10-11-2018

# Challenges and Practical Solutions to Managing Municipal Stormwater Systems

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# *Challenges and Practical Solutions to Managing Municipal Stormwater Systems*

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Stories from the end of the pipe

# Project Partners

- City of Dover, NH Staff
- UNH Stormwater Center
- NH Department of Environmental Services
- Environmental Protection Agency, Region 1

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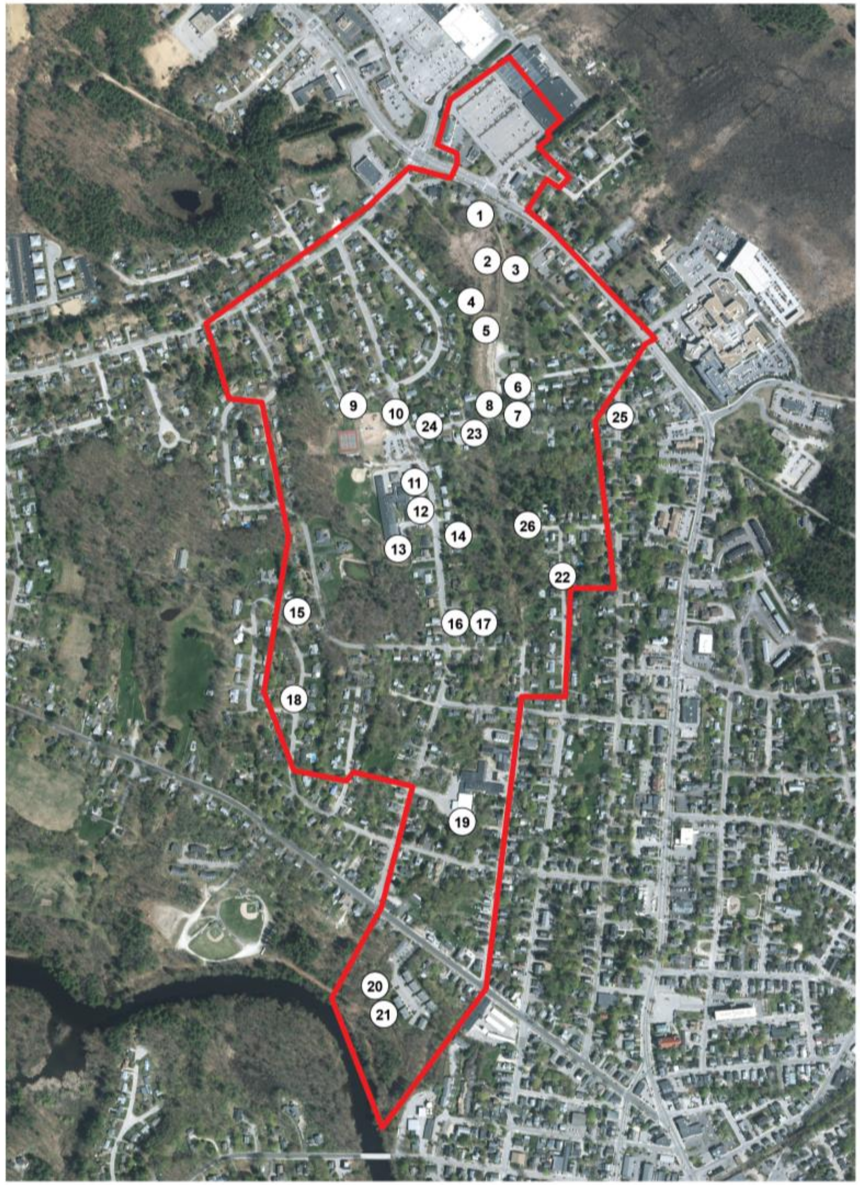
# Berry Brook Watershed Management Plan –Implementation Projects Phase III


**Final Report to**
**The New Hampshire Department of Environmental Services**
**Submitted by**

**The City of Dover and the UNH Stormwater Center**
**December, 2017**

https://www.unh.edu/unhsc/berry-brook-project




N

# Berry Brook BMPS

0 0.0450.09 0.18 0.27 0.36 Miles

**Legend**

**New BMPs**

BB_Watershed

**2015 1-foot Orthophotography**

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# BMPs

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Installations include:

- 12 bioretention systems,
- a tree filter,
- a subsurface gravel wetland,
- one acre of new wetland,
- daylighted and restored 1,100 linear feet of stream at the headwaters and restored 500 linear feet of stream at the confluence including two new geomorphically-designed stream crossings
- 3 grass-lined swales
- 2 subsurface gravel filters
- an infiltration trench system
- 3 innovative filtering catch basin designs

# Funding and Results

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Funding: 3 watershed assistance grants (sec 319) and 1 aquatic resource mitigation grant, all with min 40% match from the city.

| Berry Brook Project: Getting to 10% | |
|---|---|
| Cost | $1,322,000 |
| Grant Funds | $793,000 |
| Match (min estimate) | 529,000 |
| BMPs | 26 |
| DCIA Reduced | 37 acres |
| TSS Reductions (lb./yr.) | 57,223 |
| TP Reductions (lb./yr.) | 201 |
| TN Reductions (lb./yr.) | 1,127 |

# Typical Project Approach

Develop a watershed management plan (a-i)

Optimize placement of BMPs for maximum gain

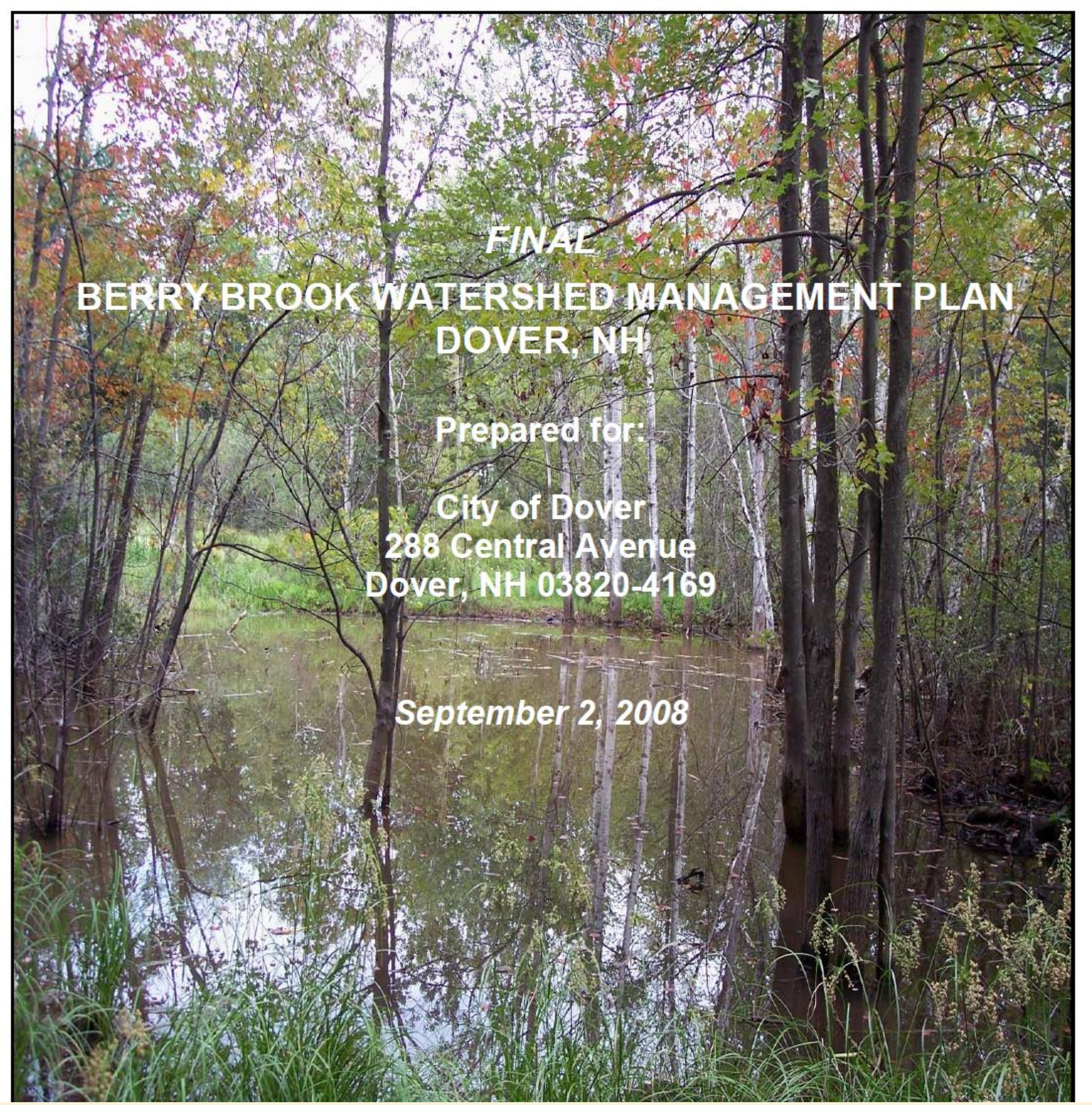
Implement

Model

Outreach and education on project results

Report

# Typical Project Approach



# Optimize Again…

## 2011 Watershed Restoration Grants for
# Impaired Waters

## Section B: PRE-PROPOSAL APPLICATION FORM
### Watershed Restoration Grants for
### Impaired Waters

### I. Proposal Title

**Berry Brook Watershed Restoration through Low Impact Development Retrofits in an Urban Environment**

### II. Contact Information


Primary contact person: Dean Peschel
Organization: Environmental Project Manager, City of Dover DPW
Street address: 288 Central Avenue
City, State, ZIP: Dover, NH, 03820-4169
Day phone: (603) 516-6094 Fax: ( ) Email: dean.peschel@ci.dover.nh.us

Secondary contact person: Robert M. Roseen, Ph.D., D.WRE, P.E.
Organization: Director, The UNH Stormwater Center
Street address: 35 Colovos Road
City, State, ZIP: Durham, NH, 03824
Day phone: (603)862-4024 Fax: (603)862-3957 Email: robert.roseen@unh.edu


Signature of Applicant: ________________

Date of signature: 9/2/10

### III. Project Summary

Berry Brook is a highly urbanized 1st order stream located in Dover, NH, that is classified as Class B waters. . The Brook is located in a built-out, 164-acre watershed with 25% impervious cover (IC) and includes medium-density housing with commercial and industrial uses. The stream has been placed on the NHDES 2006 Section 303(d) list and is impaired for primary recreation and for aquatic life. The source of this impairment includes urbanization resulting in an increase of pollutant mass and runoff volumes from stormwater.

# And then you implement –
# Inside a historic 40,000 sf slow sand filter

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National Historic Preservation Act Section 106 Compliance for the Regulatory Program

# Reality

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**Redesign**

**Reconfigure**

**… and optimize**

**Again…**

# And more implementation…

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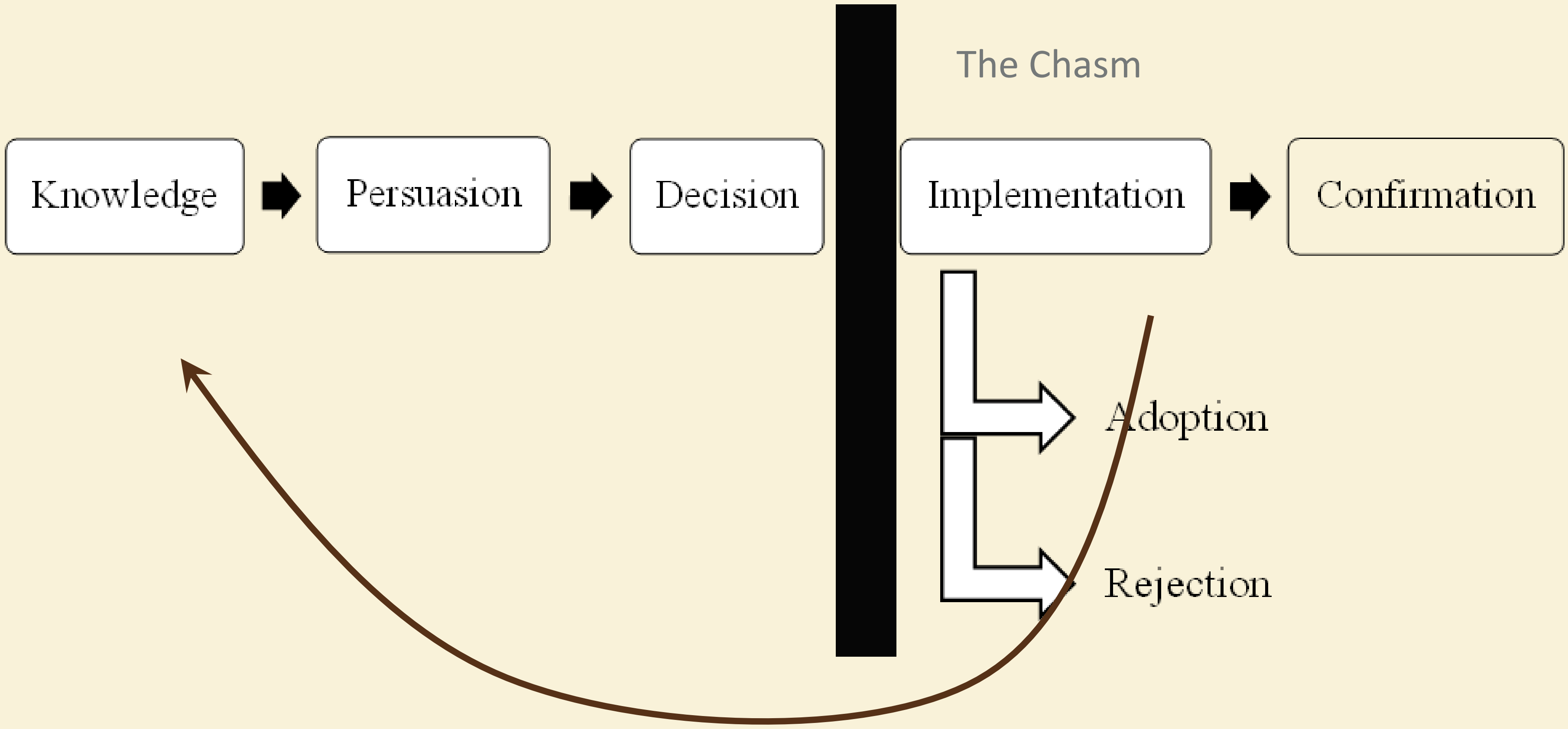
# Innovation Decision Process




Ability to reinvent to reflect local needs and foster ownership

Rogers, 2003

# The tale of two raingardens …

# And more adaptation…NDP!

# Maintenance Must be Included in the Design Process

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Not by the designers, but by the people who are expected to do it and pay for it

# Decadal Reflections:
# Cart Before the Horse

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**The expression cart before the horse is an idiom or proverb used to suggest something is done contrary to a conventional or culturally expected order or relationship.**

# "Bioretention Design"

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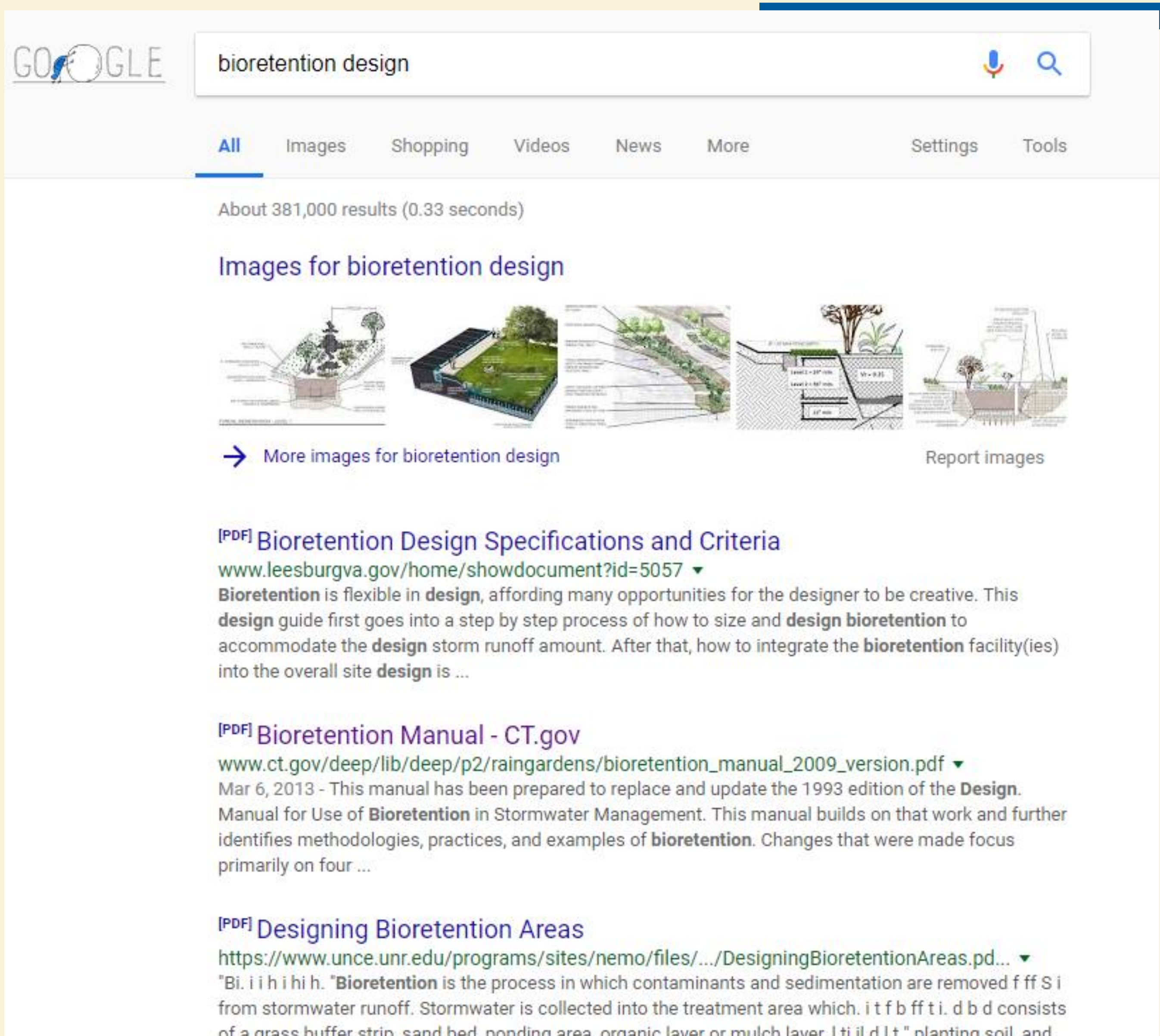
## 381,000 results!


bioretention design

All Images Shopping Videos News More Settings Tools

About 381,000 results (0.33 seconds)

Images for bioretention design

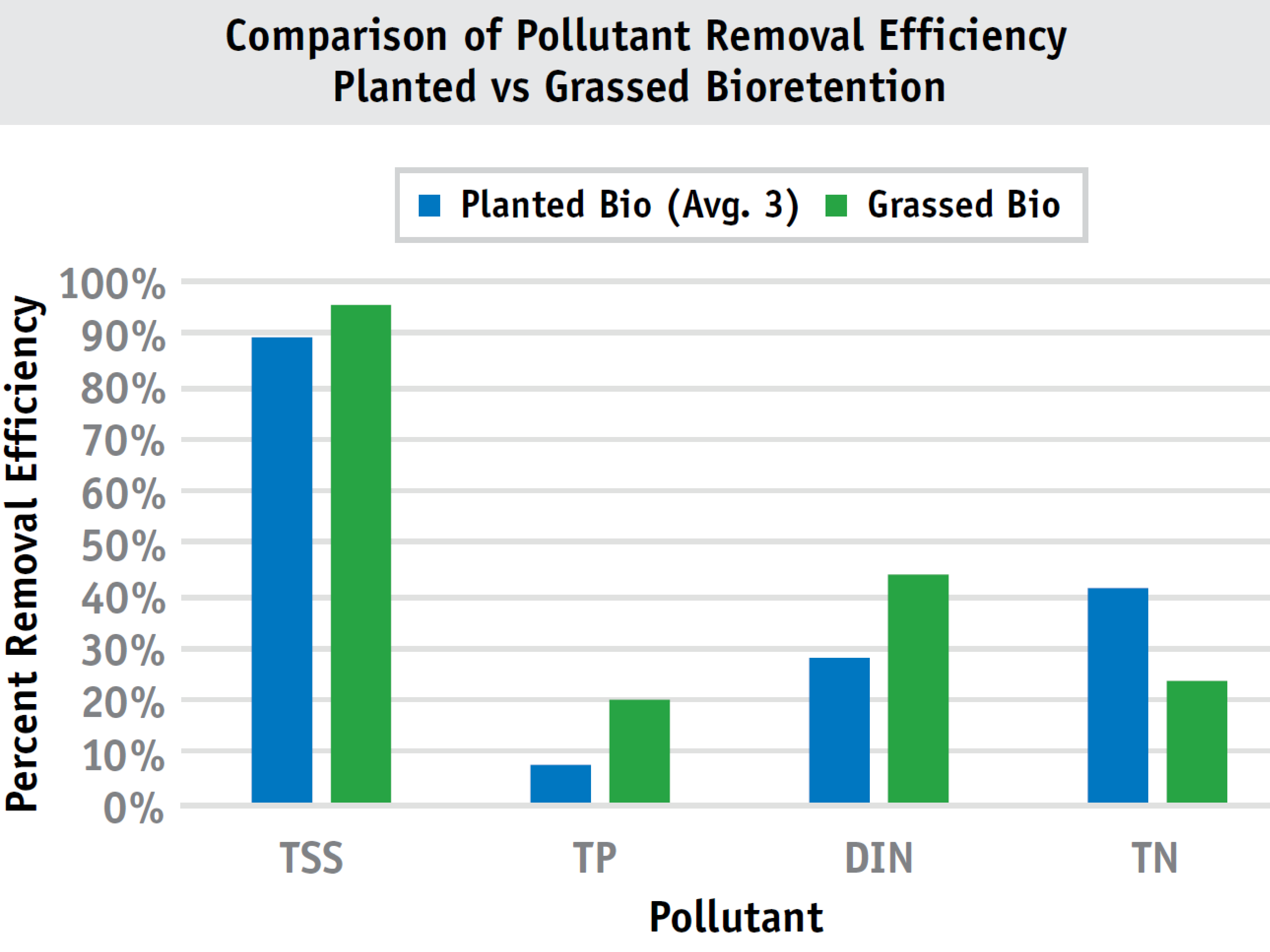
More images for bioretention design

Report images

[PDF] Bioretention Design Specifications and Criteria
www.leesburgva.gov/home/showdocument?id=5057
**Bioretention** is flexible in **design**, affording many opportunities for the designer to be creative. This **design** guide first goes into a step by step process of how to size and **design bioretention** to accommodate the **design** storm runoff amount. After that, how to integrate the **bioretention** facility(ies) into the overall site **design** is ...

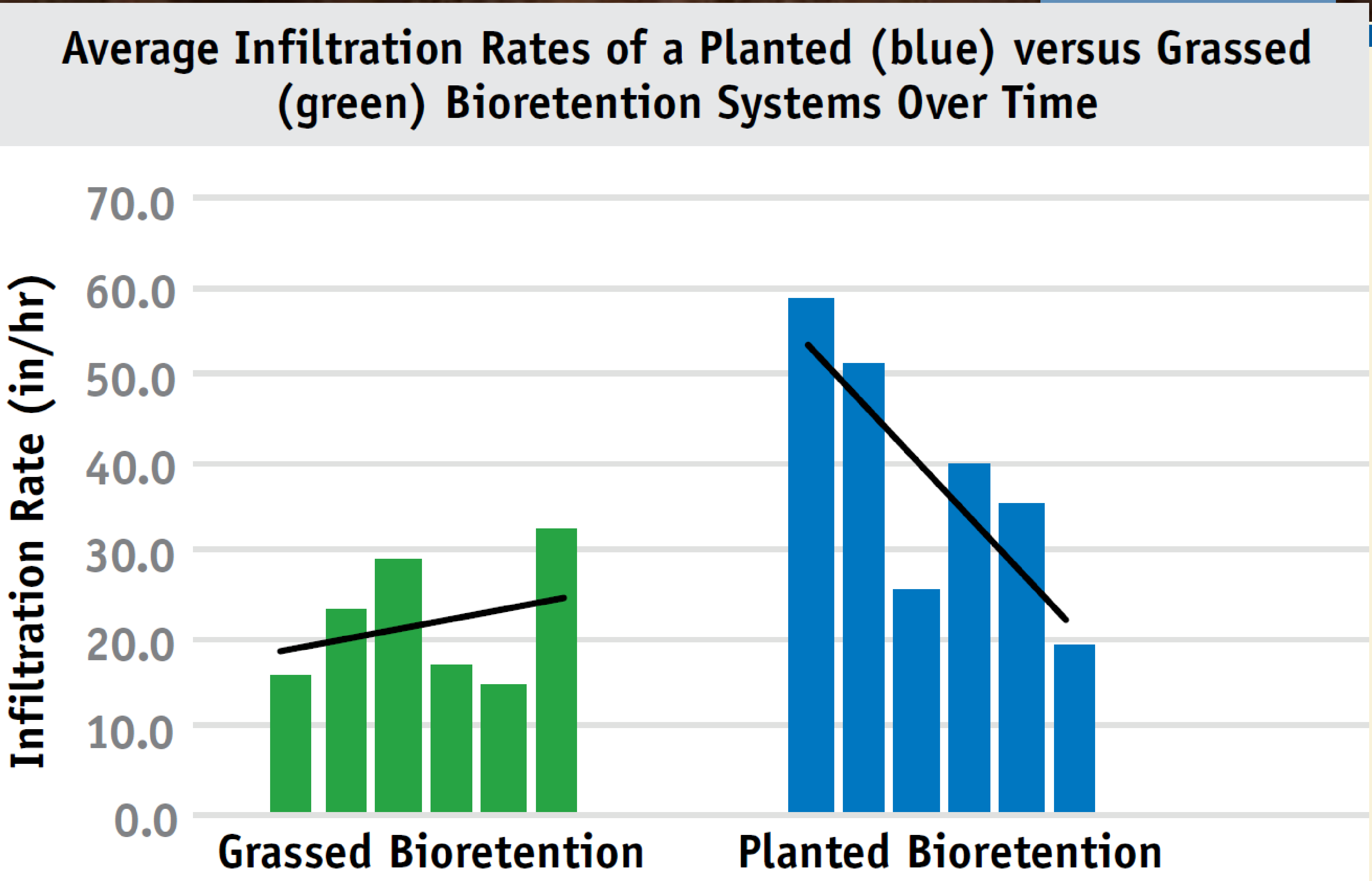
[PDF] Bioretention Manual - CT.gov
www.ct.gov/deep/lib/deep/p2/raingardens/bioretention_manual_2009_version.pdf
Mar 6, 2013 - This manual has been prepared to replace and update the 1993 edition of the **Design**. Manual for Use of **Bioretention** in Stormwater Management. This manual builds on that work and further identifies methodologies, practices, and examples of **bioretention**. Changes that were made focus primarily on four ...

[PDF] Designing Bioretention Areas
https://www.unce.unr.edu/programs/sites/nemo/files/.../DesigningBioretentionAreas.pd...
"Bi. i i h i hi h. "**Bioretention** is the process in which contaminants and sedimentation are removed f ff S i from stormwater runoff. Stormwater is collected into the treatment area which. i t f b ff t i. d b d consists of a grass buffer strip, sand bed, ponding area, organic layer or mulch layer, l ti il d l t " planting soil, and



Comparison of Pollutant Removal Efficiency
Planted vs Grassed Bioretention
Planted Bio (Avg. 3)
Grassed Bio
Percent Removal Efficiency
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
TSS
TP
DIN
TN
Pollutant

# Grassed vs Planted Surface IR



# Traditional Approach

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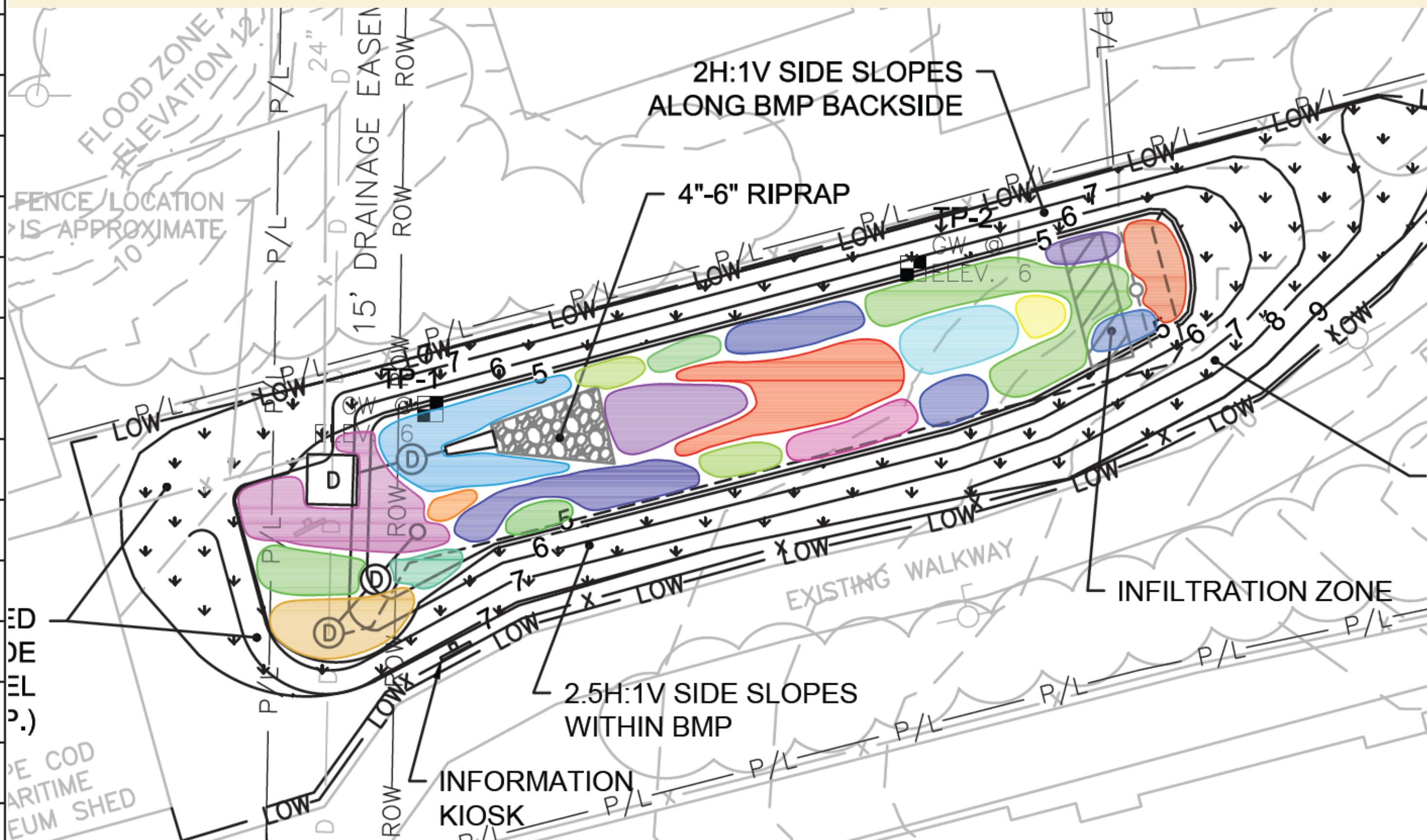
| KEY | QUANTITY | NAME |
|---|---|---|
| | 50 | TUSSOCK SEDGE *(Carex stricta)* |
| | 75 | COMMON RUSH *(Juncus effusus)* |
| | 350 | SWITCHGRASS *(Panicum virqatum)* |
| | 15 | BLUE FLAB *(Iris versicolor)* |
| | 50 | JOE PYE WEED *(Eupatorium maculatum)* |
| | 20 | BLUE CARDINAL FLOWER *(Lobelia siphilitica)* |
| | 100 | FOX SEDGE *(Carex Vulpinoidea)* |
| | 15 | NEW YORK ASTER *(Aster novi-belgii)* |
| | 20 | NEW YORK ASTER *(Aster novi-belgii)* |
| | 40 | BLUE CARDINAL FLOWER *(Lobelia siphilitica)* |
| | 50 | NEW YORK IRONWEED *(Vernonia noveboracensis)* |
| | 50 | NEW ENGLAND ASTER *(Aster novae-angliae)* |
| | 150 | BITTER PANICGRASS *(Panicum amarum)* |
| | 40 | BLUE CARDINAL FLOWER *(Lobelia siphilitica)* |
| | 35 | BLUE FLAB *(Iris versicolor)* |
| | 75 | COMMON RUSH *(Juncus effusus)* |
| | 50 | NEW YORK IRONWEED *(Vernonia noveboracensis)* |
| | 15 | NEW YORK ASTER *(Aster novi-belgii)* |
| | 15 | SWITCHGRASS *(Panicum virqatum)* |
| | 20 | BLUE CARDINAL FLOWER *(Lobelia siphilitica)* |
| | 50 | TUSSOCK SEDGE *(Carex stricta)* |
| | 20 | BLUE CARDINAL FLOWER *(Lobelia siphilitica)* |



# The Site Today

# Add it to the toolbox!

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Inevitably we need to expand our toolbox

The more SCMs/Modifications /Innovations the better

There is not a lot of room for “turf” battles!

# Cart Before the Horse?

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**Are we focusing too much on modeling?**

**Are we focusing enough on implementation and adaptation?**

# Results

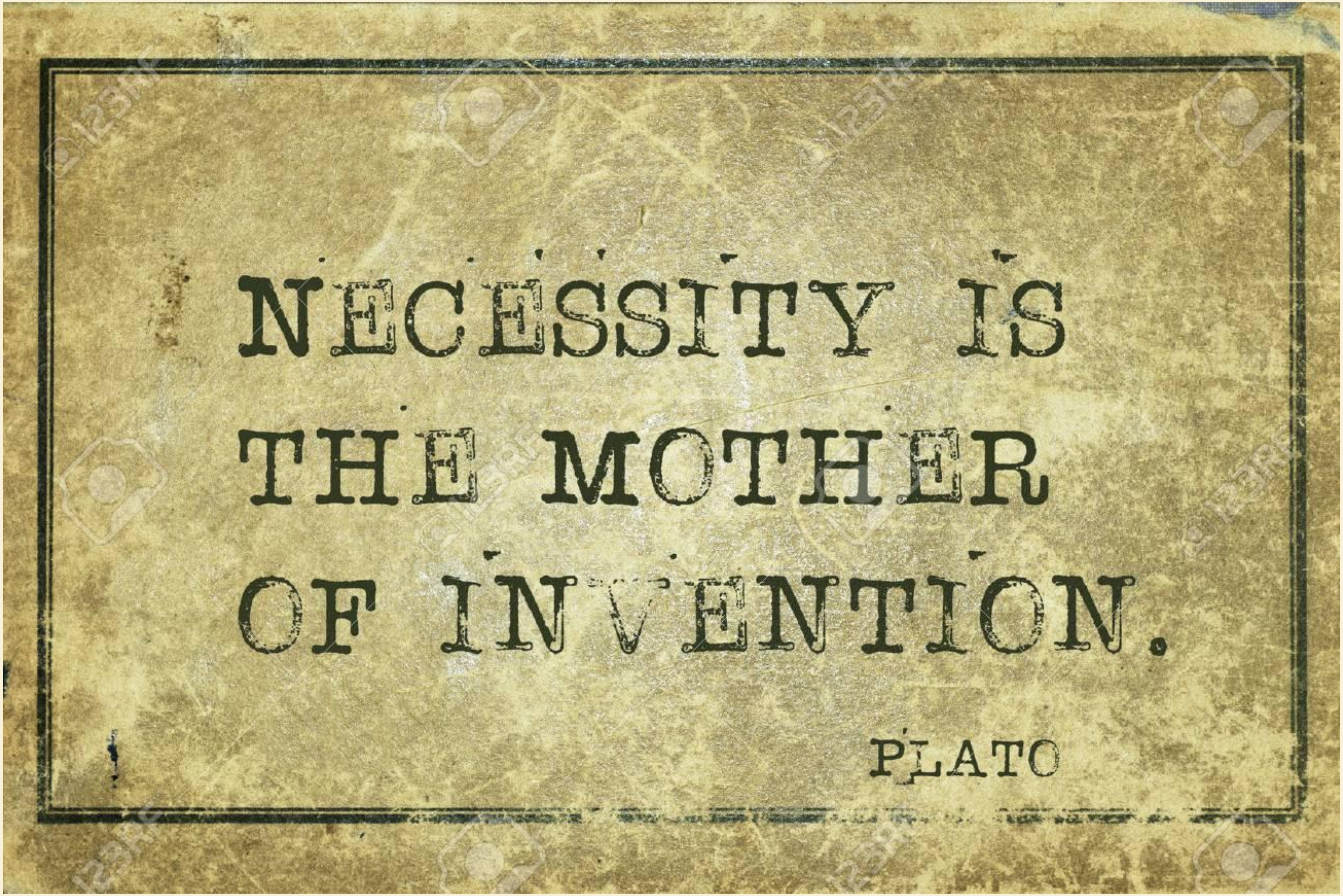
Not one single installation was installed as originally planned

The entire project required flexibility in relation to all BMPs installed

Overall goals of the project (disconnection of EIC) was considered paramount objective over actual implementation sites.

# Are we at the Finish Line or the Starting Line?

# If necessity is the mother of invention?...



# Need for Innovation

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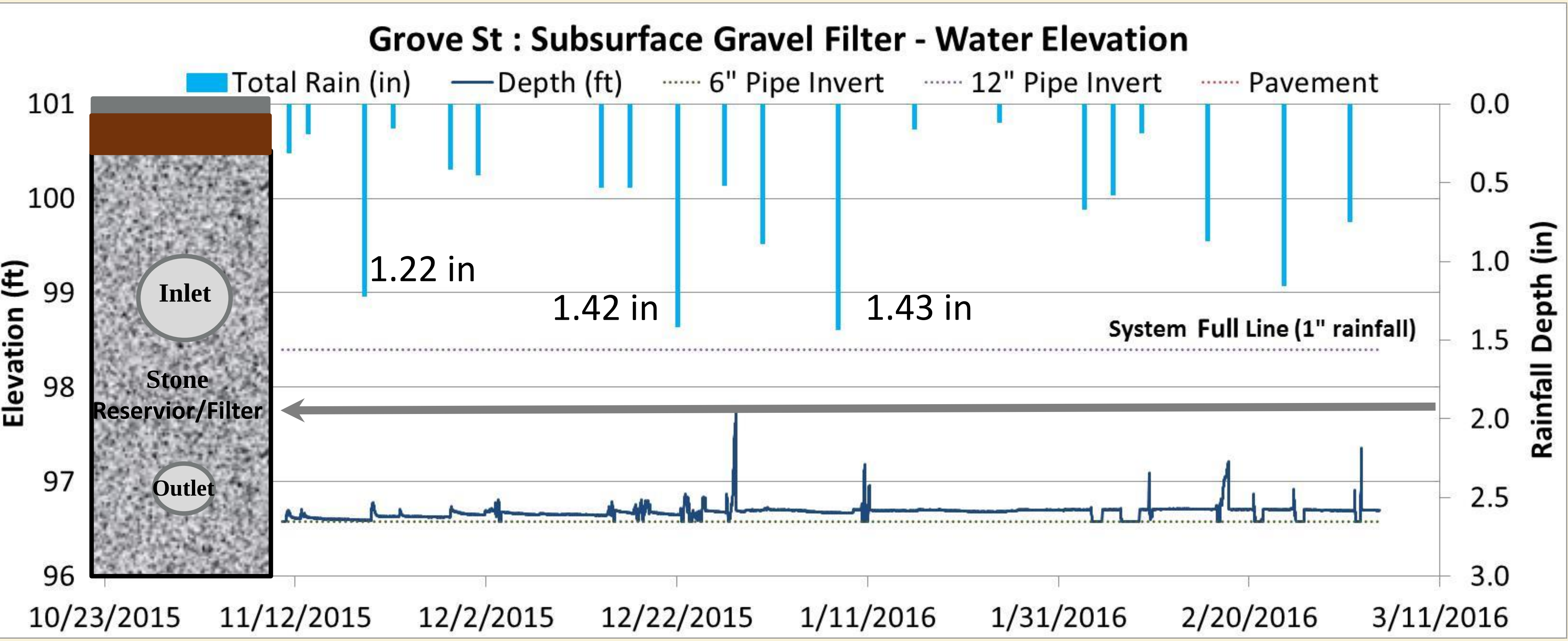
- “Boulanginator” (subsurface gravel filter) mimics performance of PA with regular pavement.
- The hydraulic inlet and outlets are controlled through perforated pipes and underdrains.
- treat runoff from 1.96 acres and 0.61 acres DCIA

# Boulangenator Performance



# Need for Innovation

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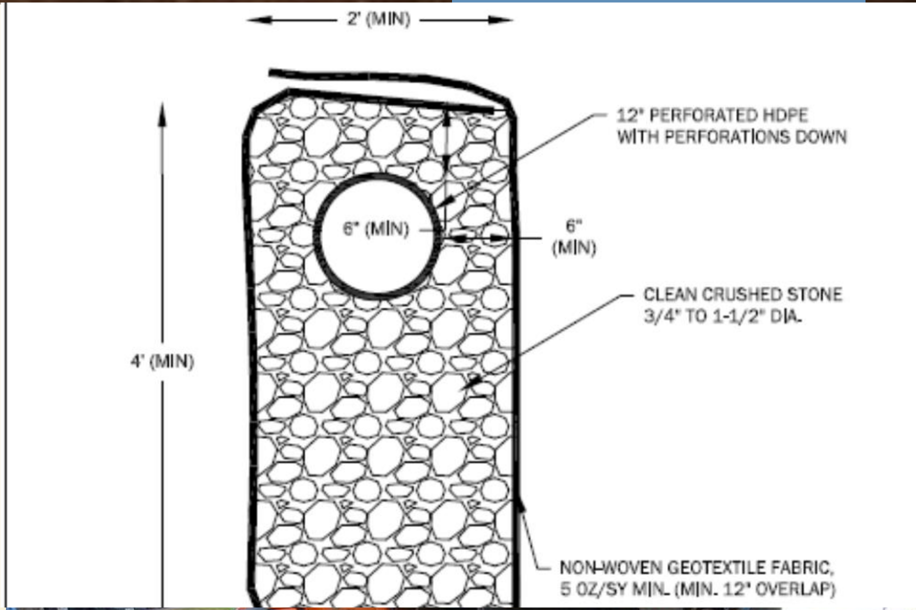
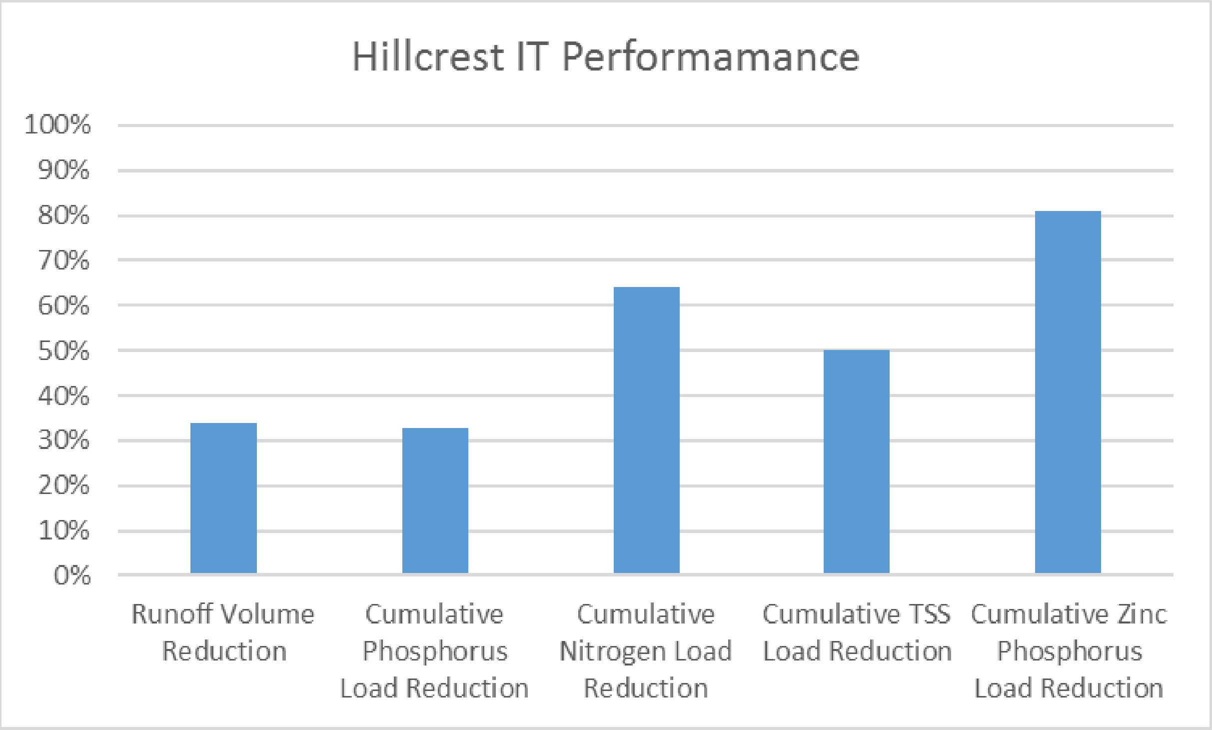
- In HSG A installed an infiltration trench between two conv CBs
- A simple but effective adaptation instead of solid pipe.
- Treats runoff from 3.36 acres and 1.04 acres DCIA




# Modeled Performance

| Infiltration Trench (2.41 in/hr) BMP Performance Table | |
|---|---|
| **BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)** | 0.1 |
| **Runoff Volume Reduction** | 34% |
| **Cumulative Phosphorus Load Reduction** | 33% |
| **Cumulative Nitrogen Load Reduction** | 64% |
| **Cumulative TSS Load Reduction** | 50% |
| **Cumulative Zinc Phosphorus Load Reduction** | 81% |



# SGWS Costs

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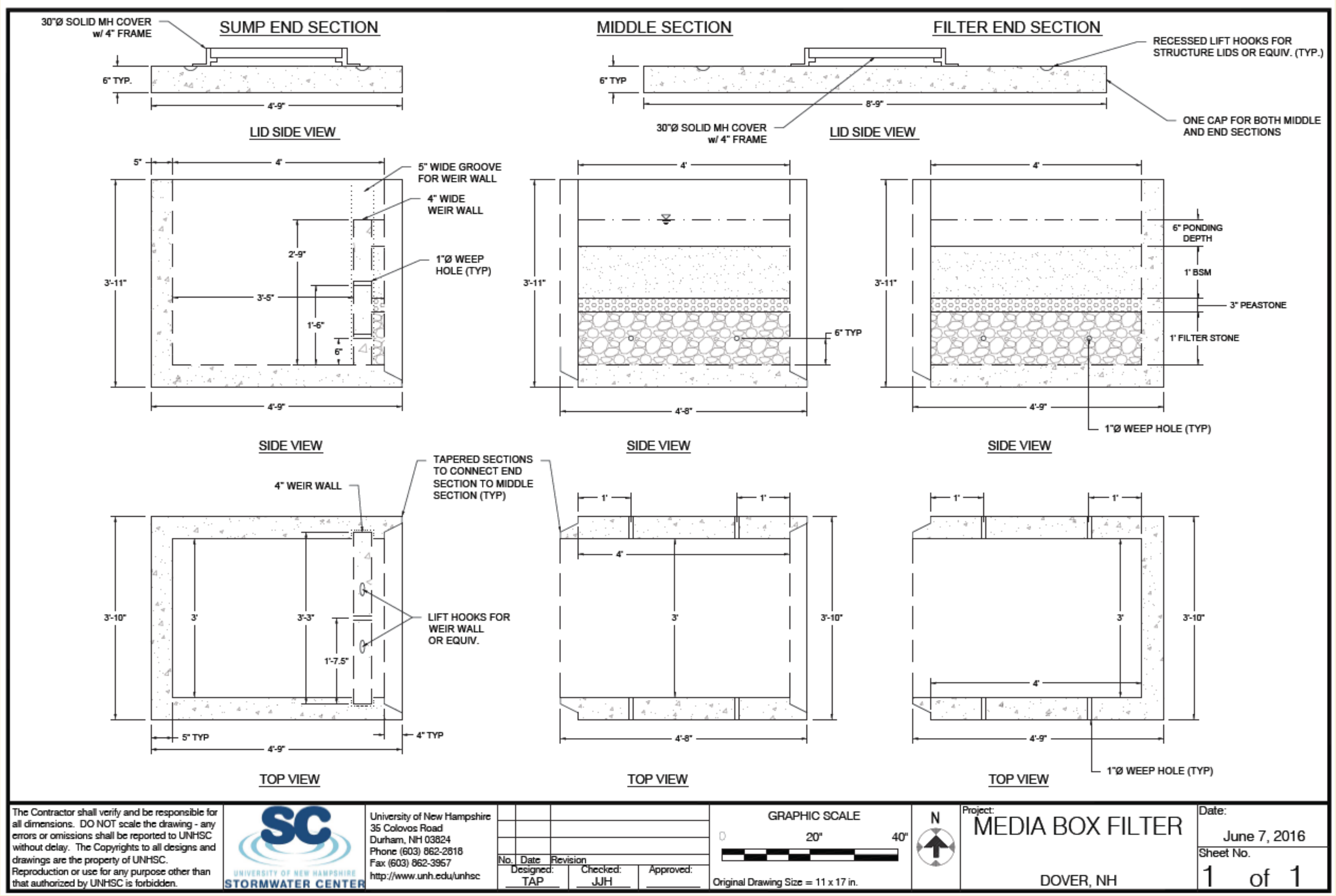
| Site Characteristics and System Treatment Capacity | | | | | | Annual Removals (lbs/yr) | | |
|---|---|---|---|---|---|---|---|---|
| **Project** | **Impervious Area (sf)** | **Impervious Area (acres)** | **Best Management Practice** | **Hydrologic Soil Group** | **Depth of Runoff Treated from Impervious Area (in)** | **Total Suspended Sediment** | **Total Phosphorus** | **Total Nitrogen** |
| Hillcrest IT | 39,640 | 0.91 | Infiltration Trench | B | 0.10 | 97 | 0.35 | 8.8 |

| <u>Water Quality Volume</u> | Hillcrest IT |
|---|---|
| Drainage Area ($ft^2$) | 39,640 |
| % Impervious Cover | 100% |
| Impervious Area ($ft^2$) | 39,640 |
| Conv WQV ($ft^3$) (@ P = 1.0in) | 3,303 |
| **System Treatment** | |
| System Area ($ft^2$) | 10 |
| Reservior Storage ($ft^3$) | 400 |
| System Storage ($ft^3$) | 320 |
| Rainfall Depth Treated (in) | 0.10 |

| Marginal Extra Materials | Marginal Cost Difference |
|---|---|
| 700 cf stone | $10,000 |

# Need for Innovation

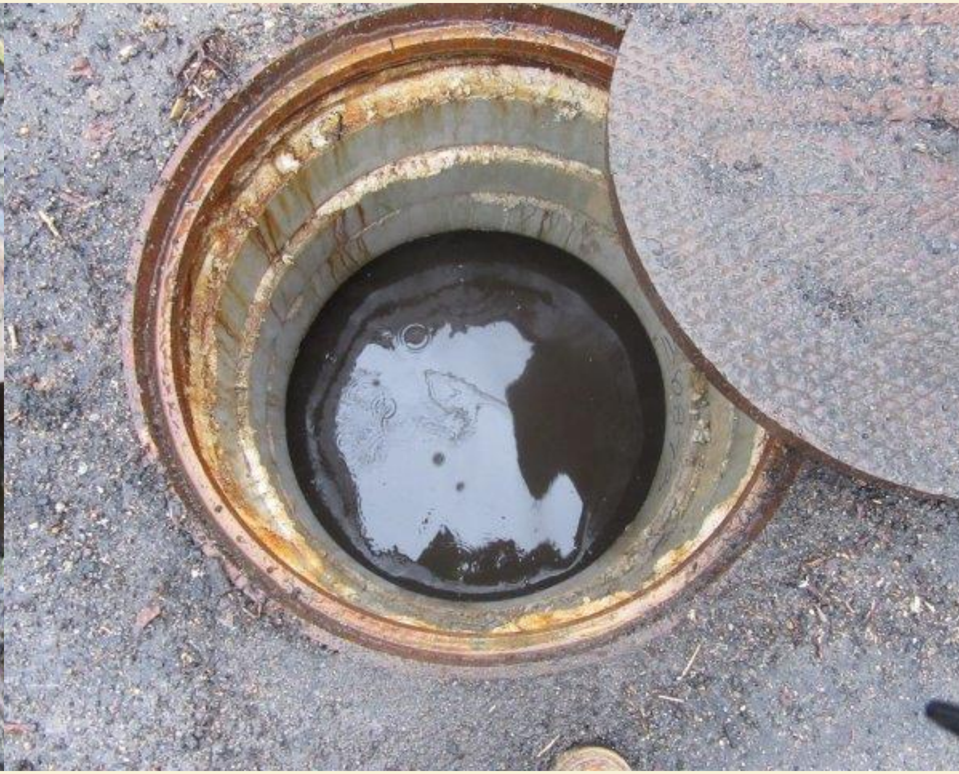
## Sectional Media Box Filter Design – version 3



# August 2017

- Filtering Catch Basin Designed to replace conv DSCB where applicable
- This system was the third iteration
- The City has purchased four additional filtering catch basins and will install them in other areas throughout the city.
- The system is designed to treat 0.5 acres (0.25 acres/section) of IC per section and costs 2,400 per

# In Operation



# Update May 2018

# Update May 2018

# Update May 2018

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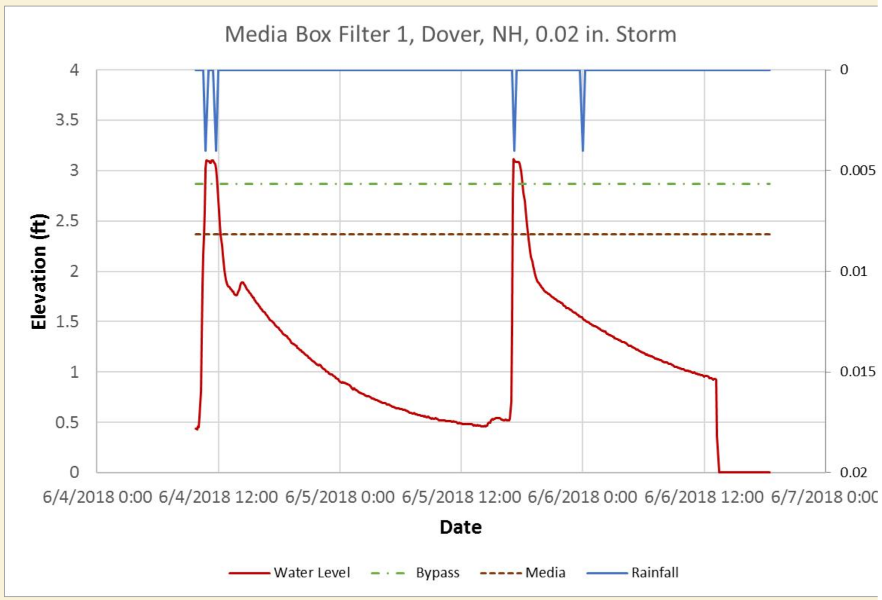
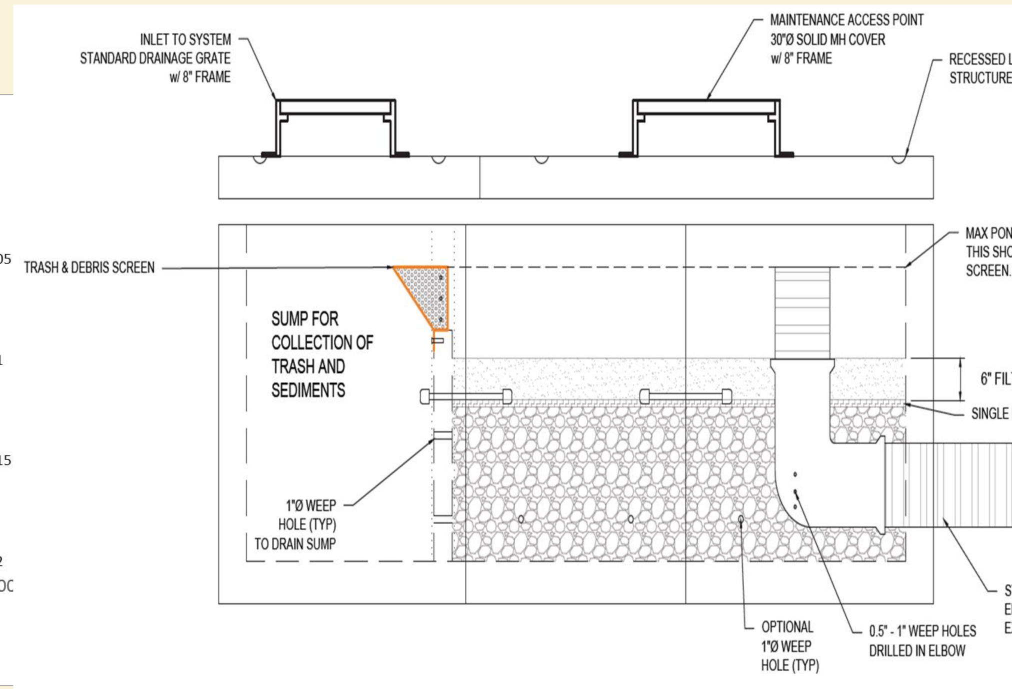


Media Box Filter 1, Dover, NH, 0.02 in. Storm
Elevation (ft)
Date
6/4/2018 0:00
6/4/2018 12:00
6/5/2018 0:00
6/5/2018 12:00
6/6/2018 0:00
6/6/2018 12:00
6/7/2018 0:00
Water Level
Bypass
Media
Rainfall

INLET TO SYSTEM
STANDARD DRAINAGE GRATE
w/ 8" FRAME
MAINTENANCE ACCESS POINT
30"Ø SOLID MH COVER
w/ 8" FRAME
TRASH & DEBRIS SCREEN
SUMP FOR COLLECTION OF TRASH AND SEDIMENTS
1"Ø WEEP HOLE (TYP) TO DRAIN SUMP
OPTIONAL 1"Ø WEEP HOLE (TYP)
0.5" - 1" WEEP HOLES DRILLED IN ELBOW

# New Project Approach

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Desktop designs invariably change when in-depth site specific investigations begin.

Better to quickly and coarsely develop a handful of candidate sites

Conduct inexpensive site queries of local areas of concern to further develop a practical  mitigation approach.

Implement where and however much feasible

municipal implementation efforts adapt or innovate “text book” research-based designs with what is practical for a public works department working in an urban setting leading to lower costs and more effective systems.

# New Project Approach

Large Project approach vs. every day counts approach

For the largest seacoast community there is:

- Over 2800 catch basins
- 65 linear miles of pipes
- 200 outfall locations

When all this infrastructure was originally designed the approach was very different.

Correction is not going to happen overnight!

# End?  More Cart Before the Horse?

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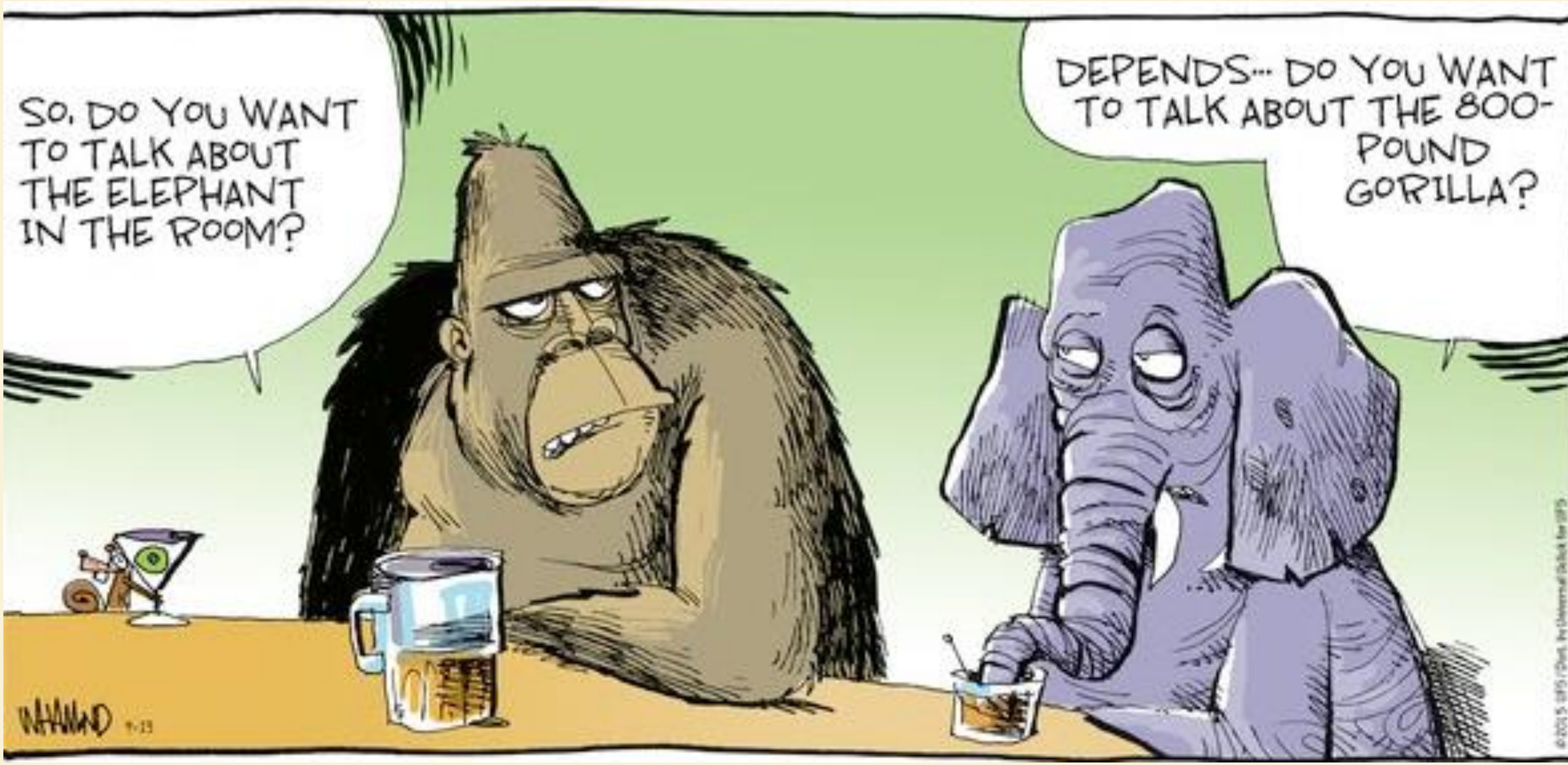
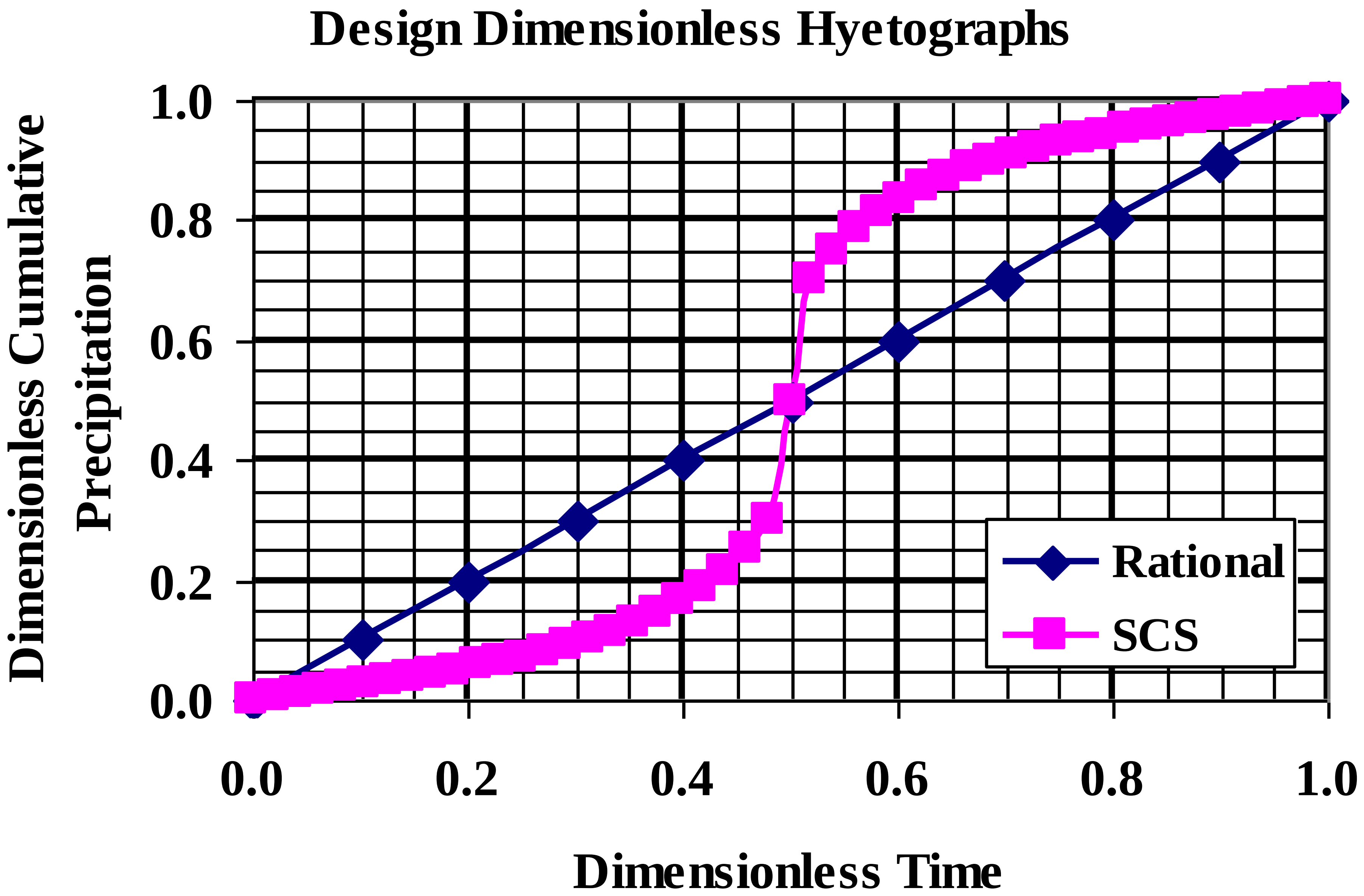
**Stormwater Modeling**

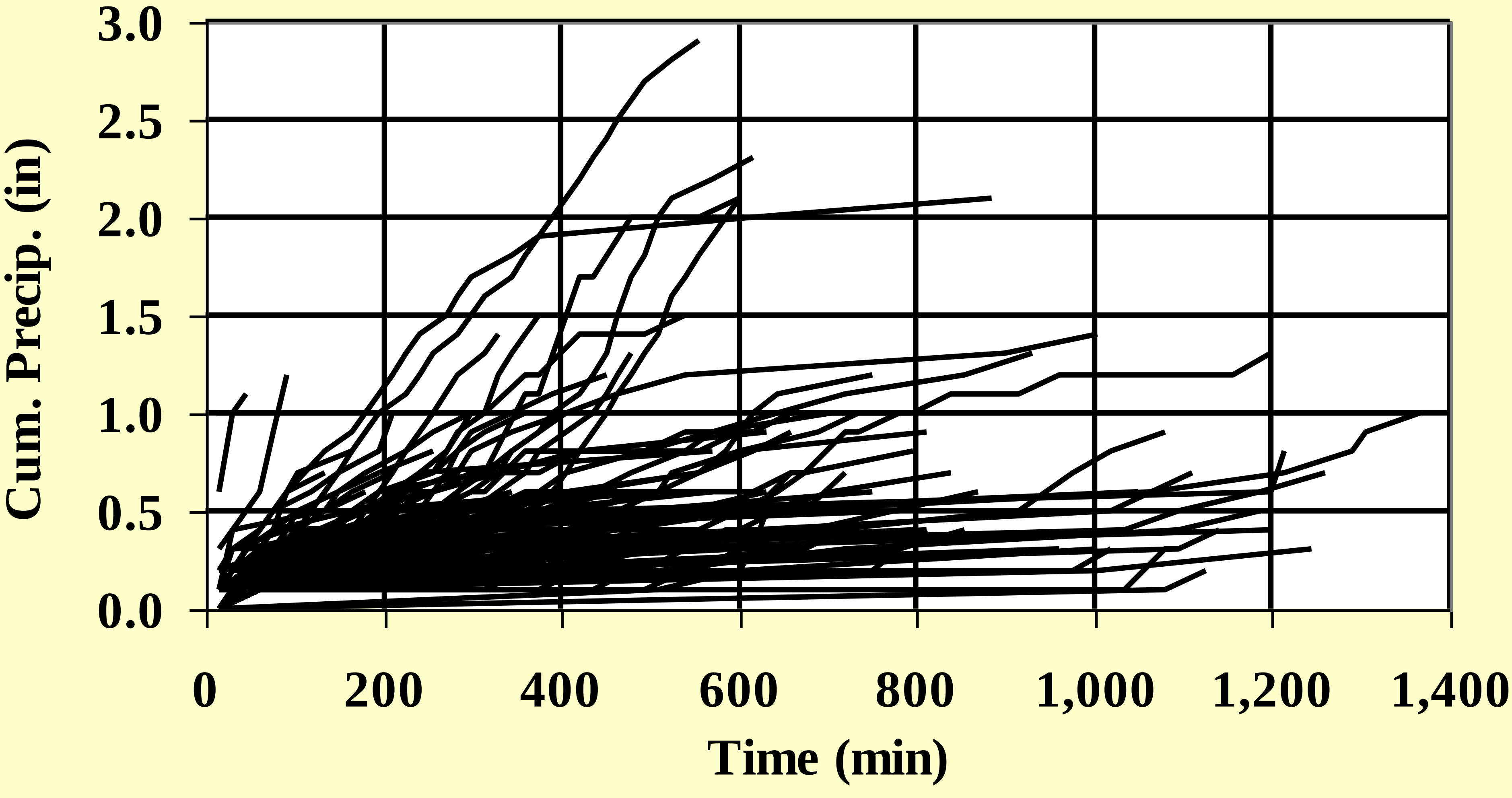
**Do we know what we are doing?**

# Yes, climate change gives us pause to think, but IC is the 800-pound gorilla




Design Dimensionless Hyetographs
Dimensionless Cumulative Precipitation
Dimensionless Time
1.0
0.8
0.6
0.4
0.2
0.0
0.0
0.2
0.4
0.6
0.8
1.0
Rational
SCS

# Sampling of Observed Hyetographs
## Durham, NH NOAA Gage



# Sizing for Performance

# Sizing Details

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| System | WQV $ft^3$ $(m^3)$ | Actual WQV $ft^3$ $(m^3)$ | % of normal design | Rain Event in (mm) | Sizing Method |
|---|---|---|---|---|---|
| SGWSC | 7,577 (214.6) | 720 (20.4) | 10% | 0.10 (2.5) | Static |
| IBSCS | 1,336 (37.8) | 310 (8.8) | 23% | 0. 23 (5.8) | Dynamic |

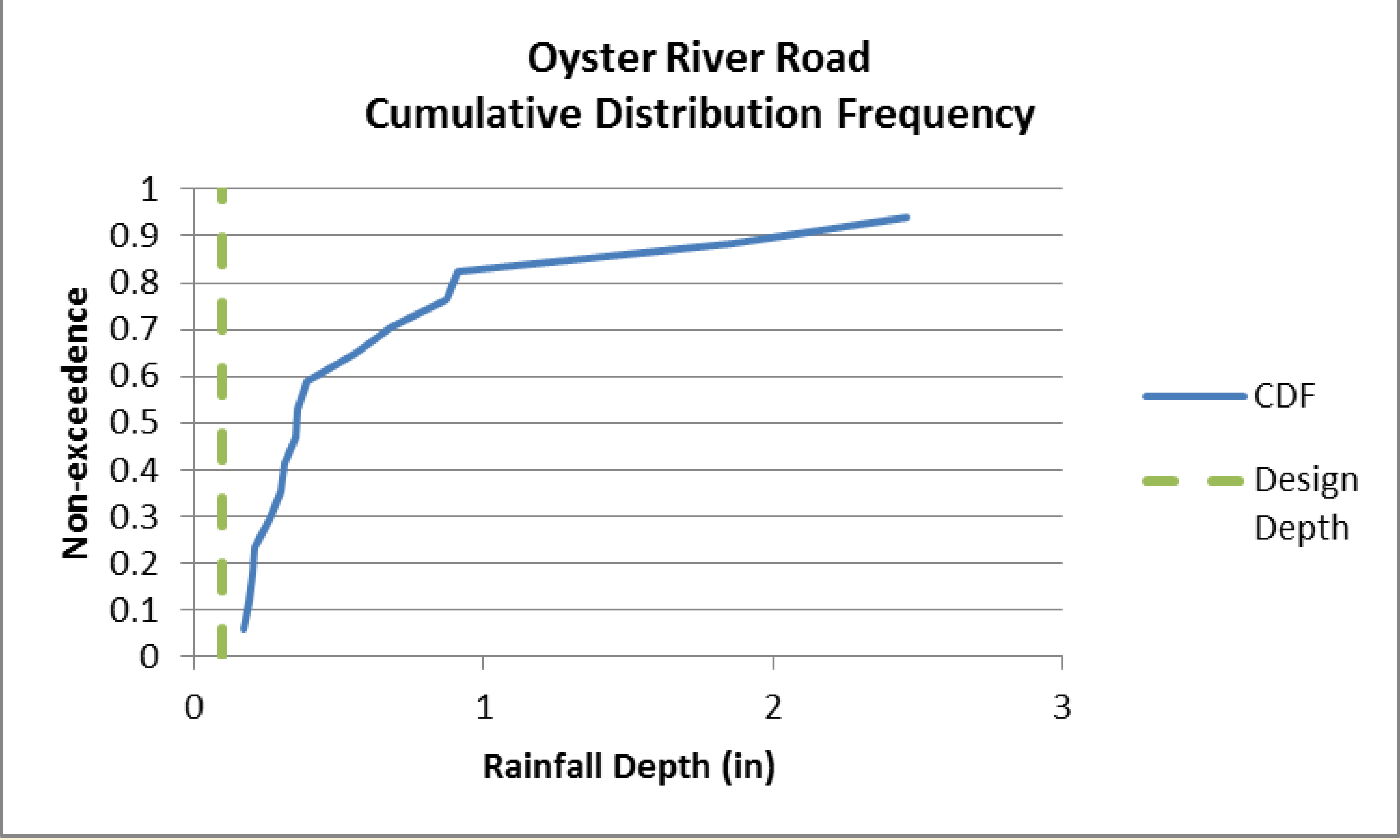
$$WQV = \left(\frac{P}{12}\right) x\ IA$$

Dynamic Bioretention Sizing

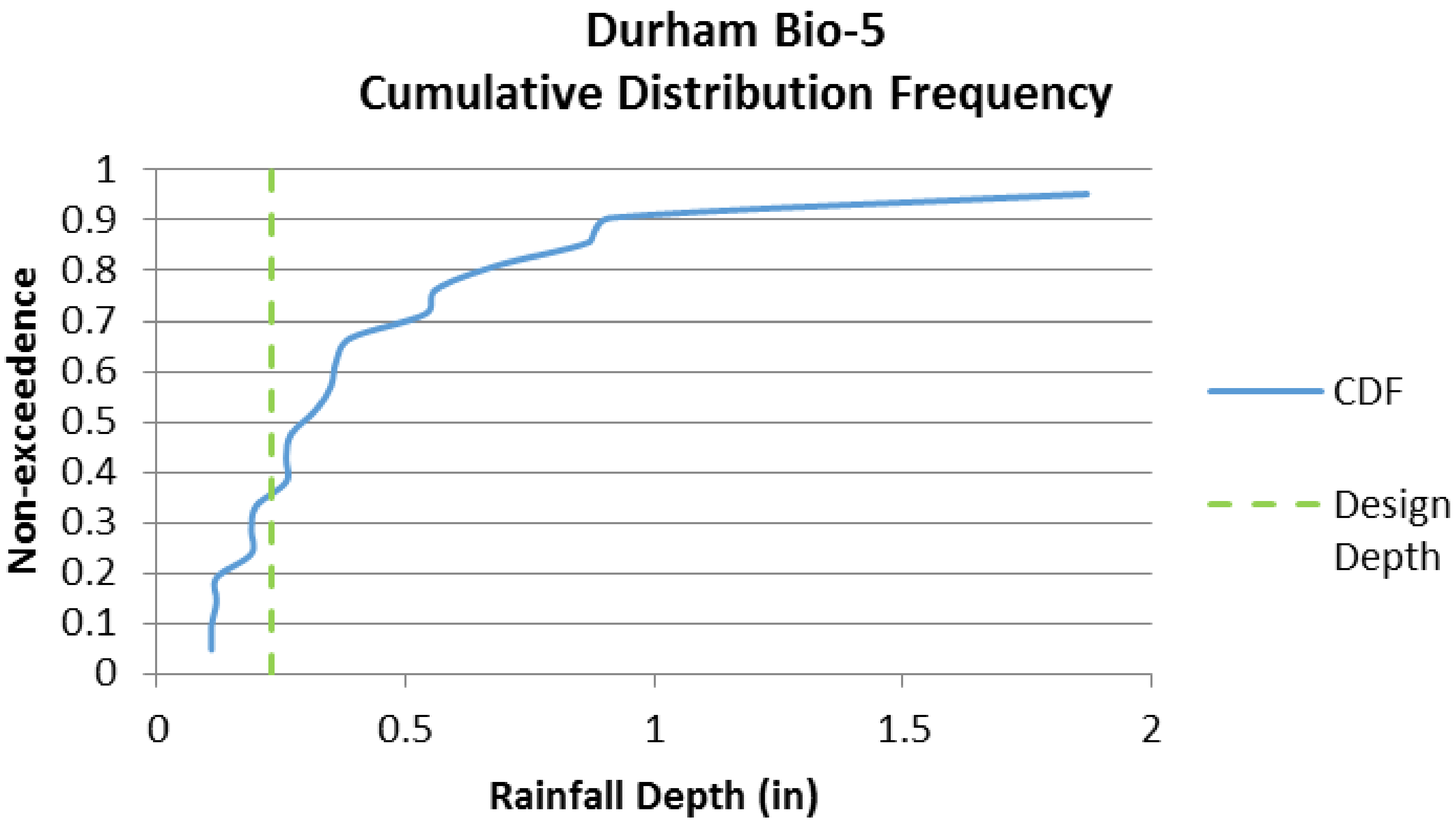
$$Af = Vwq * \frac{df}{(i(hf + df)tf)}$$

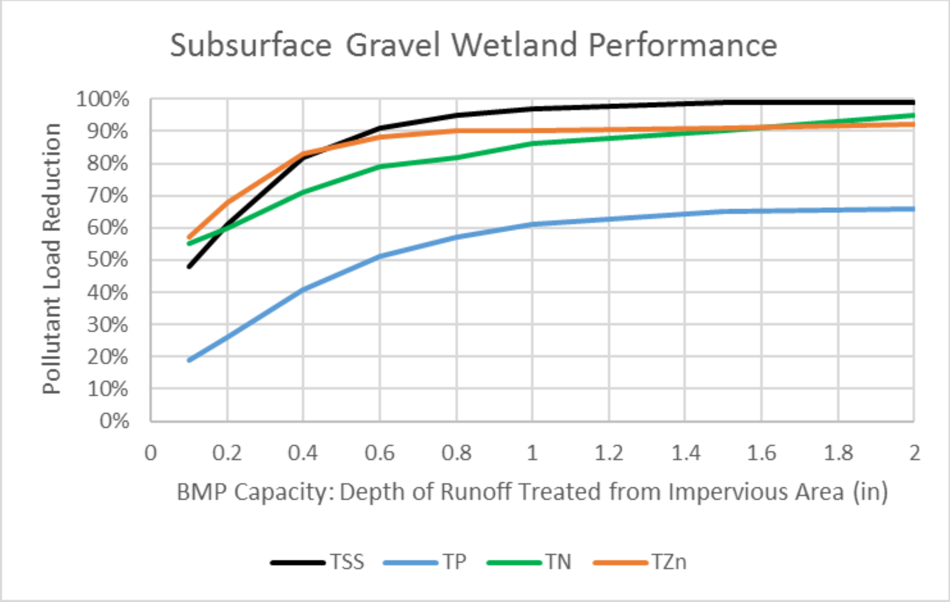
Static SGW System Sizing

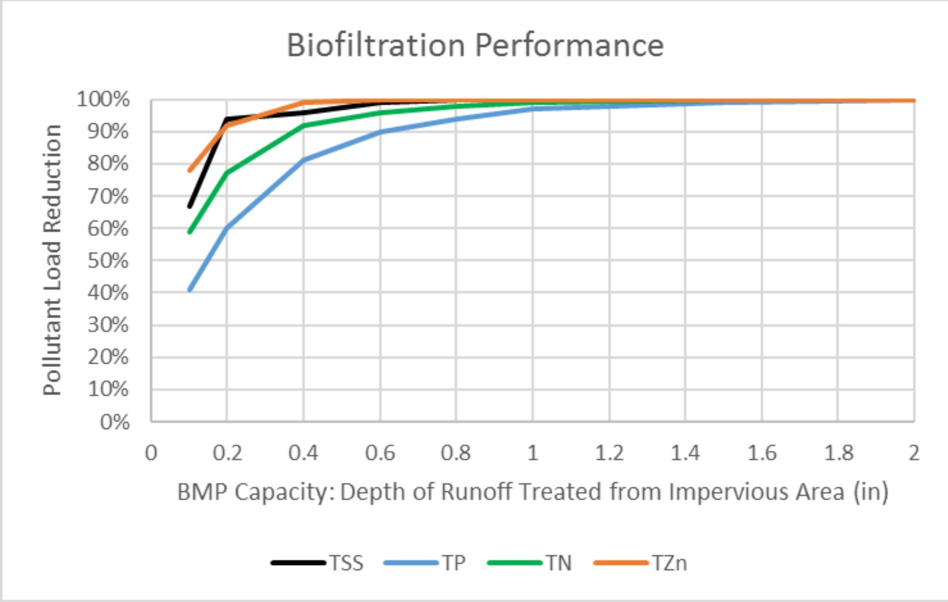
$$Q = CdA\sqrt{2gh}$$



Oyster River Road
Cumulative Distribution Frequency
Non-exceedence
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
1
2
3
Rainfall Depth (in)
CDF
Design Depth


Durham Bio-5
Cumulative Distribution Frequency
Non-exceedence
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
0
0.5
1
1.5
2
Rainfall Depth (in)
CDF
Design Depth




Design Storage Volume (DSV) - runoff depth from IA (in)

| Analyte | Depth txt | Modeled RE | Measured RE |
|---|---|---|---|
| TSS | 0.1 | 48 | 75 |
| TZn | 0.1 | 57 | 75 |
| TN | 0.1 | 55 | 23 |
| TP | 0.1 | 19 | 53 |

| Analyte | Depth txt | Modeled RE | Measured RE |
|---|---|---|---|
| TSS | 0.23 | 70 | 81 |
| TZn | 0.23 | 88 | 86 |
| TN | 0.23 | 60 | 27 |
| TP | 0.23 | 35 | 45 |

# Region 1 GI Cost Estimates

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| BMP (From Opti-Tool) | Cost ($/ft³) [1] | Cost ($/ft³) – 2016 dollars[6] |
|---|---|---|
| Bioretention (Includes rain garden) | 13.37 [2,4] | 15.46 |
| Dry Pond or detention basin | 5.88 [2,4] | 6.80 |
| Enhanced Bioretention (aka-Bio-filtration Practice) | 13.5 [2,3] | 15.61 |
| Infiltration Basin (or other Surface Infiltration Practice) | 5.4 [2,3] | 6.24 |
| Infiltration Trench | 10.8 [2,3] | 12.49 |
| Porous Pavement - Porous Asphalt Pavement | 4.60 [2,4] | 5.32 |
| Porous Pavement - Pervious Concrete | 15.63 [2,4] | 18.07 |
| Sand Filter | 15.51 [2,4] | 17.94 |
| Gravel Wetland System (aka-subsurface gravel wetland) | 7.59 [2,4] | 8.78 |
| Wet Pond or wet detention basin | 5.88 [2,4] | 6.80 |
| Subsurface Infiltration/Detention System (aka-Infiltration Chamber) | 54.54[5] | 67.85 |

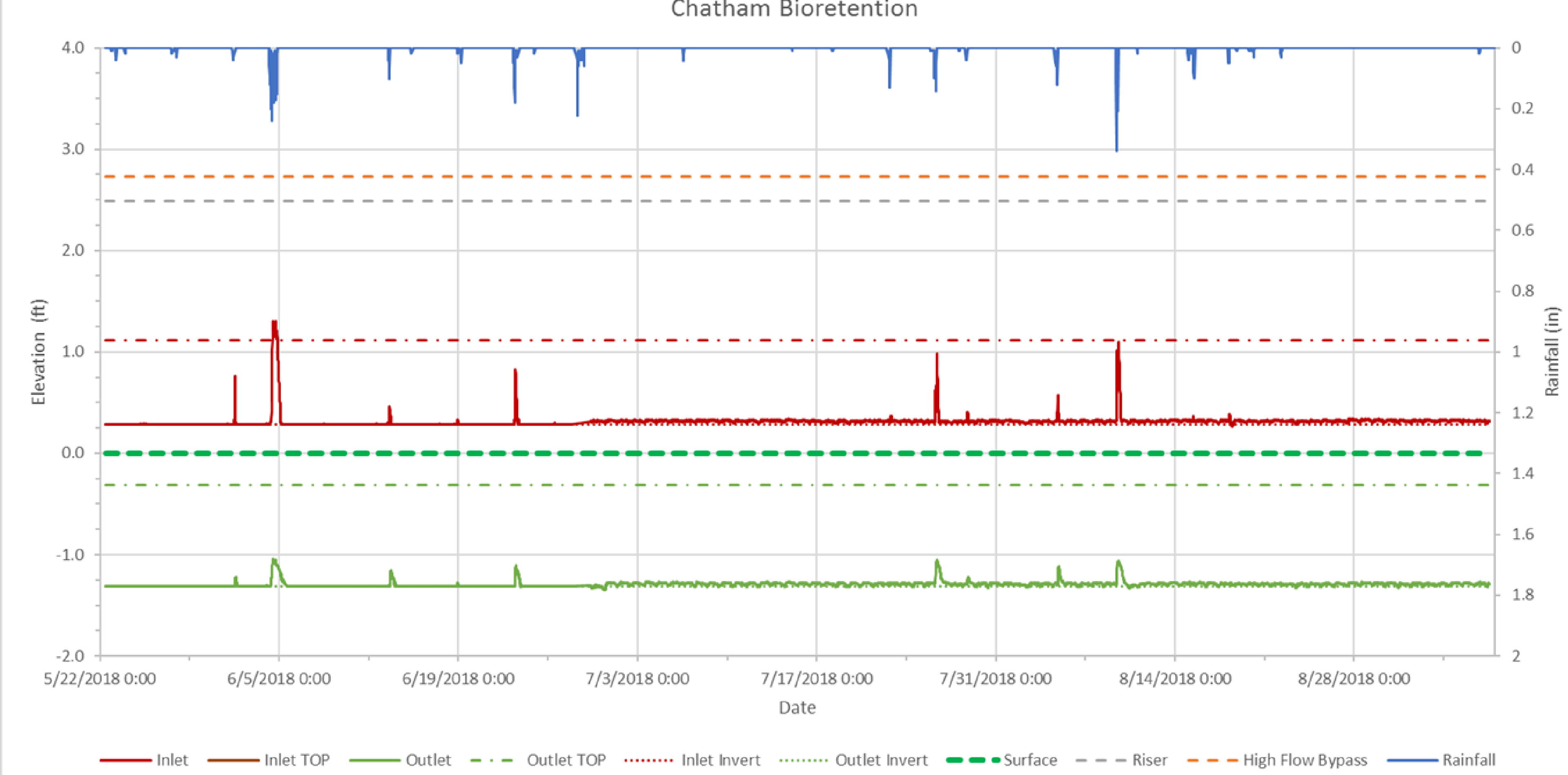
[1] **Footnote: Includes 35% add on for design engineering and contingencies**

https://www.unh.edu/unhsc/news/ms4-tools

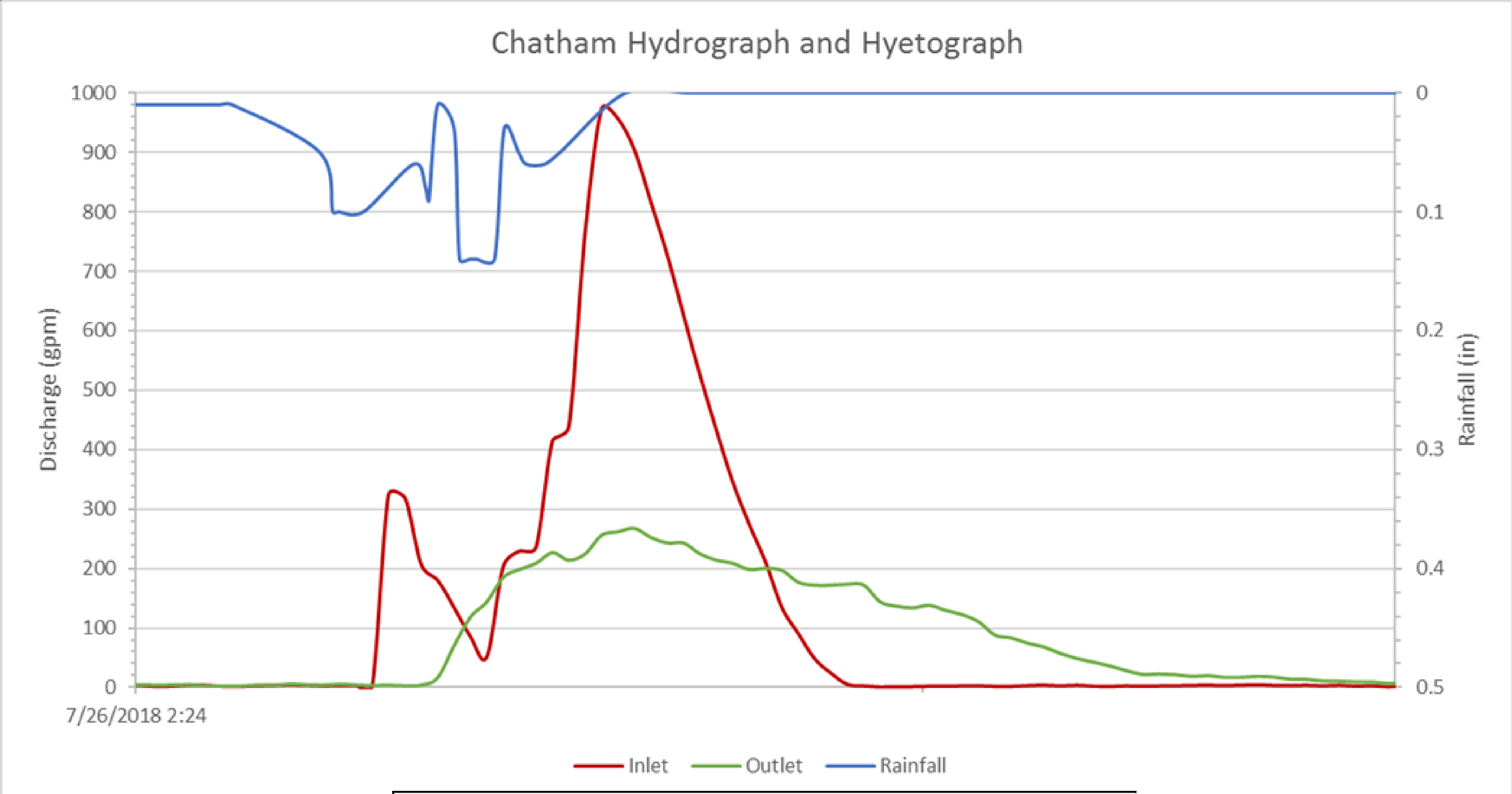
https://www3.epa.gov/region1/npdes/stormwater/ma/green-infrastructure-stormwater-bmp-cost-estimation.pdf

# GI Implementation Cost Comparisons

| Costs per disconnected acre of IC | | | |
|---|---|---|---|
| | PA | NY | NH |
| Actual | $250,000.00 | $320,000.00 | $30,000.00 |




| | DATE | Event Rainfall (in) | Antecedent (day) | Peak Flow Reduction | Volume Reduction |
|---|---|---|---|---|---|
| | 5/27/2018 | 0.15 | 3.6 | 88% | 94% |
| | 6/1/2018 | 0.27 | 4.3 | 95% | 59% |
| | 6/4/2018 | 4.94 | 2.7 | 72% | 28% |
| | 6/23/2018 | 0.92 | 4.1 | 76% | 48% |
| | 7/25/2018 | 1.50 | 3.1 | 73% | 34% |
| | 8/4/2018 | 0.97 | 6.8 | 42% | -31% |
| | 8/9/2018 | 2.46 | 4.5 | 76% | 62% |
| | | | | | |
| **Statistics:** | **min** | **0.15** | **2.67** | **0.42** | **-0.31** |
| | **med** | **0.97** | **4.13** | **0.76** | **0.48** |
| | **mean** | **1.60** | **4.18** | **0.74** | **0.42** |
| | [illegible] | [illegible] | [illegible] | [illegible] | [illegible] |




| Gravel Wetland BMP Performance Table | | | | |
|---|---|---|---|---|
| **BMP Capacity: Depth of Runoff Treated from Impervious Area (inches)** | 0.1 | 0.2 | 0.3 | 0.4 |
| **Cumulative Phosphorus Load Reduction** | 19% | 26% | 34% | 41% |
| **Cumulative Nitrogen Load Reduction** | 55% | 60% | 66% | 71% |
| **Cumulative TSS Phosphorus Load Reduction** | 48% | 61% | 72% | 82% |
| **Cumulative Zinc Phosphorus Load Reduction** | 57% | 68% | 76% | 83% |

# Questions???