Rhode Island Stormwater Design and Installations Manual
Public Review Draft

Public Review Meeting: June 4, 2009

Why Update the 1993 Manual

and

What is Different?

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Why is the manual being updated

- A lot of technical/scientific advances since 1993;
- Methods and techniques have failed to protect water resource quality;
- Hydrologic alteration of new development not addressed in the 1993 manual (recharge and volume controls);
- 80% TSS removal requirement has not prevented resources from degrading; and
- Widely recognized that a more holistic management approach is necessary.

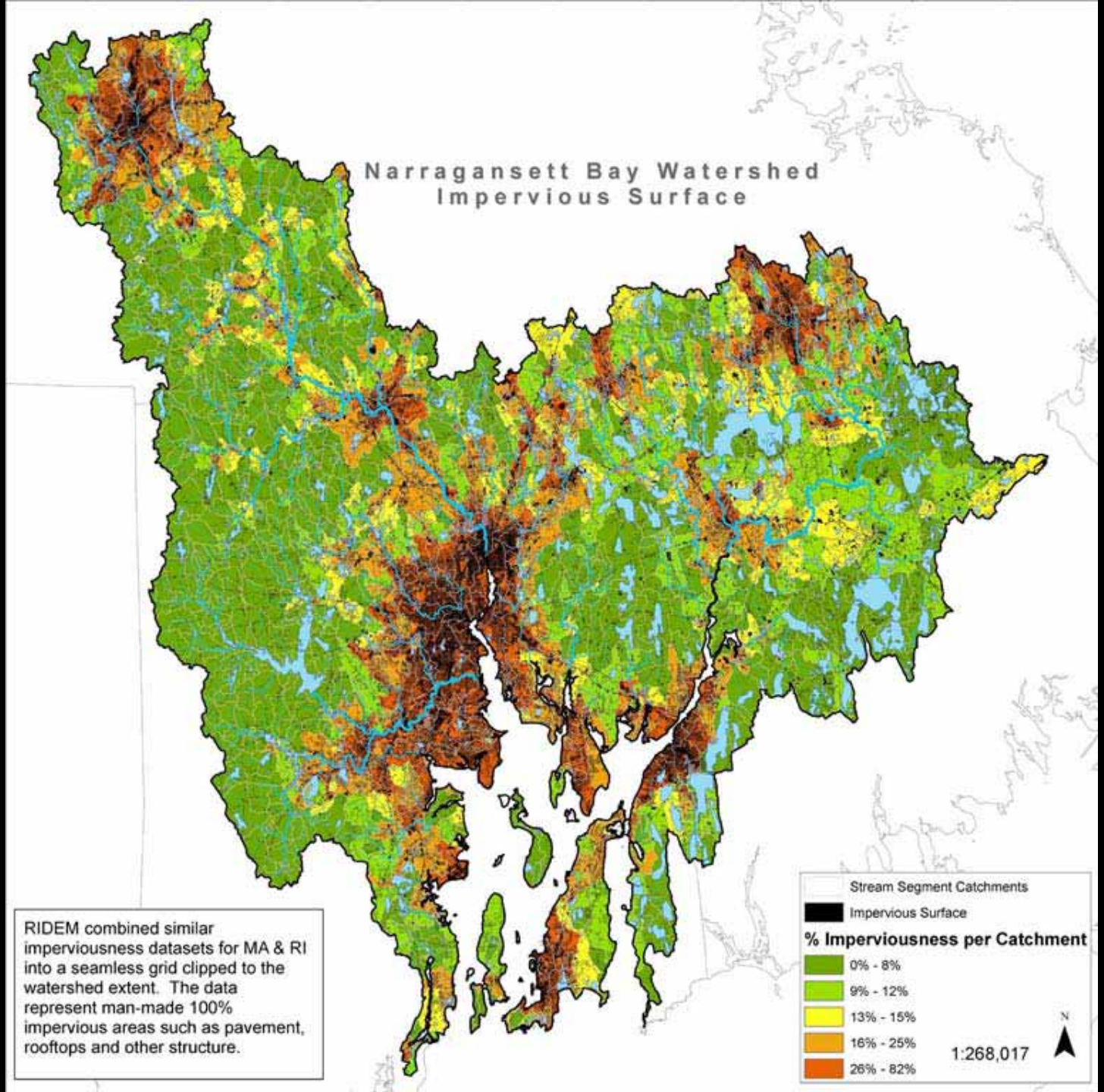
Legislative Mandate

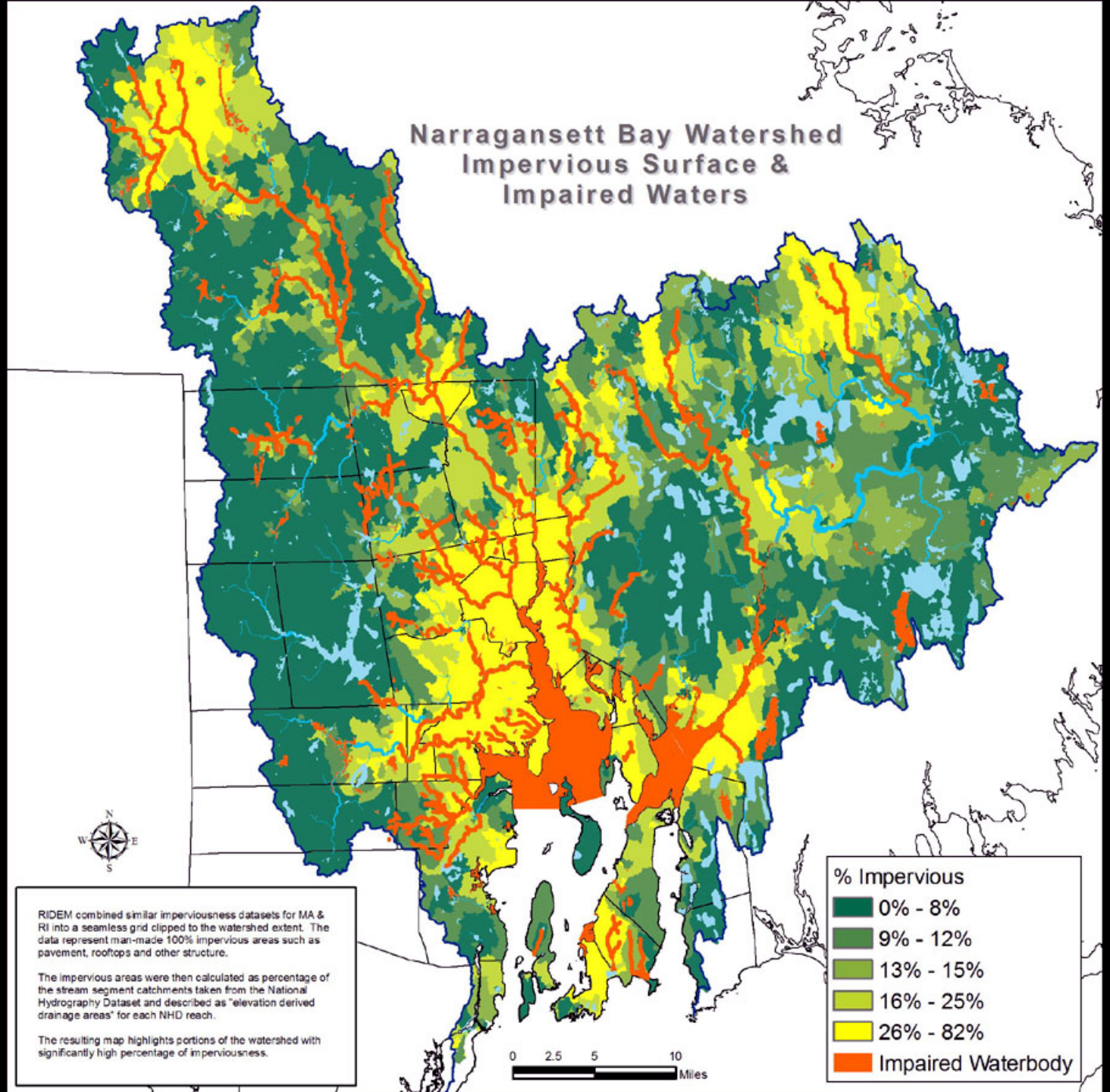
Rhode Island General Law, Section 45, Chapter 61.2, entitled "The Smart Development for a Cleaner Bay Act of 2007" states that "stormwater, when not properly controlled and treated, causes pollution of the waters of the state…" and "development often results in increased stormwater runoff by increasing the size and number of paved and other impervious surfaces…" The Bay Act of 2007 requires DEM and CRMC to amend the 1993 Stormwater Design and Installation Standards Manual to:

a) Maintain groundwater recharge to predevelopment levels;

b) Maintain post-development peak discharge rates to not exceed pre-development rates; and

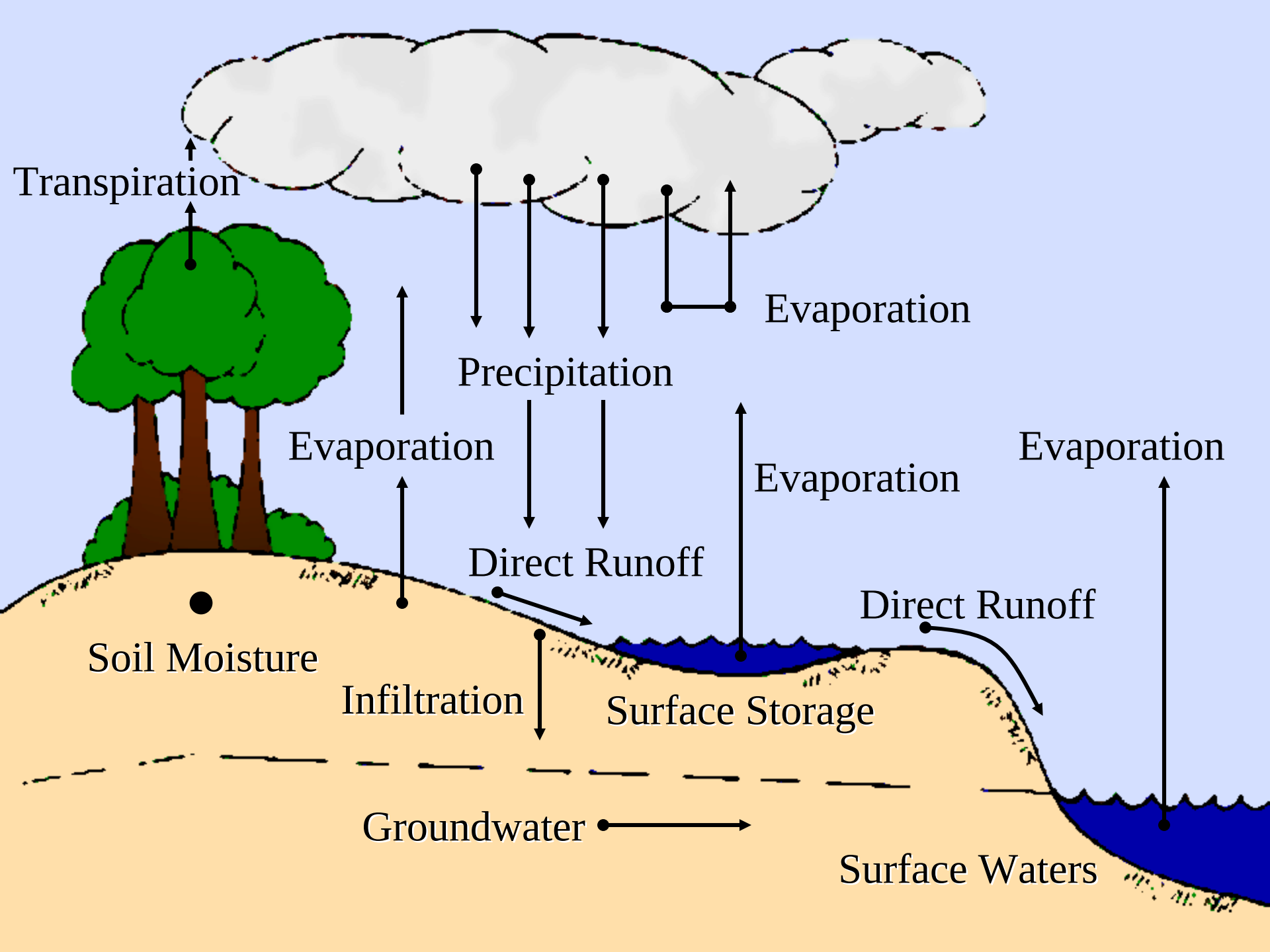
c) Use LID techniques as the primary method of stormwater control to the maximum extent practicable.


Narragansett Bay Watershed
Impervious Surface
RIDEM combined similar imperviousness datasets for MA & RI into a seamless grid clipped to the watershed extent. The data represent man-made 100% impervious areas such as pavement, rooftops and other structure.
Stream Segment Catchments
Impervious Surface
% Imperviousness per Catchment
0% - 8%
9% - 12%
13% - 15%
16% - 25%
26% - 82%
1:268,017
N


Narragansett Bay Watershed
Impervious Surface &
Impaired Waters
N
W
E
S
RIDEM combined similar imperviousness datasets for MA & RI into a seamless grid clipped to the watershed extent. The data represent man-made 100% impervious areas such as pavement, rooftops and other structure.
The impervious areas were then calculated as percentage of the stream segment catchments taken from the National Hydrography Dataset and described as "elevation derived drainage areas" for each NHD reach.
The resulting map highlights portions of the watershed with significantly high percentage of imperviousness.
0 2.5 5 10
Miles
% Impervious
0% - 8%
9% - 12%
13% - 15%
16% - 25%
26% - 82%
Impaired Waterbody

Orchard Meadows Dr
Orchard Meadows Dr
Cedar Meadows Dr

Westmoreland Ln


Transpiration
Evaporation
Precipitation
Evaporation
Evaporation
Evaporation
Direct Runoff
Direct Runoff
Soil Moisture
Infiltration
Surface Storage
Groundwater
Surface Waters

40 yds
© 2009 Microsoft Corporation © 2009 NAVTEQ © AND
© 2009 Pictometry International Corp.

Technical Results

Post-construction Impacts on Water Quantity

Construction | Post-construction

After all of the impervious surfaces were installed and construction ceased in the Traditional subdivision, the volume, depth and peak discharge of stormwater leaving the site increased significantly (Figure 1). In contrast, after construction finished in the LID subdivision, stormwater runoff volume significantly *decreased* from pre-construction levels. These changes can also be seen in the hydrograph below (Figure 2), which is representative data from a single September storm.

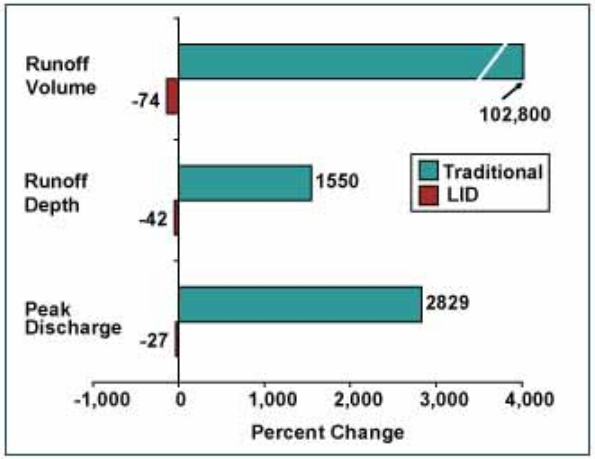


Figure 1. Significant changes in runoff volume (m^3/week), runoff depth (cm/week) and peak discharge (m^3/sec/week) after construction was completed.

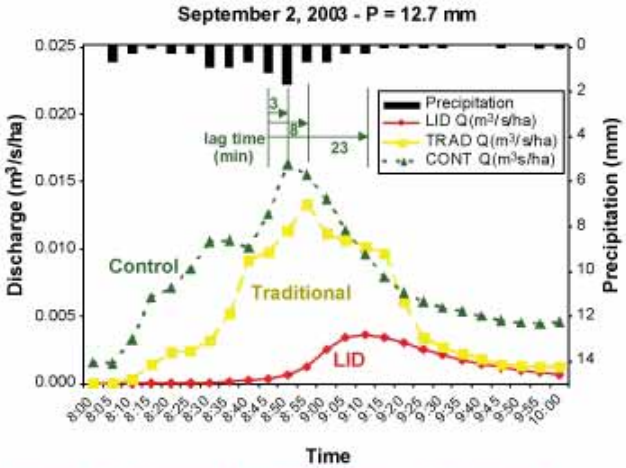
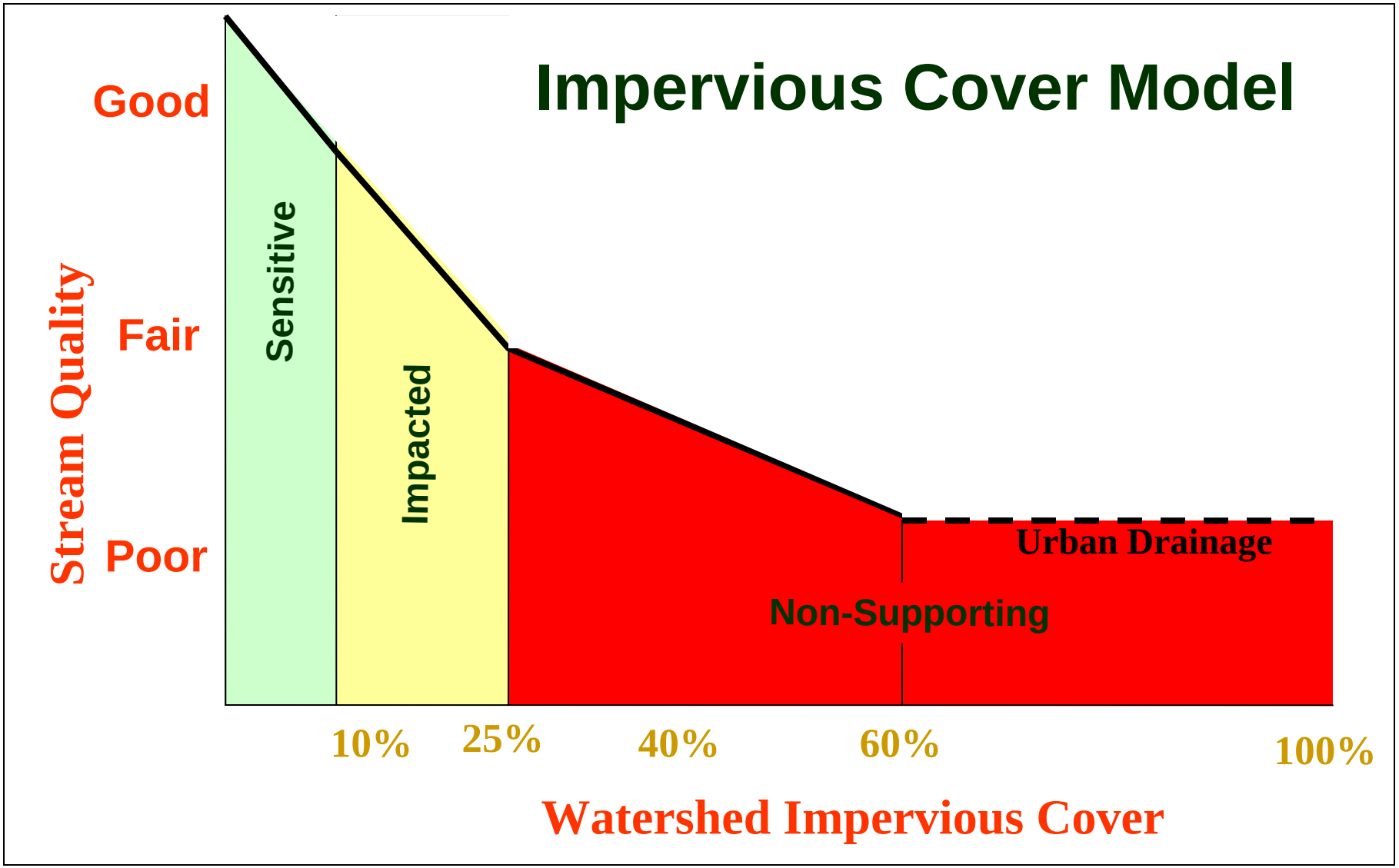
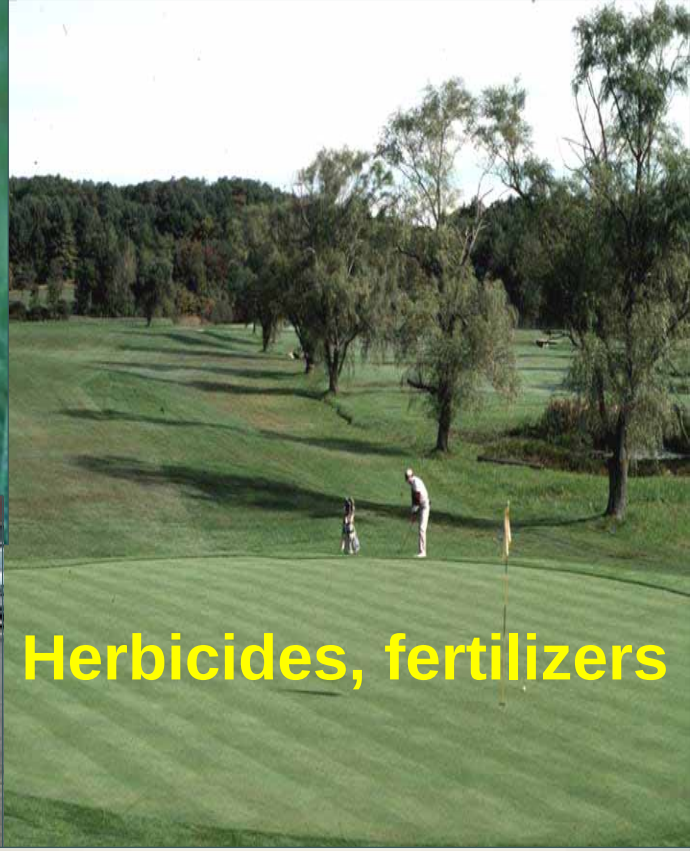


Figure 2. Hydrograph of all three subdivisions in project, showing the larger volume and rate of runoff from the traditional and control subdivisions, as compared to the LID.

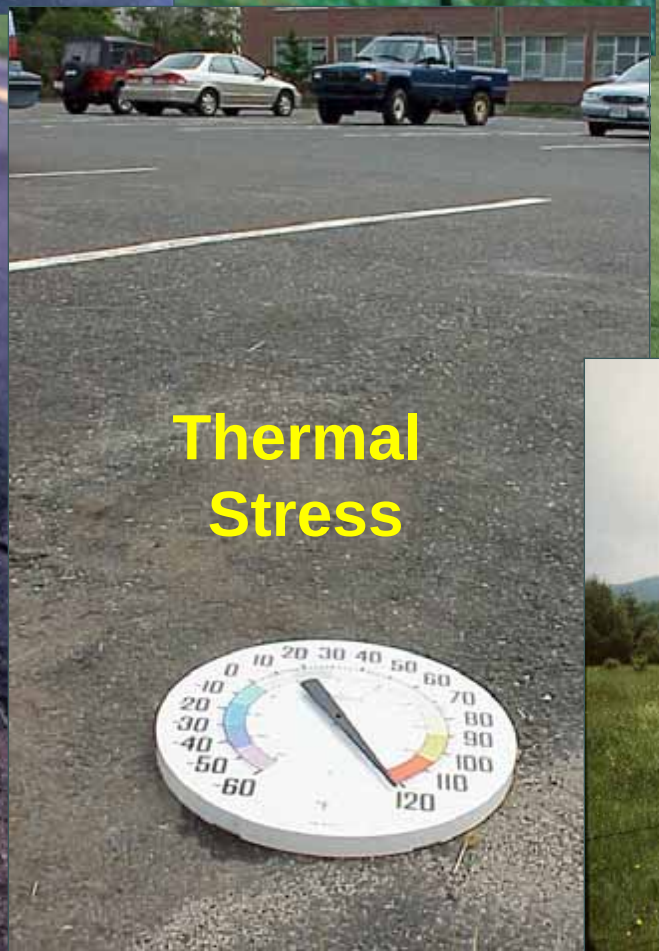

Impervious Cover Model
Good
Fair
Poor
Stream Quality
Sensitive
Impacted
Urban Drainage
Non-Supporting
10%
25%
40%
60%
100%
Watershed Impervious Cover

Detergents

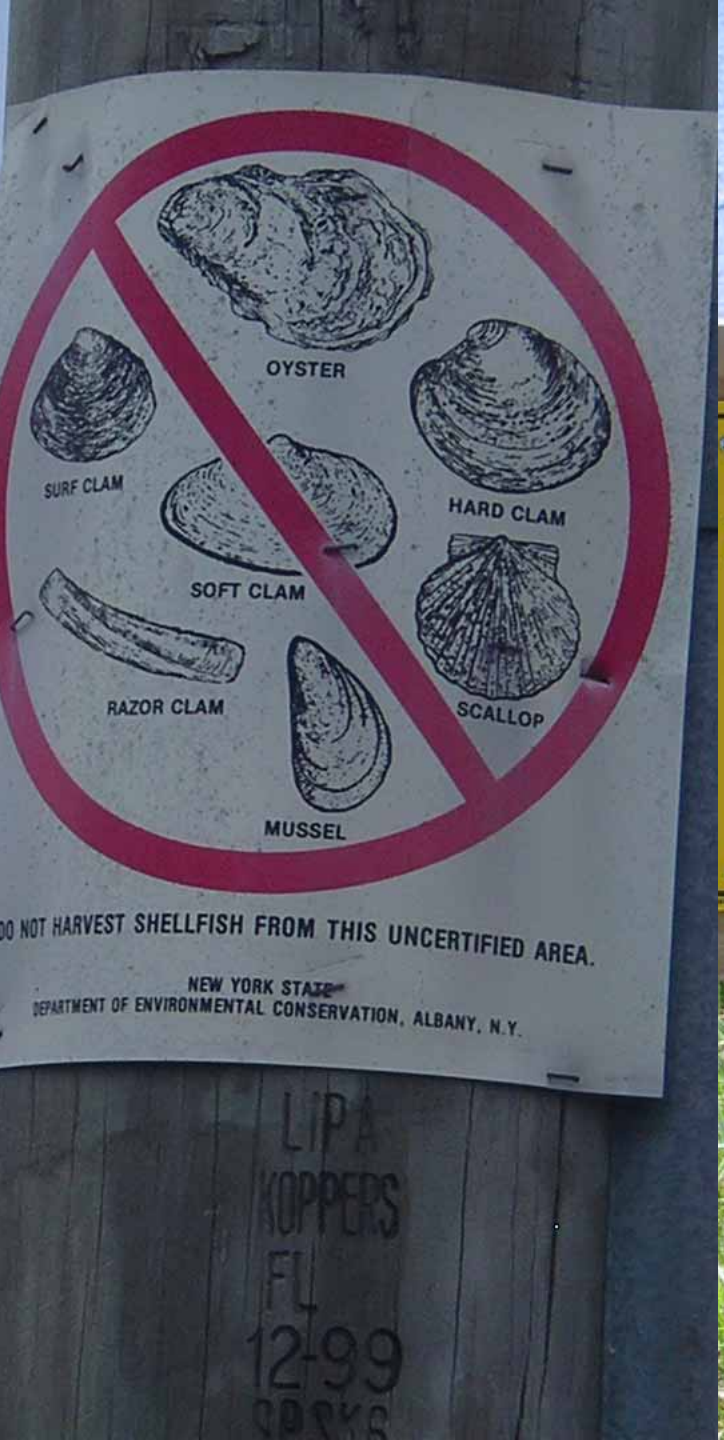
CAUTION
PESTICIDE APPLICATION
KEEP
OFF
Toxic
Contaminants


Herbicides, fertilizers

Debris,
Salt,
Sediment,
Oils &
Grease

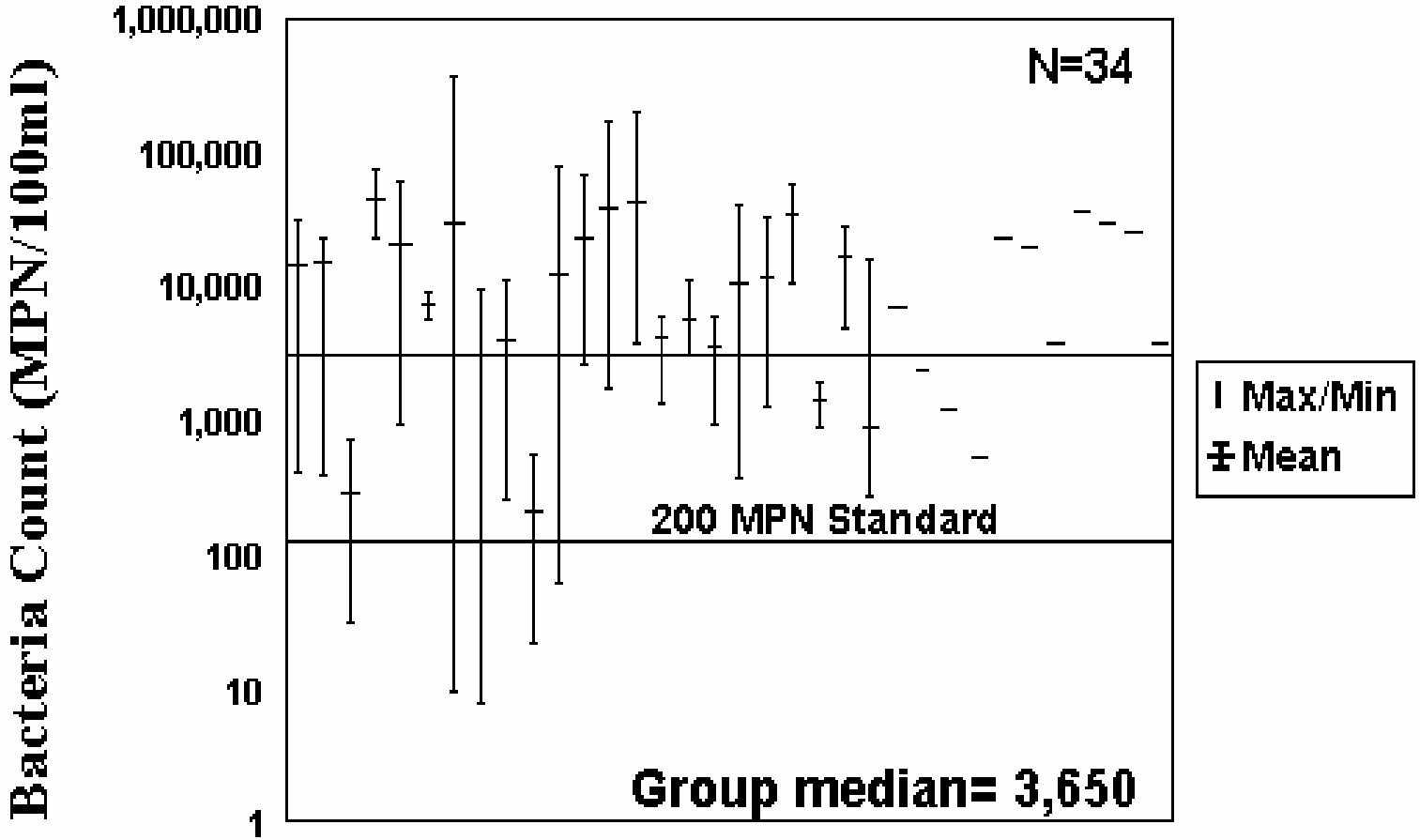

Thermal
Stress

Nutrients and
Pathogens


OYSTER
SURF CLAM
HARD CLAM
SOFT CLAM
RAZOR CLAM
SCALLOP
MUSSEL
DO NOT HARVEST SHELLFISH FROM THIS UNCERTIFIED AREA.
NEW YORK STATE
DEPARTMENT OF ENVIRONMENTAL CONSERVATION, ALBANY, N.Y.
LIPA
KOPPERS
FL
12-99

CLOSED AREA
NO SHELLFISHING
Due to fecal coliform bacterial contamination
PER ORDER OF
MASSACHUSETTS DIVISION OF MARINE
FISHERIES
PAUL S. MONTAGUE, SHELLFISH CONSTABLE
508-548-7611 ext. 334
GATHERING OYSTERS, CLAMS, AND
MUSSELS PROHIBITED BY LAW
FINES UP TO $100.00 OR 30 DAYS
IN JAIL FOR EACH VIOLATION.
WARNING
PROHIBITED AREA
THE CONSUMPTION OF OYSTERS, CLAMS,
AND MUSSELS FROM THIS AREA MAY
CAUSE SERIOUS ILLNESS.
RELAYING OR TRANSPLANTING ALLOWED
BY SPECIAL PERMIT ONLY.
S.C. DEPT. OF HEALTH &

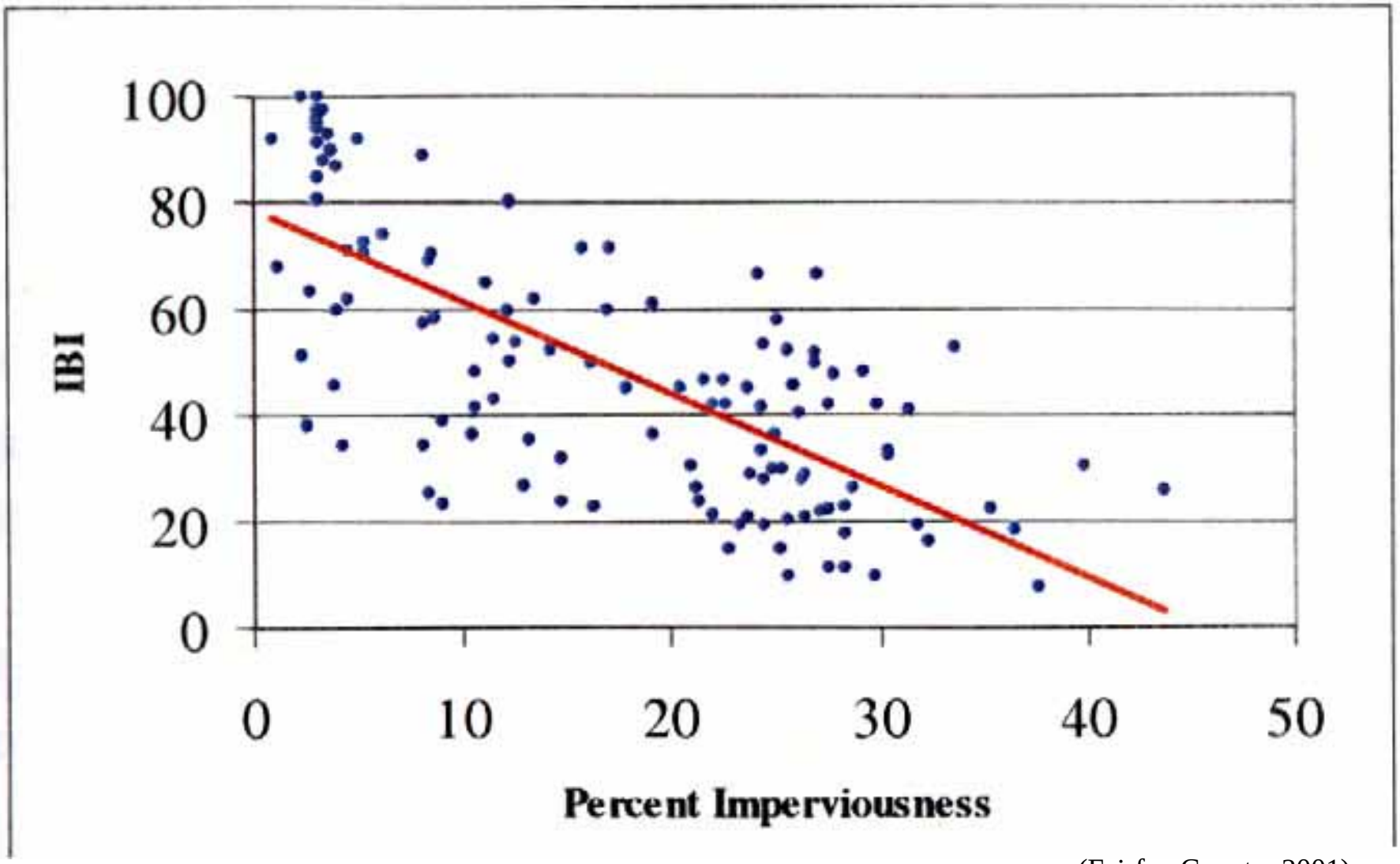
Fecal Coliform Levels in Urban Stormwater: A National Review



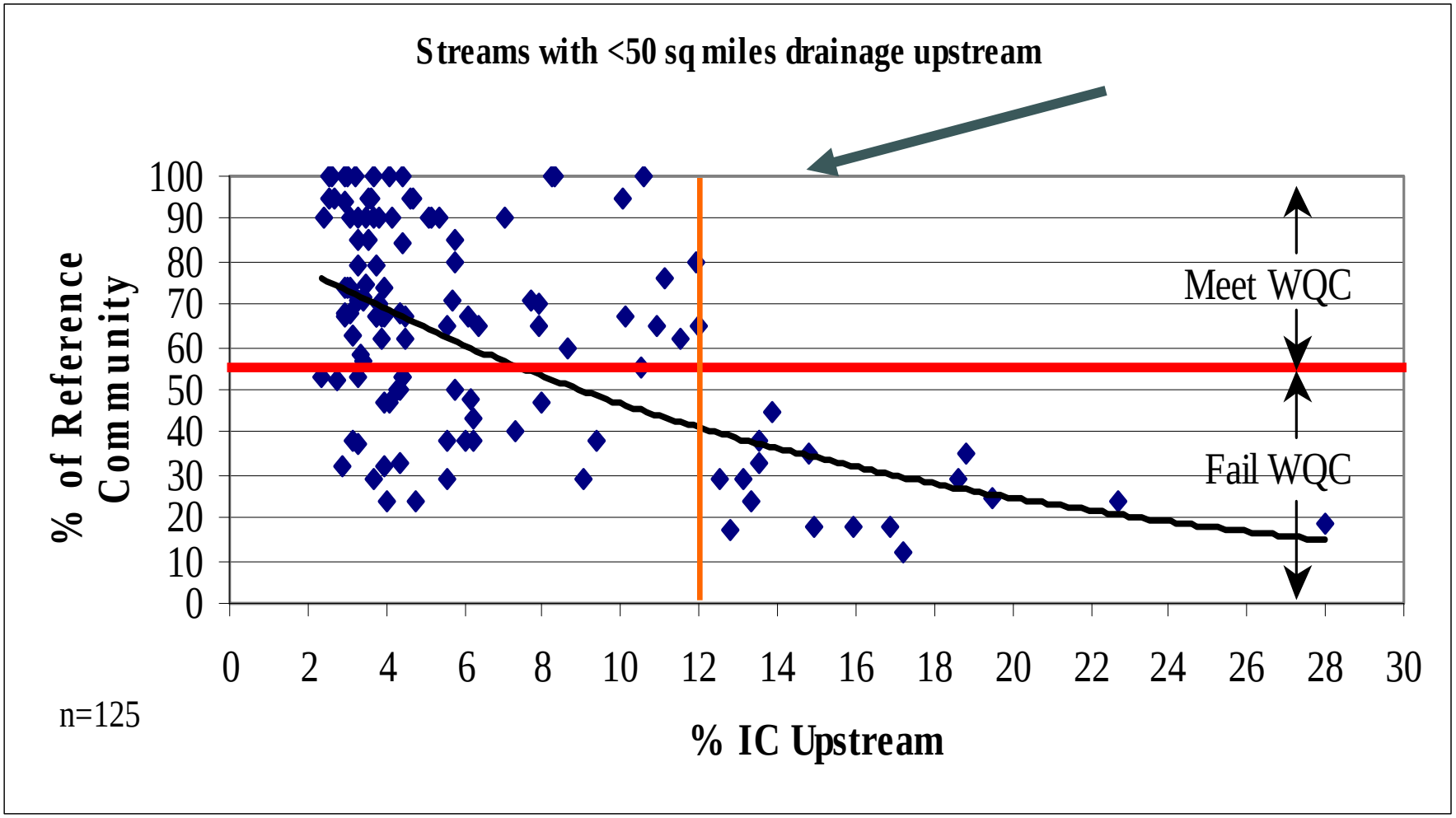
Stormwater runoff levels from 34 small catchments in 13 monitoring studies conducted:

AL, AZ, ID, KY, MD, NC, NH, NY, SD, TN, TX, WA, WI

Index of Biological Integrity vs. Impervious Cover



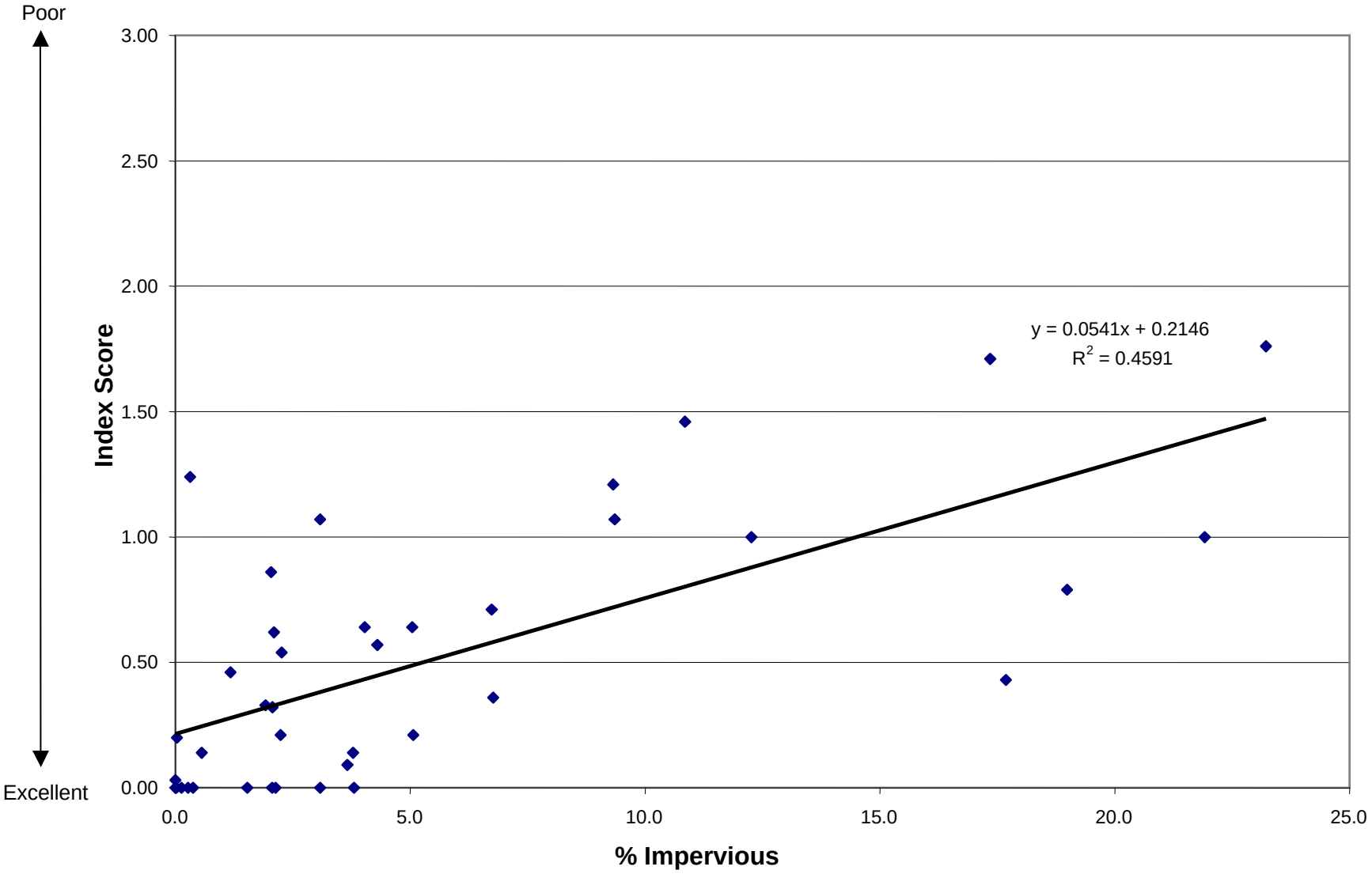
(Fairfax County, 2001)



C. Bellucci - CTDEP

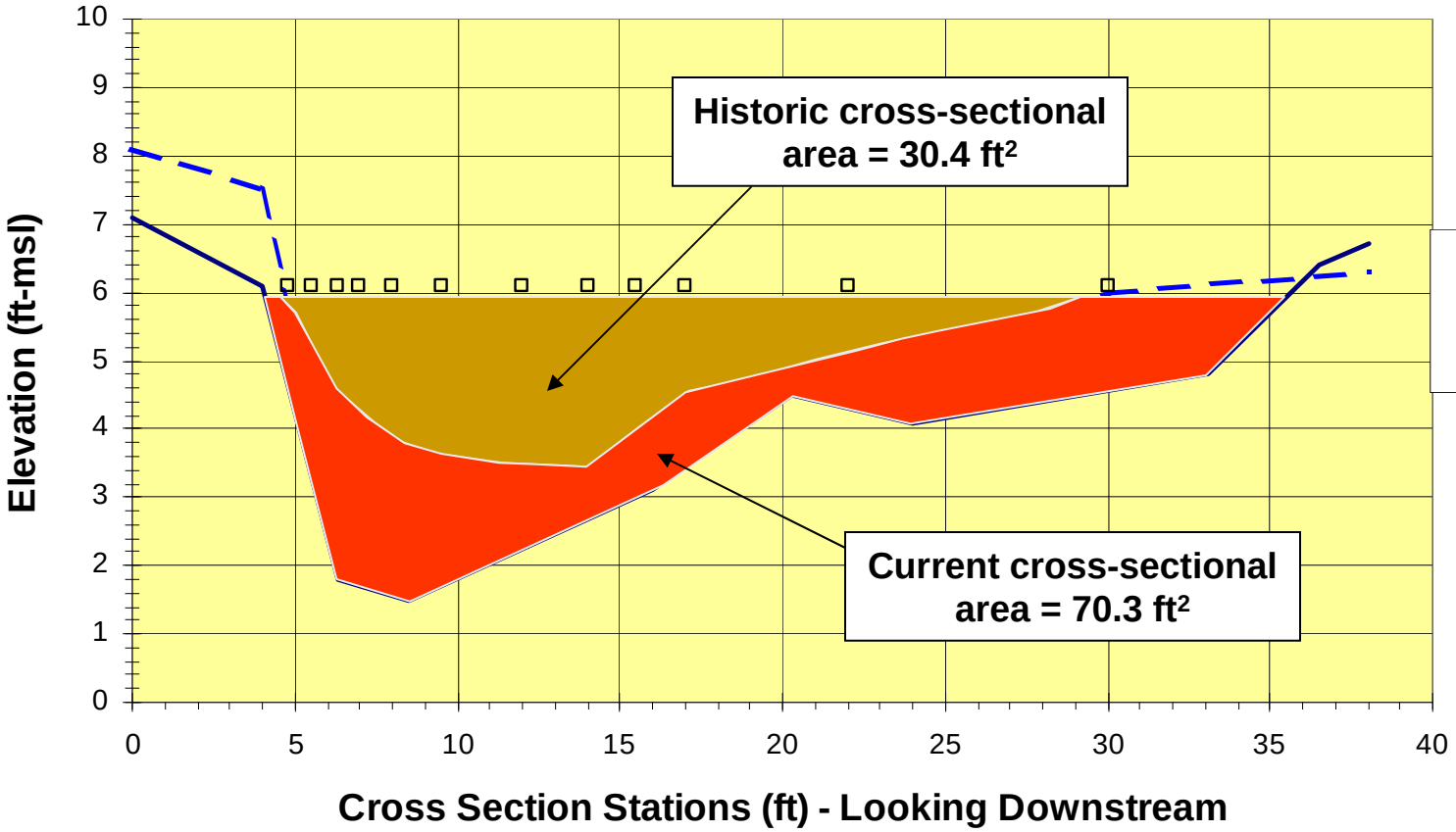
Watershed Imperviousness vs. Macroinvertebrate Index

For 39 Vermont Watersheds



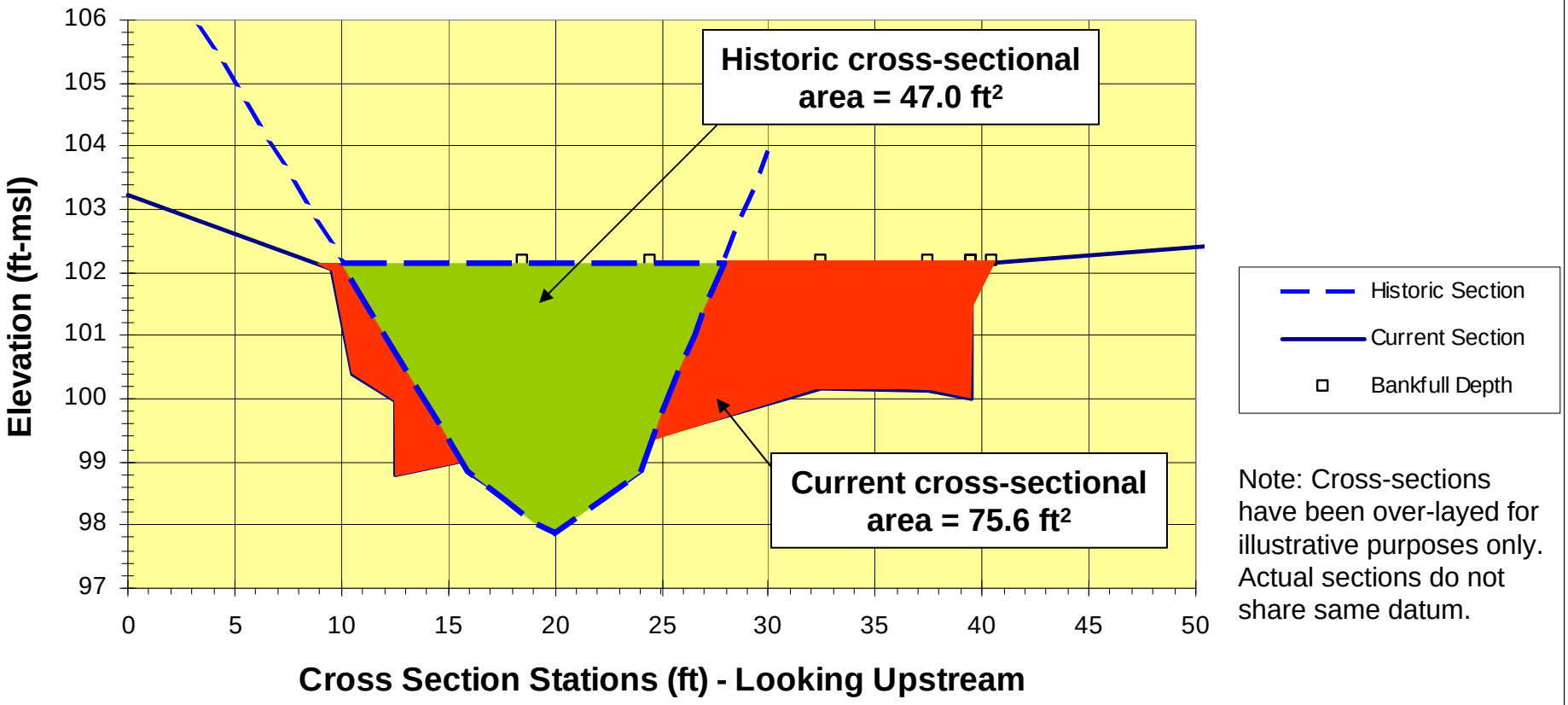
Source: Leopold, 1994

Comparison of Historic vs. Current Cross-Sections at Station WAT7 (Leopold Site 44A-45)



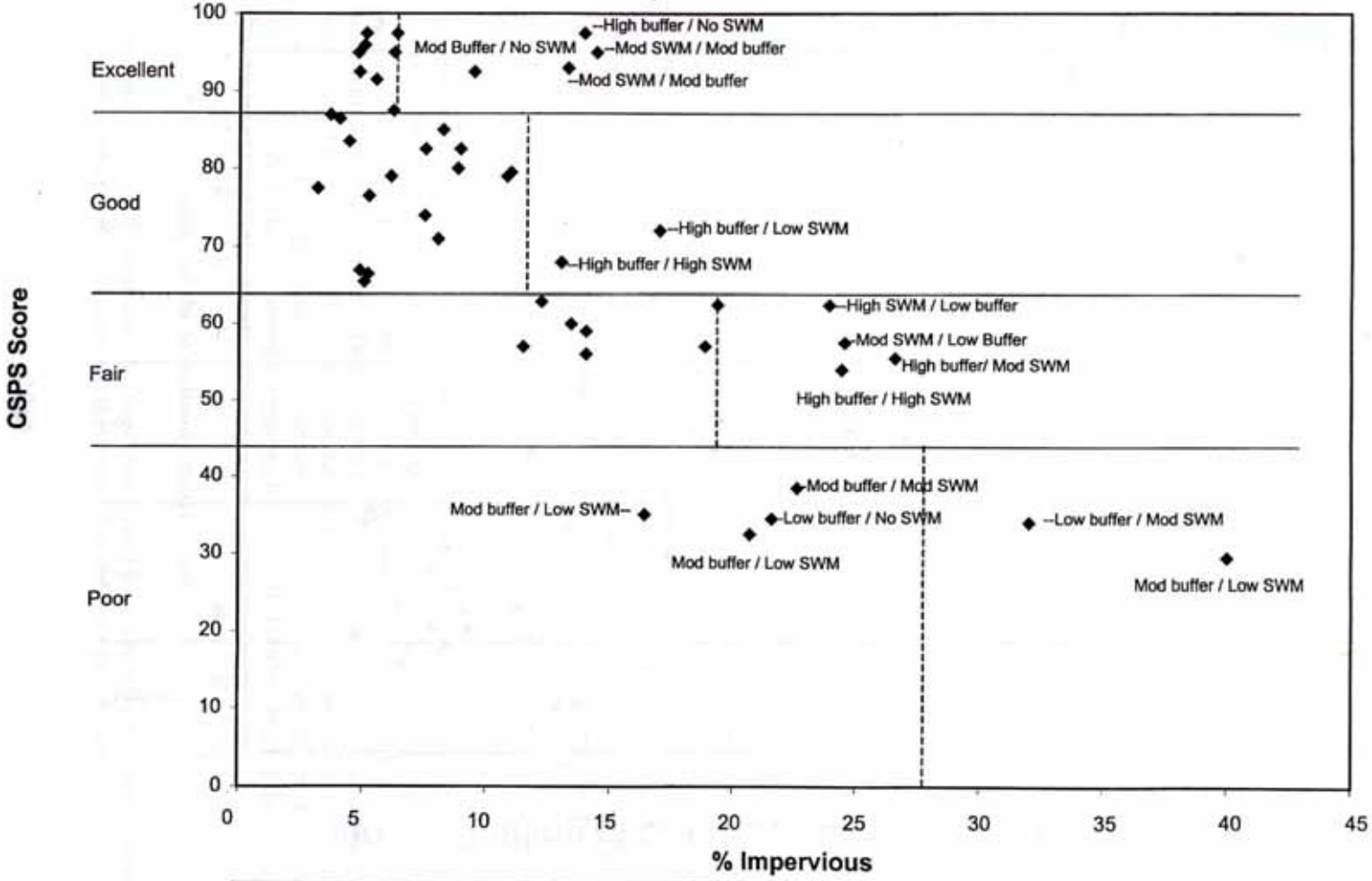
Note: Cross-sections have been overlayed for illustrative purposes only. Actual sections do not share same datum.

Comparison of Historic vs. Current Cross-Sections at Station POT1



Note: Cross-sections have been over-layed for illustrative purposes only. Actual sections do not share same datum.

Figure 8: Use of SWM and Buffers as Modifiers of Imperviousness[1]



Notes

High Buffer - >66% of buffer forested
Moderate Buffer – 33-66% of buffer forested
Low Buffer - <33% of buffer forested

High SWM - >66% of impervious managed with SWM
Moderate SWM – 33-66% of impervious managed with SWM
Low SWM - <33% of impervious managed with SWM

(Booth, 2000)

Where did 80% TSS Removal Originate?

- The 80% standard was a product of the Coastal Zone Act Reauthorization Amendments of 1990 (CZARA) requiring EPA to develop NPS guidance based on being:
  - economically achievable
  - reflect the greatest degree of pollutant reduction achievable through the application of the best available non-point pollution control practices.

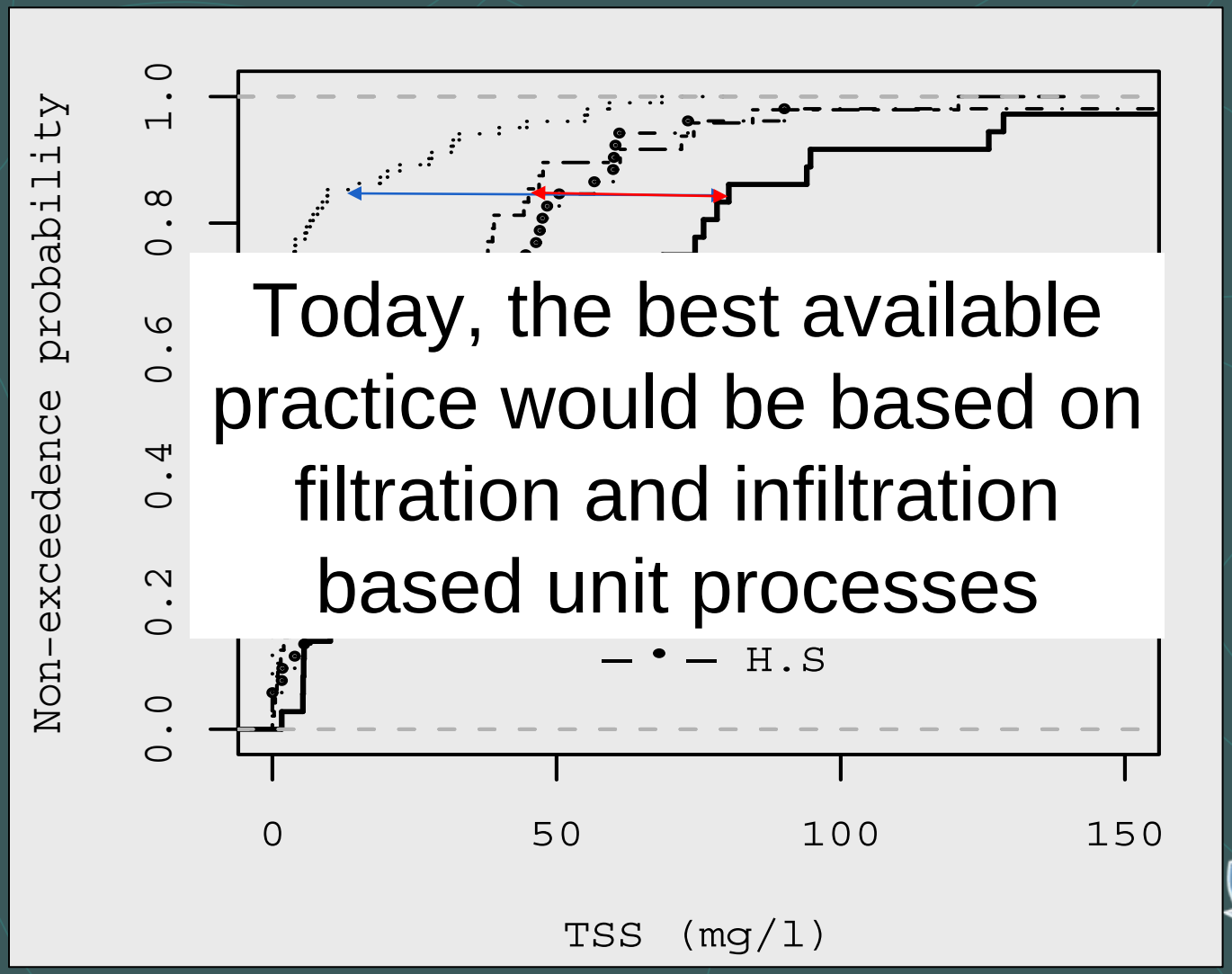
1993 EPA Guidance

Guidance Specifying Management Measures for Sources of Nonpoint Pollution in Coastal Waters (1993)

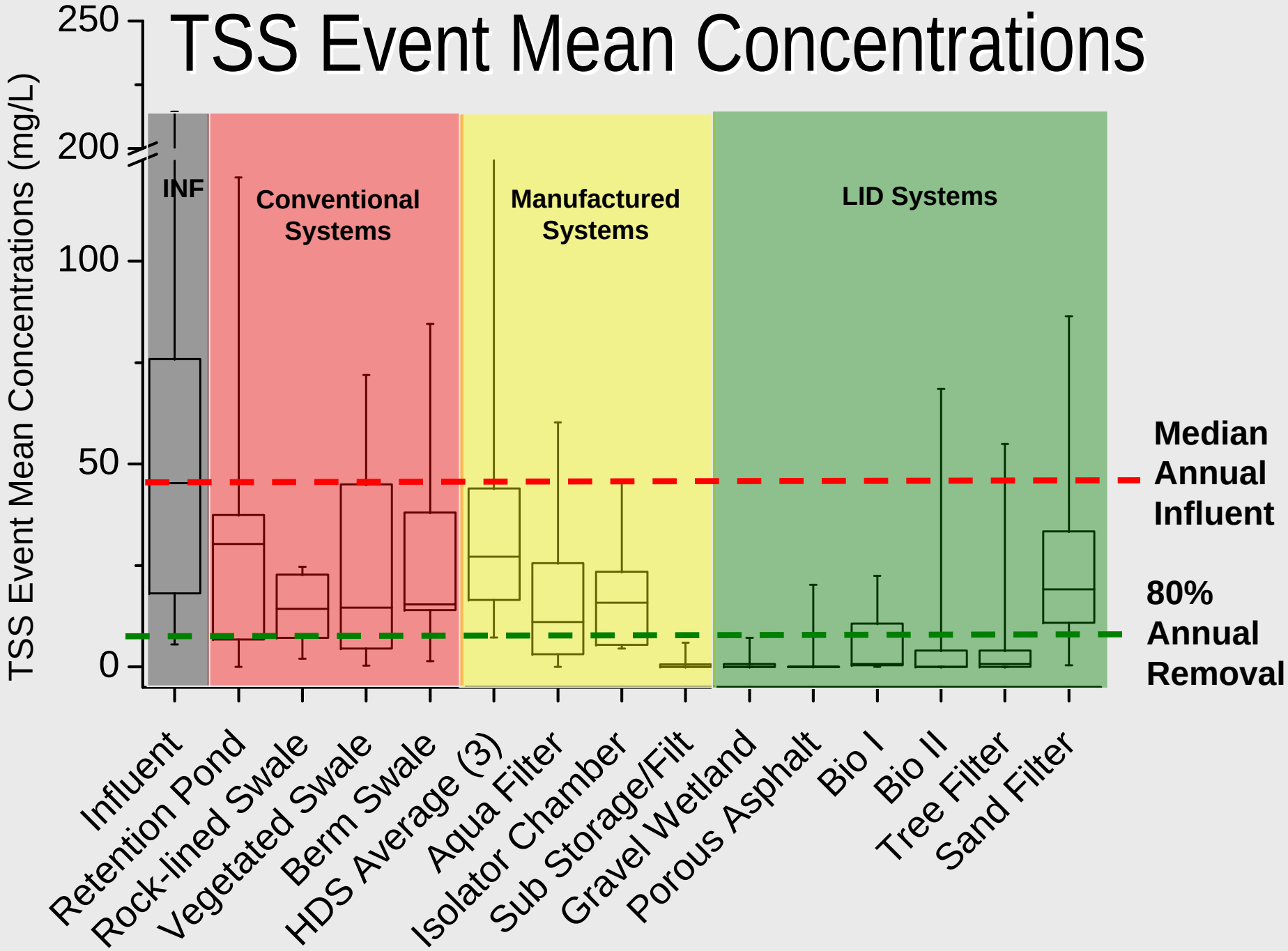
Recommends by design or performance:

1. Either
   a. Post construction reduce average annual TSS loadings by 80% …or
   b. Reduce post-development loadings of TSS so that average annual TSS load = pre-development conditions
2. To the MEP maintain post-development peak runoff rate AND average rainfall volume at levels similar to pre-development conditions

Performance By Unit Process



Today, the best available practice would be based on filtration and infiltration based unit processes


TSS Event Mean Concentrations
TSS Event Mean Concentrations (mg/L)
250
200
100
50
0
INF
Conventional Systems
Manufactured Systems
LID Systems
Median Annual Influent
80% Annual Removal
Influent
Retention Pond
Rock-lined Swale
Vegetated Swale
Berm Swale
HDS Average (3)
Aqua Filter
Isolator Chamber
Sub Storage/Filt
Gravel Wetland
Porous Asphalt
Bio I
Bio II
Tree Filter
Sand Filter

What are the most significant changes to the 1993 manual

- Low impact development (LID) required to the maximum extent practicable;
- Recharge criteria added to infiltrate runoff from up to 0.6 inches per impervious acre;
- Revised design precipitation rates based on latest rainfall data;
- Raised water quality pollutant removal targets (90% TSS, 90% FC, 40% TP, 30% TN);
- Reduces the number of options for water quality treatment (extended detention and wet basins no longer acceptable as stand-alone practices);
- Changes infiltration practice application – must pre-treat for direct discharge at a high rate, not permitted in fill, no dewatering;
- Special design requirements for discharges in cold-water fisheries;
- Extended detention of the 1-year storm required;
- Elimination of sub-drains/French drains near OWTSs; and
- New approach and criteria for re-development projects.

PODS
PODS
PODS
PODS
PODS

12 Stormwater Management Standards

1. Low Impact Development Site Planning and Design
2. Groundwater Recharge
3. Water Quality
4. Conveyance and Channel Protection
5. Overbank Protection
6. Redevelopment Projects
7. Pollution Prevention
8. Land Uses with Higher Potential Pollutant Loads (LUHPPLs)
9. Illicit Discharges
10. Construction Erosion and Sedimentation Control
11. Stormwater Management System Operation and Maintenance
12. Stormwater Management Plan

Rhode Island Stormwater Design and Installations Manual

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Minimum Standards

and

Performance Criteria

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Minimum Standard 1: LID Site Planning and Design Strategies

Objective - to provide a process by which LID is considered at an early stage in the planning process to prevent stormwater impacts rather than mitigate them.

- LID site planning and design strategies must be used to the maximum extent practicable.
- All projects must include a completed Stormwater Management Checklist (Appendix A) for review that shows compliance with this standard.
- If full compliance is not provided, an applicant must document why key steps in the process could not be met and what is proposed as mitigation.

LID Site Planning and Design Criteria

- Protect undisturbed open space;
- Maximize the protection of natural drainage areas, streams, surface waters, and wetlands;
- Minimize land disturbance;
- Minimize soil compaction;
- Provide low-maintenance landscaping;
- Minimize impervious surfaces;
- Minimize the decrease in the "time of concentration" from pre-construction to post-construction;
- Provide vegetated conveyance and treatment systems; and
- Break up or disconnect runoff over impervious surfaces;
- Provide source controls to prevent / minimize the release of pollutants into stormwater runoff.

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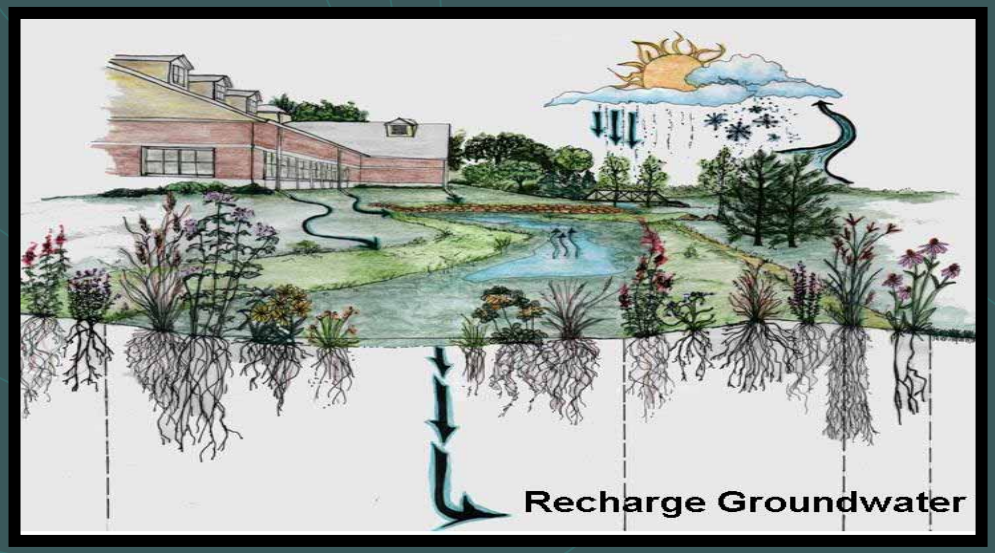
Minimum Standard 2: Groundwater Recharge

Objective - to protect water table levels, stream baseflow, wetlands, and soil moisture levels.

- Stormwater must be recharged to maintain baseflow at pre-development levels to the maximum extent practicable.
- Recharge may be achieved by both structural and nonstructural practices (Stormwater Credit)



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Recharge Criteria, Rev

Requires that the following volume of stormwater be recharged:

$$Rev = (1") (F) (I) / 12$$

where:

Rev = recharge volume (in acre-feet)

I = impervious area in acres

HSG	Recharge Factor (F)
A	0.60
B	0.35
C	0.25
D	0.10

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Minimum Standard 3: Water Quality

Objective - to reduce the water quality impacts from stormwater on downstream waters.

- Stormwater runoff from a site must be adequately treated to achieve the following minimum pollutant removal requirements at each discharge location:
  - 90% of total suspended solids (TSS),
  - 90% removal of bacteria, and
  - either 40% removal of total phosphorus (TP) for discharges to sensitive freshwater systems, or 30% removal of total nitrogen (TN) for discharges to saltwater systems.
- May need to achieve higher pollutant removal efficiencies for impaired waters, SAMPs, or TMDLs.
- Structural BMPs in Chapter Five can be assumed to meet these standards when designed for the water quality volume.

Water Quality Criteria, WQv

The WQv is calculated using the following equation:

$$WQv = (1'') (I) / 12$$

where:

WQv = water quality volume (in acre-feet)

I = impervious area in acres

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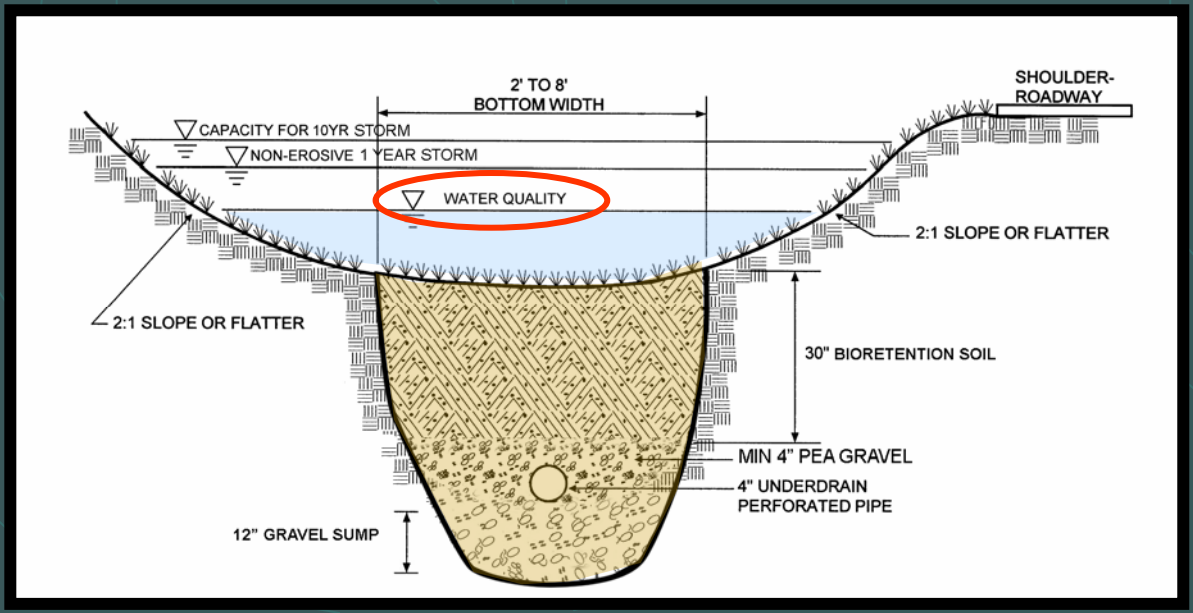
Hydrologic Basis for Design

- Impervious cover measured from site plan (for entire site);
- WQ_v treated by an acceptable BMP;
- Non-structural practices can be used to reduce treatment volume (Stormwater Credit);
- Off-site areas treated as “pre-developed” (only on-site treatment is required - but flow must be accounted for if draining to a BMP).



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Minimum Standard 4: Conveyance and Channel Protection

Objective - to prevent erosive flow within natural channels and drainage ways.

- Conveyance systems must be designed for the 10-year, 24-hour design storm event.
- Channel protection must be supplied by providing 24-hour ED of the one-year, 24-hour design storm event.
- If a stormwater discharge is to a coldwater fish habitat, surface detention practices have additional restrictions.

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Hydrologic Basis for Design

- TR-55 or TR-20 (or equiv) used for determining peak discharge;
- Off-site areas modeled as “present condition”;
- Length of overland flow used in t_c limited to 100’ for post-developed conditions;
- 24-hour ED determined as the center of mass of the inflow and outflow hydrographs; and
- Cp_v <u>not required</u> for:
  - discharges to a large river (i.e., 4th-order stream), lake, estuary, or tidal waters where the development area is less than 5% of the watershed area upstream of the development site.
  - small sites with impervious cover ≤ 1 acre
  - Sites where peak flow < 2 cfs

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RI Region	24-Hour Rainfall Amount (inches)						
	1-Year	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year
Northern: Providence County	**2.7**	**3.4**	**4.2**	**5.0**	**6.2**	**7.5**	**8.9**
Eastern: Newport & Bristol Counties	**2.7**	**3.4**	**4.3**	**5.1**	**6.3**	**7.6**	**9.1**
Southern: Kent & Washington Counties	**2.7**	**3.5**	**4.4**	**5.2**	**6.4**	**7.7**	**9.3**

Minimum Standard 5: Overbank Flood Protection

Objective - to prevent an increase in the frequency and magnitude of overbank flooding and to protect downstream structures from flooding.

- Downstream overbank flood protection must be provided by controlling the post development peak discharge rate to the predevelopment rate for the 10-year and 100-year, 24-hour design storm events.
- The Qp criteria <u>can be waived</u> for sites that:
  - Discharge to a large river (i.e., 4th order stream), lake, estuary, or tidal waters where the development area is less than 5% of the watershed area upstream of the development site.
  - A downstream analysis indicates that peak discharge control is not necessary.

Hydrologic Basis for Design

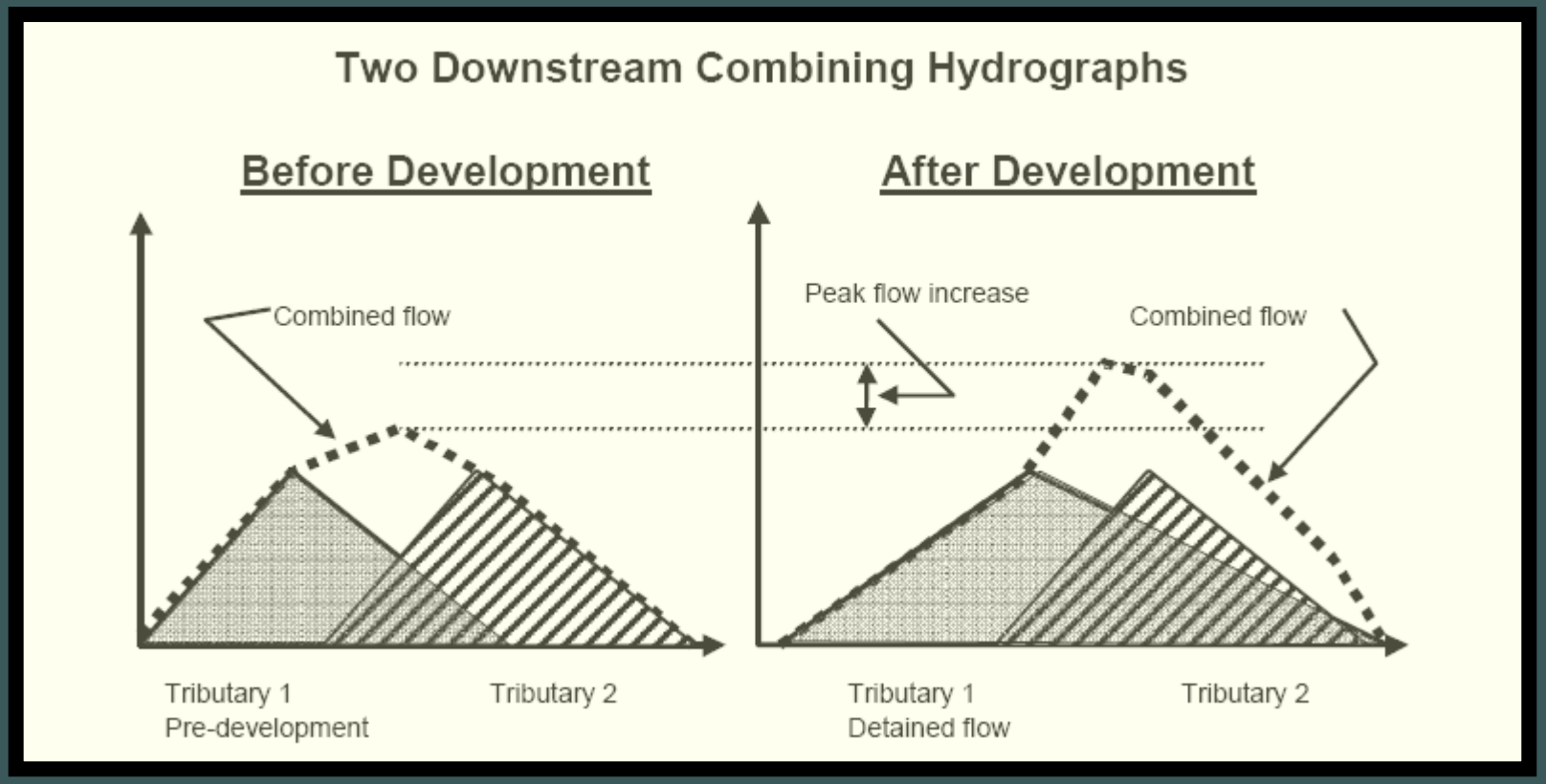
- TR-55 or TR-20 used for determining peak discharge;
- Pre-developed conditions for on-site areas will be woods, meadow, or rangeland;
- Off-site areas modeled as “present condition” for storage requirements;
- Off-site areas that drain to a facility must demonstrate safe passage of the 100-year storm under ultimate buildout conditions; and
- Length of overland flow used in time of concentration limited to 150’ for pre-developed conditions and 100’ for post-developed conditions.
- Must demonstrate that flows from the 100-yr event will be safely conveyed.

Downstream Analysis

- Required for projects of certain size AND impervious cover (see table)
- Determine if peak flow impacts attenuated by controlling the 10- and 100-year events
- “10% rule” used for the limit of the downstream analysis

Site Size (acres)	Impervious Cover (%)
>5 to10	>75
>10 to 25	>50
>25 to 50	>25
>50	all sites

Graphical Depiction of Coincident Peak Phenomena



Minimum Standard 6: Redevelopment

Objective - to allow flexibility to meet the goals of improved water quality and channel protection to receiving waters while still promoting redevelopment.

- Redevelopment is defined as any construction, alteration, or improvement that disturbs a total of 10,000 square feet or more of existing impervious area where the existing land use is commercial, industrial, institutional, governmental, recreational, or multifamily residential.
- Redevelopment sites with less than 40% impervious coverage must meet new development criteria. For sites with more than 40%, requirements are based on 50% improvement.

Minimum Standard 7: Pollution Prevention

Objective - to prevent, to the maximum extent practicable, pollution from entering water resources.

- All development projects must implement source control and pollutant prevention measures outlined in a stormwater pollution prevention plan.

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Minimum Standard 8: Land Uses with Higher Potential Pollutant Loads (LUHPPLs)

Objective - to prevent, to the maximum extent practicable, pollution from entering water resources.

- Stormwater discharges from LUHPPLs require the use of specific source control/pollution prevention measures and BMPs approved for such use.
  - Industrial sites subject to RIPDES Multi-Sector General Permit
  - Auto fueling facilities
  - Exterior vehicle service, maintenance, and equipment cleaning areas
  - Road salt storage and loading areas (if exposed to rainfall)
  - Outdoor storage and loading/unloading of hazardous materials

Photo Copyright 1999, Center for Watershed Protection

Minimum Standard 9: Illicit Discharges

Objective - to prevent pollutants from being discharged into MS4s and Waters of the State, and to safeguard the environment and public health, safety, and welfare.

- All illicit discharges to stormwater management systems are prohibited, including discharges from onsite wastewater treatment systems (OWTS), and sub-drains and French drains near OWTSs that do not meet the State's OWTS Rules.

Minimum Standard 10: Construction Erosion and Sedimentation Control

Objective - to prevent erosion and sedimentation from construction site runoff.

- Erosion and sedimentation control (ESC) practices must be utilized during the construction phase as well as during any land disturbing activities.
  - temporary sediment trapping practices must be sized for 1 inch of runoff, and
  - temporary conveyance practices must be sized to handle flow from the 10-year, 24-hour design storm.
- ESC practices must be designed according to the guidelines in the most recent edition of the "Rhode Island Erosion and Sediment Control Handbook."

Minimum Standard 11: Stormwater Management System Operation and Maintenance

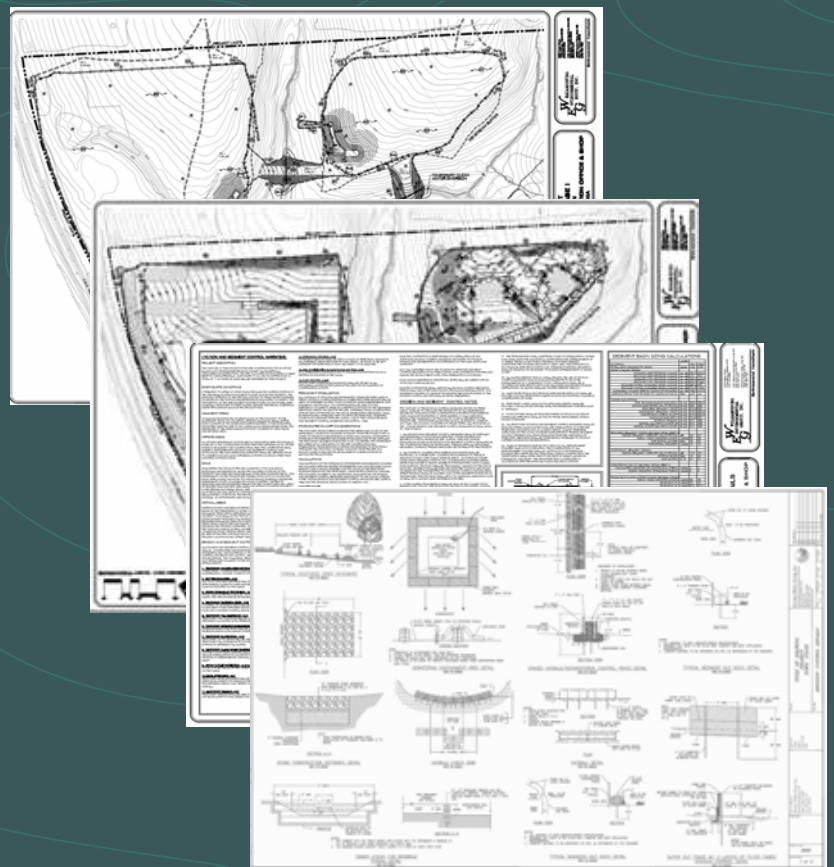
Objective - to ensure that stormwater BMPs continue to function as designed.

The stormwater management system must have an operation and maintenance plan that shall at a minimum include:

- Stormwater management system(s) owners;
- The party(ies) responsible for operation and maintenance;
- The routine and non-routine maintenance tasks and a schedule;
- A plan that shows the location of all stormwater BMPs and discharge points;
- A description and delineation of public safety features; and
- An estimated budget ; and
- Funding source.

Minimum Standard 12: Stormwater Management Plan

- All development proposals must include a stormwater management site plan for review.
- The plan set must address all of the minimum standards.



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LID Site Planning and Design Strategies

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Horsley Witten Group

Hilton
Garden Inn

“Conventional” Planning and Design

- Style of suburban development that has evolved over the past 50 years;
- Generally involves larger lot development;
- Clearing and grading of significant portions of a site;
- Wider streets and larger cul-de-sacs;
- Enclosed drainage systems for stormwater conveyance; and
- Large “hole-in-the-ground” detention ponds (HIGS)

Minimum Standard No. 1
LID Site Planning and Design Strategies

- Must be used to the maximum extent practicable;
- Reduce runoff;
- Document compliance, and why elements not incorporated in Accordance with Checklist in Appendix A of Manual;
- What mitigation is offered.

“Low-Impact” Site Planning and Design

“LowER Impact”

“Better Site Design”

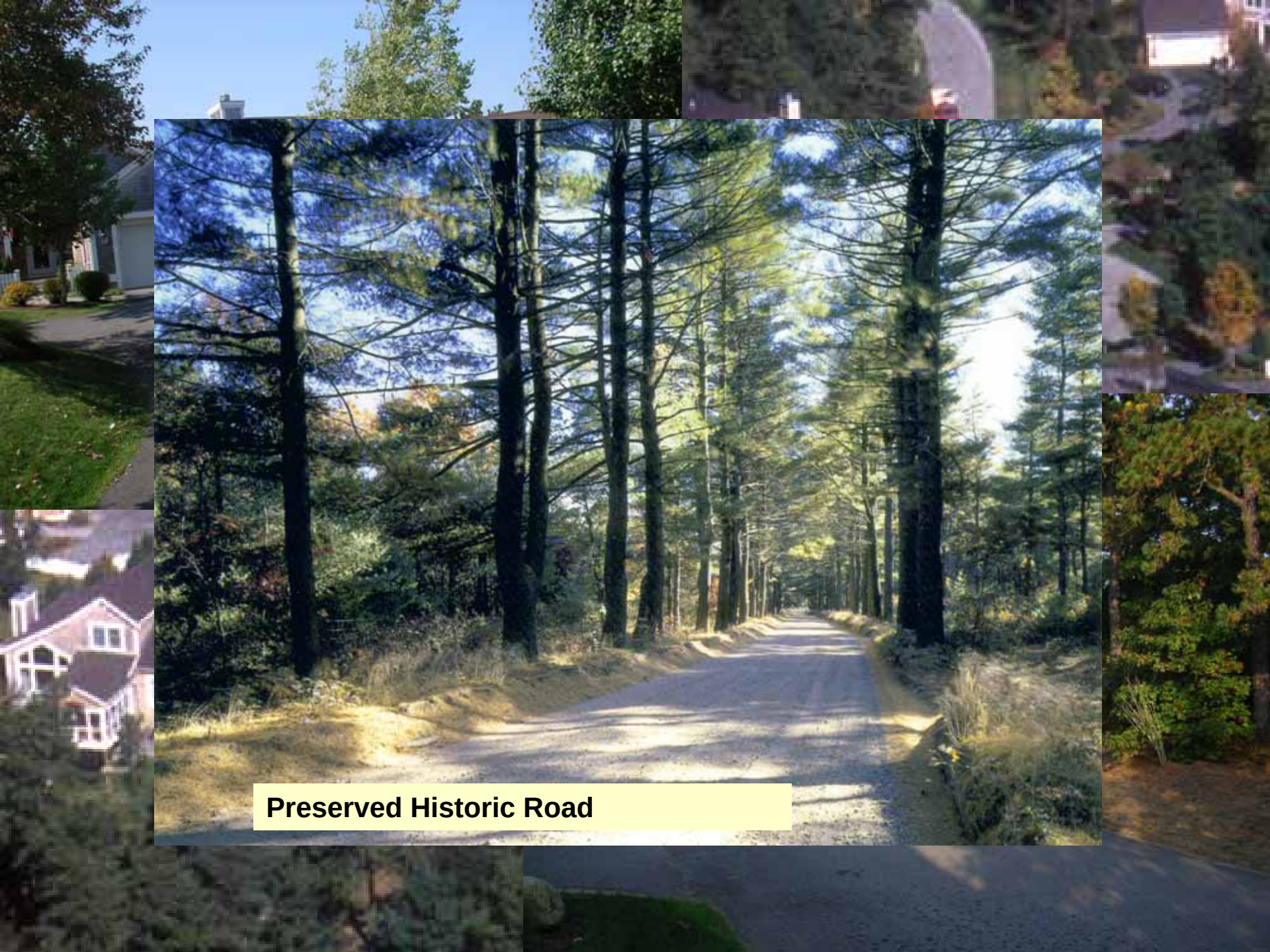
“Smart Growth”

Incorporates non-structural and natural approaches to new and redevelopment projects to reduce impacts on watersheds by:

- conserving natural areas (avoid impacts)
- Reducing and disconnecting impervious cover (reduce impacts)
- better integration of stormwater management (manage impacts)

LID 10 Required Objectives

1. Protect natural areas;
2. Minimize impervious surfaces;
3. Break up or disconnect the flow of runoff over impervious surfaces;
4. Maximize protection of natural drainage features;
5. Minimize the decrease in the "time of concentration“ from pre-dev Conditions;
6. Minimize land disturbance, clearing and grading;
7. Minimize soil compaction;
8. Provide low-maintenance landscaping;
9. Provide vegetated open-channel conveyance systems; and
10. Provide other source controls to prevent or minimize the use or exposure of pollutants.

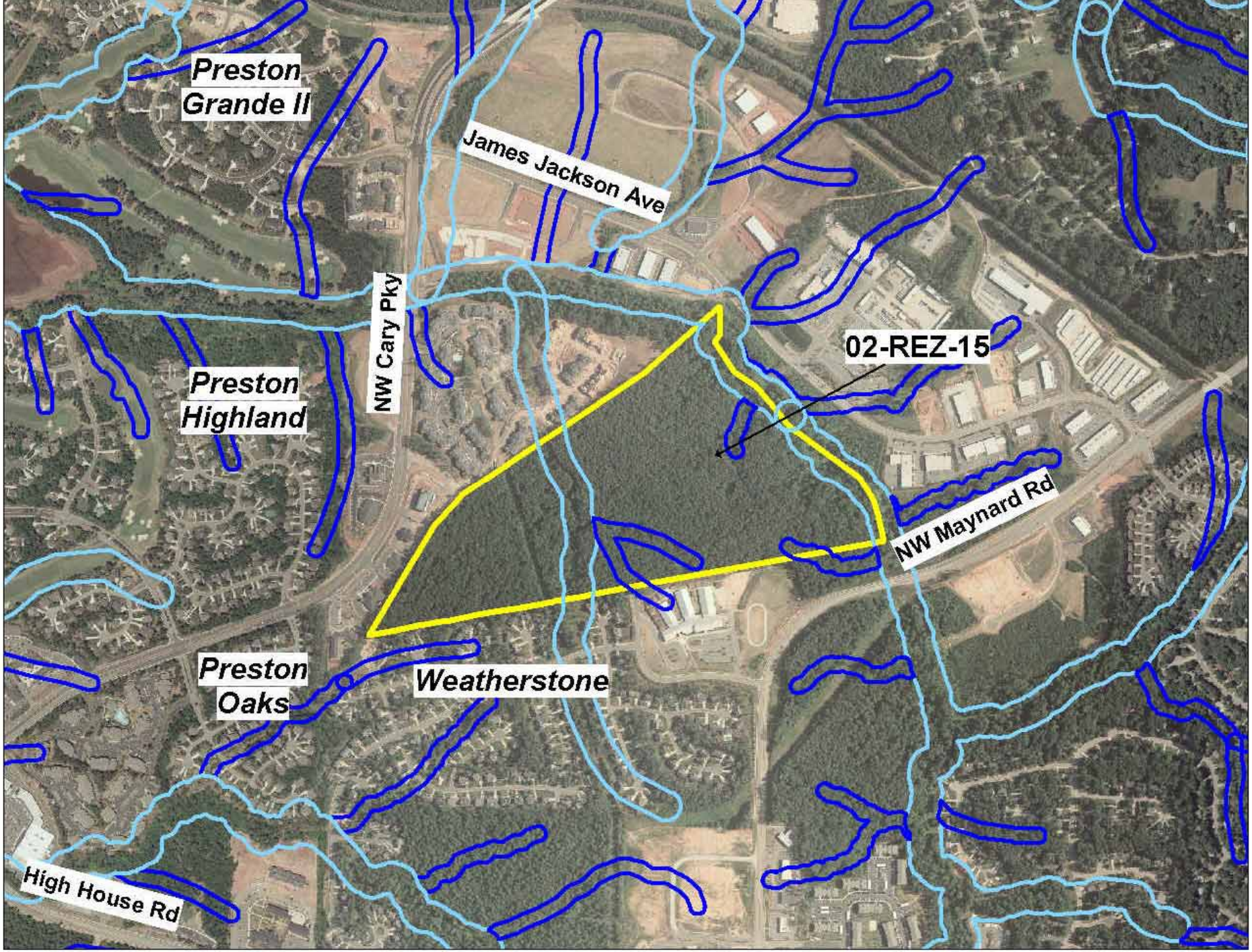


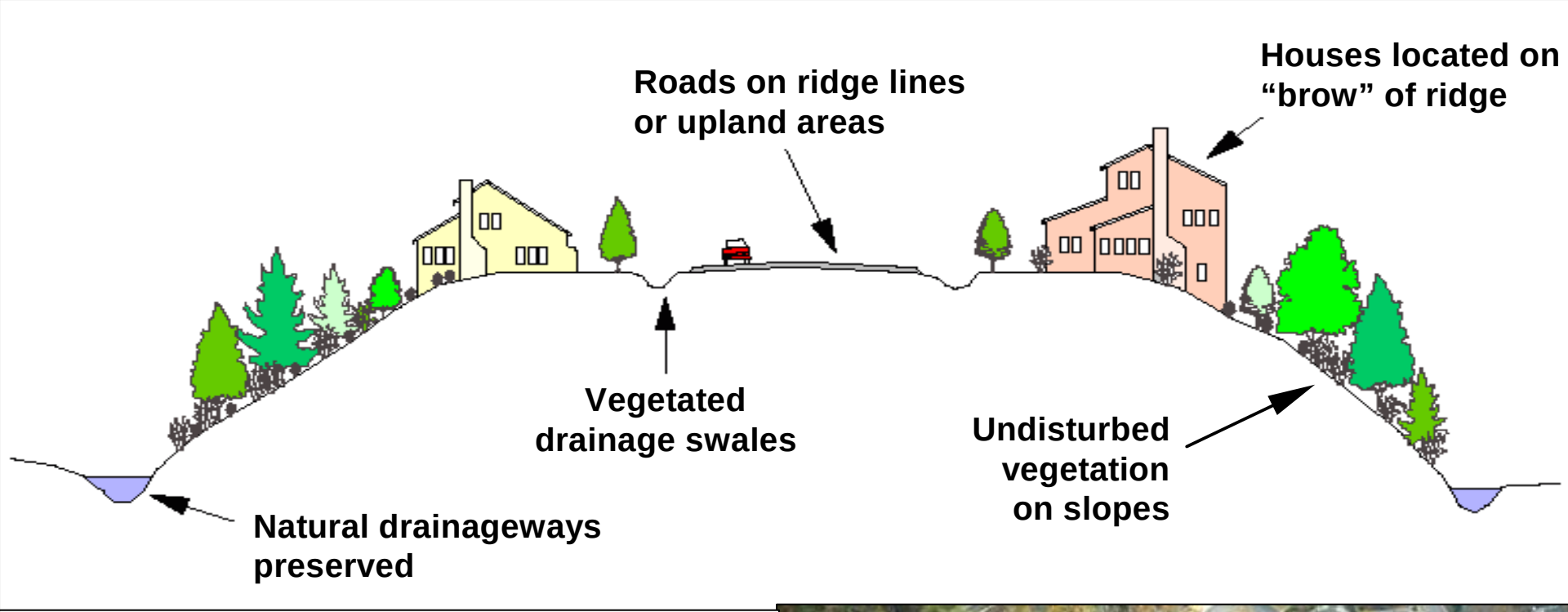
Preserved Historic Road

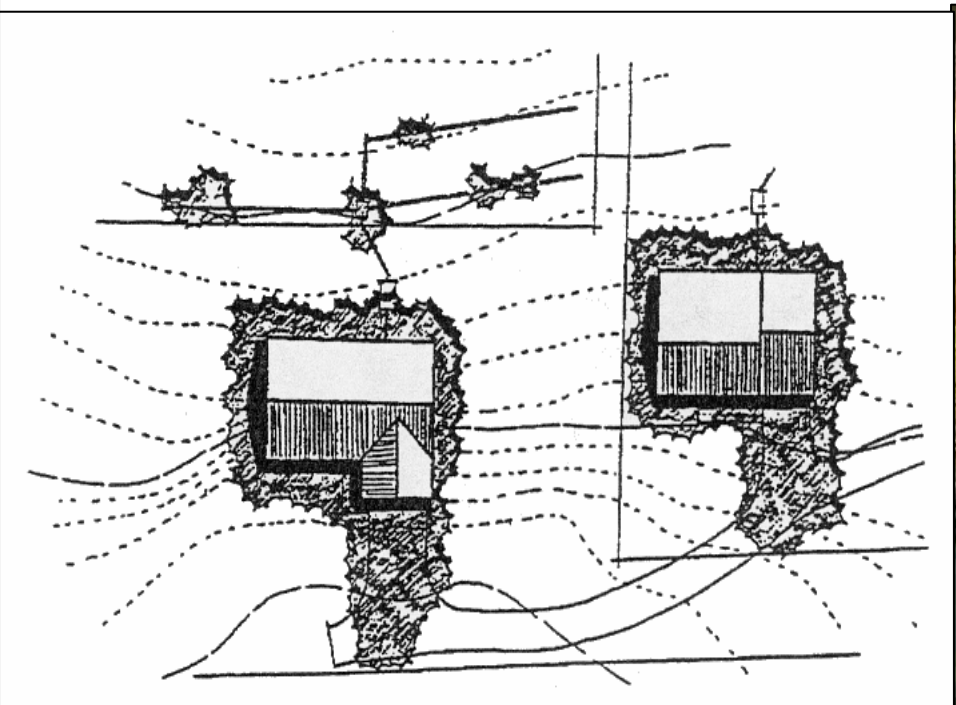
Avoid the Impacts
Preservation of Natural Features & Compact Development

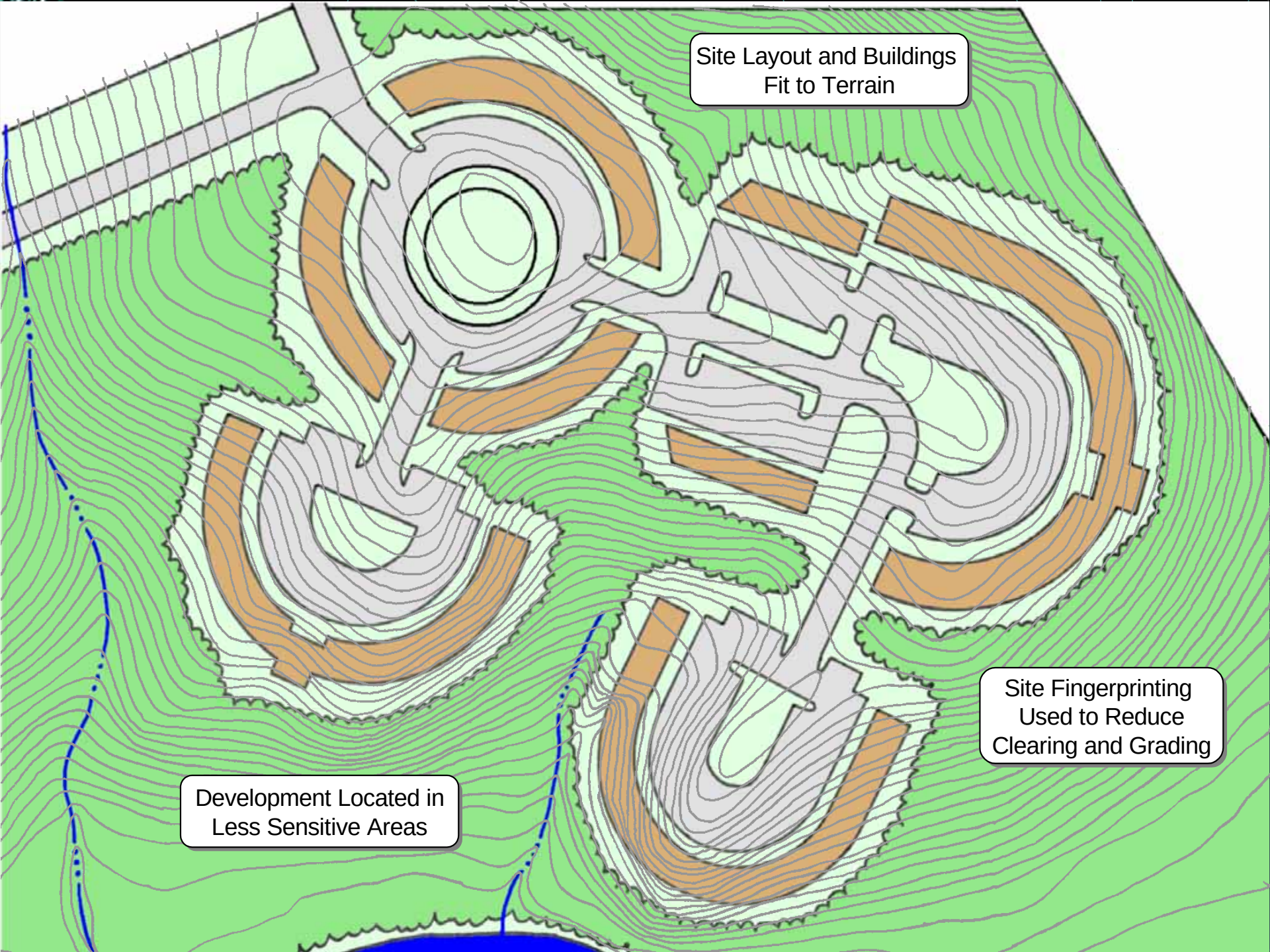
- Preservation of undisturbed areas;
- Preservation of buffers, natural drainage systems;
- Reduction of clearing and grading;
- Locating sites in less sensitive areas;
- Compact development; and
- Working with natural conditions (landscape, hydrology, soils)

Forest Edge
Forest Edge


Preston
Grande II
James Jackson Ave
NW Cary Pky
02-REZ-15
Preston
Highland
NW Maynard Rd
Preston
Oaks
Weatherstone
High House Rd


Roads on ridge lines
or upland areas
Houses located on
“brow” of ridge
Vegetated
drainage swales
Undisturbed
vegetation
on slopes
Natural drainageways
preserved




Site Layout and Buildings Fit to Terrain
Site Fingerprinting Used to Reduce Clearing and Grading
Development Located in Less Sensitive Areas

Reduce the Impacts
Reduction of Impervious Cover

- Roadway Reduction;
- Sidewalk Reduction;
- Driveway Reduction;
- Cul-de-sac Reduction;
- Building Footprint Reduction; and
- Parking Reduction.

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Lower Impact

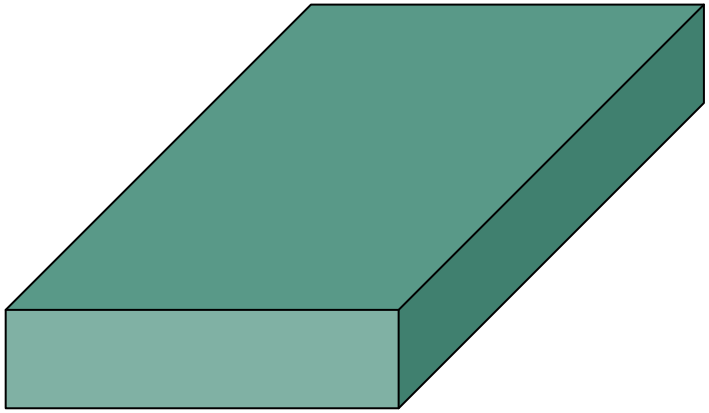
Photo Copyright 1999, Center for Watershed Protection

Shared driveways reduce total area

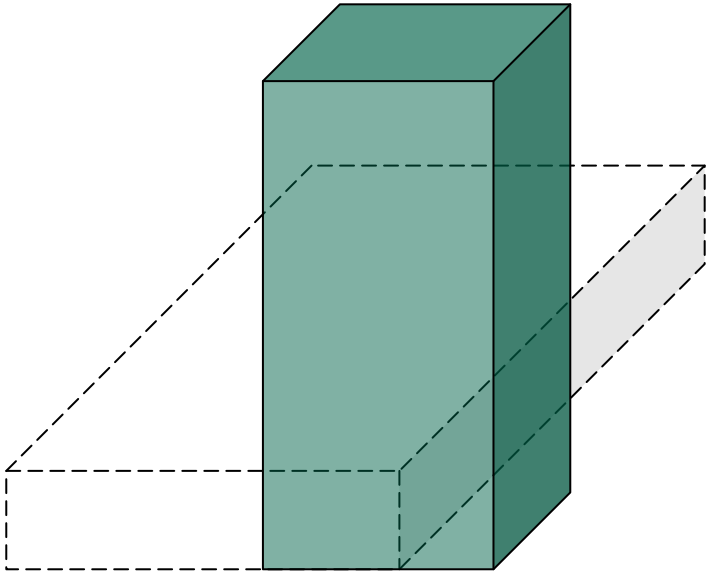
Photo Copyright 1999, Center for Watershed Protection

Rain Gardens/Bioretention

Hammerhead

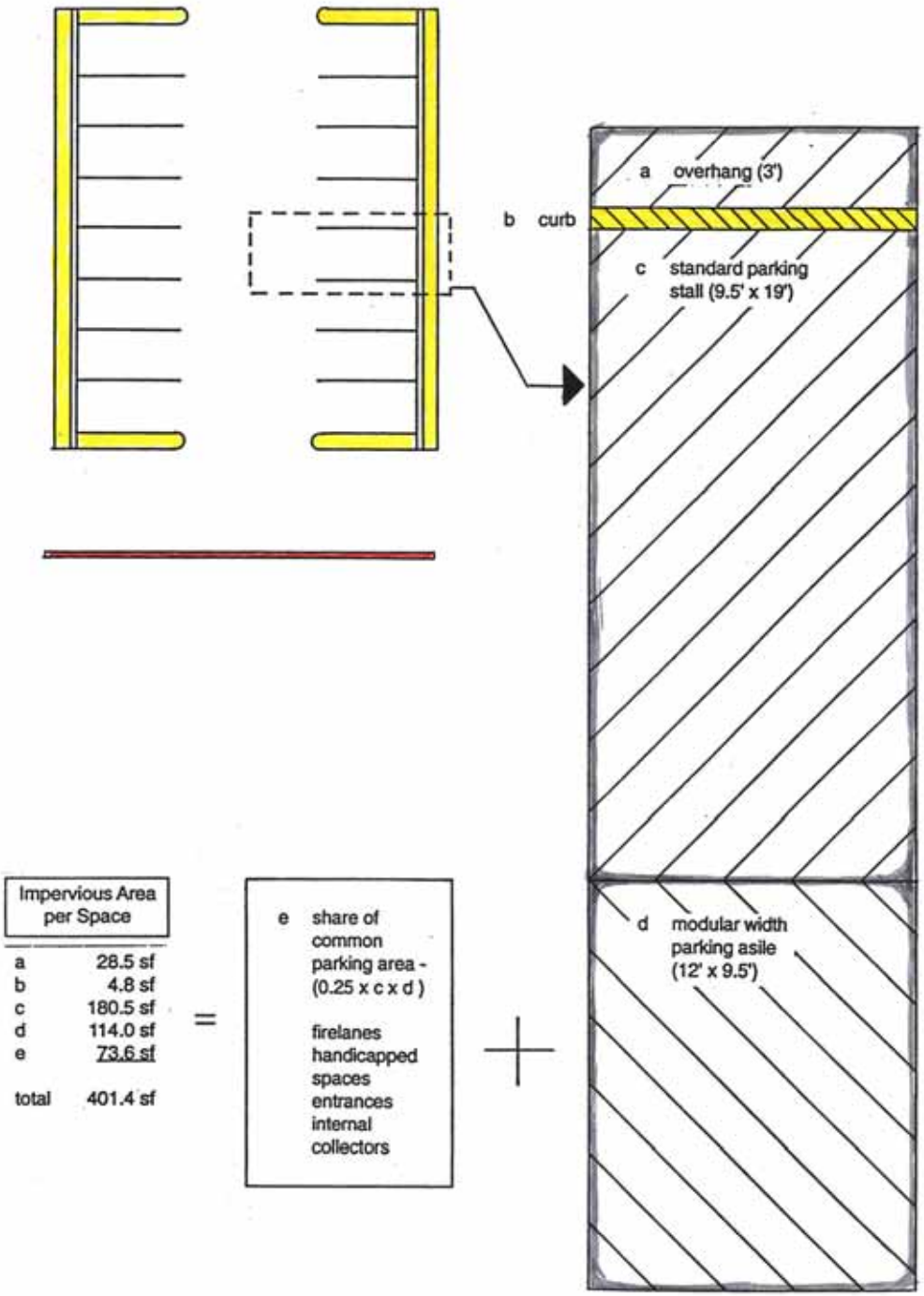


Single Story
Building



Four Story
Building
(75% Less
Impervious Cover)

SUPER STOP & SHOP



The total amount of impervious cover needed to serve a single parking stall

Copyright 1999, Center for Watershed Protection

Permeable pavers are an alternative

Manage the Impacts
Source Controls/Structural Controls

- Disconnection of Impervious surfaces;
- Mitigation of runoff*;
- Stream restoration; and
- Reforestation.

*BMPs that rely on natural systems (e.g., bioretention, WVTS, infiltration, filtering)

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Photo Copyright 1999, Center for Watershed Protection

Impervious Cover Disconnection

Mild vegetated slope

Adjacent to small parking lots and roadways

Source: City of Portland, OR

Source: City of Portland, OR

Rain Barrels and Cisterns

MAY 29 2001

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Center for Watershed Protection

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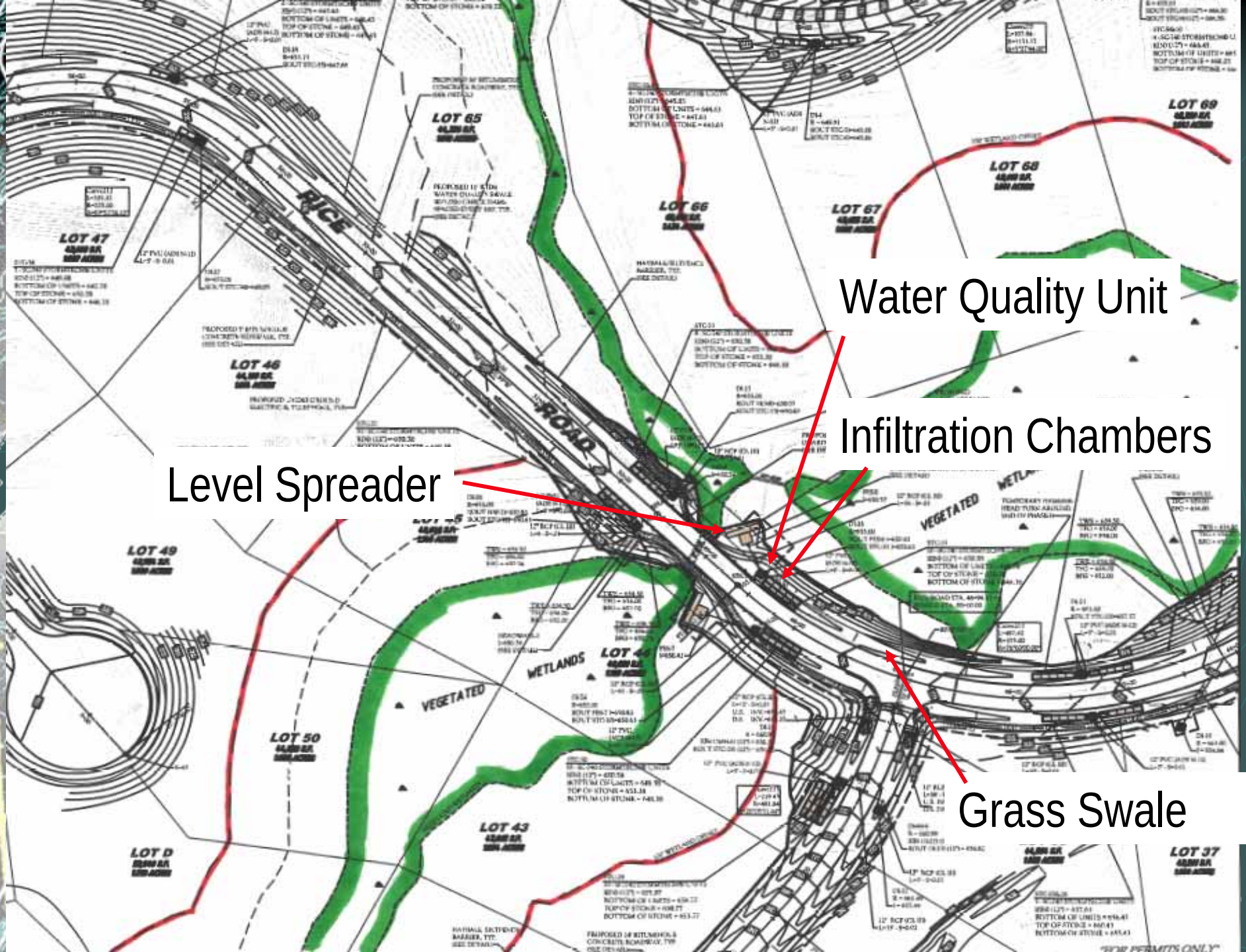
Is this Really LID?


Water Quality Unit
Infiltration Chambers
Level Spreader
Grass Swale
LOT 65
LOT 66
LOT 67
LOT 68
LOT 69
LOT 47
LOT 46
LOT 49
LOT 50
LOT 43
LOT D
LOT 37
RICE
ROAD
WETLANDS
VEGETATED

LID Stormwater Credits

LID Site Design Credit:

Disconnected Rooftop Runoff

Disconnected Non-Rooftop Runoff

Credit can be used to reduce or eliminate Rev and WQv storage requirements.

LID Stormwater Credits

- Still need to meet other Standards;
- Must maintain engineering “standard of care” and “good drainage design;”
- Direct runoff over qualifying pervious areas; and
- LUHPPL runoff not eligible for credit.

Qualifying Pervious Area (QPA)

- Natural or landscaped vegetated areas;
- Fully stabilized;
- CNs based on “good hydrologic conditions;”
- Must be shown on site plans;
- Must have 2 inches of topsoil and located outside regulated wetlands and buffer zones; and
- Excessively fertilized lawn areas are not QPAs.

Credit Restrictions

- Qualifying Pervious Area (QPA) located 10 ft from bldg foundation;
- Every 1000 sq ft of impervious area must have at least 75 linear feet pervious sheet flow and be longer than the contributing flow length; and
- Can be no overlap for QPA;

Credit Restrictions
(Continued)

- Lots > 6,000 ft^2 for rooftops;
- Slope of QPA < 5.0%;
- QPAs located over A or B soils;
- No construction traffic over QPA;
- O&M Plan required;
- QPA cannot be a wetland resource; and
- QPA must be controlled by the owner/applicant

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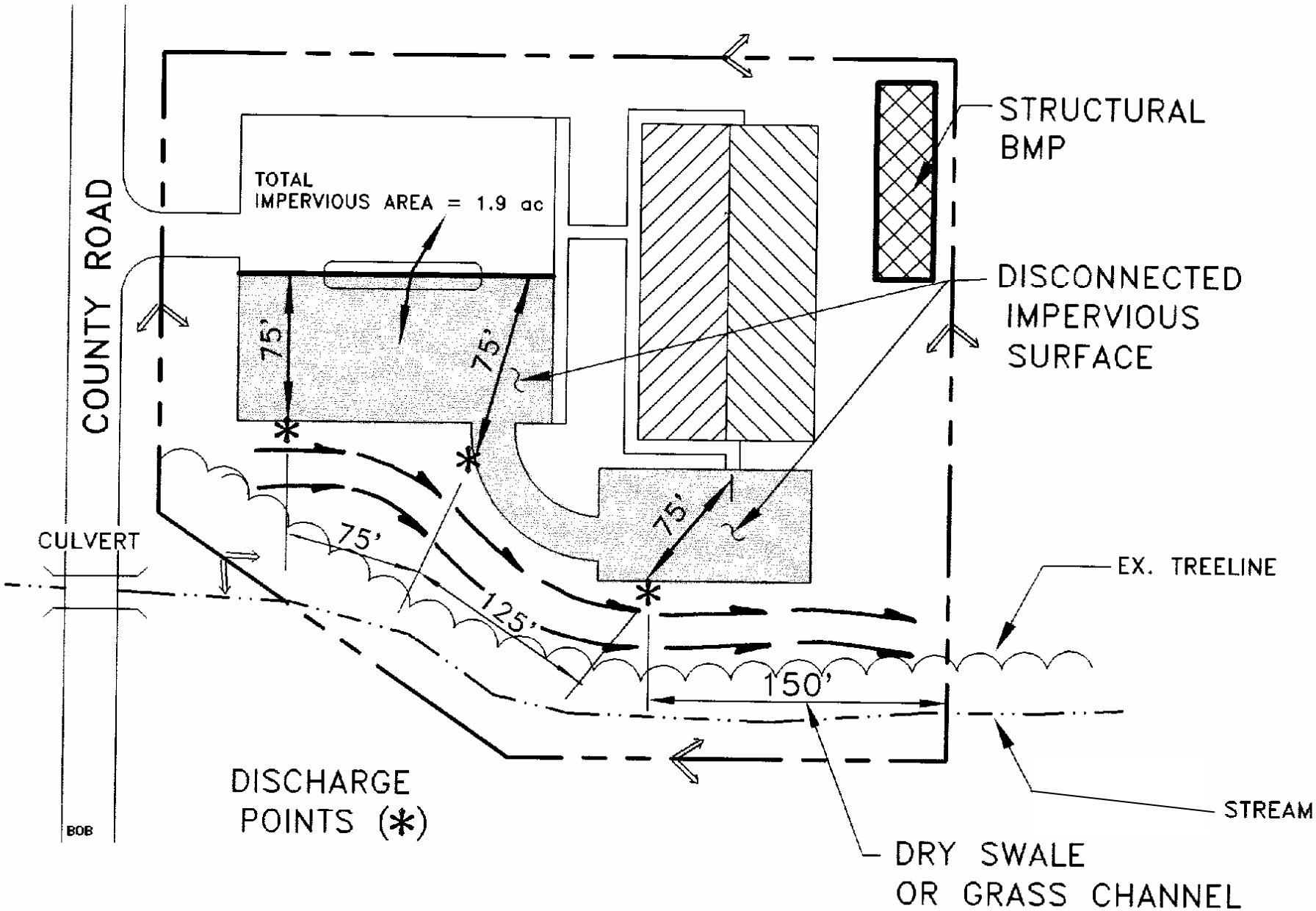
Stormwater Credit (Recharge; Rev)

- Two Methods:
  - Percent Volume – storage provided based on volume required for Re_v and/or WQ_v
  - Percent Area (Re_a) – required impervious area to drain to a QPA based on:

Rea = (F)(I), where

F = Recharge Factor based on soils (dimensionless)

I = Impervious area (in acres or ft^2)


COUNTY ROAD
TOTAL
IMPERVIOUS AREA = 1.9 ac
STRUCTURAL
BMP
DISCONNECTED
IMPERVIOUS
SURFACE
75'
75'
75'
75'
125'
150'
CULVERT
EX. TREELINE
STREAM
DISCHARGE
POINTS (*)
DRY SWALE
OR GRASS CHANNEL
BOB

Sample Recharge Calculation

Site Imp. Area = 1.9 ac (all "A" soils)

Re_v = 0.6"*1.9 ac/12"/ft = 0.095 ac-ft

0.095 ac-ft = 4,138 ft^3

Re_a = 0.6*1.9 ac = 1.14 ac

Assume 45% of imp. area drains to a QPA

(0.45*1.9 ac = 0.855 ac)

Recharge provided by QPA = 1.14 ac-0.855 ac = 0.285 ac

Remaining Re_v = 0.285 ac/1.9 ac = 0.15*4,138 ft^3 = 621 ft^3

% Re_v provided: (1 - 621 ft^3/4,138 ft^3)*100 = 85%

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LID Strategies and Associated Methods

Appendix A Checklist

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Avoid the Impacts

- Preservation of Undisturbed Areas
  - Limit disturbance to protect natural areas
  - Map soil groups
  - Delineate building envelopes
  - New lots not within wetlands
  - Important natural site features protected
- Preservation of Buffers and Floodplains
  - Applicable vegetated buffers preserved
  - Limits of disturbance delineated to protect buffers
- Reduction of Clearing and Grading
  - Clearing and grading limited/restricted (w/in 15 ft of building; 5 ft beyond road)

Avoid the Impacts
(continued)

- Locating Sites in Less Sensitive Areas
  - Conservation development process utilized, where allowed
  - Development located in areas with least hydrologic value
  - Development on steep slopes/ridges avoided
- Compact Development
  - Conservation development process utilized, where allowed
  - Reduced setbacks, frontages, and right-of-way widths
- Natural Landscape Conditions, Hydrology and Soils
  - Natural pre-development hydrology maintained
  - Post-development Tc = pre-development Tc.
  - Travel time is approximately constant
  - Flow velocity kept as low as possible
  - Soil compaction has been minimized
  - Grading (cut and fill quantities) minimized

Reduce the Impacts

- Reduction of Roadway Area
  - Lengths and widths minimized
- Reduction of Sidewalk Area
  - One side of the street
  - Pedestrian pathways integrated into site design
- Reduction of Driveway Area
  - Shared driveways
  - Alternative paving surfaces
  - Narrower widths

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Reduce the Impacts
(continued)

- Reduction of Cul-de-Sac Area
  - Eliminate the use of large radii bulbs, fully paved
  - Alternative turn- arounds
  - Grid design
- Reduction of Building Footprint
  - Less sprawling building footprints
  - Multi-story commercial buildings
  - Mixed use development
- Reduction of Parking Lot Area
  - Parking ratio evaluated (maximum and minimum)
  - Size of spaces/stalls
  - Shared parking
  - Structured parking
  - Alternative paving surfaces for overflow parking

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Manage the Impacts

- Disconnecting Impervious Area
  - Impervious surfaces disconnected to qualified pervious areas
- Mitigation Runoff
  - Roof runoff directed to a lower impact practice
  - A green roof has been designed to reduce runoff
- Stream Restoration
  - Natural channel design/stream channels restored
- Reforestation
  - Trees planted or conserved
  - Low maintenance landscaping and native vegetation

Acceptable BMPs for Water Quality and Associated Pollutant Removal Performance

Robert Roseen, PE, PhD
The UNH Stormwater Center
Environmental Research Group, Department of Civil Engineering
University of New Hampshire

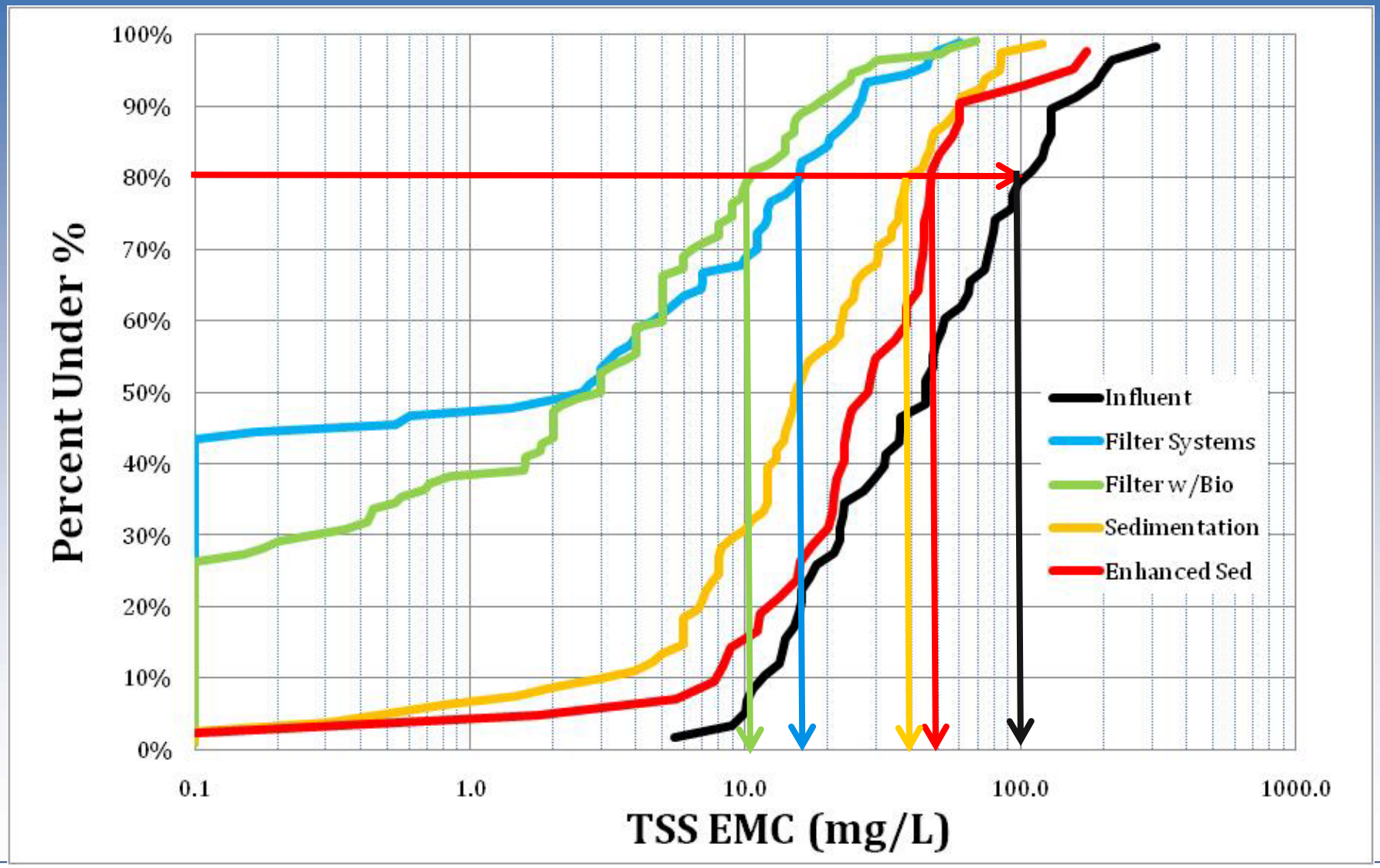
RHODE ISLAND STORMWATER DESIGN AND INSTALLATION STANDARDS MANUAL – REVISION SUMMARY
PUBLIC REVIEW MEETING – JUNE 4, 2009

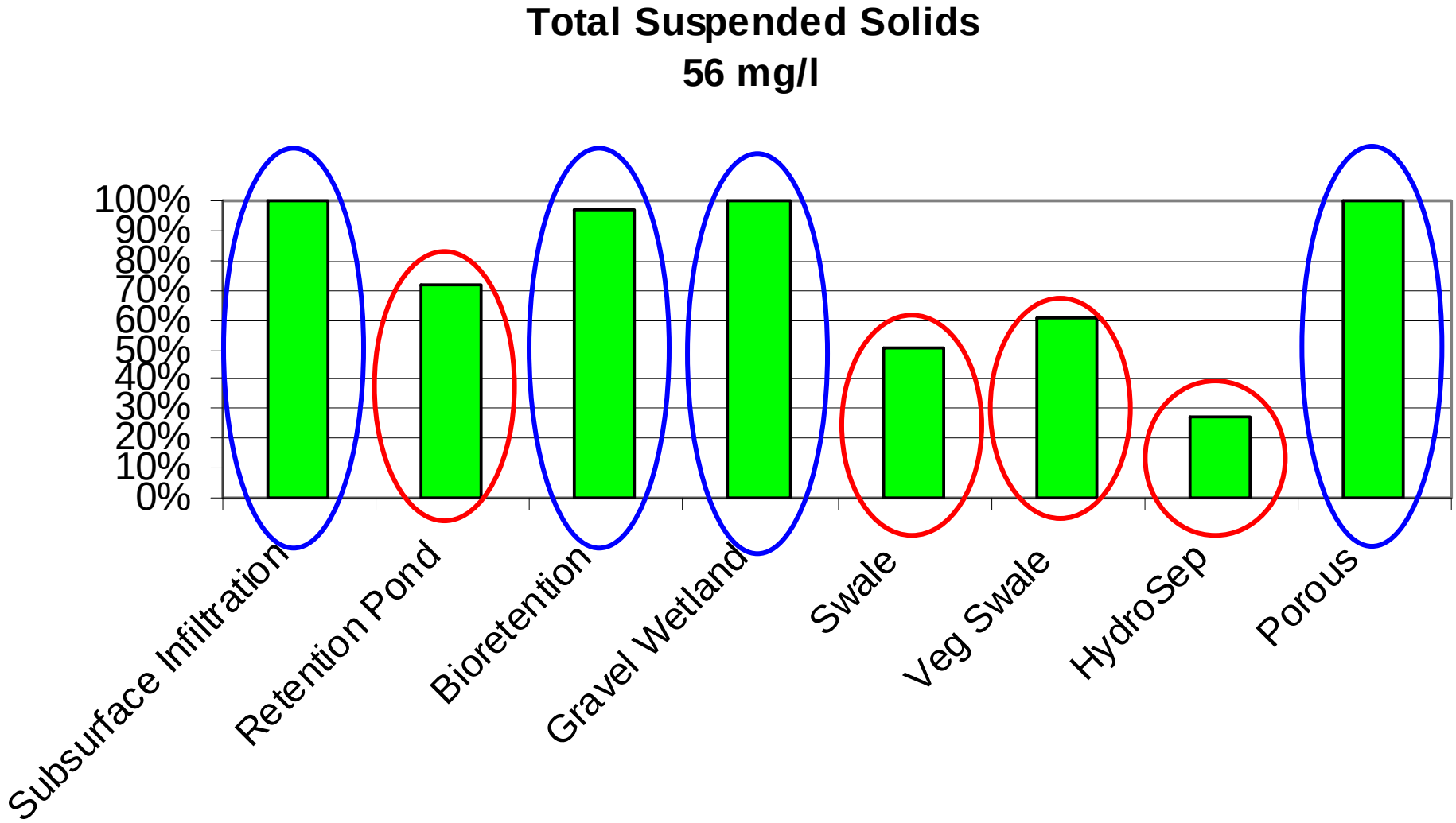
UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

Acceptable BMPs

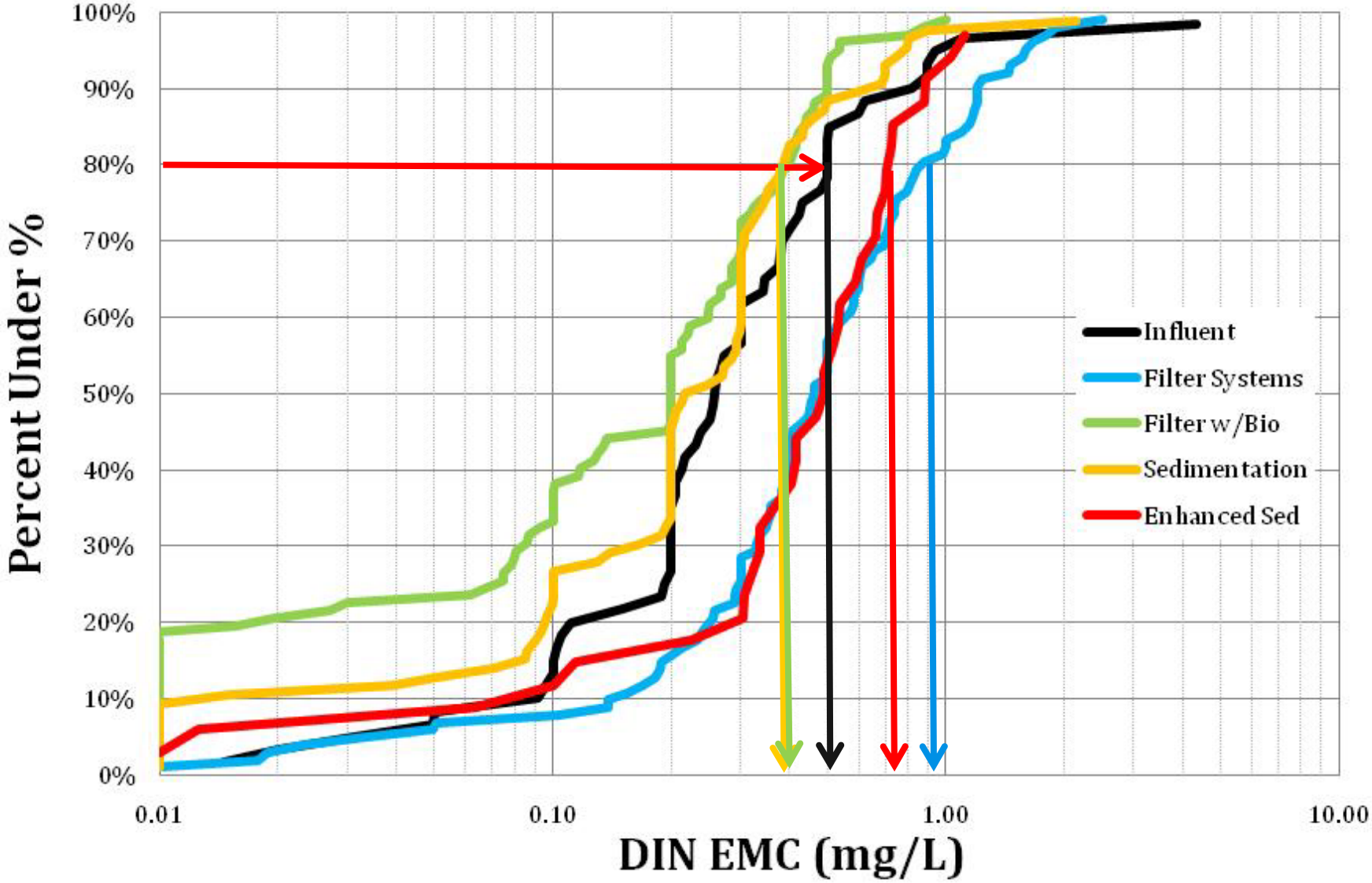
- 5.2 Wet Vegetated Treatment Systems (WVTS)
- 5.3 Stormwater Infiltration Practices
- 5.4 Permeable Paving
- 5.5 Filtering Systems-Bioretention
- 5.6 Green Roofs
- 5.7 Open Channel Systems

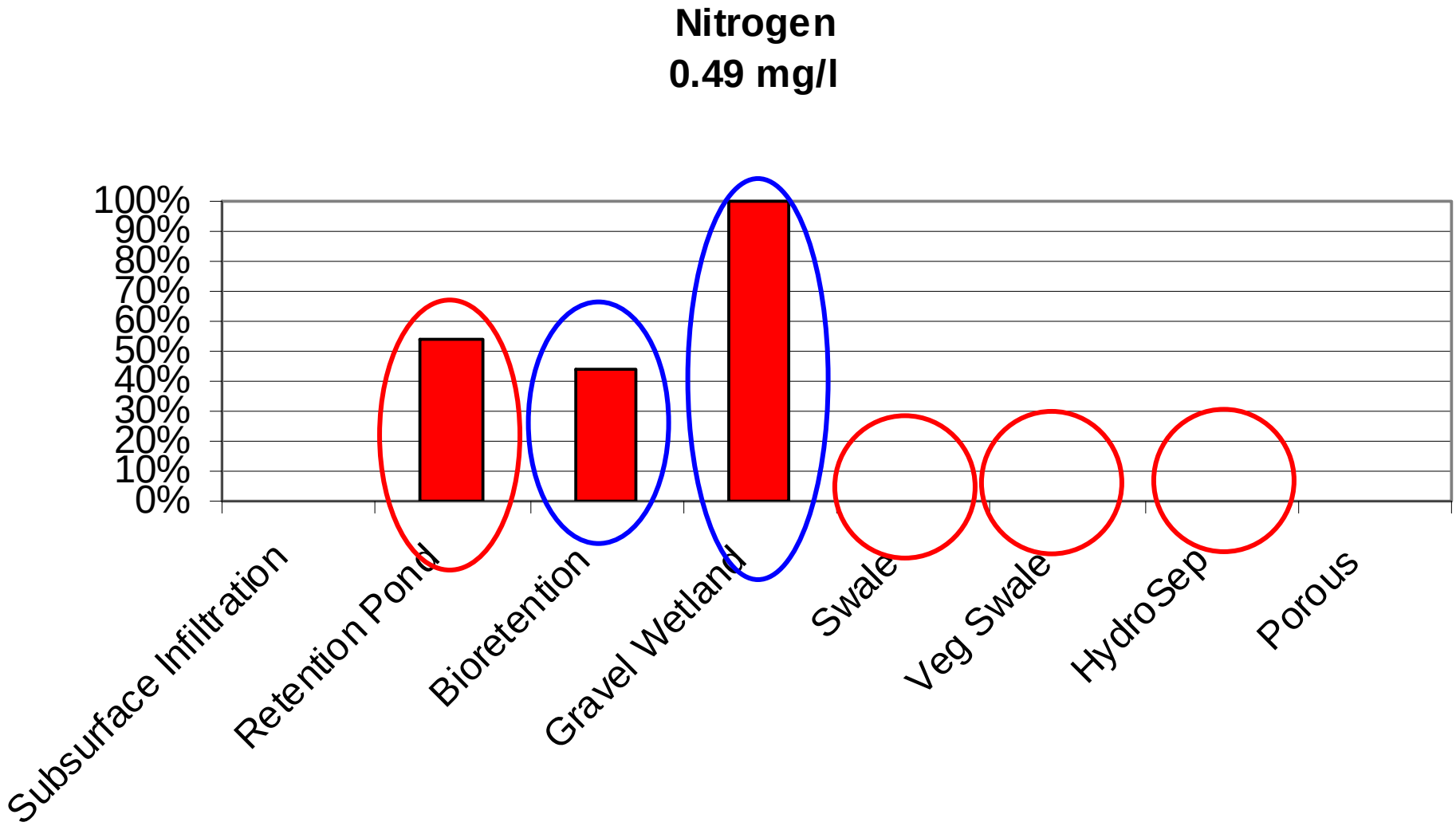
TSS Removal Performance



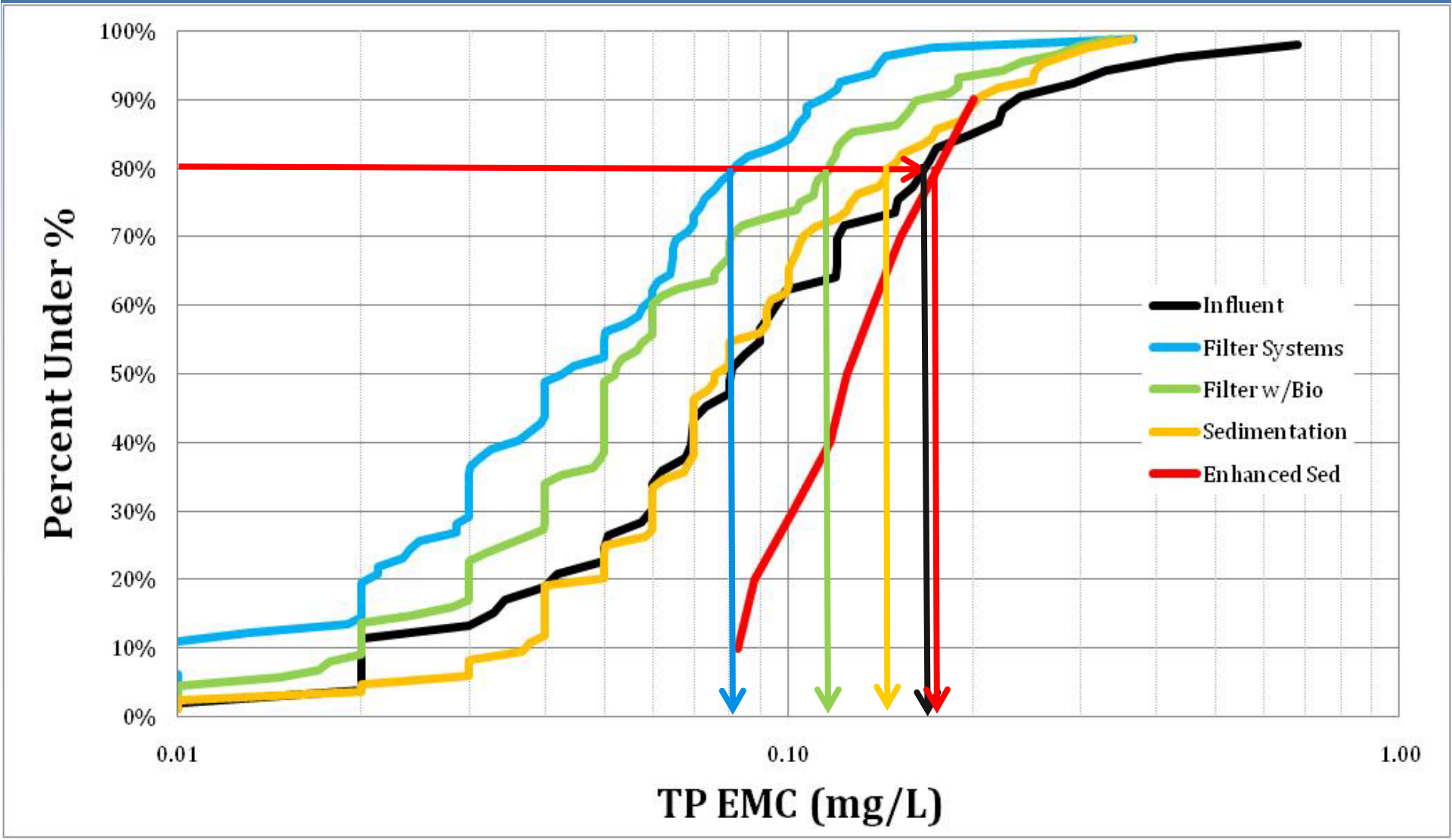

Total Suspended Solids
56 mg/l
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Subsurface Infiltration
Retention Pond
Bioretention
Gravel Wetland
Swale
Veg Swale
HydroSep
Porous

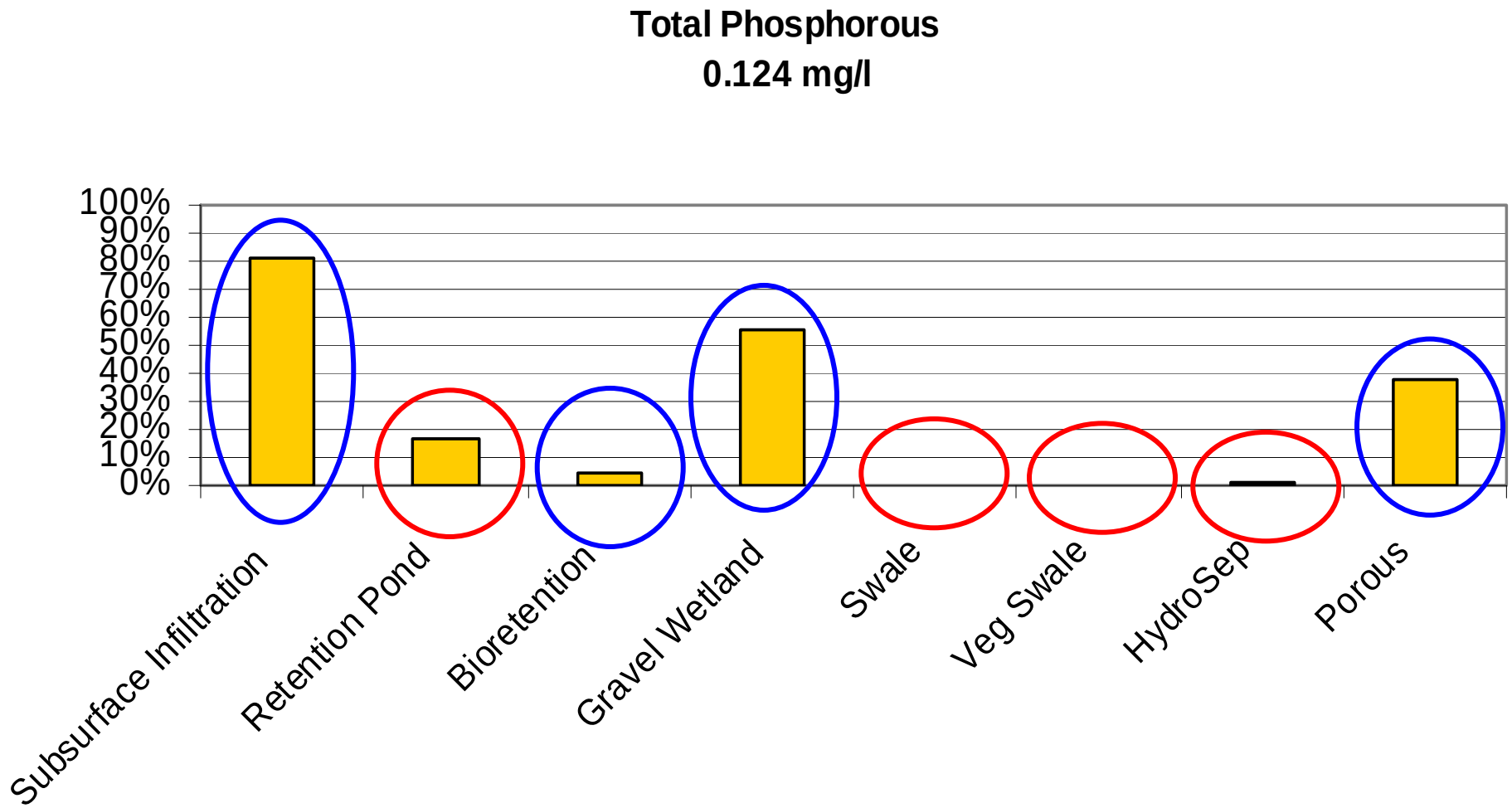
Nitrogen Removal Performance



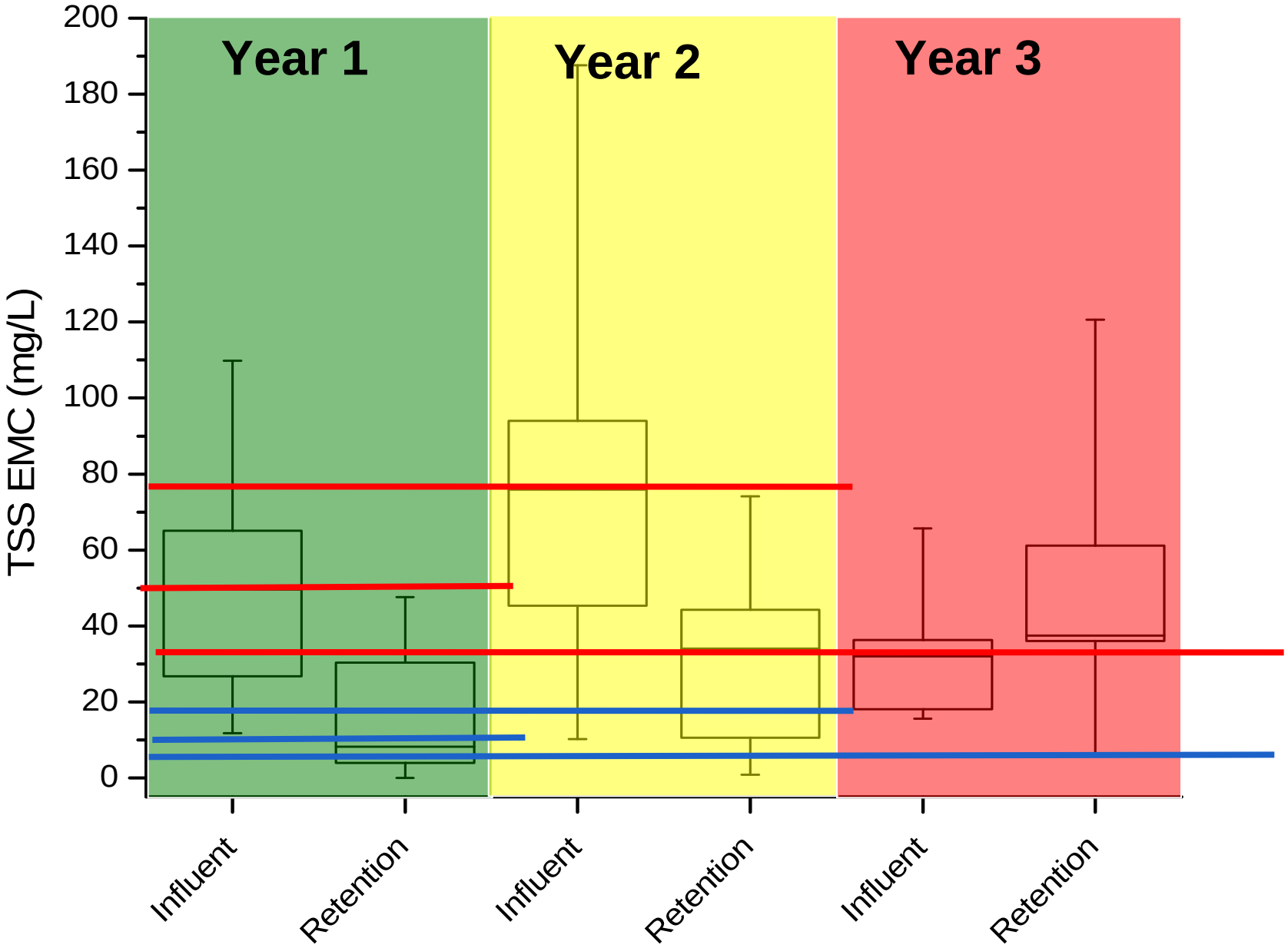

Nitrogen
0.49 mg/l
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Subsurface Infiltration
Retention Pond
Bioretention
Gravel Wetland
Swale
Veg Swale
HydroSep
Porous

Phosphorous Removal Performance




Total Phosphorous
0.124 mg/l
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
Subsurface Infiltration
Retention Pond
Bioretention
Gravel Wetland
Swale
Veg Swale
HydroSep
Porous

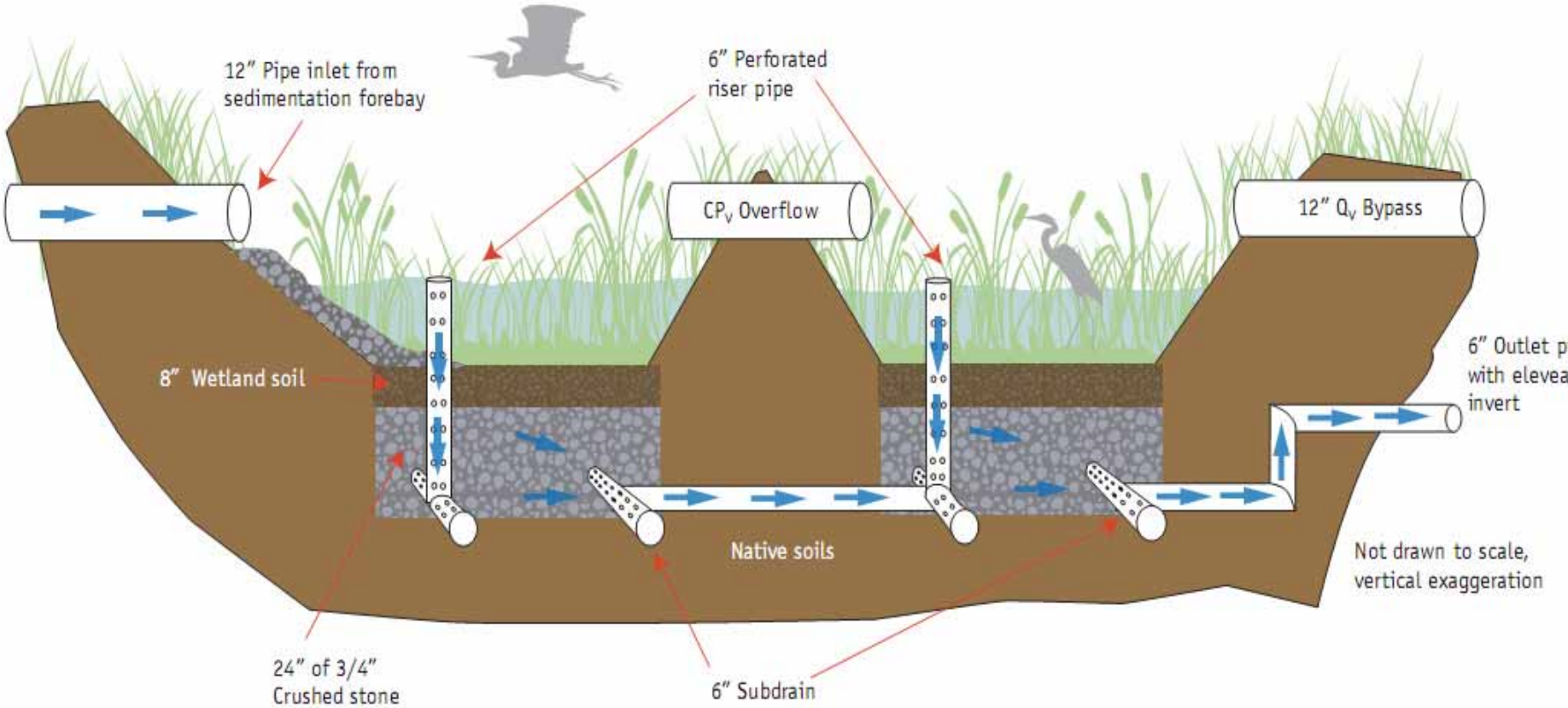
Pond: 3-year Break Down TSS



Wet Vegetated Treatment Systems

'00 5 24

Gravel WVTS


12" Pipe inlet from sedimentation forebay
6" Perforated riser pipe
CPv Overflow
12" Qv Bypass
8" Wetland soil
6" Outlet p
with elevea
invert
Native soils
Not drawn to scale, vertical exaggeration
24" of 3/4" Crushed stone
6" Subdrain

Infiltration

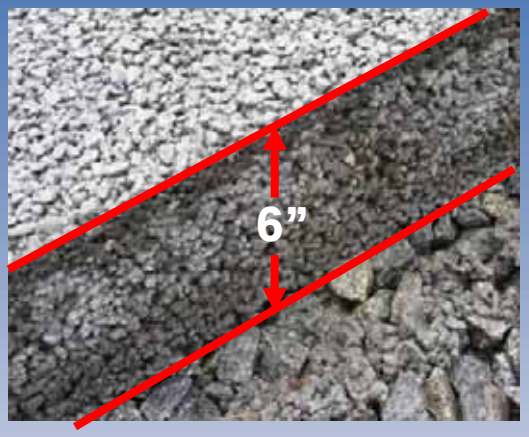
Small-scale Infiltration

Cascade Station (NE Airport Way & I-205)

Porous Pavements

Porous Pavements

- Aggregate gradation: No fines added to mix
- Air voids: 18-20%
- Cold climate and WQ functionality dependent on sub base design
- Long-term FX dependent on production, not maintenance



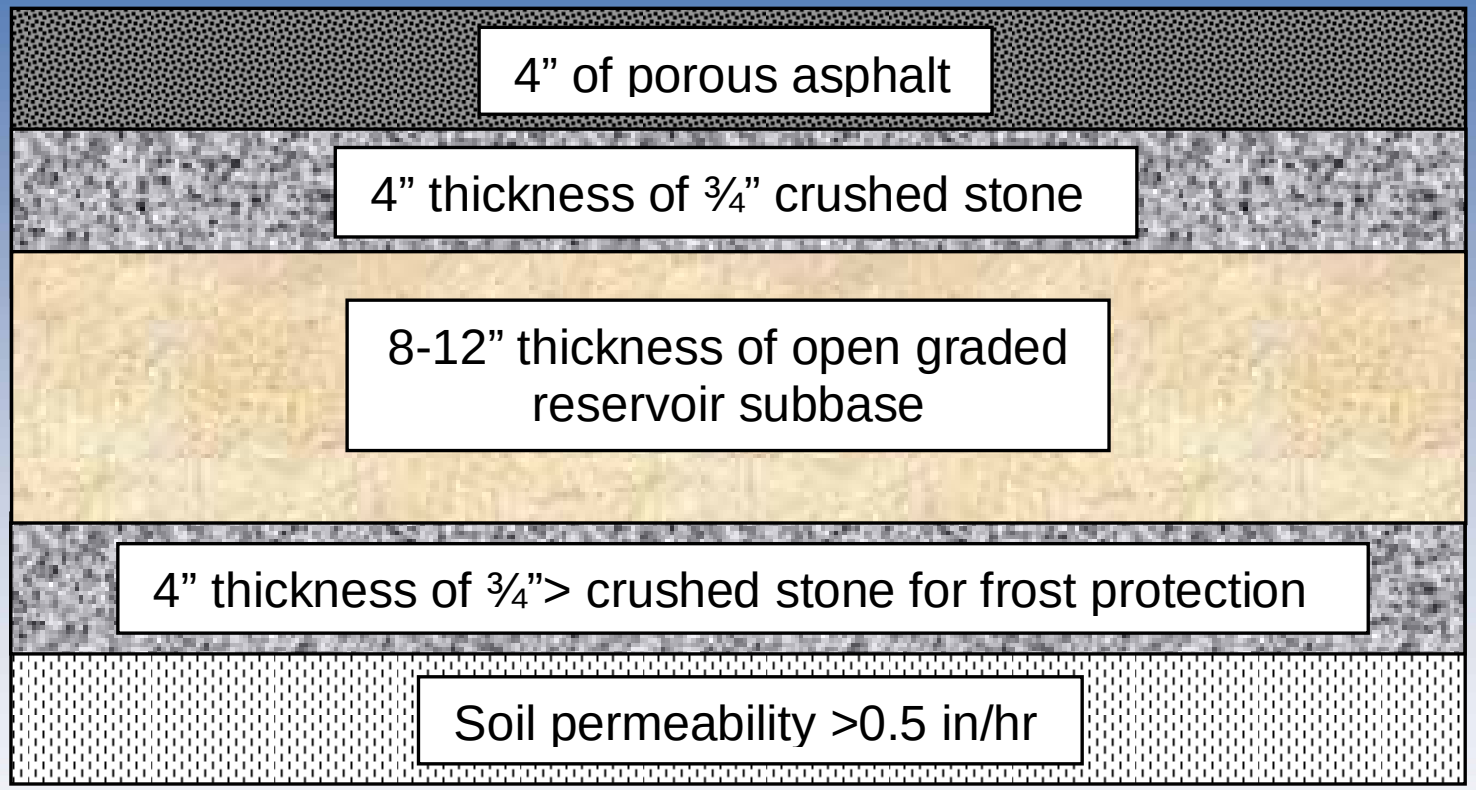
Pervious Concrete

- Placement is challenging and requires certified installers
- Compressive strength:
  3000 psi at 7 days
- Concrete is very resistant to aging

Porous Asphalt

- Modification of Open Grade Friction Course (OGFC)
- Asphalt binder often modified (polymers, fibers) but not necessary
- QC production at plant is crucial, install is simple

Typical Porous Pavement Parking Lot System Cross-Section



- Diverged from design guidance for use of filter coarse for improved water quality function
- Common base stone is 1-3” minus bank run sand and gravel used here

Infiltration using permeable pavement

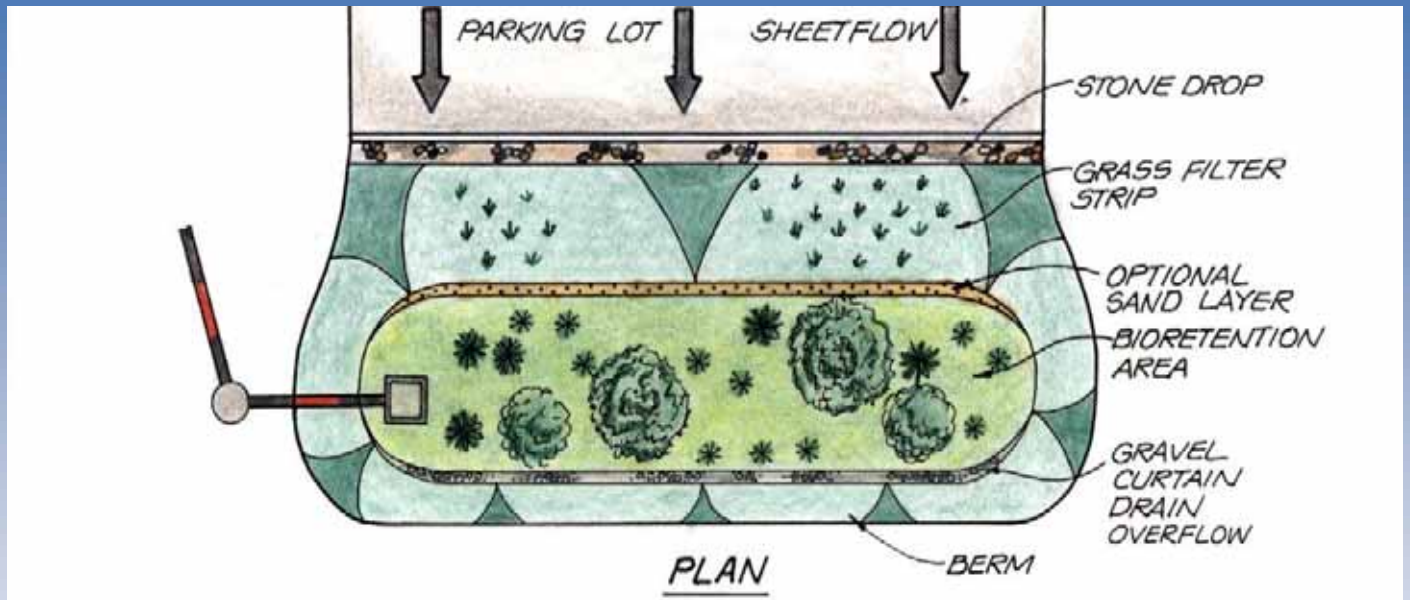
~20” of Gravel Storage Layer

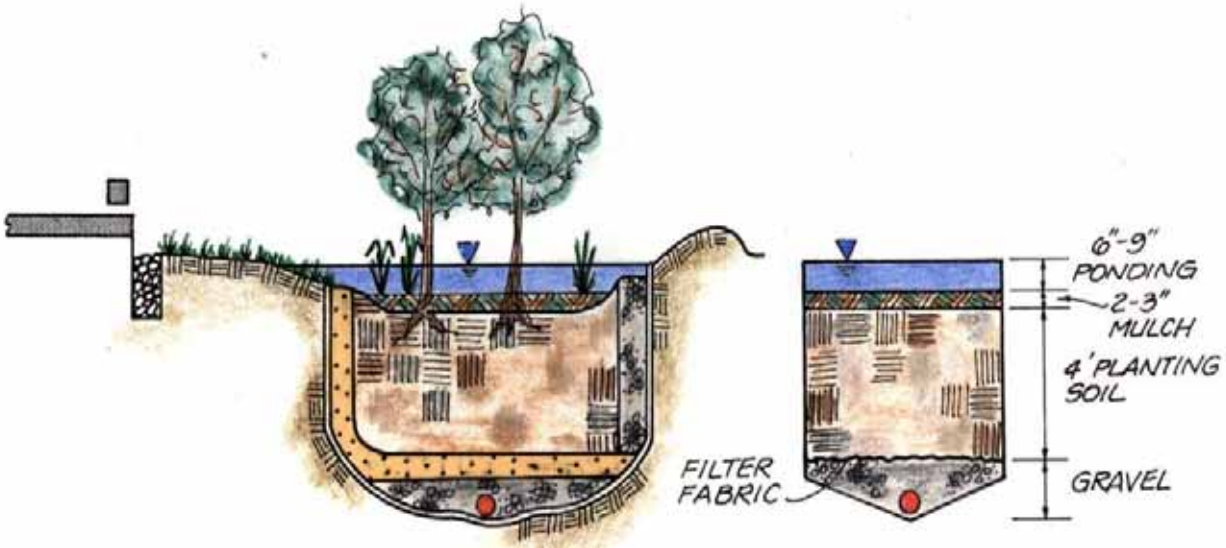
Typical Applications

JCPenney

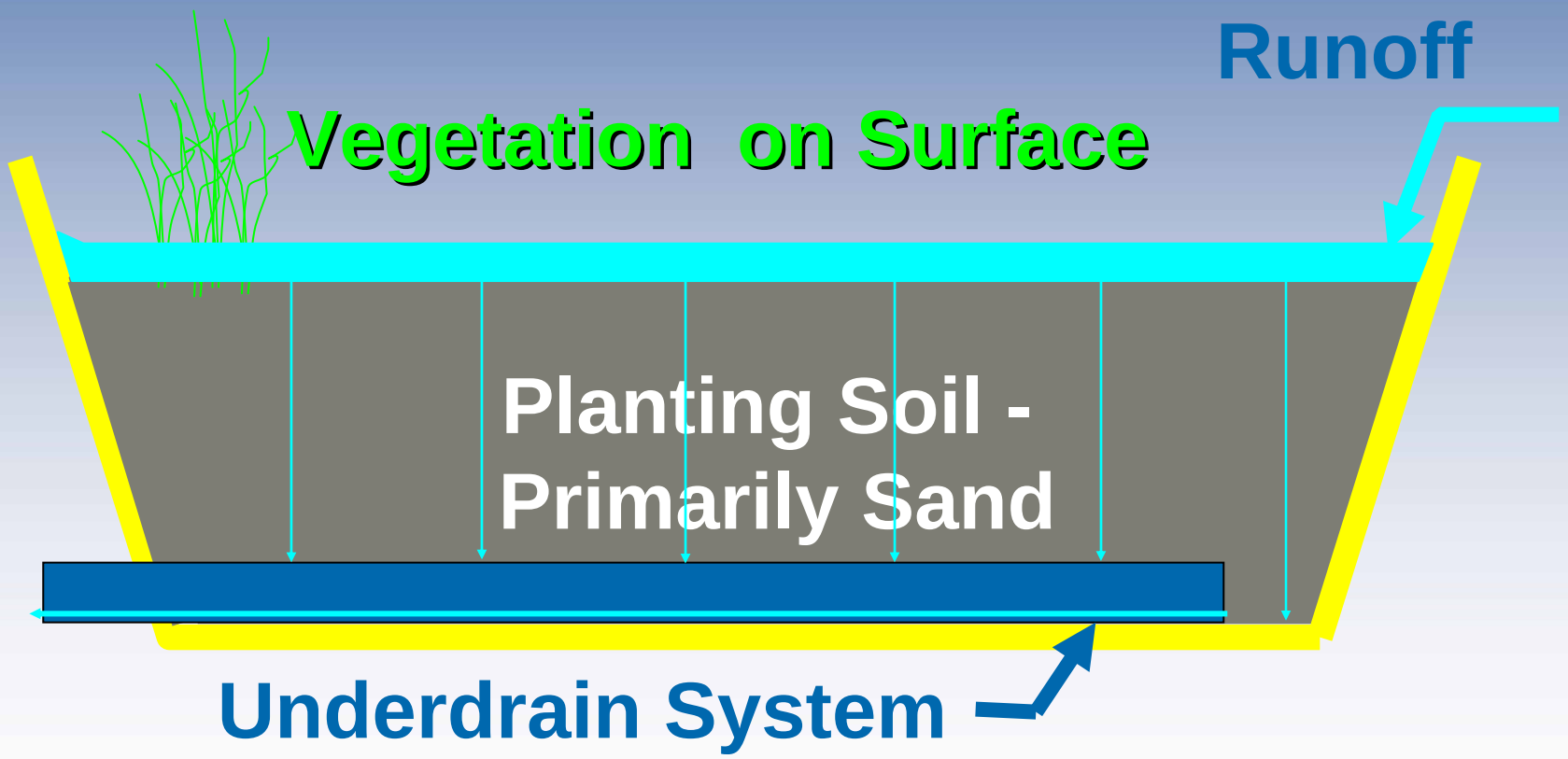
G919

Filters

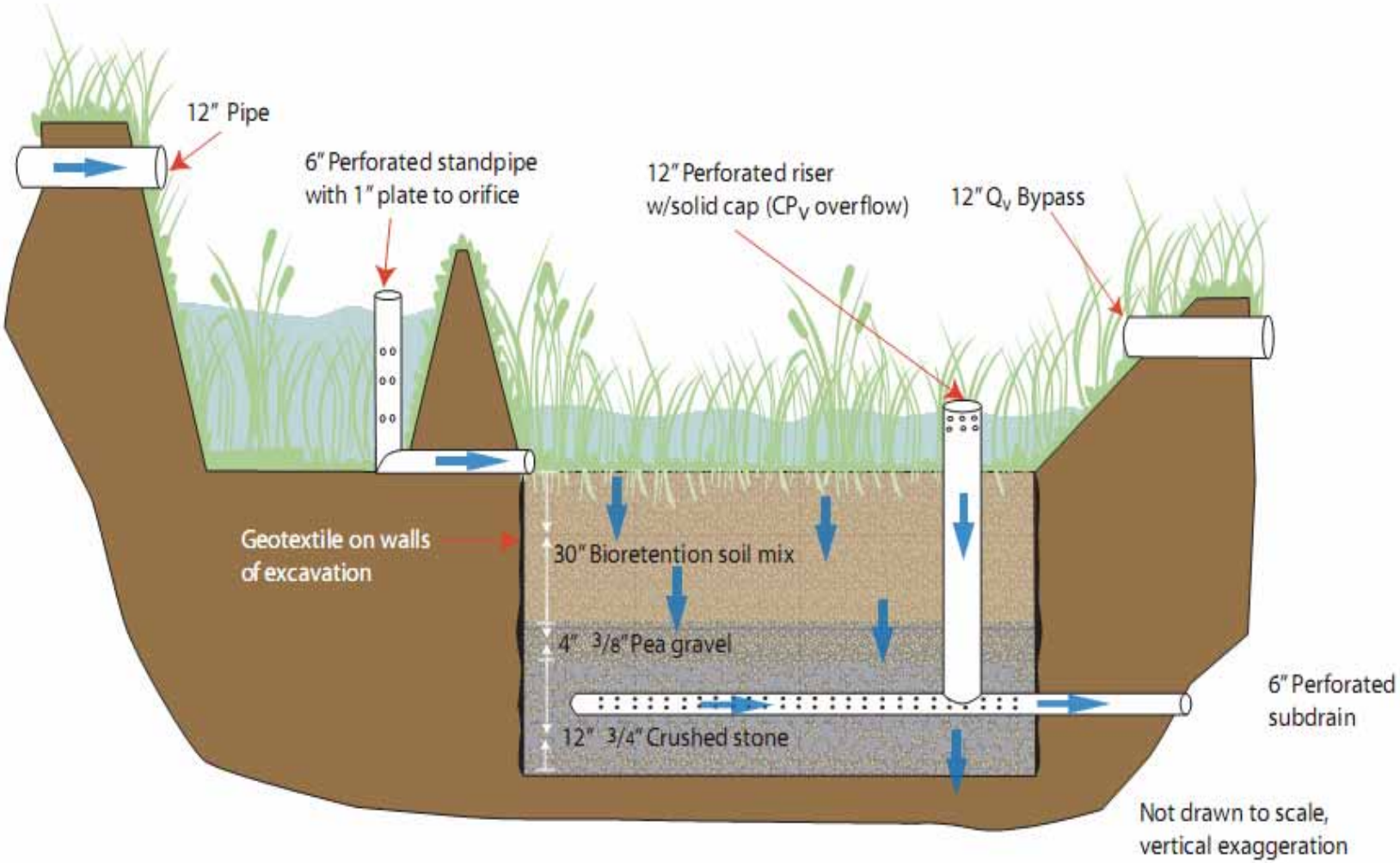

PARKING LOT
SHEETFLOW
STONE DROP
GRASS FILTER STRIP
OPTIONAL SAND LAYER
BIORETENTION AREA
GRAVEL CURTAIN DRAIN OVERFLOW
BERM
PLAN


6"-9" PONDING
2-3" MULCH
4' PLANTING SOIL
FILTER FABRIC
GRAVEL

Bioretention Schematic



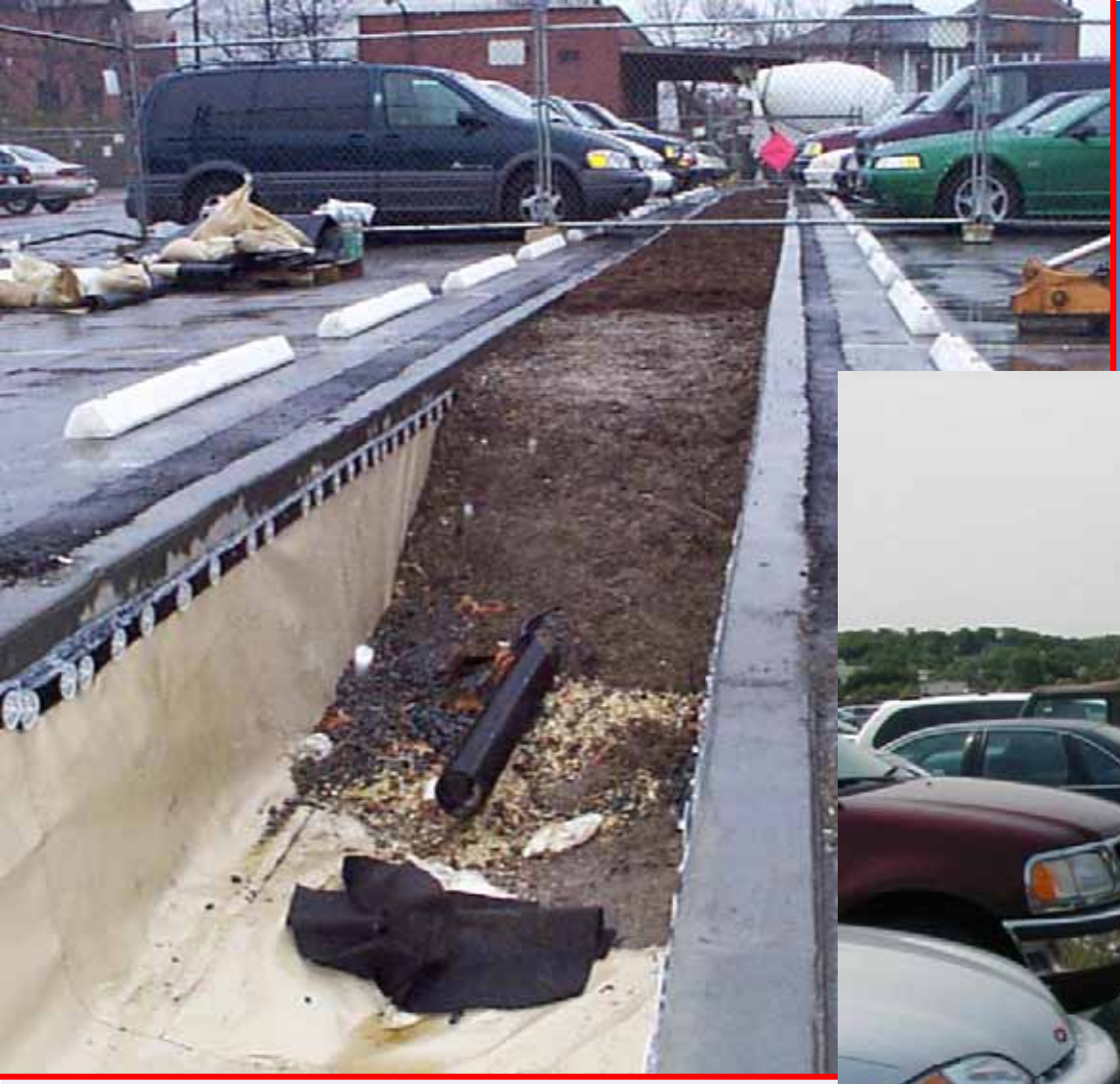
Bioretention



Cul-de-Sac Application

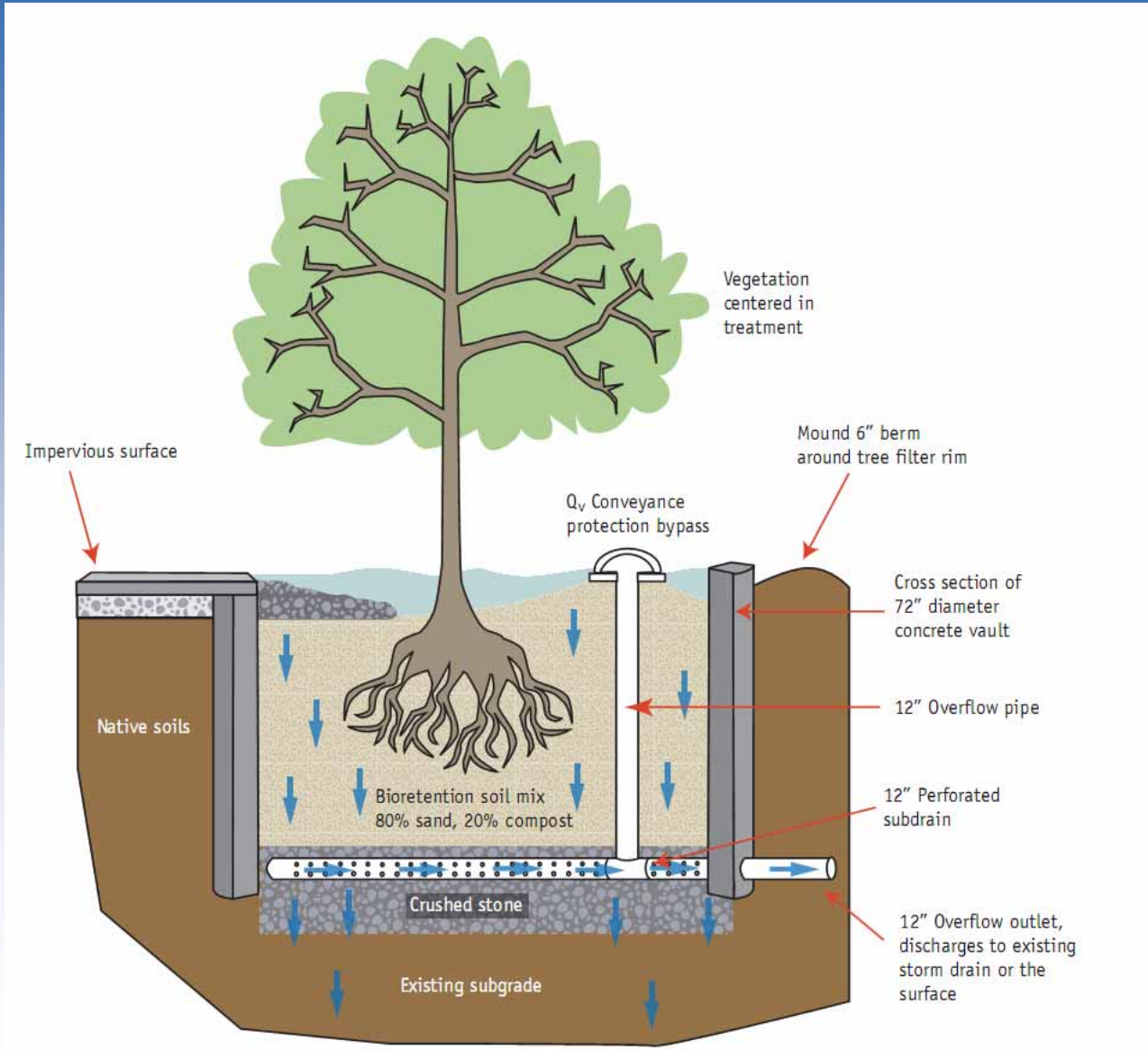
Commercial Application

Municipal Application

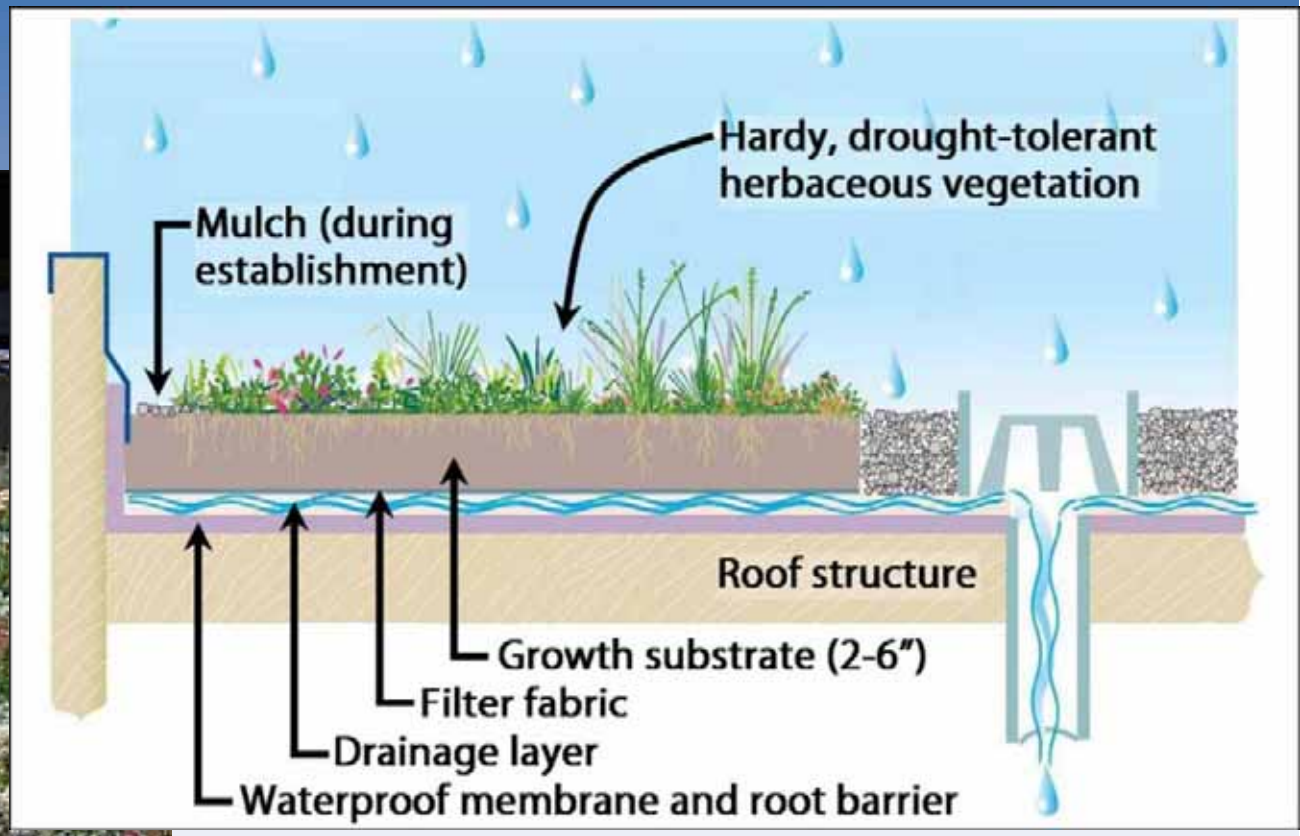


Retrofit Application

Tree Filter


Vegetation centered in treatment
Impervious surface
Mound 6" berm around tree filter rim
Q_v Conveyance protection bypass
Cross section of 72" diameter concrete vault
12" Overflow pipe
Native soils
Bioretention soil mix 80% sand, 20% compost
12" Perforated subdrain
Crushed stone
12" Overflow outlet, discharges to existing storm drain or the surface
Existing subgrade

Green Roofs


Hardy, drought-tolerant herbaceous vegetation
Mulch (during establishment)
Roof structure
Growth substrate (2-6")
Filter fabric
Drainage layer
Waterproof membrane and root barrier

Chicago Rooftop Retrofit

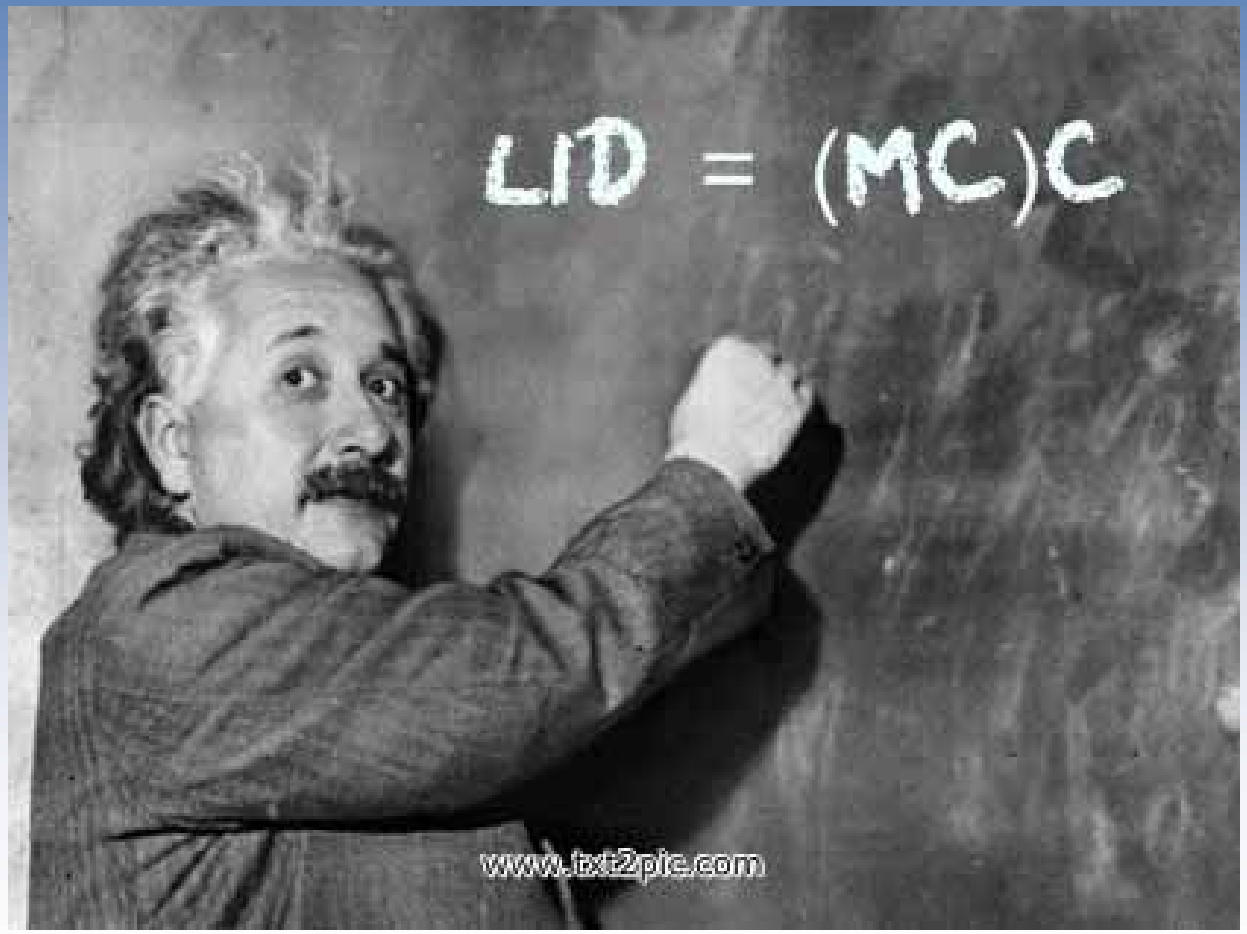
Before

After

Open Vegetated Channels

9.15.2004

LID Designs Are Not Rocket Science



Rhode Island Stormwater Design and Installations Manual

Public Review Meeting: June 4, 2009

BMP Design, Maintenance,

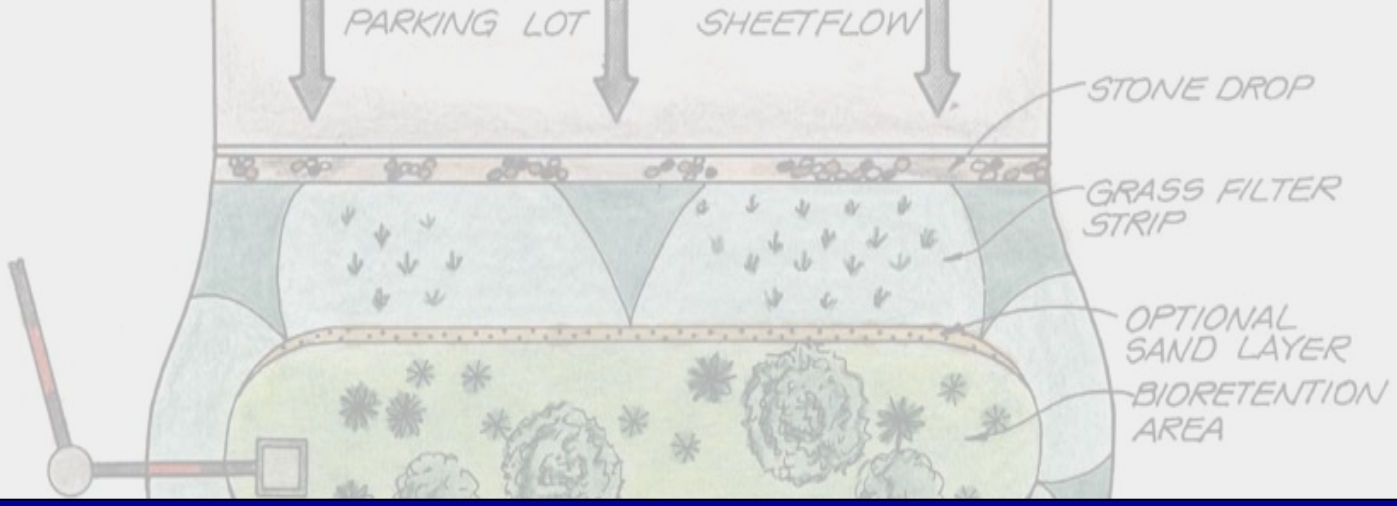
and

Selection Criteria

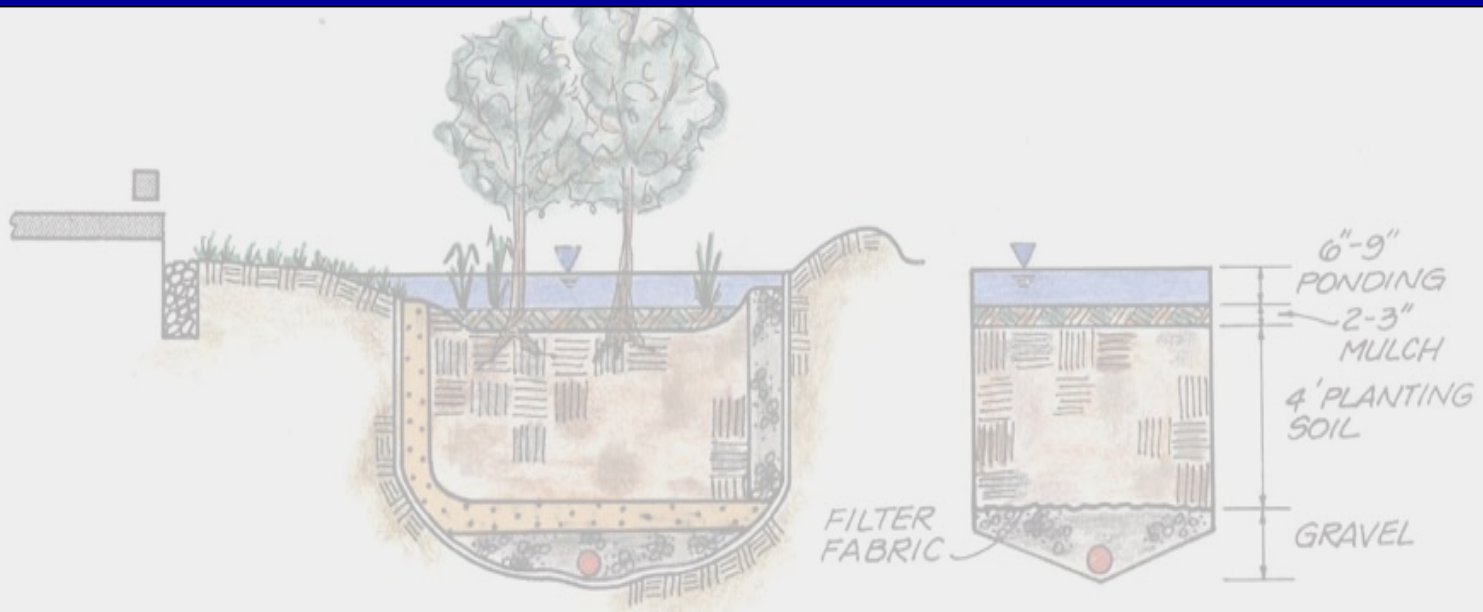
Horsley Witten Group

Presentation Outline

I. Design and Maintenance Criteria for Stormwater BMPs
II. How to Choose Appropriate BMPs for a Particular Site



I. Design and Maintenance Criteria for Stormwater BMPs



Minimum Design Criteria

- Required Elements and Design Guidance
  - If required elements can’t be met, select a different BMP
- Six Categories
  - Feasibility
  - Conveyance
  - Pretreatment
  - Treatment
  - Landscaping
  - Maintenance

Horsley Witten Group

Wet Vegetated Treatment Systems

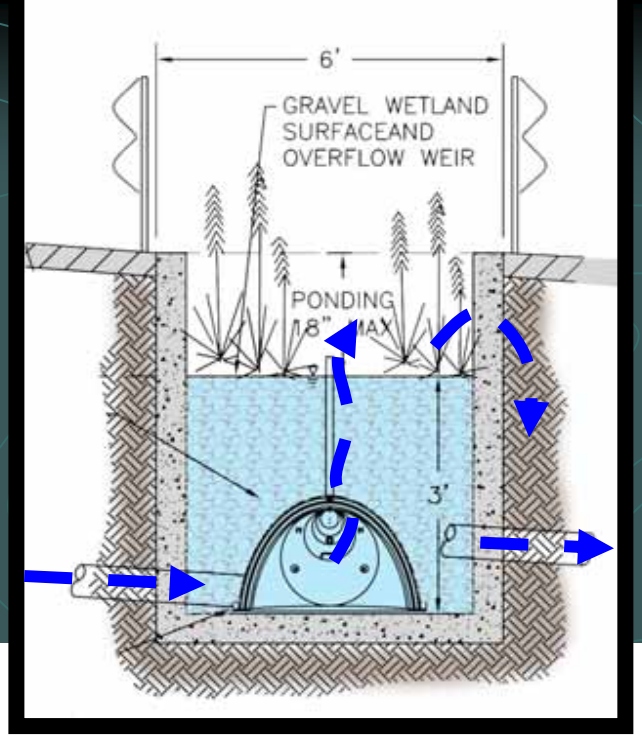
WVTS: Design Notes

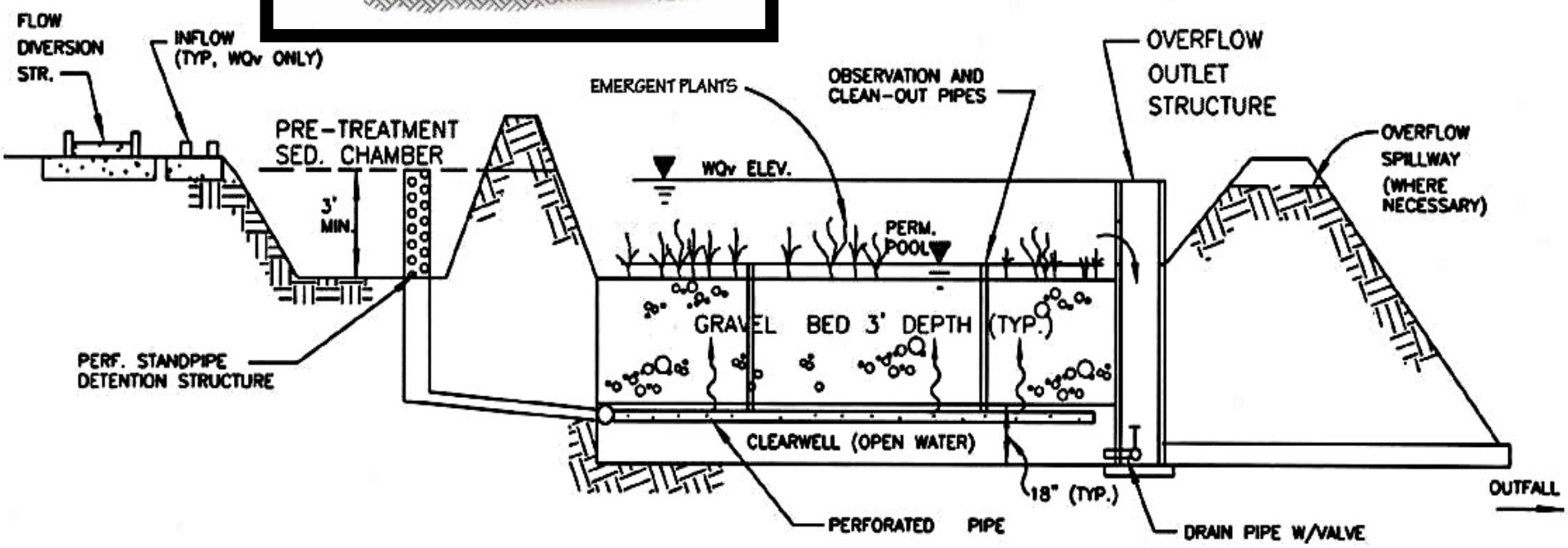
- Shall not be located within jurisdictional waters, except may be allowed in previously developed upland buffers
- Restricted in cold-water fisheries watersheds
  - Discharges prohibited within 200 ft of jurisdictional waters
  - Beyond 200 ft, discharges shall be designed to discharge up to the CPv through an underdrained gravel trench outlet
- LUHPPL runoff requires a 3-ft separation to groundwater, no separation distance required for non-LUHPPL runoff
- Forebay required for pretreatment, 10% of WQv

Shallow WVTS: Design Notes

- Minimum flowpath of 2:1 (length to width)
- Deeper forebay and micropool are essential (25% of WQv)
- Shallow depths over remaining surface area
- High surface area to volume ratio
- Complex internal microtopography
- Potential wildlife habitat creation
- Consumes most land of any BMP option
  - 1.5% of DA

Gravel WVTS


6'
GRAVEL WETLAND
SURFACEAND
OVERFLOW WEIR
PONDING
3'


FLOW
DIVERSION
STR.
INFLOW
(TYP. WQv ONLY)
PRE-TREATMENT
SED. CHAMBER
3'
MIN.
EMERGENT PLANTS
OBSERVATION AND
CLEAN-OUT PIPES
OVERFLOW
OUTLET
STRUCTURE
OVERFLOW
SPILLWAY
(WHERE
NECESSARY)
WQv ELEV.
PERM.
POOL
GRAVEL BED 3' DEPTH (TYP.)
PERF. STANDPIPE
DETENTION STRUCTURE
CLEARWELL (OPEN WATER)
18" (TYP.)
OUTFALL
PERFORATED PIPE
DRAIN PIPE W/VALVE
PROFILE

Gravel WVTS: Design Notes

- Minimum flowpath of 0.5:1 (length to width), 15 ft
- 10% WQv in sediment forebay
- Remaining 90%, a combination of one or more basins/chambers filled with gravel and open ED above the gravel
- Upflow filter
- Outlet invert just below gravel surface
- Surface area must be minimum 0.35% of DA

WVTS - Maintenance

- Replace dead/damaged vegetation
- Vegetation management around perimeter of WVTS (mow access road, area near control structure; remove trees/shrub from embankment);
- Clean-out trash racks and access gates;
- Remove sediment from forebay when 50% volume reduction;
- Repair minor gullying.
- Repair embankment structural integrity (borrowing animals, seepage, slope sloughing);
- Repair structural elements (spillways, etc.);
- Major erosion (inflow/exit channels)
- Remove organic build-up from gravel WVTS ~2 yrs

Infiltration

Infiltration - Design Notes

- Field verification of soil permeability/texture essential;
- Pretreatment essential – minimum 25% of WQv;
- Bottom of infiltration facility cannot be located in fill, must have 3' separation from gw and bedrock;
- Size facility based on design infiltration rates through floor of practice;
- Distributed treatment: Keep drainage areas small to each one, may reduce some potential problems;
- Cannot be used if contributing drainage is a LUHPPL;
- Frequent maintenance necessary to retain soil permeability;
- Stabilize site prior to installation;
- Must meet variety of UIC setbacks; and
- May be used for larger storm events if infiltration rate > 5 in/hr, mounding analysis may be required

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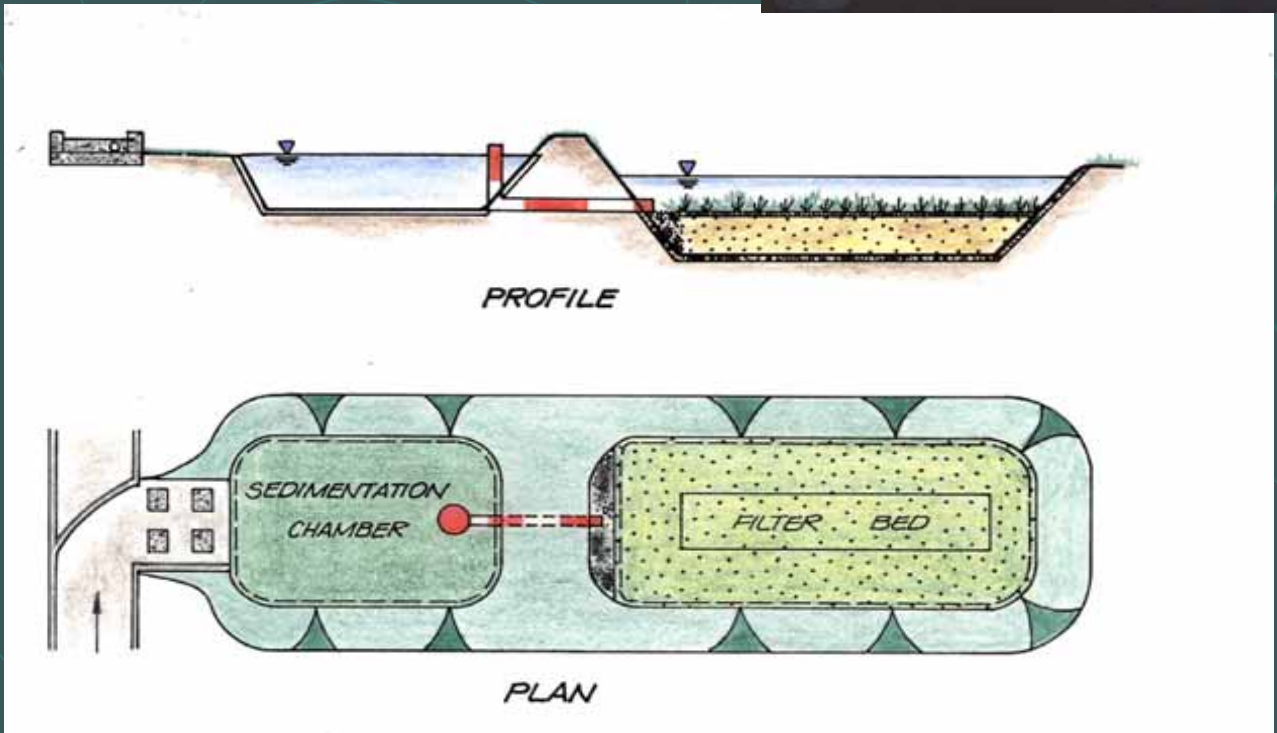
Infiltration - Maintenance

- Never use basin or area as temporary E&SC facility;
- Provide observation well in all trenches/chambers;
- Provide direct access for maintenance/rehab;
- Basin: Routine sediment cleanout, mowing, revegetate bare areas, litter & debris removal, & rejuvenation (roto-till surface soils).
- Trench/chambers: Pretreatment and trench sediment cleanout.
- Drywell: Pretreatment cleanout. Gutter/downspout system cleaning if needed.
- Permeable pavement: Vacuum sweeping and education.

Filtering Practices

- Sand/organic filters
- Bioretention areas/Tree filters



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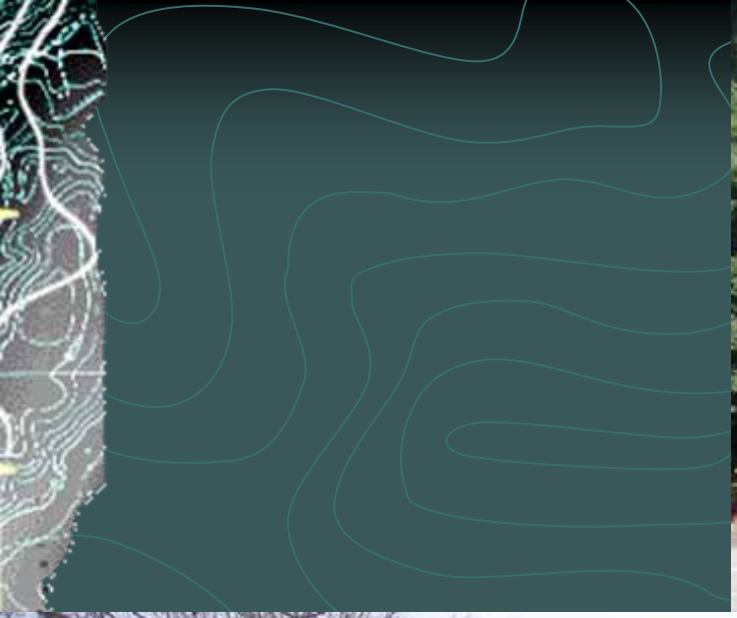
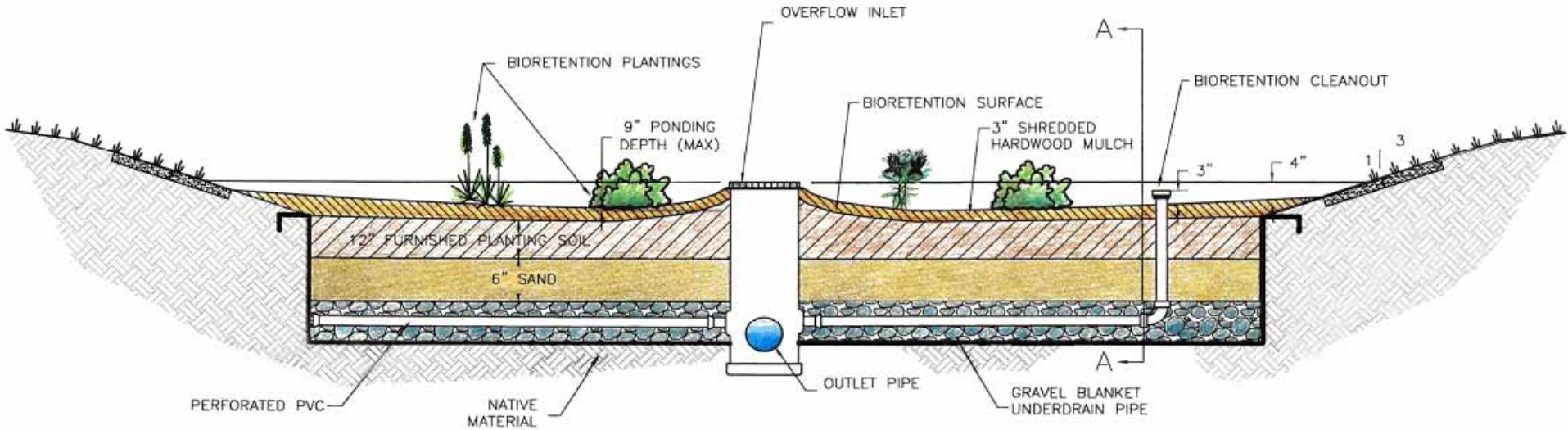
Sand/Organic Filter: Design Notes

- Pretreatment essential (dry or wet sedimentation)
- Need maintenance access to filter bed
- Useful to treat LUHPPL runoff
- Organic media can include compost (based on native materials)
- Use a conservative permeability coefficient



Bioretention: Design Notes

- Pretreatment essential (grass channel/filter strip, gravel trench, mulch layer)
- 6”-9” ponding above surface
- Typically, 2’-4’ planting soil bed
- Specific engineered soil media
- Use a conservative permeability coefficient
- Detailed landscape plan required


OVERFLOW INLET
A
BIORETENTION PLANTINGS
BIORETENTION CLEANOUT
BIORETENTION SURFACE
9" PONDING DEPTH (MAX)
3" SHREDDED HARDWOOD MULCH
3"
4"
1
3
12" FURNISHED PLANTING SOIL
6" SAND
A
OUTLET PIPE
PERFORATED PVC
NATIVE MATERIAL
GRAVEL BLANKET UNDERDRAIN PIPE

Bioretention Planting Soil and Mulch

- Loamy Sand to a Sandy Loam
  - 85-88 % sand
  - 8-12 % silt
  - 0-2 % clay
- Well-aged graded compost (25% of soil mix)
- Layer of well-aged, shredded hardwood mulch (aged 6 months, if possible)

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444H

Filter Sizing Equation

$$A_f = (WQ_v)\,(d_f) \,/\, [(k)\,(h_f + d_f)\,(t_f)]$$

Where: A_f = surface area of filter bed (ft^2)

d_f = filter bed depth (ft)

k = coefficient of permeability of filter media (ft/day)

h_f = average height of water above filter bed (ft)

t_f = design filter bed drain time (days) (2 days is recommended)

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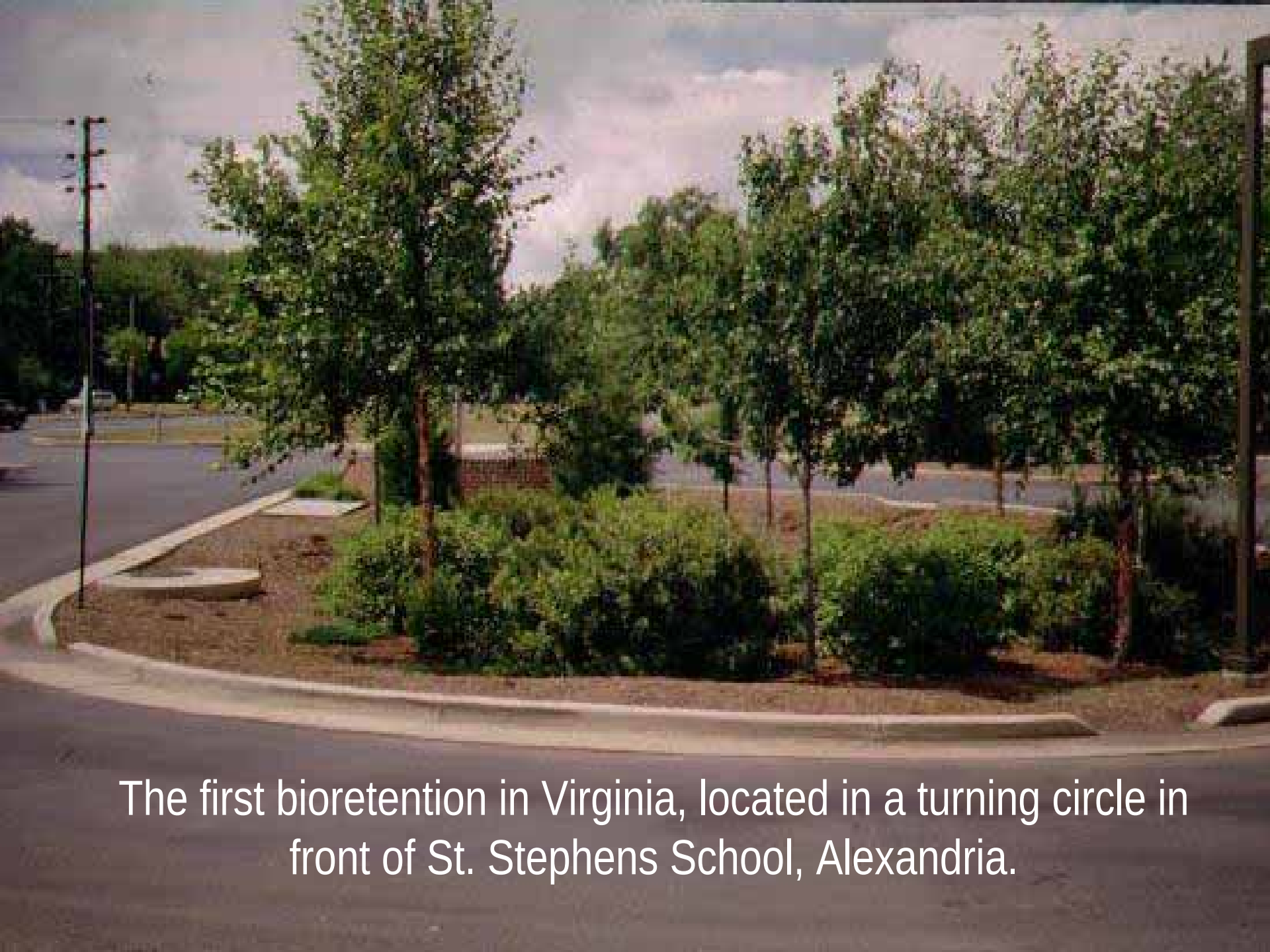
Sand/Organic Filters - Maintenance

- Clean-out pretreatment chamber when approx ½ full via vactor truck, clam shell or equiv;
- If standing water is observed above filtration bed, the top 6” should be removed and replaced;
- Repair structural components (concrete, valves, pipes, inlet frame/grate, underdrain system).

Bioretention/Tree Filter - Maintenance

- Remove sediment from pretreatment when depth exceeds 6”, clean/repair when drawdown exceeds 36 hours;
- Remove sediment from filter bed when depth exceeds 1”, rehabilitate bed if standing water is present 48 hours after a storm (roto-till or aerate);
- Refurbish mulch every other year (till existing materials into soil) as needed;
- Prune dead/dying limbs off woody vegetation, remove and/or redistribute overcrowded vegetation, replace dead plants;
- Repair erosion gullies; repair structural components.

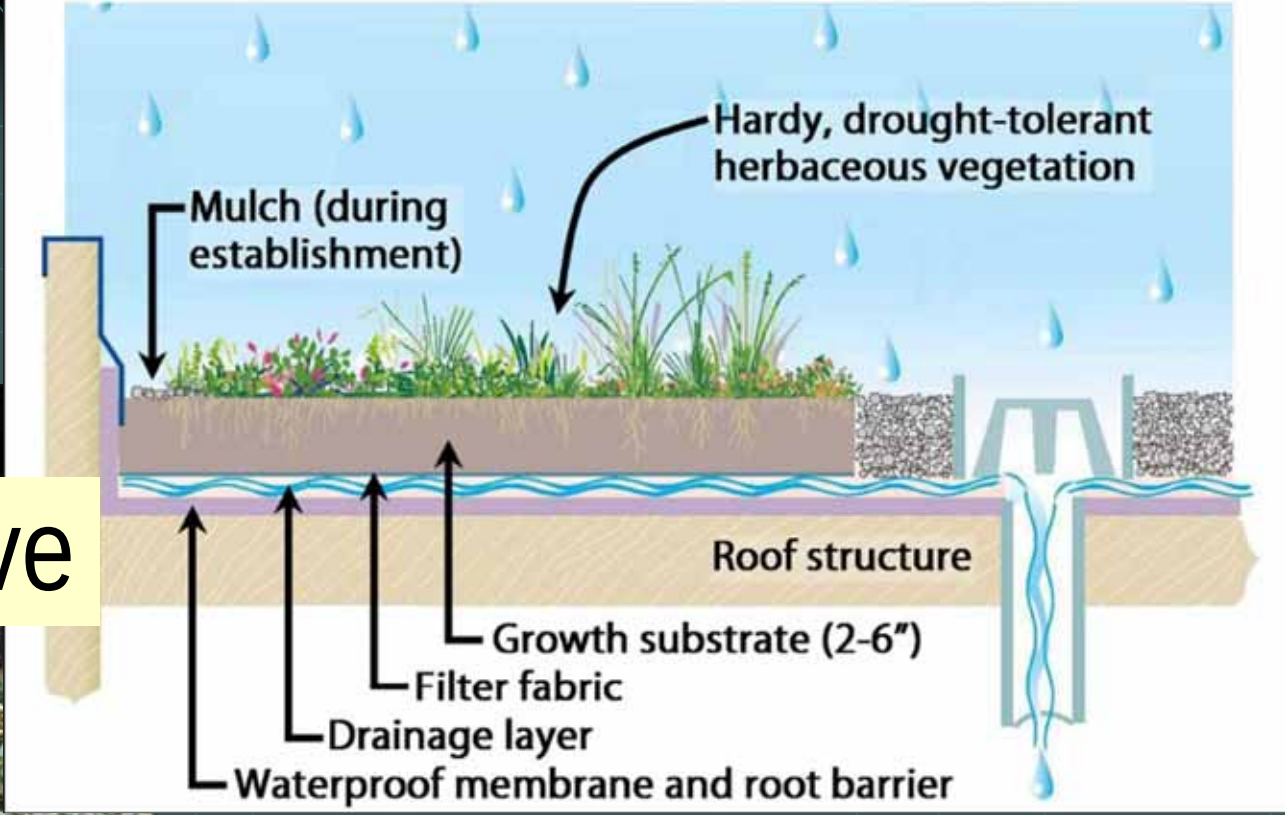


The first bioretention in Virginia, located in a turning circle in front of St. Stephens School, Alexandria.

St. Stephens Bioretention - 5 years later.

Green Roofs

Extensive



Intensive

Green Roof: Design Notes

- Designed to manage WQv without bypass
- Safely convey runoff from larger storm events to a downstream drainage system
- No pretreatment required

Green Roof: Maintenance

- Extensive
  - Vegetation may need to be watered/weeded
- Intensive
  - Vegetation should be maintained as any other landscaped area, e.g., pruning, irrigation.

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Open Channels

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10 YR. DESIGN STORM CAPACITY
NON-EROSIVE @ 2 YR. Qp
W.Q. TREATMENT VOL. (Vt)
DETAINED OR INFILTRATED
(c) DRY SWALE

Dry Swale

Dry Swale: Design Notes

- Swale has engineered soil matrix and underdrains to promote filtration and prevent “nuisance water”
- Ideal for open section roads, lower density residential streets and small parking lots
- Gentle grades and side slopes
- Select the most appropriate native seed mix for expected swale conditions
- Erosion control fabric for steeper grades
- May need some topsoil, fertilization, and irrigation to get grass established
- Design for at least 30 minutes contact time in swale for a WQv storm (or), add check dams to promote trapping and storage
- Application on slopes greater than 2% is problematic w/o cells or checkdams
- Use filter sizing equation

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Wet Swale

Wet Swale: Design Notes

- Used when water table is close to surface
- Creates a linear series of wetland cells
- Not recommended for residential areas
- Permanent pool may be included in WQv calculations
- Planted with emergent vegetation

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Channels - Maintenance

- Clean-out pretreatment when approx ½ full, where applicable;
- Litter/debris removal;
- Stabilization of eroded slopes;
- De-thatching swale bottom/removal of existing thatch;
- Discing/aeration of swale bottom;
- Restoration of original swale dimensions (sediment removal);
- Structural repairs (trash racks, weirs, etc).
- Long-term vegetative management is major issue:
  to mow or not to mow?

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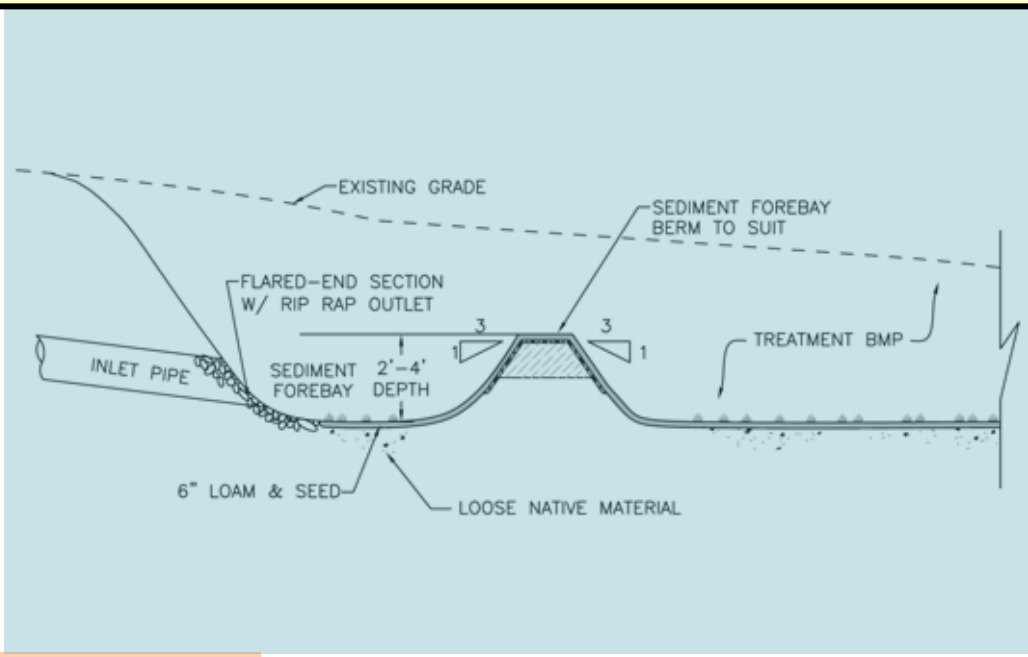
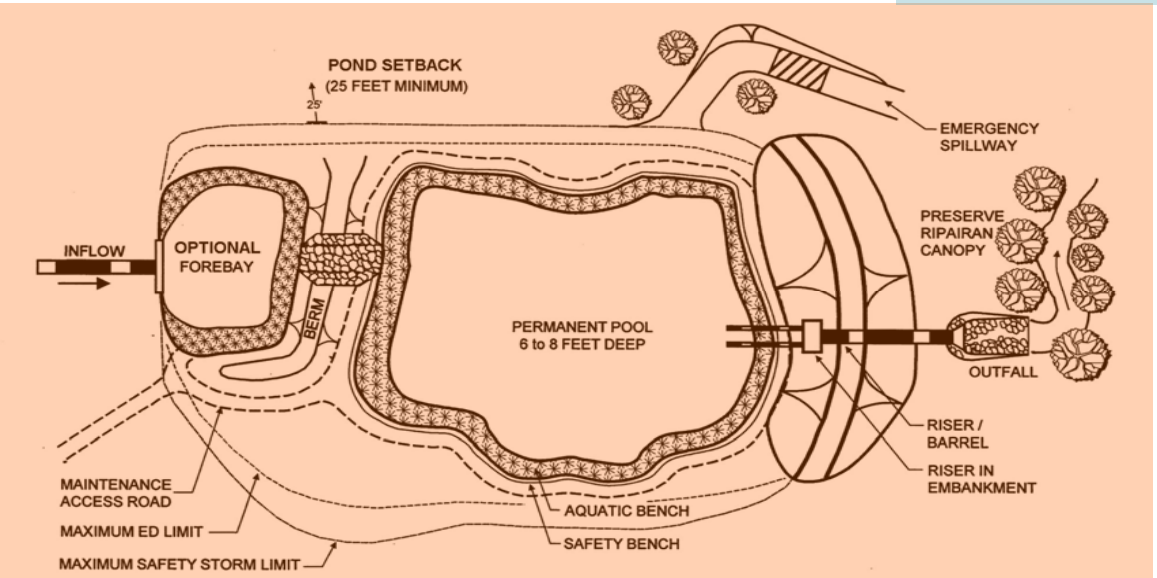
G3WD

Practices Approved for Other Criteria

- Pretreatment Practices – Chapter 6
  - Grass Channel
  - Filter Strips
  - Sediment Forebay
  - Deep Sump Catch Basins
  - Proprietary Devices





- Storage Practices – Chapter 7
  - Stormwater Basins
  - Underground Storage Devices

Table 5-3 BMP Selection Matrix 1 – Land Use

BMP Group	BMP Design	Rural	Residential	Roads and Highways	Commercial/ High Density	LUHPPL	Ultra-urban
WVTS	Shallow WVTS	○	○	◗	◗	①	●
	Gravel WVTS	○	○	◗	◗	①	●
Infiltration	Infiltration Trench/Chambers	○	◗	○	○	●	◗
	Dry Wells	○	○	◗	◗	●	◗
	Shallow I-Basin	◗	◗	◗	◗	●	◗
	Pervious Pavement	○	○	◗	◗	②	◗
Roofs	Intensive	◗	◗	●	◗	○	○
Open Channels	Dry Swale	○	◗	○	◗	②	◗
	Wet Swale	○	◗	○	●	●	●

○: Yes. Good option in most cases.
◗: Depends. Suitable under certain conditions, or may be used to treat a portion of the site.
●: No. Seldom or never suitable.
①: Acceptable option, but may require a liner to reduce risk of groundwater contamination.
②: Acceptable option, if not designed as an exfilter. (An exfilter is a conventional stormwater filter without an underdrain system. The filtered volume ultimately infiltrates into the underlying soils.)

II. Selecting the Most Effective and Appropriate Stormwater Practices

Six Selection Factors to Consider:

1. Land Use
2. Physical Feasibility
3. Watershed
4. Stormwater Management Capability
5. Pollutant Removal
6. Community and Environmental

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#1. Land Use

The land use of the contributing drainage area influences the stormwater strategy:

- Rural areas
- Residential sites
- Roads/highways
- Commercial sites
- LUHPPLs
- Urban sites (e.g., redevelopment)

AUTOMOTIVE
REGISTERED
MOTOR VEHICLE
REPAIR SHOP
SHOP
HOURS
727 - 6885

Cul-de-Sac Application

Commercial Application

Municipal Application

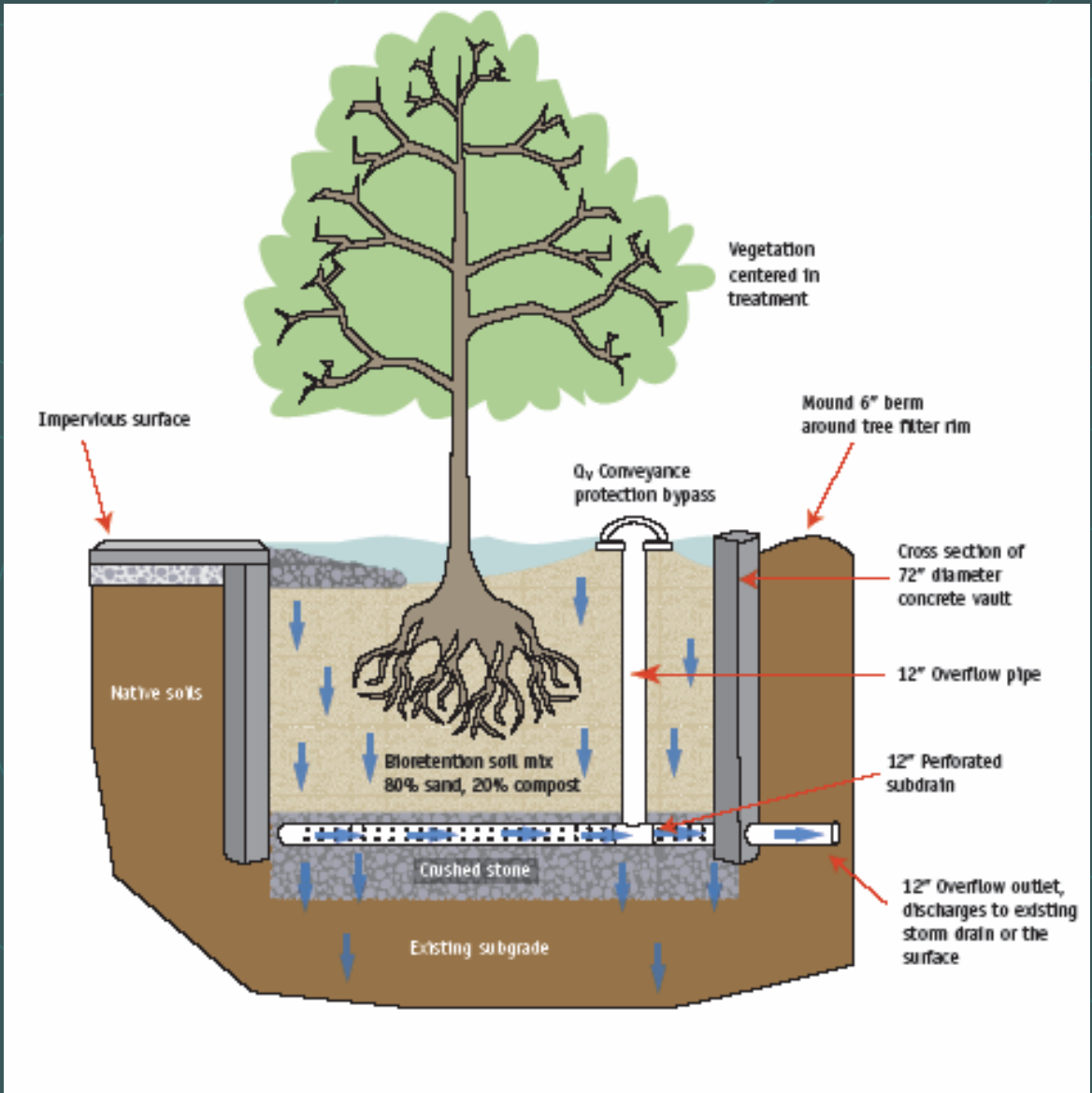
Retrofit Application

2. Physical Feasibility

Some Practices Cannot Be Used Because of Site Constraints:

- Soils
- Groundwater
- Drainage Area
- Minimum Surface Area
- Slope Restriction
- Head

Tree Filter



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NOT
TER

#3. Watershed Factors

Different Receiving Water Management Objectives Shape Stormwater Strategies:

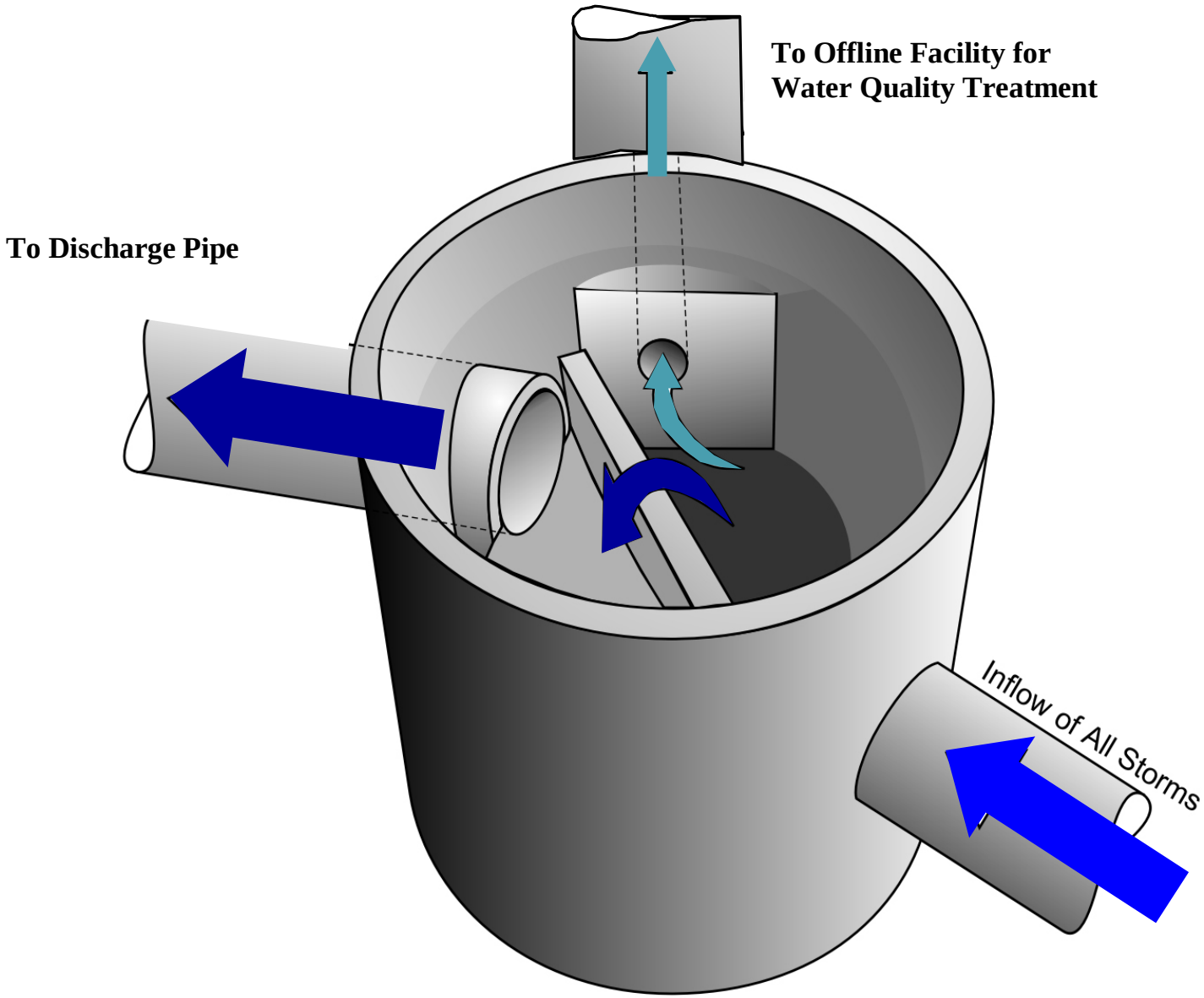
- Groundwater (Aquifer protection)
- Freshwater streams and Rivers
- Other Freshwaters (Ponds/Lakes/Wetlands)
- Coastal Waters (shellfish/beach areas

CLOSED AREA
NO SHELLFISHING
Due to fecal coliform bacterial contamination
PER ORDER OF
MASSACHUSETTS DIVISION OF MARINE
FISHERIES
PAUL S. MONTAGUE, SHELLFISH CONSTABLE
508-548-7611 ext. 334

#4. Stormwater Management Capability

No single practice achieves all stormwater management objectives. A combination of practices is often needed to provide desired level of:

- Groundwater recharge
- Water quality treatment
- Channel protection
- Flood control
- Ability to treat LUHPPLs


To Offline Facility for
Water Quality Treatment
To Discharge Pipe
Inflow of All Storms

AIN DRINKS
1.09

#5. Pollutant Removal Capability

Important when higher removals are required for impaired receiving waters and those that have completed SAMPs or TMDLS. Table 5-7 compares removal efficiencies for:

- Total Suspended Solids
- Total Phosphorus
- Total Nitrogen

#6. Community and Environmental Impacts

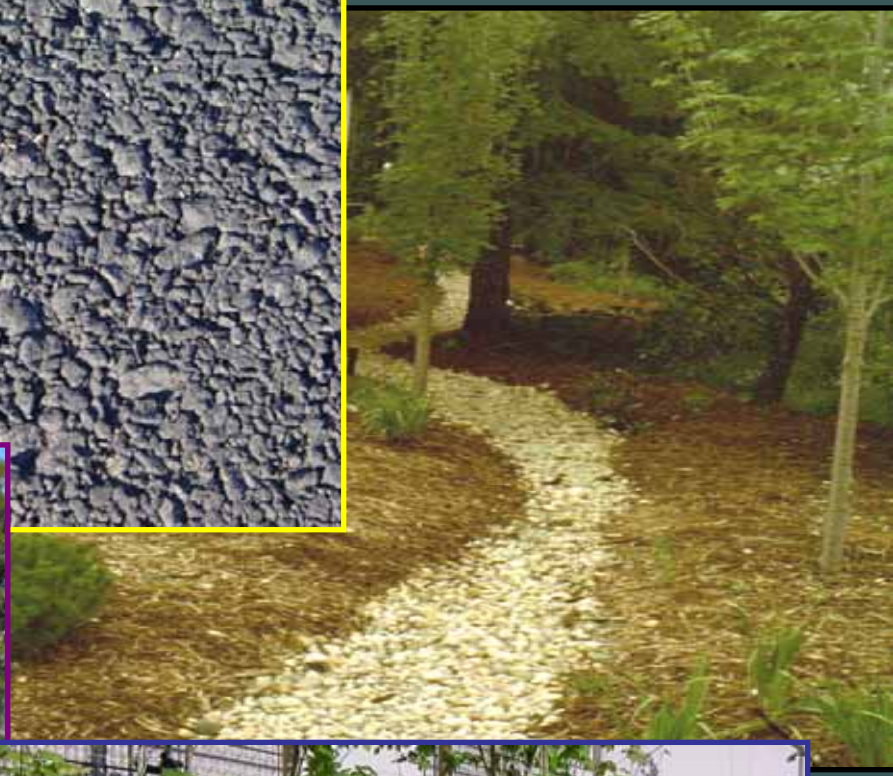
Other community and environmental impacts should be considered when selecting BMPs:

- Ease of maintenance
- Affordability
- Community acceptance/aesthetics
- Safety
- Habitat

Stormwater Practice Maintenance Burden*

Maintenance Burden is a function of the type of facility as well as the design and implementation

- WVTS ---------- Medium
- Infiltration --------- Medium to Difficult
- Filters ---------- Medium to Difficult
- Open Channels ---------- Easy

* Source: 2000 Maryland Stormwater Design Manual

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