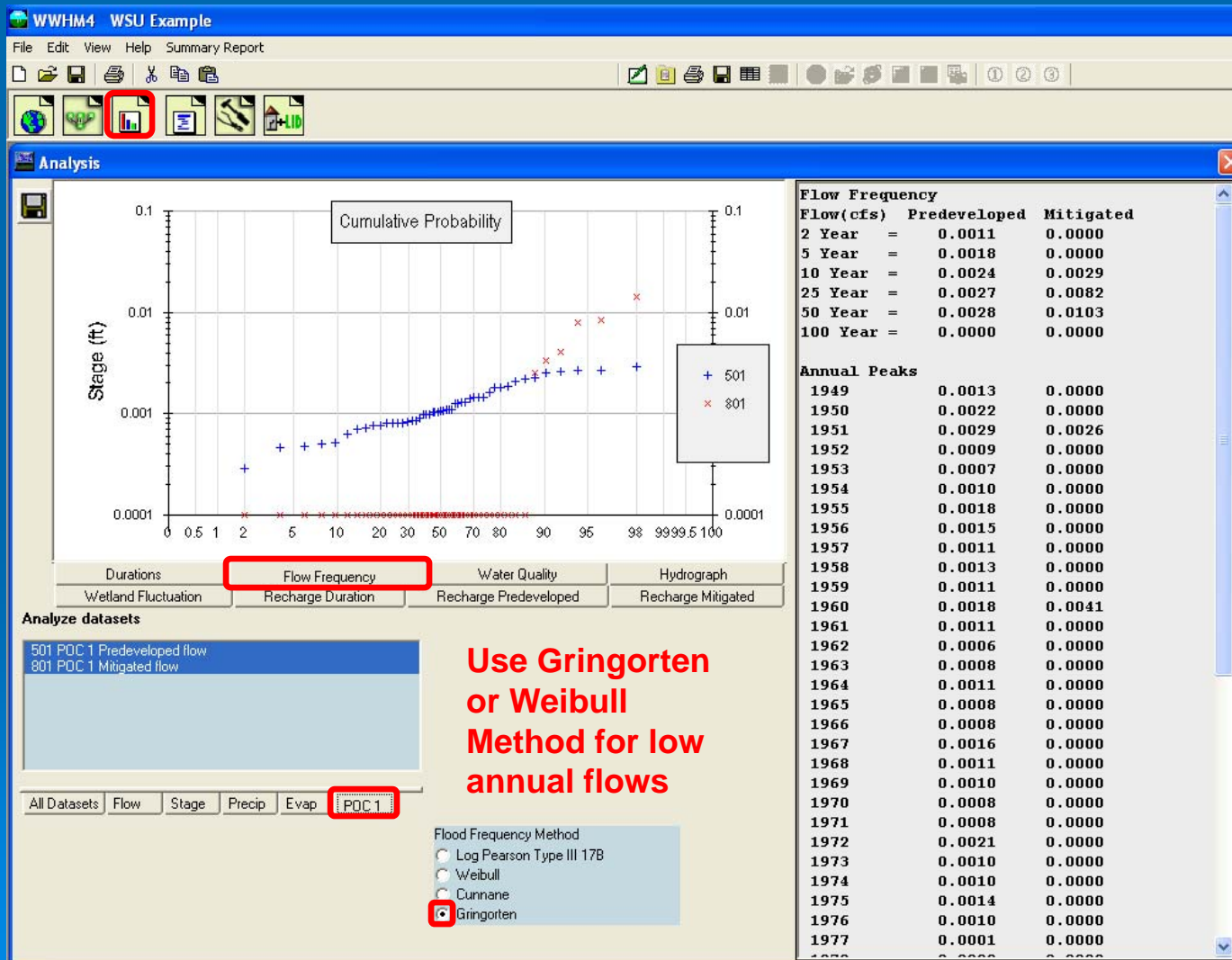
Sizing for Flow Control

Flow Frequency Results



Sizing for Flow Control

Flow Frequency Results



Water Quality Treatment

Same WWHM4 Example for Flow Control



Sizing for Treatment

Iteratively Size to Infiltrate 91% Runoff File

Bio Swale 1 Mitigated

Facility Name: Bio Swale 1

Outlet 1: 0, Outlet 2: 0, Outlet 3: 0

Downstream Connection: 0

Facility Type: Bioretention Swale

☐ Use Simple Swale

☐ Underdrain Used

Swale Bottom Elevation (ft): 0

Swale Dimensions

Swale Length (ft)	6.300
Swale Bottom Width (ft)	10.500
Freeboard (ft)	0.500
Over-road Flooding (ft)	0.000
Effective Total Depth (ft)	2.5
Bottom slope of Swale (ft/ft)	0.000

Facility Dimension Diagram

Riser Outlet Structure: 0

Outlet Structure Data

Orifice Number	Diameter (in)	Height (ft)
1	0	0
2	0	0
3	0	0

Show Swale Table Open Table

Swale Volume at Riser Head (ac-ft)	.001
Total Volume Infiltrated (ac-ft)	5.677
Total Volume Through Riser (ac-ft)	0.558
Total Volume Through Facility (ac-ft)	6.235
Percent Infiltrated	91.05

Native Infiltration YES

Measured Infiltration Rate (in/hr)	0.5
Reduction Factor (infiltr*factor)	0.5
Use Wetted Surface Area (sidewalls)	YES

Infiltrates 91%

Sizing for Treatment

Check Drawdown Criterion- WQ volume infiltrated through facility in 48 hours

WWHM4 WSU Example

File Edit View Help Summary Report

Analysis

Water Quality

On-Line BMP

24 hour Volume (ac-ft) 0.0095

Standard Flow Rate (cfs) 0.0113

Off-Line BMP

Standard Flow Rate (cfs) 0.0069

Run Analysis

Volume Infiltrated in 48 hrs = ponding area at mid-depth x infiltration rate x 48 hrs
= 162 sf x 0.25 in/hr x 48 hours = 162 cf = 0.0037 acre-ft < 0.0095 acre-ft

Analyze datasets

501 POC 1 Predeveloped flow
801 POC 1 Mitigated flow

**Does not meet
Ecology
recommendation**

All Datasets Flow Stage Precip Evap POC1

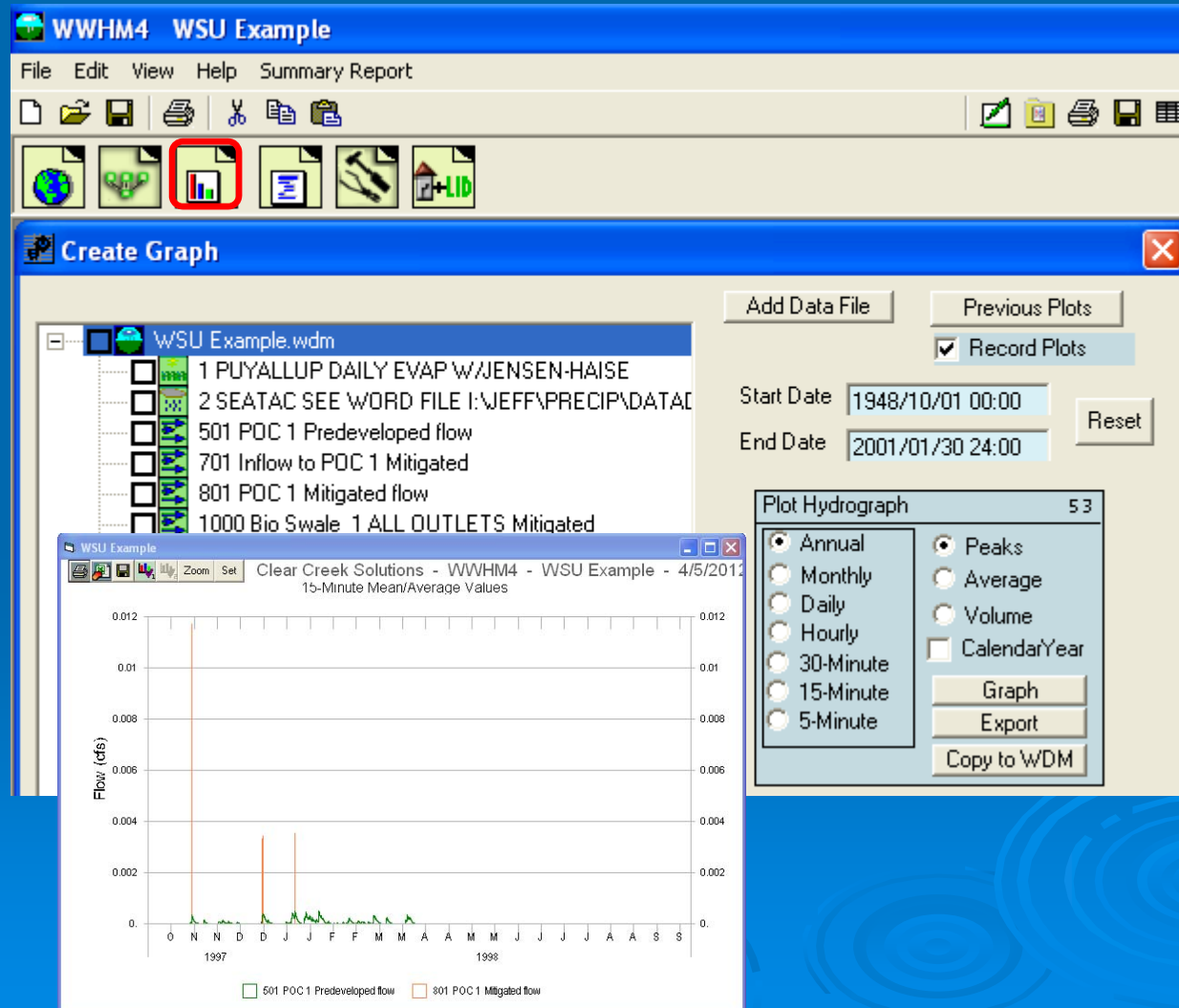
Further Analysis

WWHM4 Example



Further Analysis

Hydrograph



Further Analysis

Report

The screenshot displays the WWHM4 WSU Example software interface. The main window has a menu bar (File, Edit, View, Help, Summary Report) and a toolbar with icons for file operations. A secondary toolbar below it contains icons for various report types, with the 'Report' icon (a document with a blue header) highlighted by a red rectangle. The 'Report' window is open, showing a 'Parameter Report' tab. It contains a text area with the following information:

Project Name: WSU Example
Site Name :
Site Address:
City :
Report Date : 4/5/2012
Gage : Seatac
Data Start : 1948/10/01 00:00
Data End : 1998/09/30 00:00
Precip Scale: 1.00
Version : 2012/04/04

Low Flow Threshold for POC 1 : 50 Percent of the 2 Year

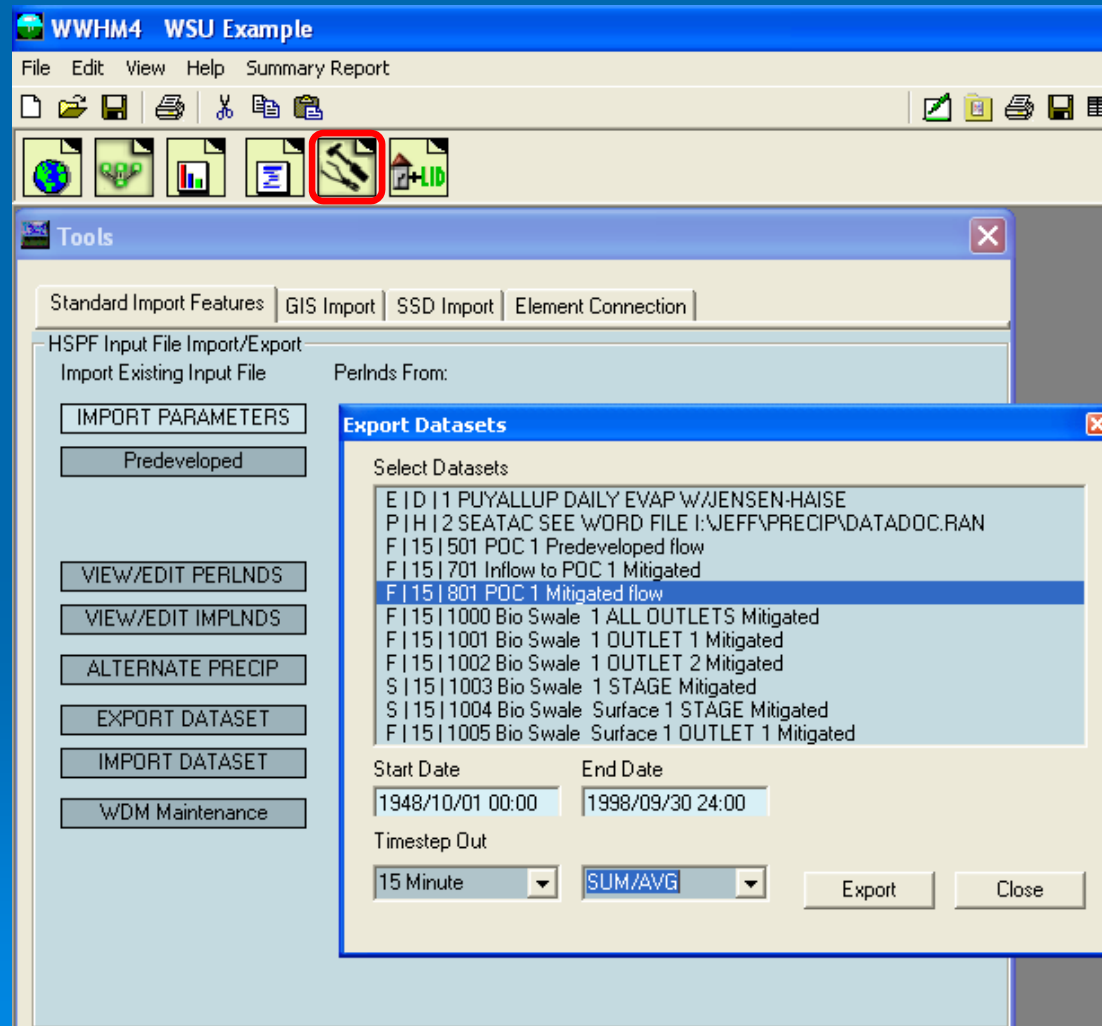
High Flow Threshold for POC 1 : 50 year

PREDEVELOPED LAND USE

Name : Predeveloped Forest
Byname : No

Further Analysis

Time Series Export



SWMM Basics

Model Inputs

- Environmental Protection Agency's (EPA's) Stormwater Management Model (SWMM)
- Meteorological Data Inputs
 - Rainfall and evaporation
- Land Surface Characteristics
- BMPs
 - LID controls allow explicit modeling of GSI

Table 5-1. Estimating Effective Impervious Surface Area

Subcatchment Type	Basis for TIA	Scaling Factor(s) (%)	Effective Impervious Surface (TIA × s)
ROW – informal	GIS or site survey	61	Calculated
ROW – curb and gutter	Site survey	95	Calculated
Parcel – w/existing IMP surface discharges directly to the public drainage system through a pipe or surface channel	Site survey	56	Calculated
Parcel – w/ existing IMP surface discharges to the private pervious surface or private drainage feature (e.g., rock pockets, large vegetated area)	Site survey	28	Calculated

GIS = geographic information system

IMP = impervious

ROW = right-of-way

TIA = total impervious area

SWMM Basics

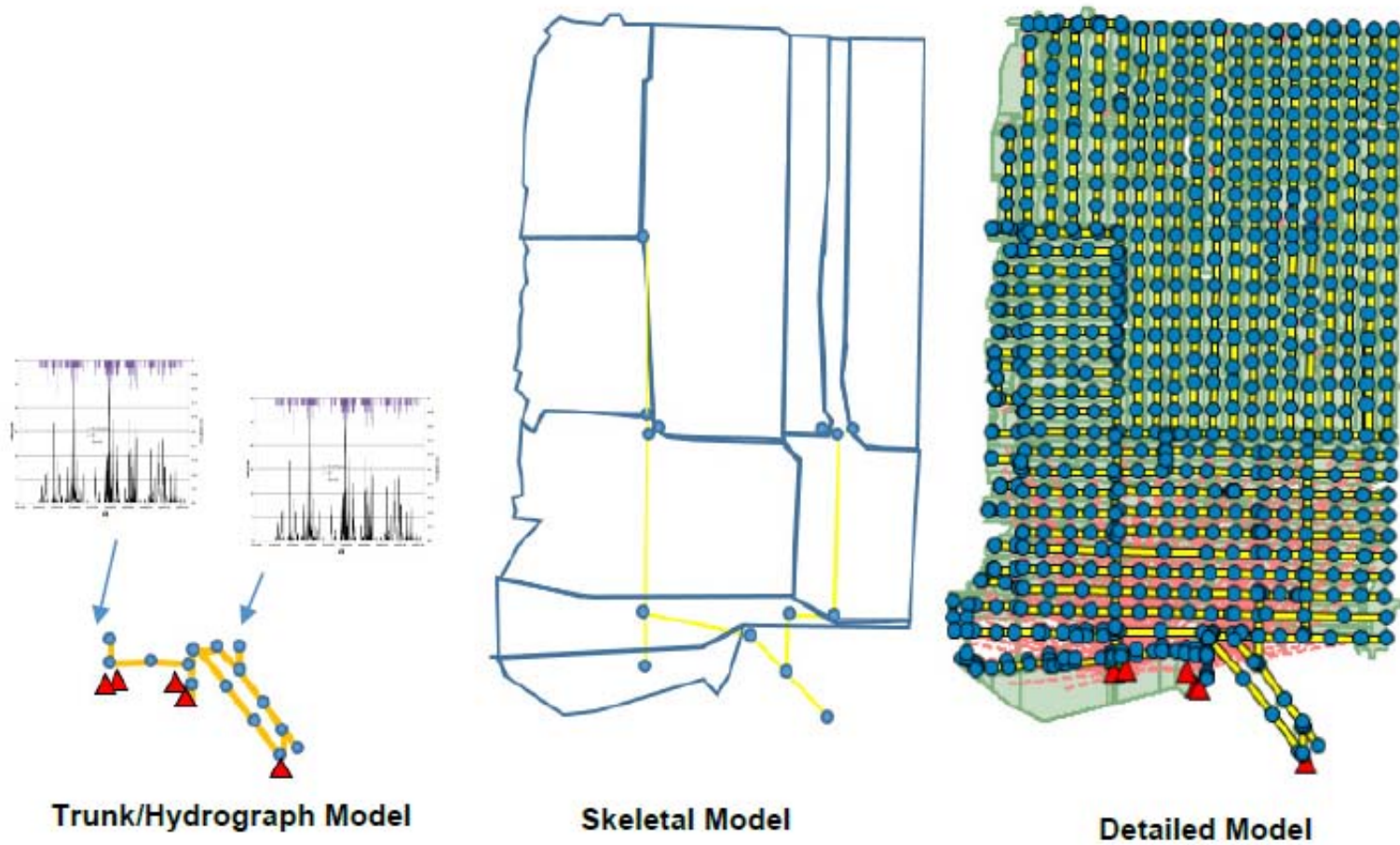
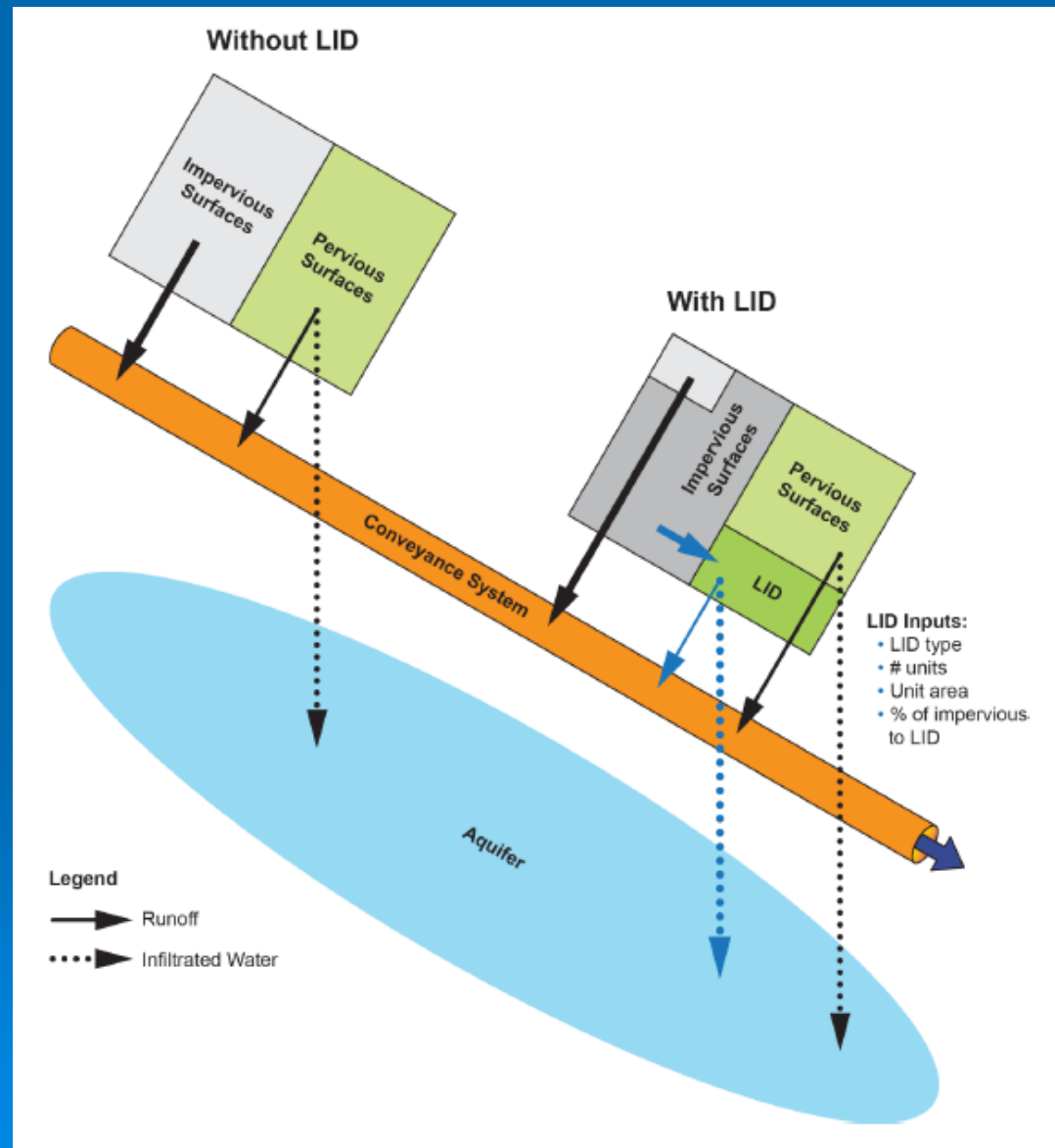


FIGURE 2-1. EXAMPLE MODEL STRUCTURES AND SCALES

SWMM Basics



SWMM Basics

LID Controls

Table 12-1. Composition of Vertical Layers in SWMM5

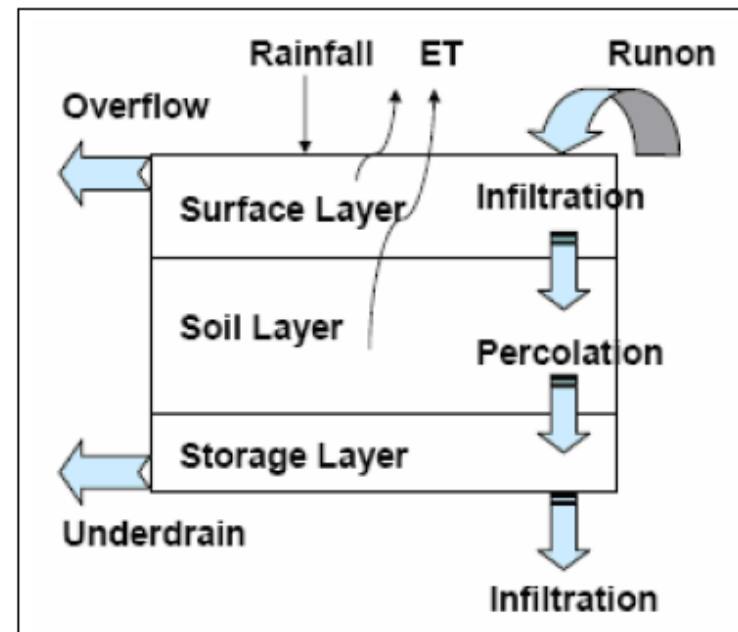
GSI Type	Surface	Pavement	Soil	Storage	Underdrain
Bioretention	√		√	√	o
Porous Pavement	√	√		√	o
Bioswale	√		o	o	o

√ = required

o = optional

GSI = green stormwater infrastructure

SWMM = stormwater management model

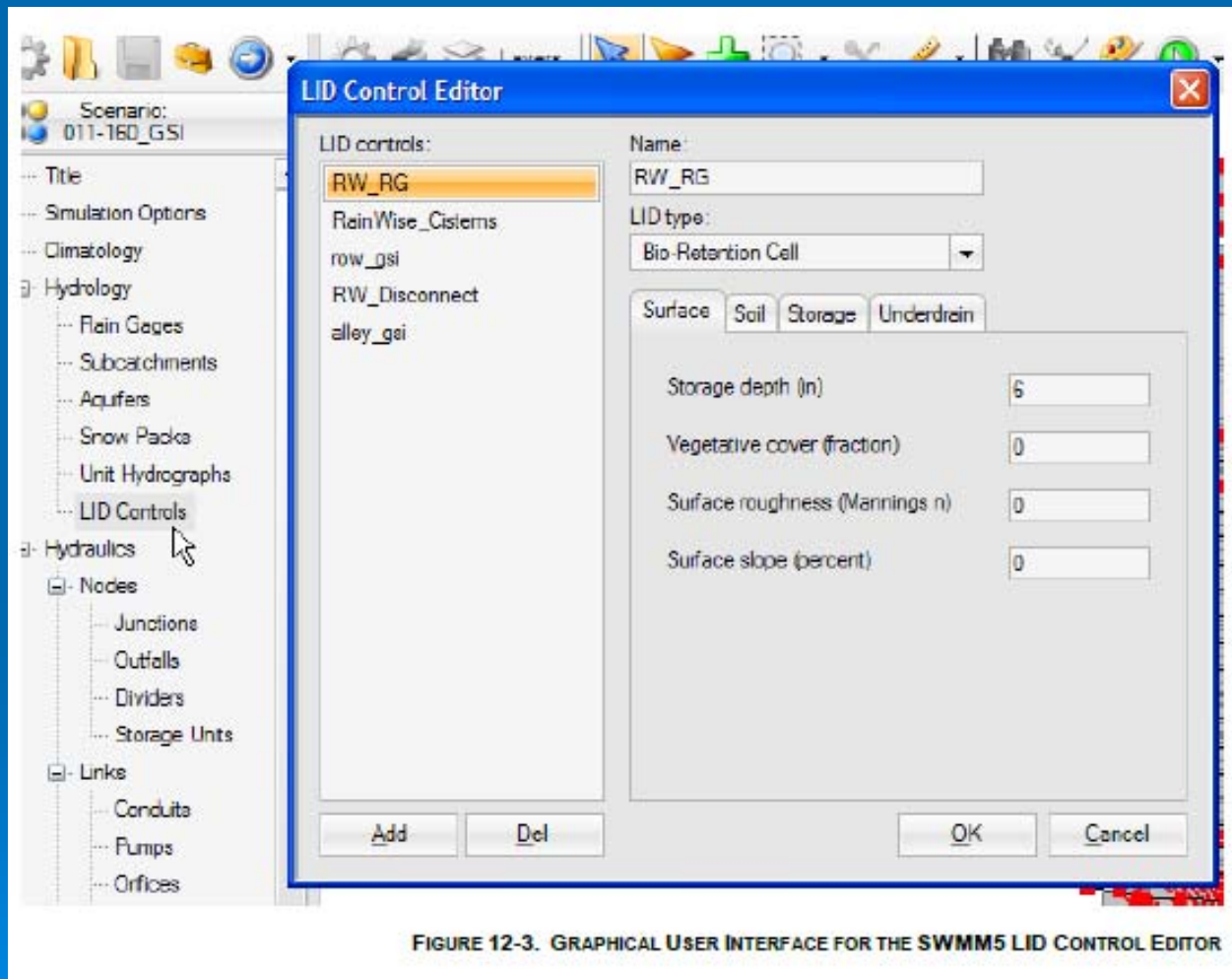


Source: SWMM5 User's Guide

FIGURE 12-2. FLOW PATHWAYS BETWEEN VERTICAL LAYERS REPRESENTING BIORETENTION

SWMM Basics

Bioretention Cell Parameters



SWMM Basics

Bioretention Cell Parameters

Table 12-2. SWMM5 Input Parameters for Bioretention GSI

Vertical Layer	Property	Description	Unit, Field ID, or Data Type	Example Value	Data Source
Surface	Storage depth	Ponding depth (do not include freeboard)	Inches	6	GSI design
	Vegetation volume fraction	Fraction of layer volume filled with vegetation	Fraction	0.1	GSI Design
Soil	Thickness	Thickness of the soil layer	Inches	12 (without UD) 24 (with UD)	SPU
	Porosity	Volume of pore space relative to total soil volume	Fraction	0.4	Rawls et al., 1998
	Field capacity	Volume of pore water relative to total volume after the soil has drained fully by gravity	Fraction	0.13	Rawls et al., 1998, for loamy sand texture
	Wilting point	Volume of pore water relative to total volume for a well-dried soil in which only bound water remains	Fraction	0.04	Rawls et al., 1998, data; difference between total and effective porosity
	Conductivity	Hydraulic conductivity for the fully saturated soil	Inches/hour	3	SPU
	Conductivity slope	Slope of the curve of log conductivity versus soil moisture content	Dimensionless	10	SWMM guidance; average of value for sand plus value for silt loam
	Suction head	Soil capillary suction along the wetting front	Inches	2.42	Assumed; loamy sand

SWMM Basics

Bioretention Cell Parameters

Table 12-2. SWMM5 Input Parameters for Bioretention GSI

Vertical Layer	Property	Description	Unit, Field ID, or Data Type	Example Value	Data Source
Storage	Height	Height of a gravel layer below the soil layer	Inches	1 (without UD) 6 (with UD)	SPU
	Void ratio	Volume of void space relative to the volume of solids in the layer	Ratio	0.667	(Equivalent to 0.4 porosity)
	Infiltration rate	Rate at which water infiltrates into the native soil below the storage layer	Inches/hour	Depends on background soil	To be provided by SPU or geotechnical analysis
	Clogging factor	Total volume of treated runoff it takes to completely clog the bottom of the layer divided by the void volume of the layer	Dimensionless	0	Not used
Underdrain	Drain coefficient	Coefficient of the equation that calculates the flow rate through the underdrain as a function of water level above the drain height	Inches ^{1/2} /hour	Depends on outlet size	SPU
	Drain exponent	Exponent of head in SWMM drain equation	Dimensionless	0.5 (orifice drain)	SWMM5 guidance
	Drain offset height	Height of underdrain pipe from the bottom of the layer or rain barrel	Inches	6	SPU

SWMM Basics

LID Usage Editor

LID Usage Editor: ROW_002-082

LID usages:

- alley_gsi
- row_gsi

LID control name: row_gsi

Number of replicate units: 1

☐ LID occupies full subcatchment

Area of each unit (ft²): 2228.5

% of subcatchment occupied: 1.000

Top width of overland flow surface of each unit (ft): 0

% initially saturated: 30

% of impervious area treated: 51.51

☐ Send outflow to pervious area

Detailed report file (optional):

Buttons: Add, Del, OK, Cancel

FIGURE 12-5. LID USAGE EDITOR

Combined Sewer Overflow Reduction

SWMM Example



Site Scale Optimization: Ballard Roadside Rain Gardens Pilot Project



The Pilot



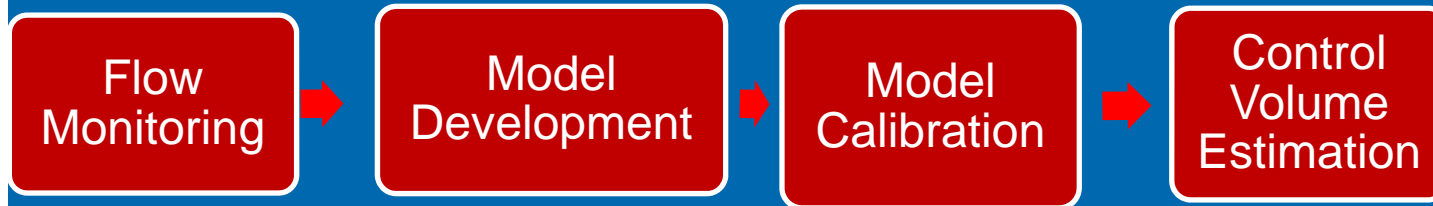
The Problem



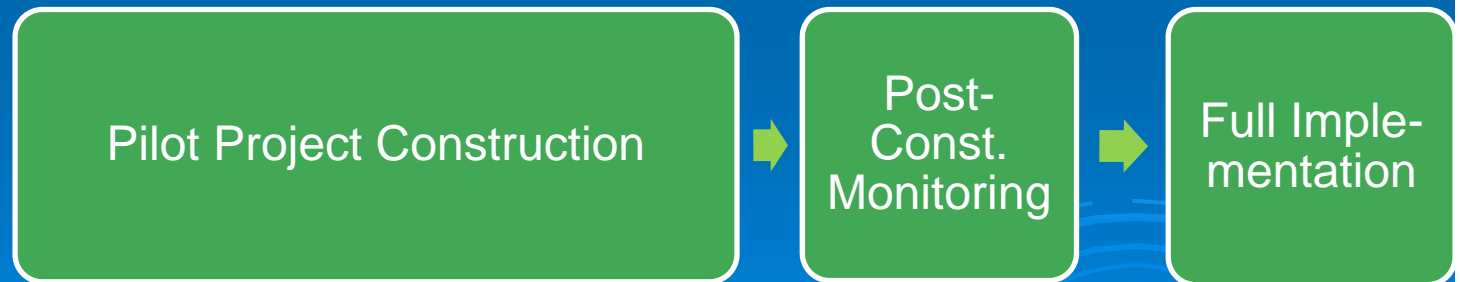
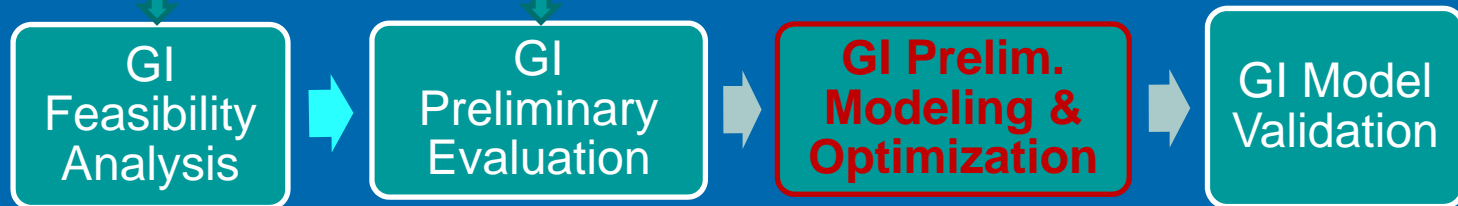
The Fix

Green Infrastructure Evaluation Process

System Modeling



GI Analysis and Modeling



GI Project Implementation

Green Infrastructure Modeling

RainWise Practices

Rain Gardens → **Bio-retention Cell**

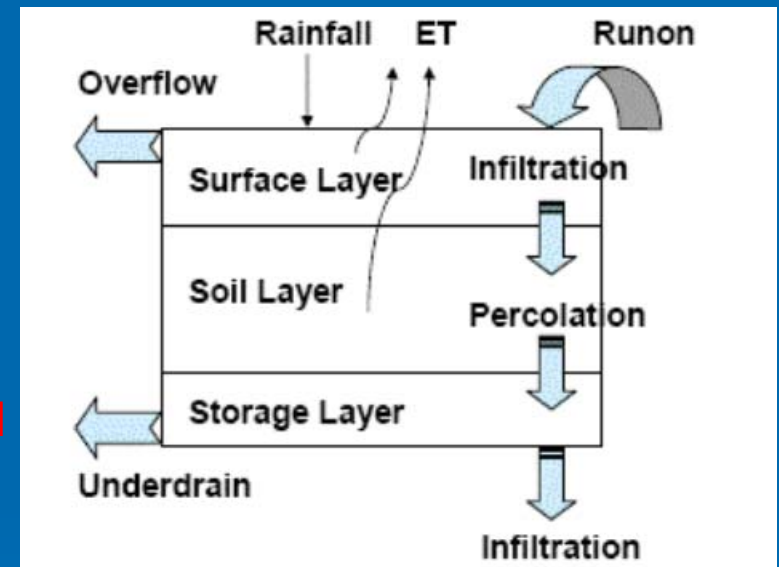
Cisterns → **Bio-retention Cell**

(non-infiltrating with underdrain)

Right-of-way CIP Practices

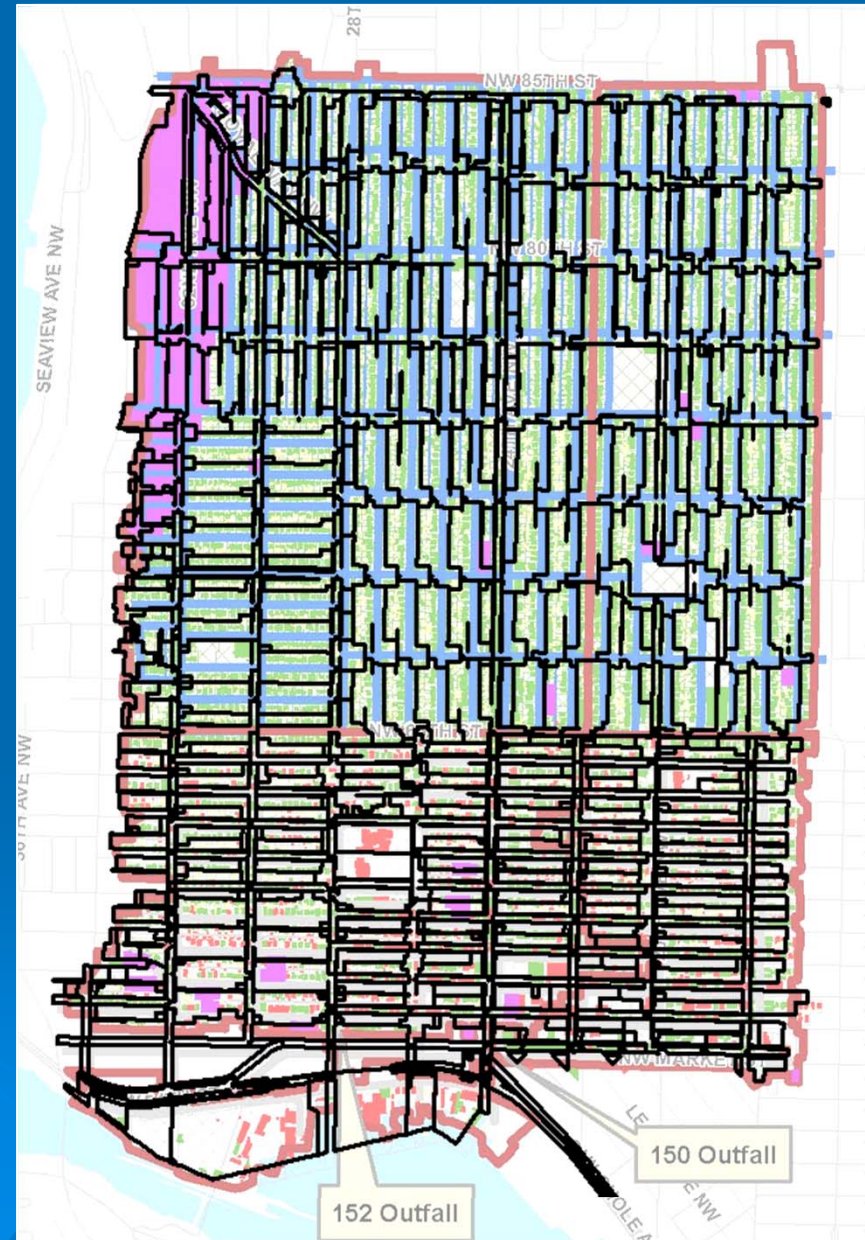
Roadside Rain Gardens → **Bio-retention Cell**

Green Alleys → **Porous Pavement**

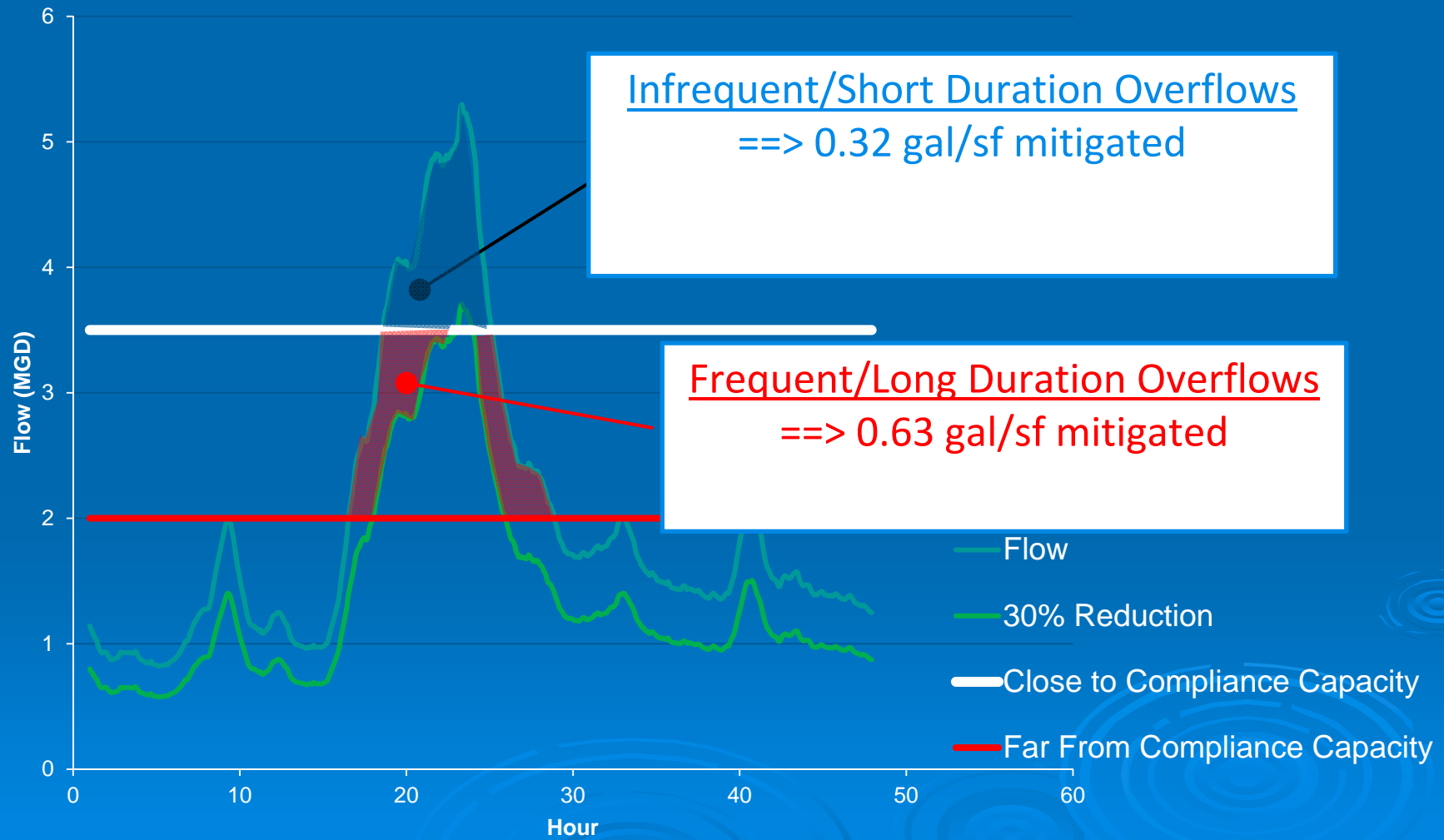


GI Modeling

- Modeled using EPA SWMM5
- 32-year long term simulations performed
- Feasibility Analysis overlaid with model subcatchment delineation to develop input files



Basin Scale Optimization: Basin-Specific Performance



Other metrics besides Control Volume reduction

Basin 150	Without GI	Reduction	% Reduction
Control Volume (MG)	0.60	0.16	26%
Events/year	12.2	5.0	41%
Annual Overflow Volume (MG/year)	3.52	0.97	28%
Basin 152	Without GI	Reduction	% Reduction
Control Volume (MG)	5.35	1.04	19%
Events/year	37.5	9.8	26%
Annual Overflow Volume (MG/year)	28.75	9.58	33%

Resources

- LID Technical Guidance Manual
http://www.pierce.wsu.edu/Water_Quality/LID/LID_manual2005.pdf
- WWHM
<http://www.clearcreeksolutions.com/>
- MGSFlood
<http://www.mgsengr.com/MGSFlood.html>
- HSPF
<http://water.usgs.gov/software/HSPF/>
- WDMUtils
<http://www.epa.gov/waterscience/basins/b3webdwn.htm>

Questions and Answers

???



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