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

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

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

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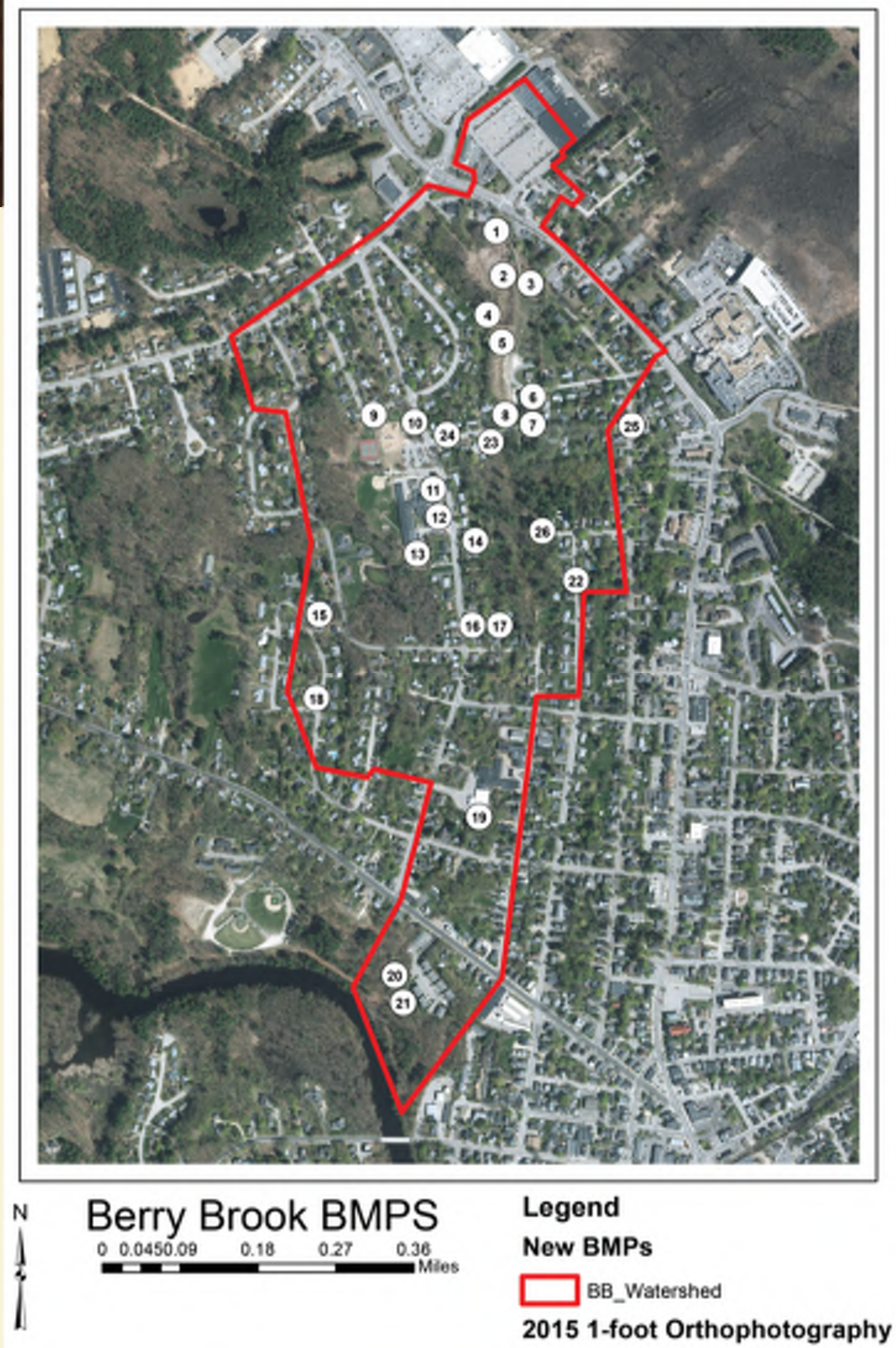


BMPs

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

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

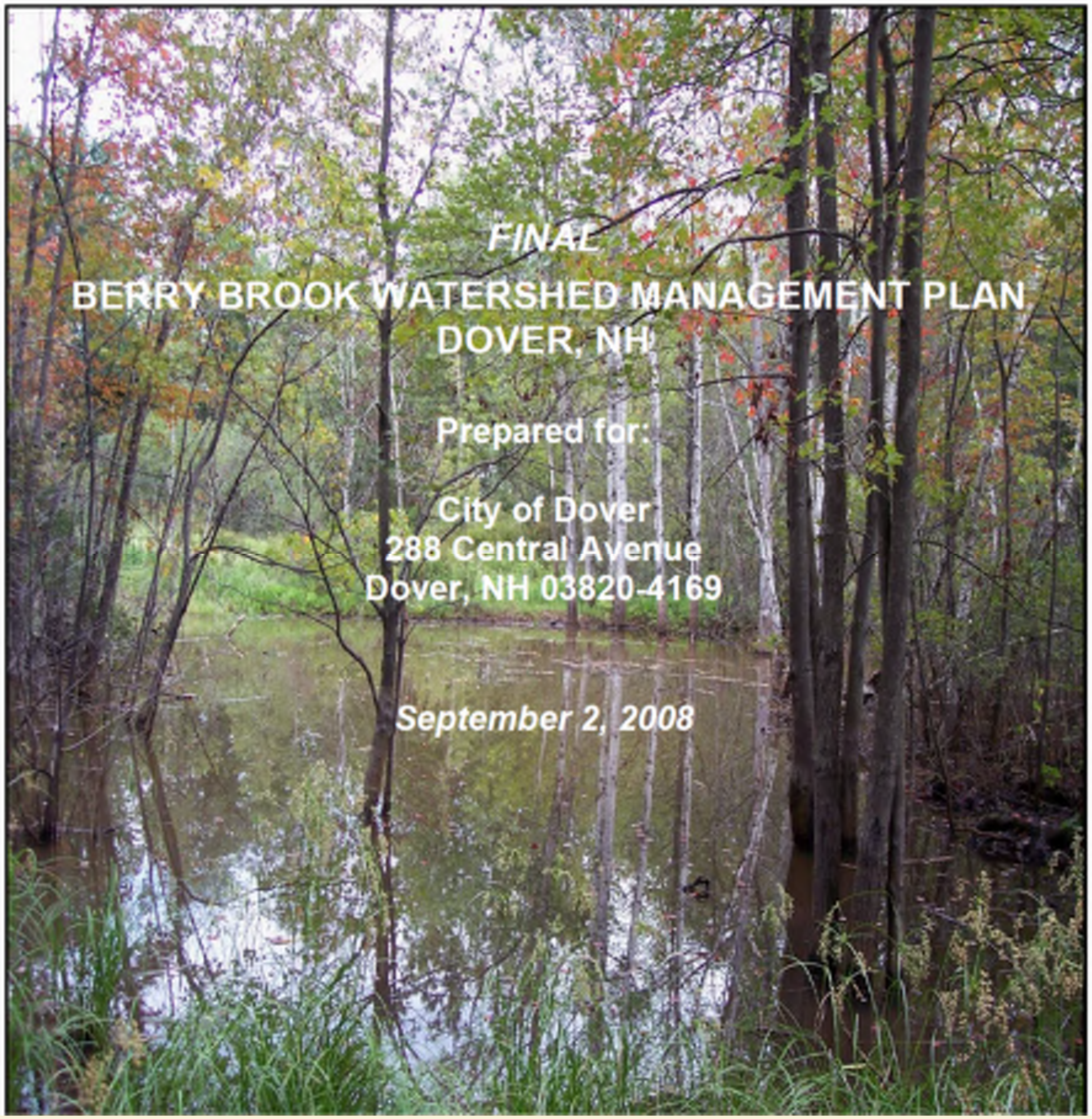
Implement

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

National Historic Preservation Act Section 106 Compliance for the Regulatory Program

Reality

Redesign

Reconfigure

… and optimize

Again…

And more implementation…

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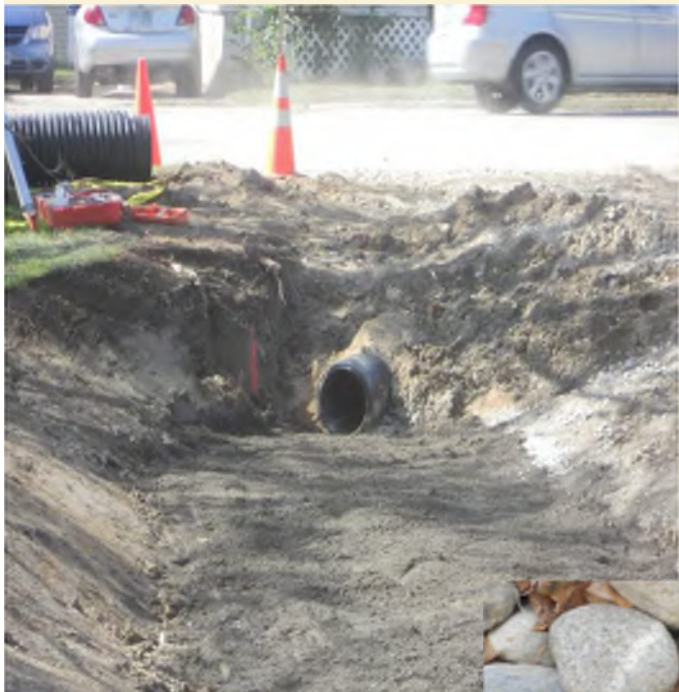
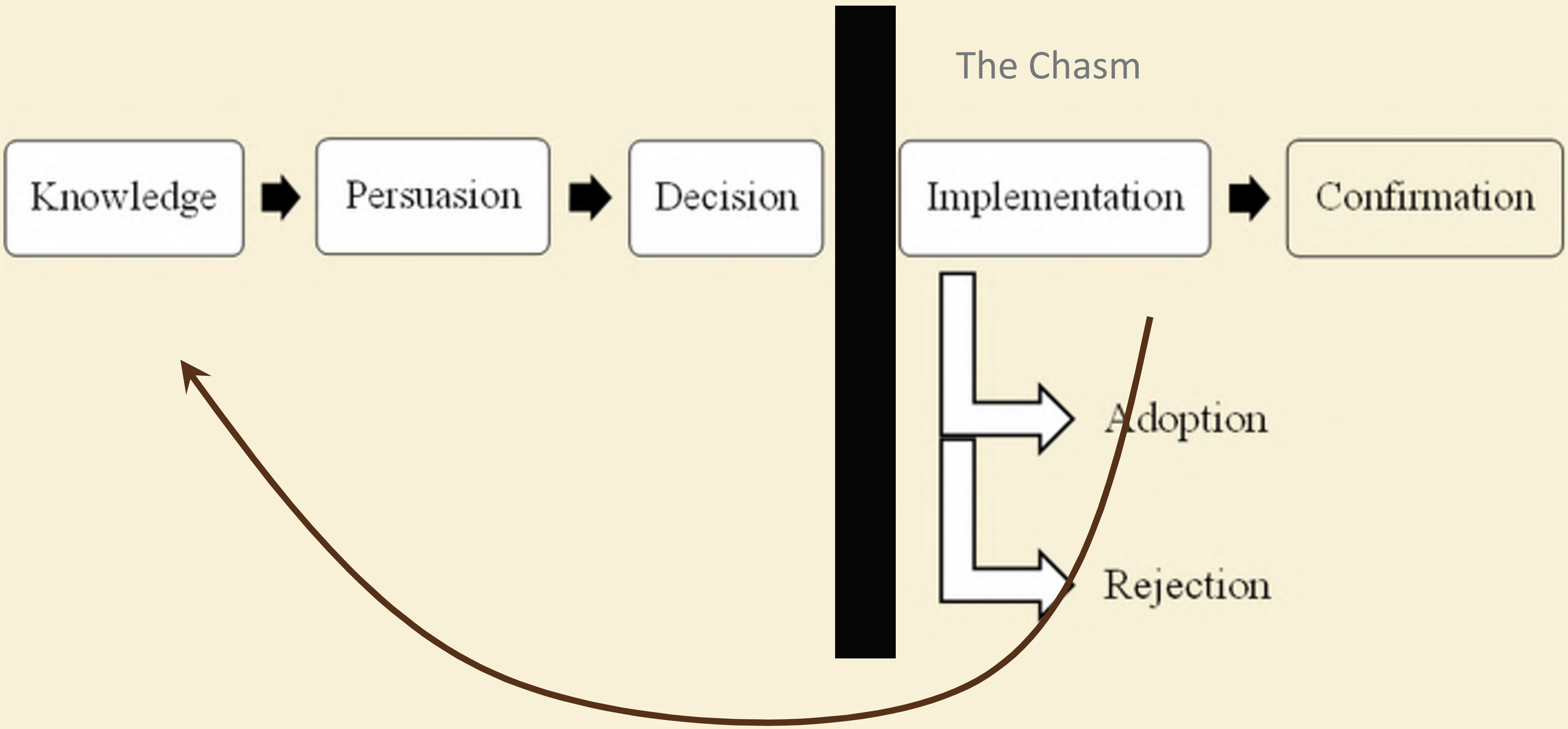


Innovation Decision Process



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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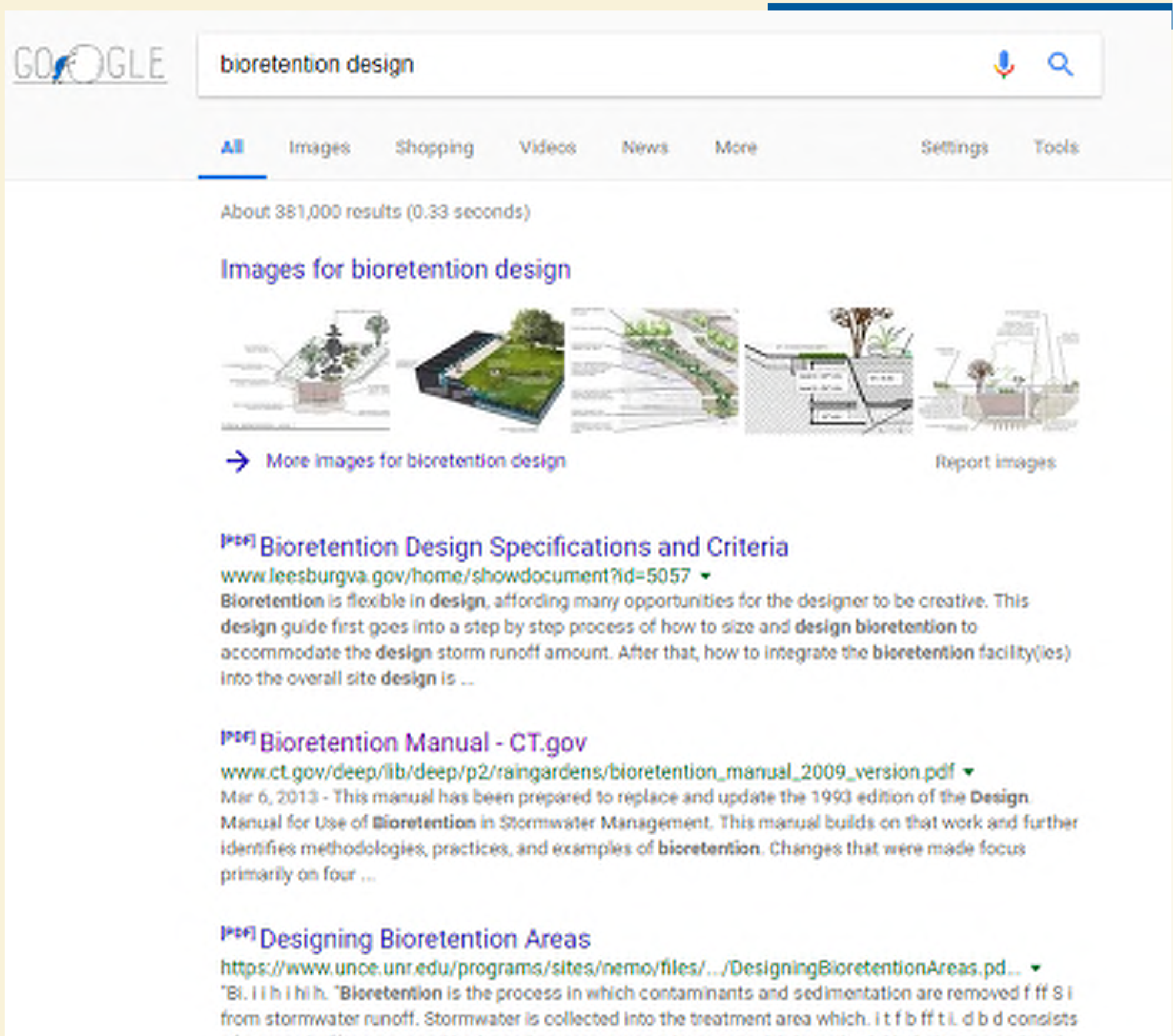
381,000 results!



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

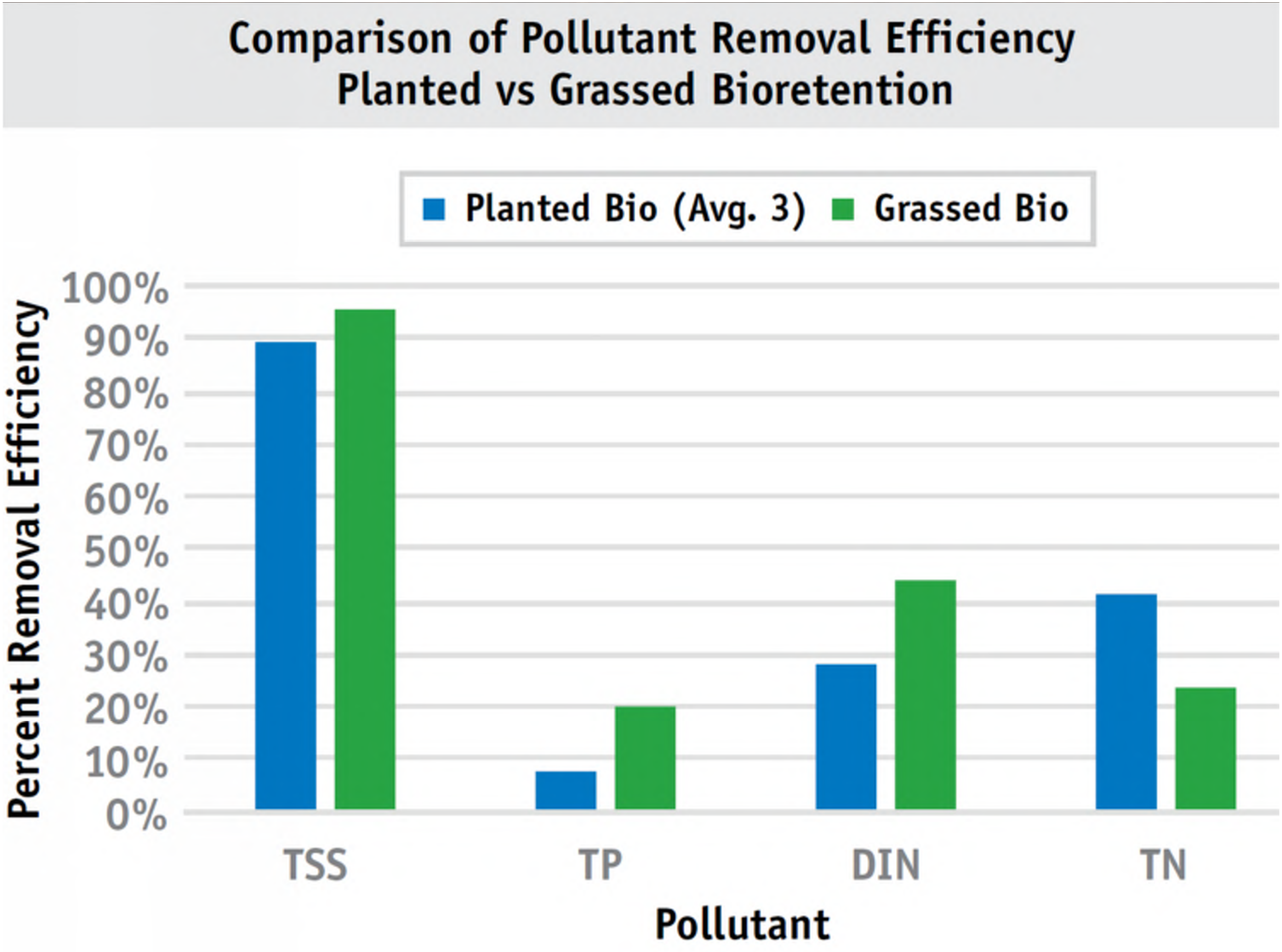
www.ct.gov/deep/lib/deep/p2/raingardens/bioretention_manual_2009_version.pdf

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


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

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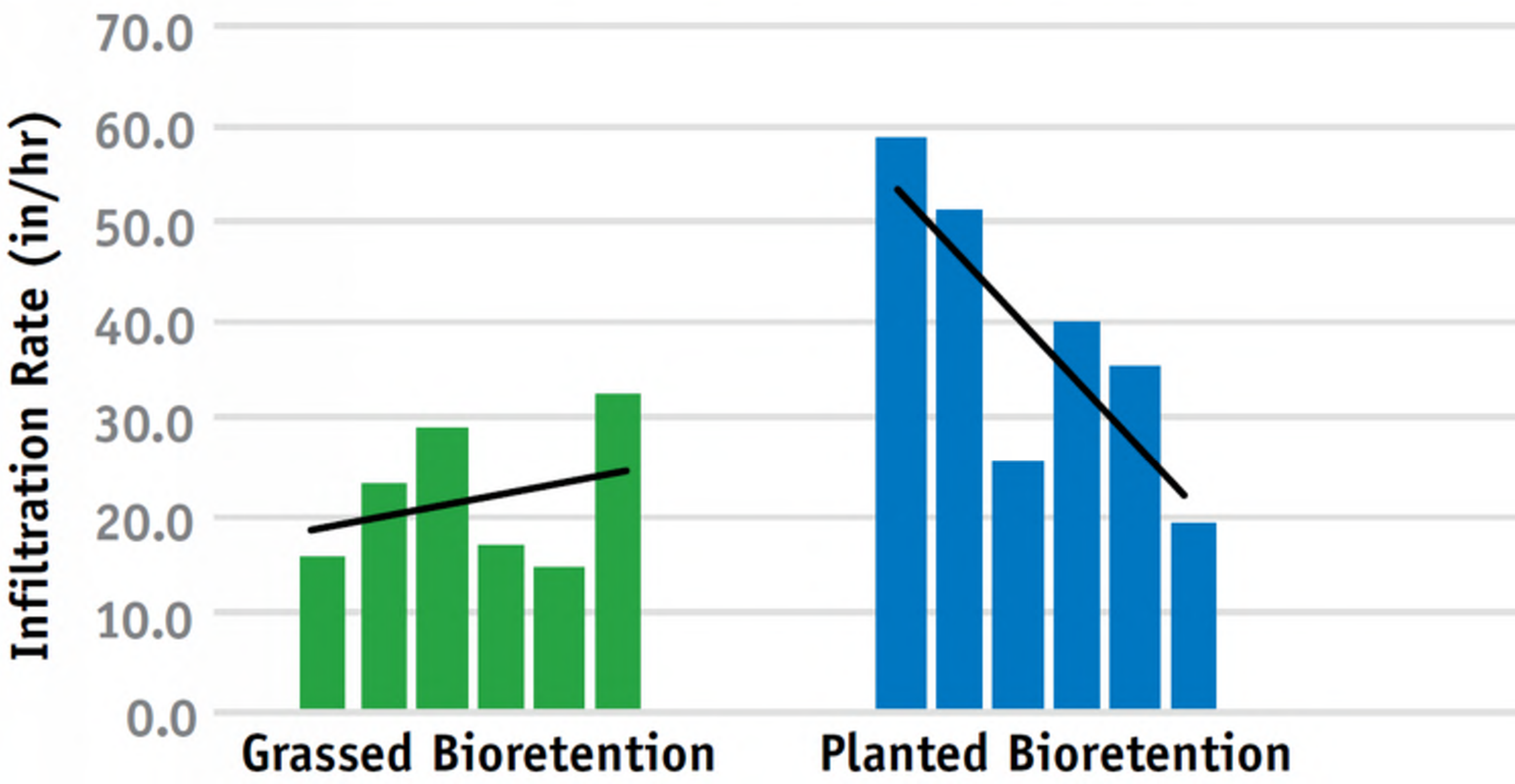
Average Infiltration Rates of a Planted (blue) versus Grassed (green) Bioretention Systems Over Time



Traditional Approach

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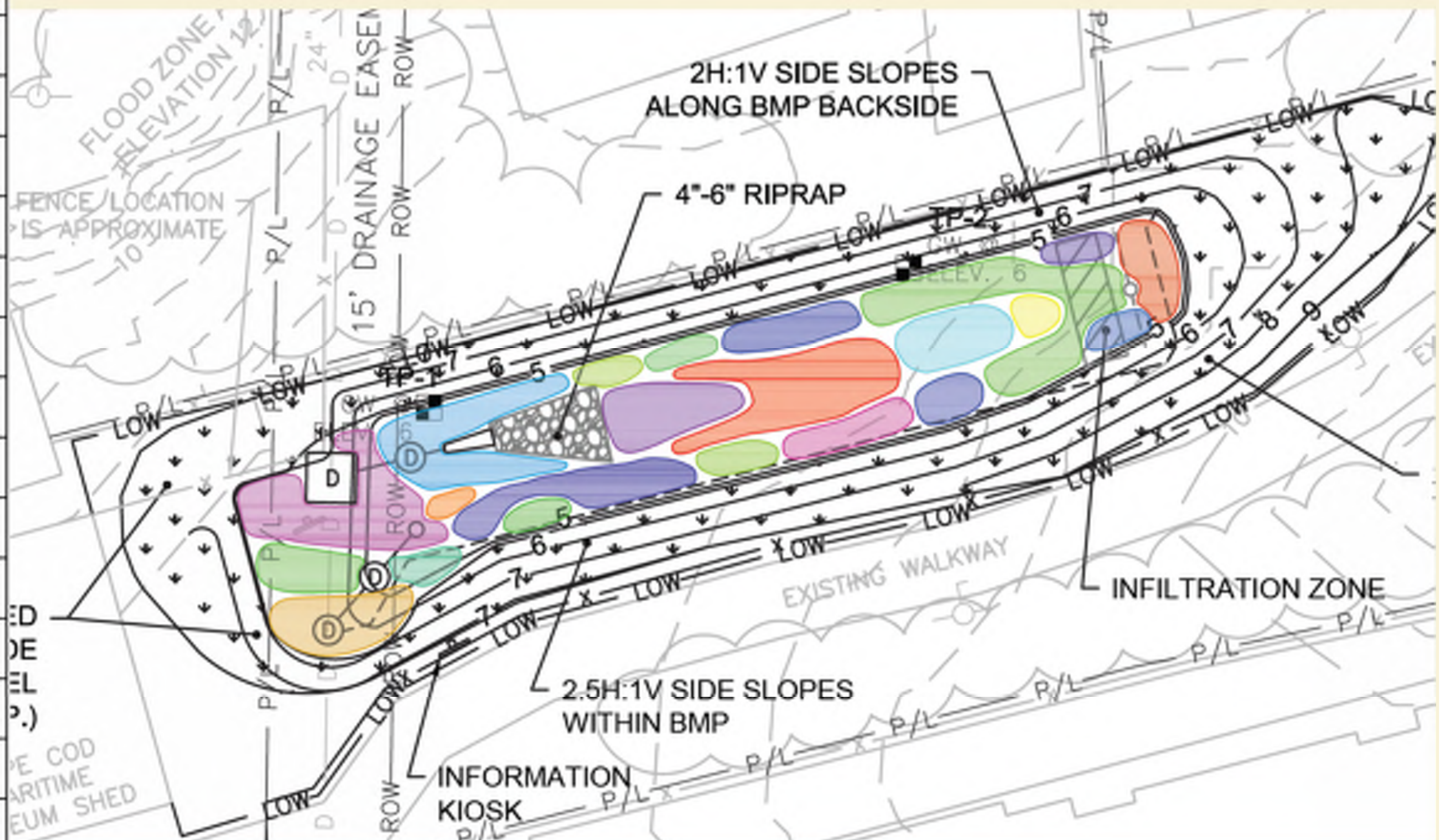
KEY	QUANTITY	NAME
	50	TUSSOCK SEDGE *(Carex stricta)*
	75	COMMON RUSH *(Juncus effusus)*
	350	SWITCHGRASS *(Panicum virgatum)*
	15	BLUE FLAB *(Iris versicolor)*
	50	JOE PYE WEED *(Eupatorium maculatum)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	100	FOX SEDGE *(Carex Vulpinoidea)*
	15	NEW YORK 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 virgatum)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*
	50	TUSSOCK SEDGE *(Carex stricta)*
	20	BLUE CARDINAL FLOWER *(Lobelia siphilitica)*



The Site Today

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Add it to the toolbox!

- 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?

Redesign

Reconfigure

… and optimize Again…

2013 Watershed Assistance Grants
PROPOSAL FORM

New Hampshire Department of Environmental Services
Celebrating 25 Years 1987 2012

SUBMISSION DEADLINE
4:00pm
November 21, 2012

1. PROJECT TITLE

Getting to 10%: Watershed Restoration through Low Impact Development Retrofits in an Urban Environment

Berry Brook/Cocheco River Watershed Management Plan Implementation Phase III.

2. PROJECT LOCATION

A. Town(s): **Dover, NH**
Does project involve other states? **Yes** ☐ **No** ☒

B. What water body does it affect? **Berry Brook/Cocheco River/Great Bay**
12-digit hydrologic unit code (HUC): 010600030608

C. Attach a project location map showing the watershed and relevant project site locations (required).

HUC look-up:
http://www2.des.nh.gov/SWQA/ or contact your DES project leader for assistance.

3. GRANT CATEGORY

Please check applicable water quality category:

a. **High Quality Waters** ☐

b. **Impaired Waters** ☒

Please list the designated uses that are impaired and the specific causes of impairments as identified on the *2010 305(b)/ 303(d) Surface Water Quality Assessment*. If the waterbody is not listed as impaired in the 2010 Surface Water Quality Assessment, then describe and attach documentation of the impairment.

2010 Surface Water Quality Assessment:
http://des.nh.gov/organization/divisions/water/wmb/swqa/2010/index.htm

Primary Contact Recreation (as a result of high bacteria concentrations) and for Aquatic Life Use due to an NHDES assessment of benthic macroinvertebrate monitoring.

Results

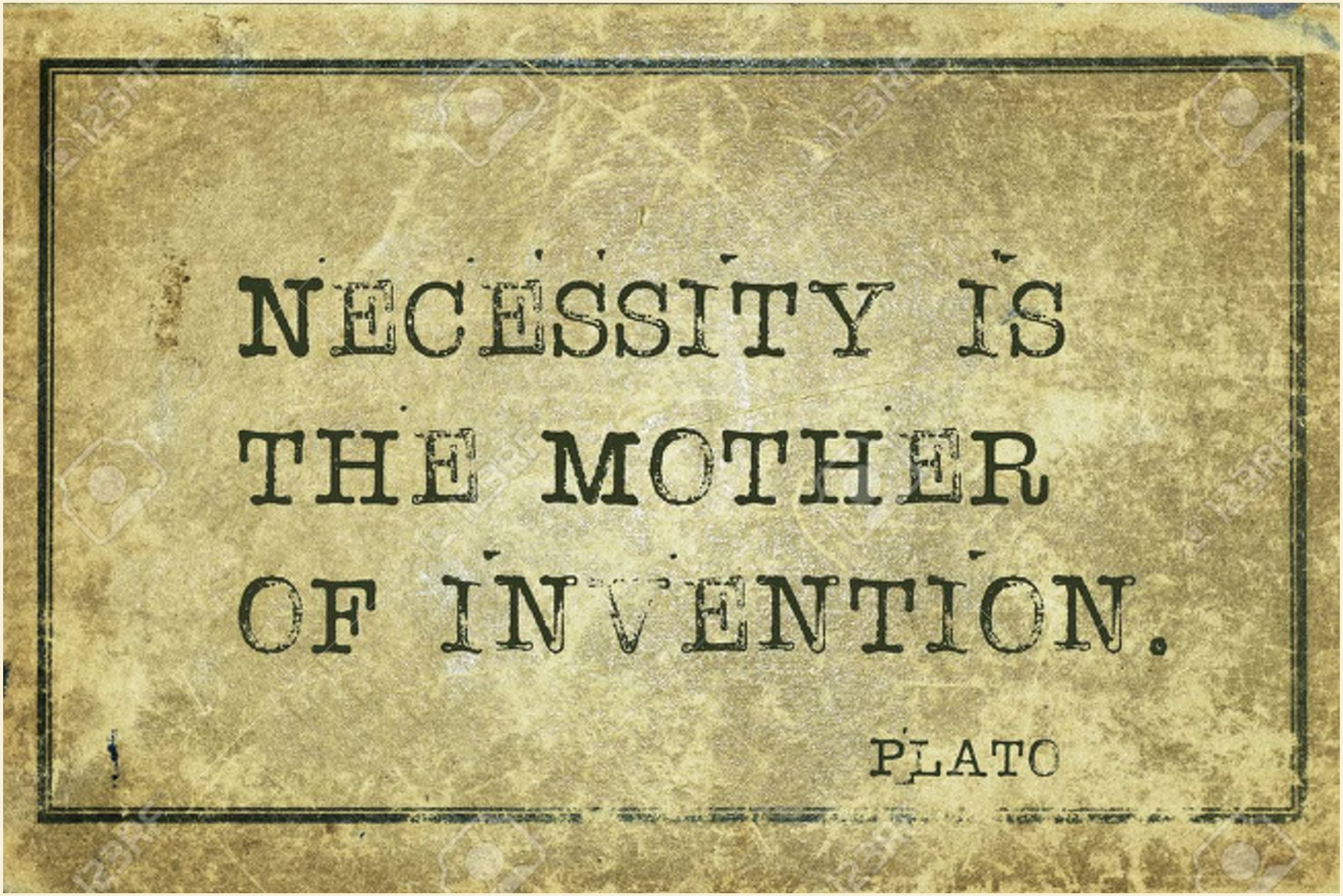
Not one single installation was installed as originally planned

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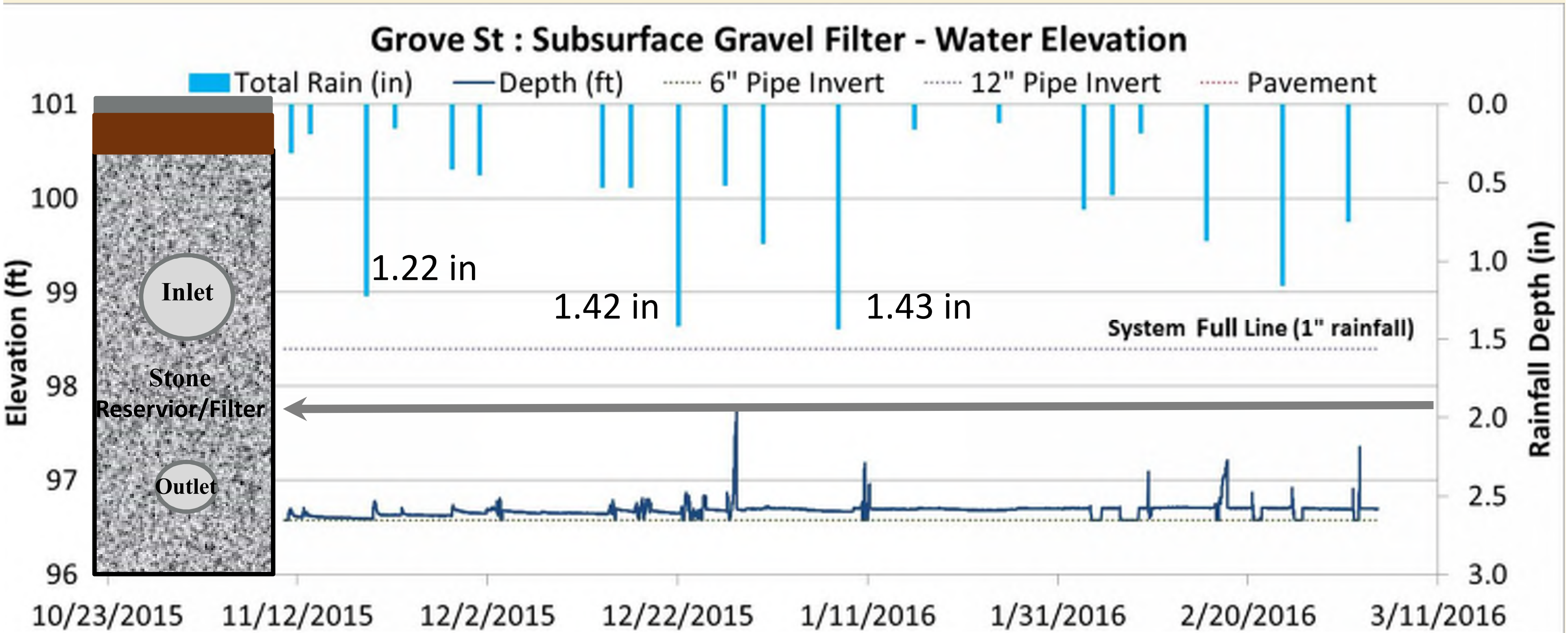
- "Boulanginator" (subsurface gravel filter) mimics performance of PA with regular pavement.
- The hydraulic inlet and outlets are controlled through perforated pipes and underdrains.
- treat runoff from 1.96 acres and 0.61 acres DCIA

Boulangenator Performance



Need for Innovation

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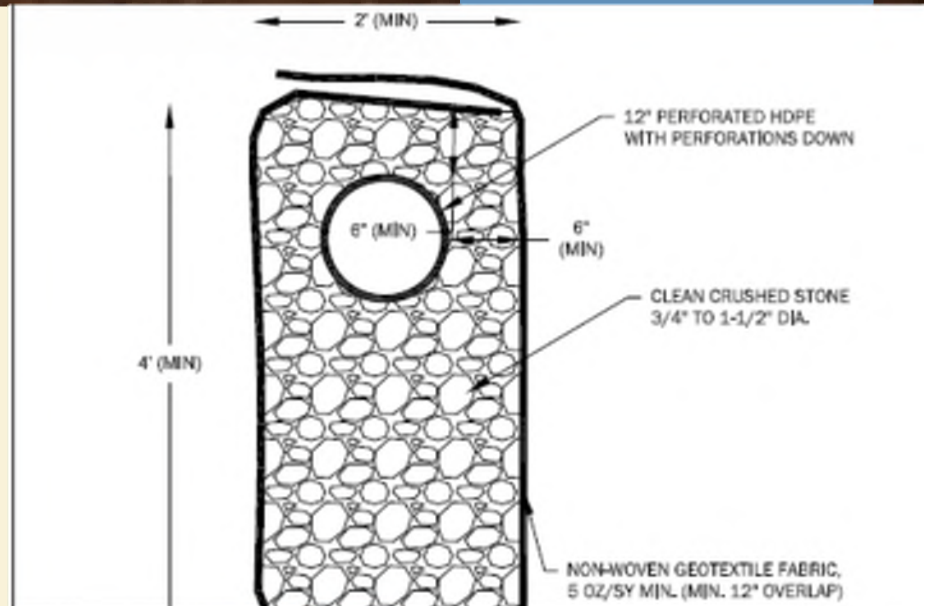
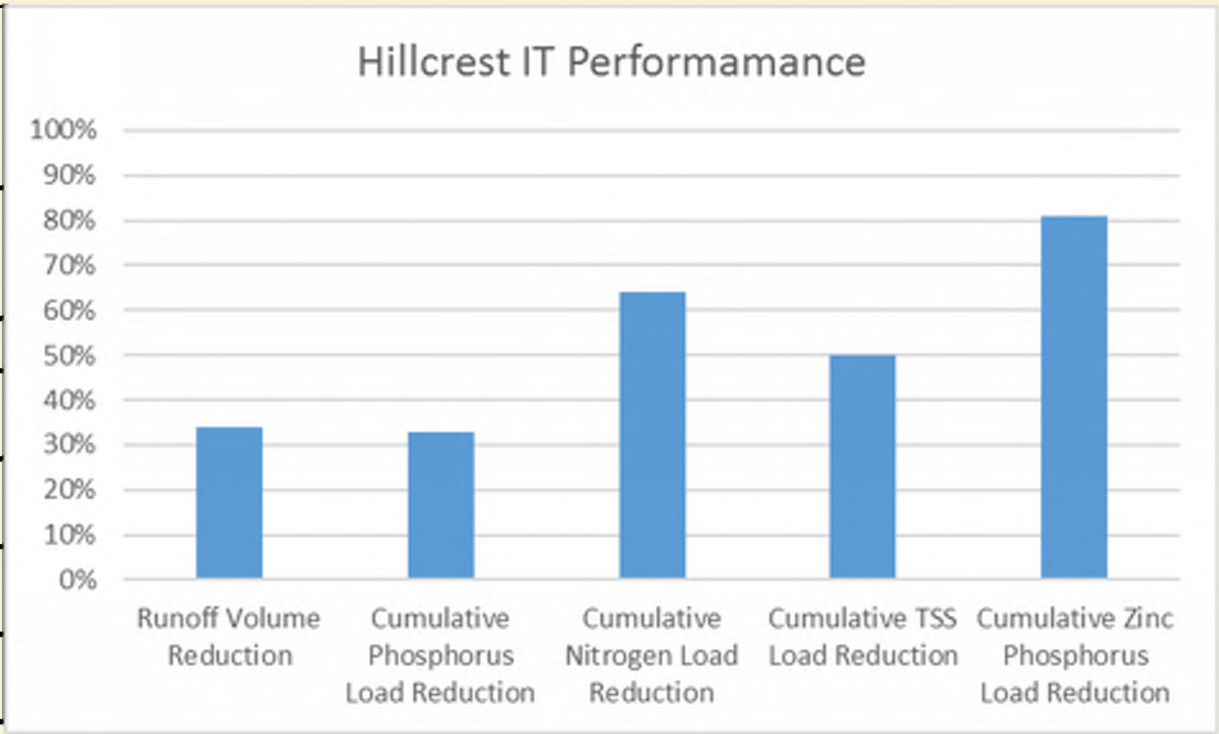
- In HSG A installed an infiltration trench between two conv CBs
- A simple but effective adaptation instead of solid pipe.
- Treats runoff from 3.36 acres and 1.04 acres DCIA



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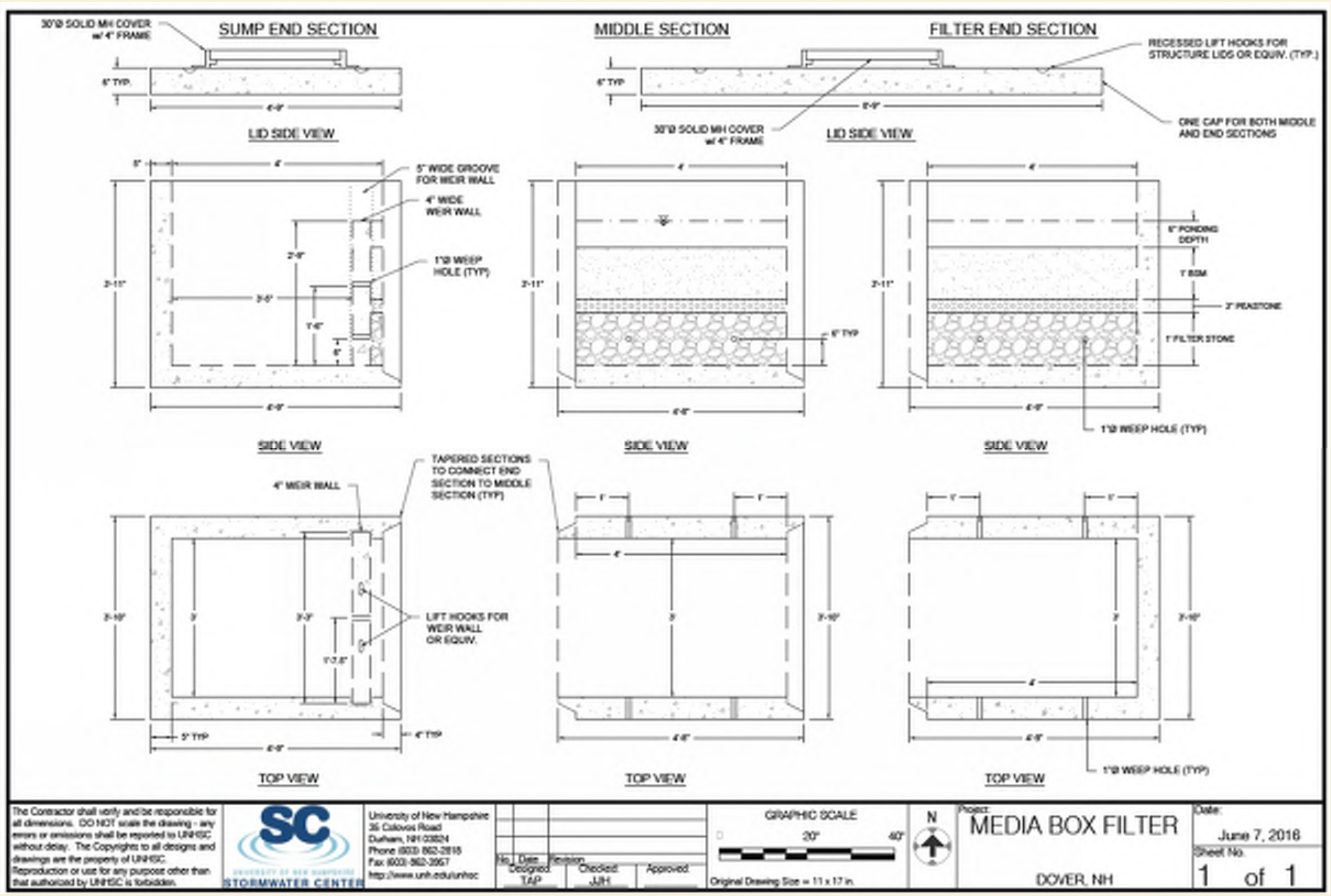
Site Characteristics and System Treatment Capacity						Annual Removals (lbs/yr)		
Project	Impervious Area (sf)	Impervious Area (acres)	Best Management Practice	Hydrologic Soil Group	Depth of Runoff Treated from Impervious Area (in)	Total Suspended Sediment	Total Phosphorus	Total Nitrogen
Hillcrest IT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

Water Quality Volume	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

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Update May 2018

Update May 2018

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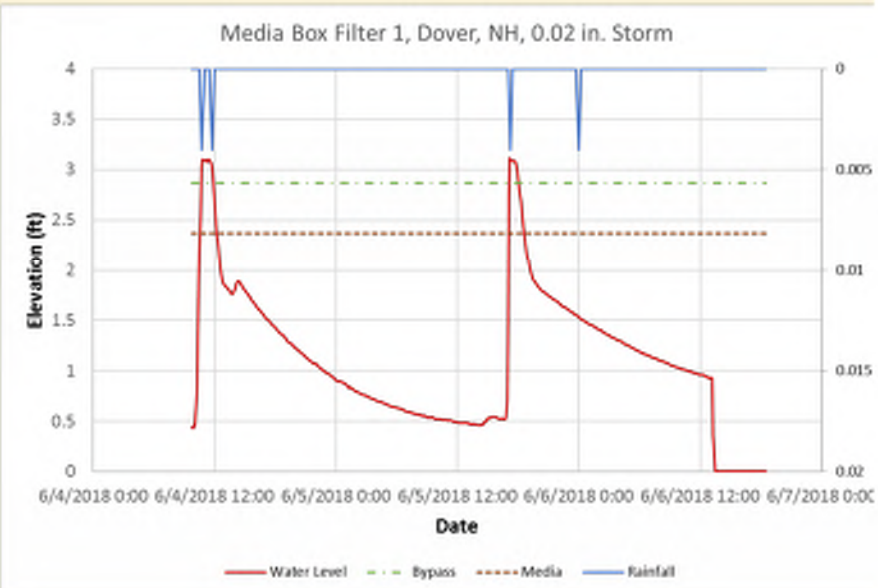

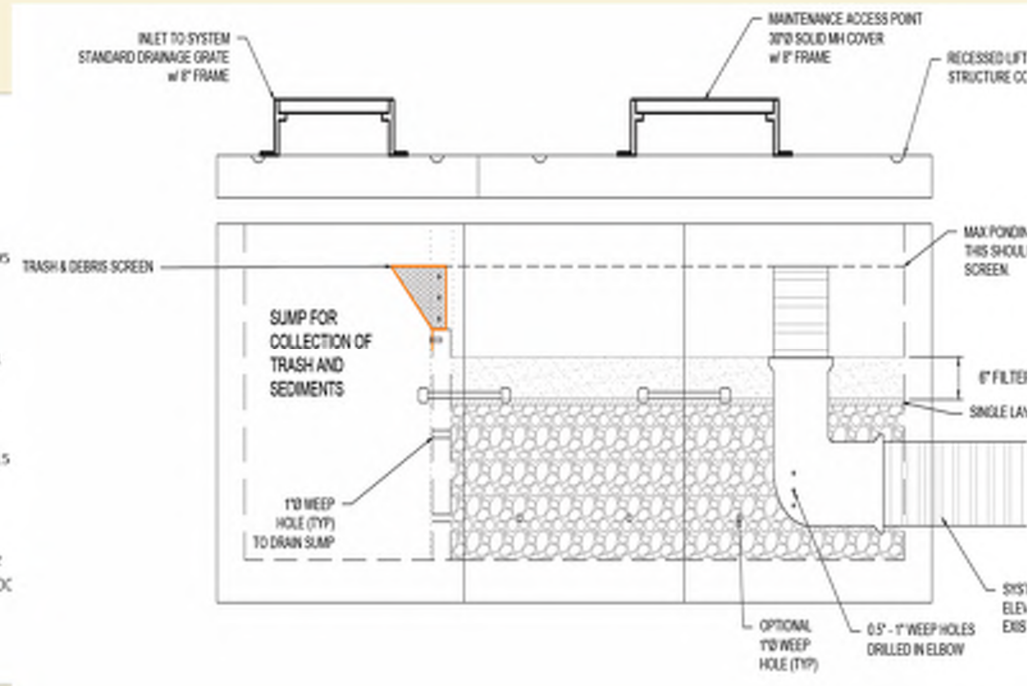

Innovations in water resource management: A common social responsibility

Conceptual Model Factors Influencing Adoption

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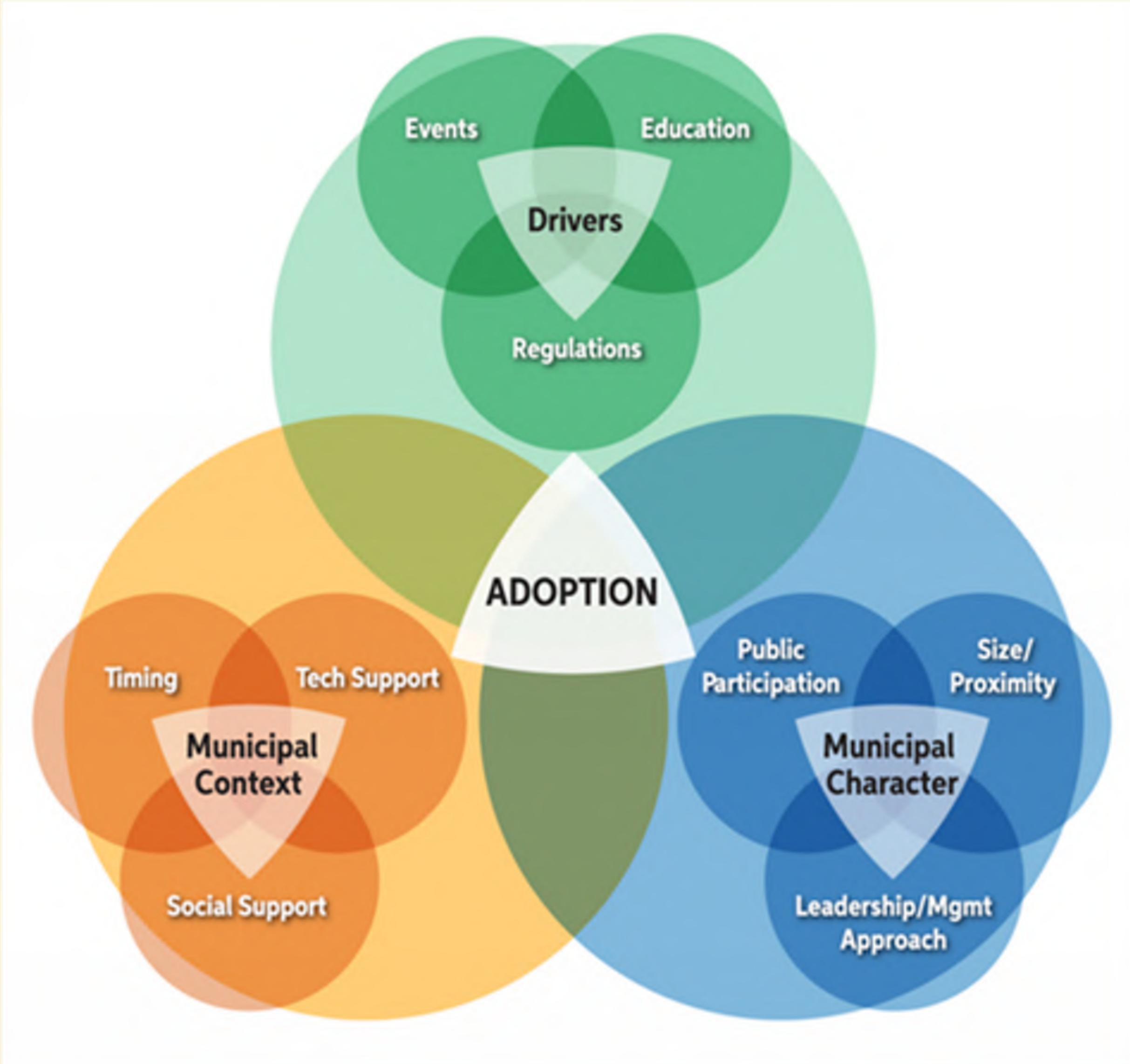
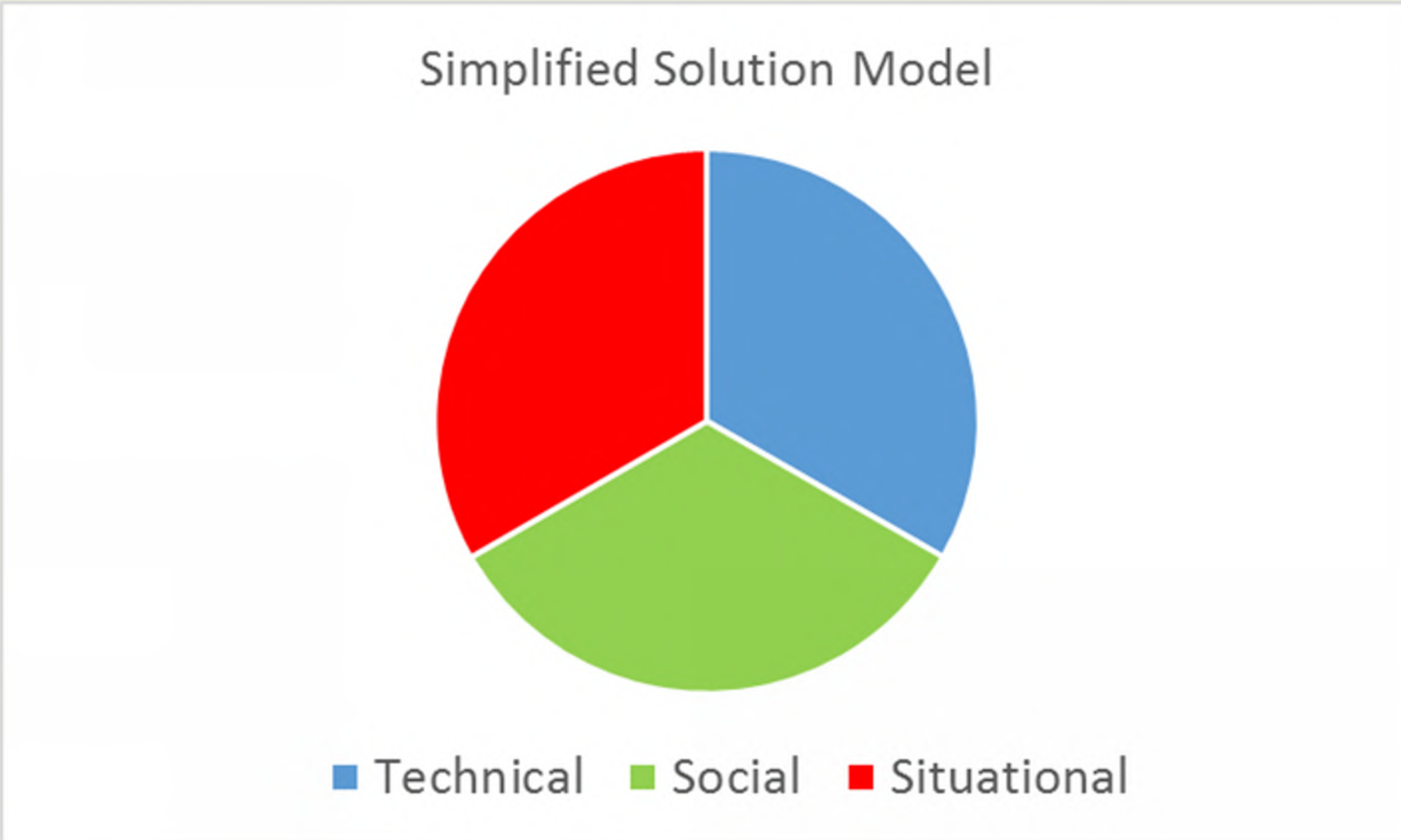
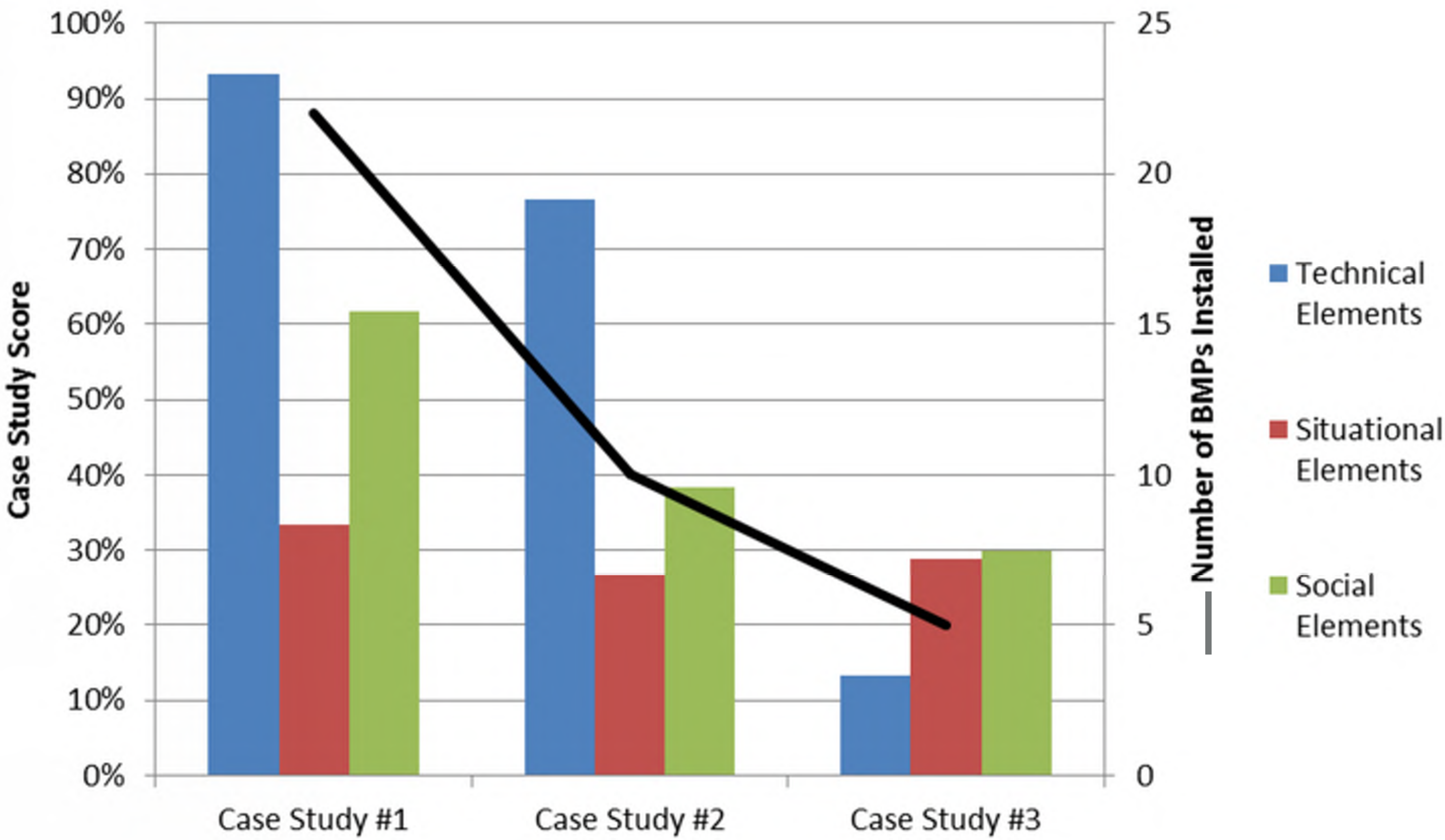
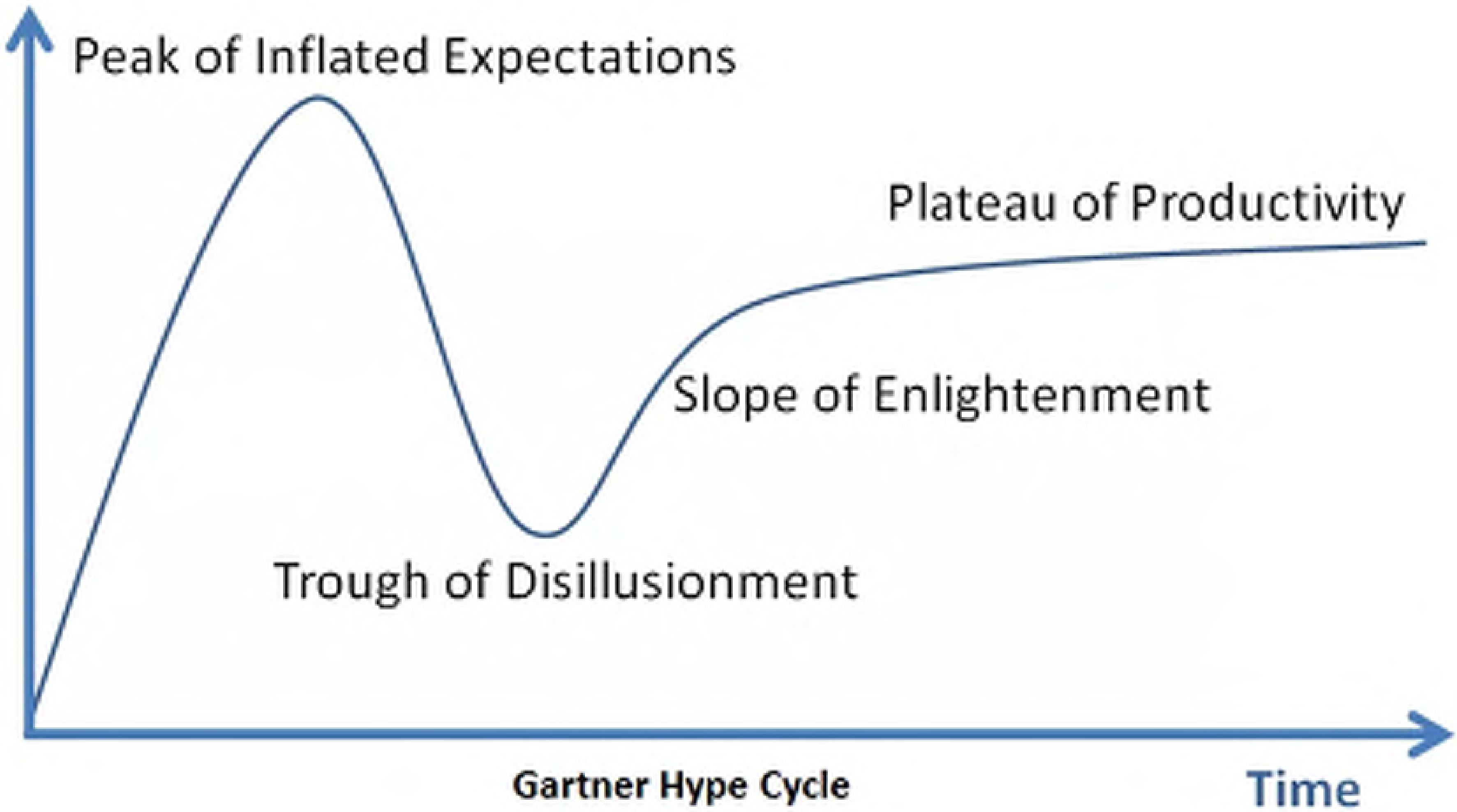



Simplified Solution Model
Technical
Social
Situational

Case Study Score vs # BMPs





Gartner Hype Cycle

New Project Approach

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!

Part of the Solution – Watershed approach all communities can access

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

Berry Brook

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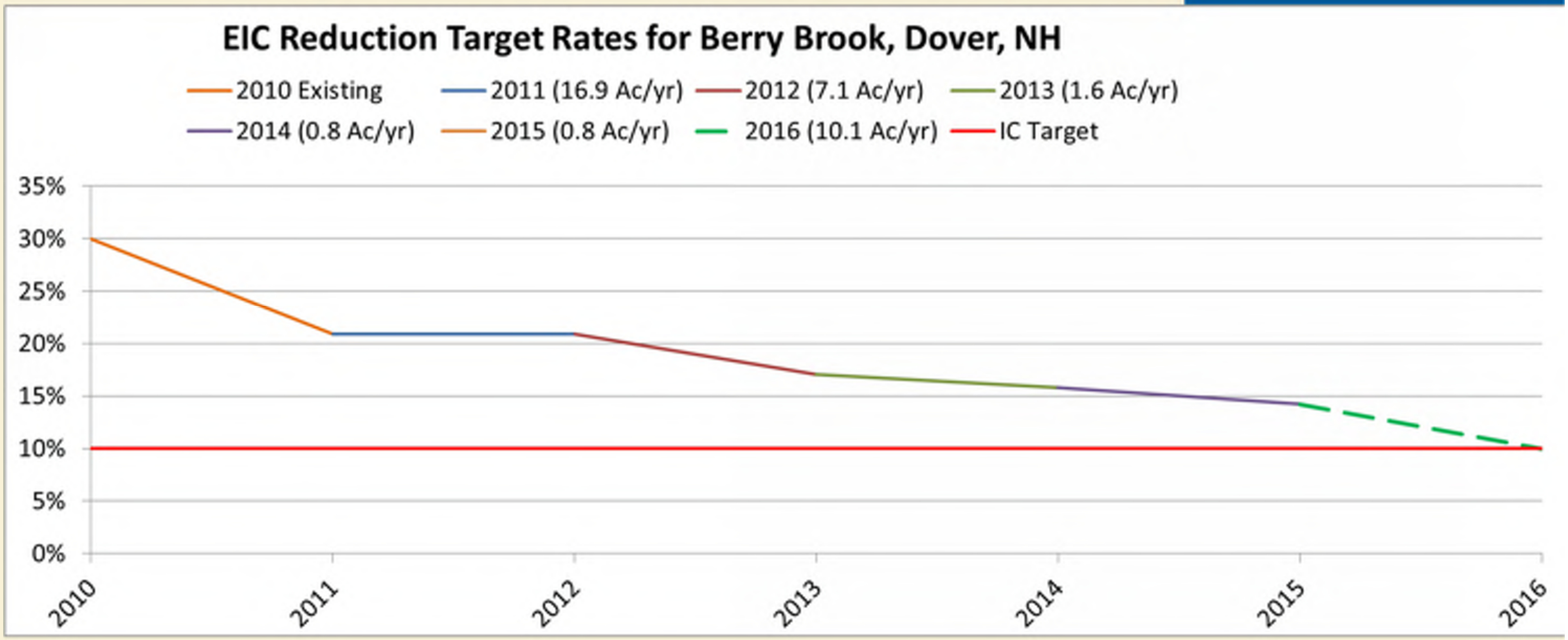
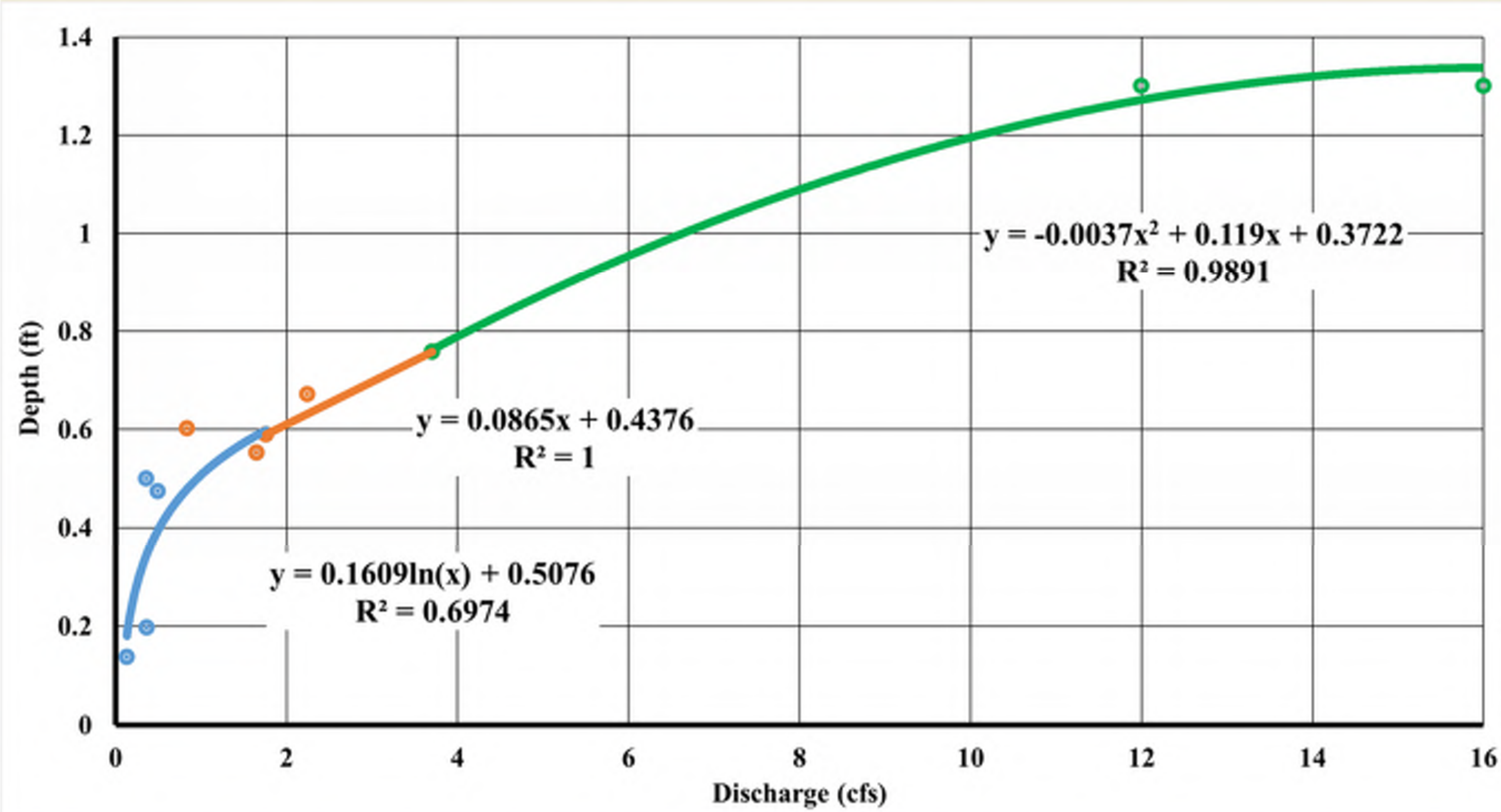


Hydrology



1.4
1.2
1
0.8
0.6
0.4
0.2
0
Depth (ft)
y = -0.0037x² + 0.119x + 0.3722
R² = 0.9891
y = 0.0865x + 0.4376
R² = 1
y = 0.1609ln(x) + 0.5076
R² = 0.6974
0
2
4
6
8
10
12
14
16
Discharge (cfs)

Hydrology

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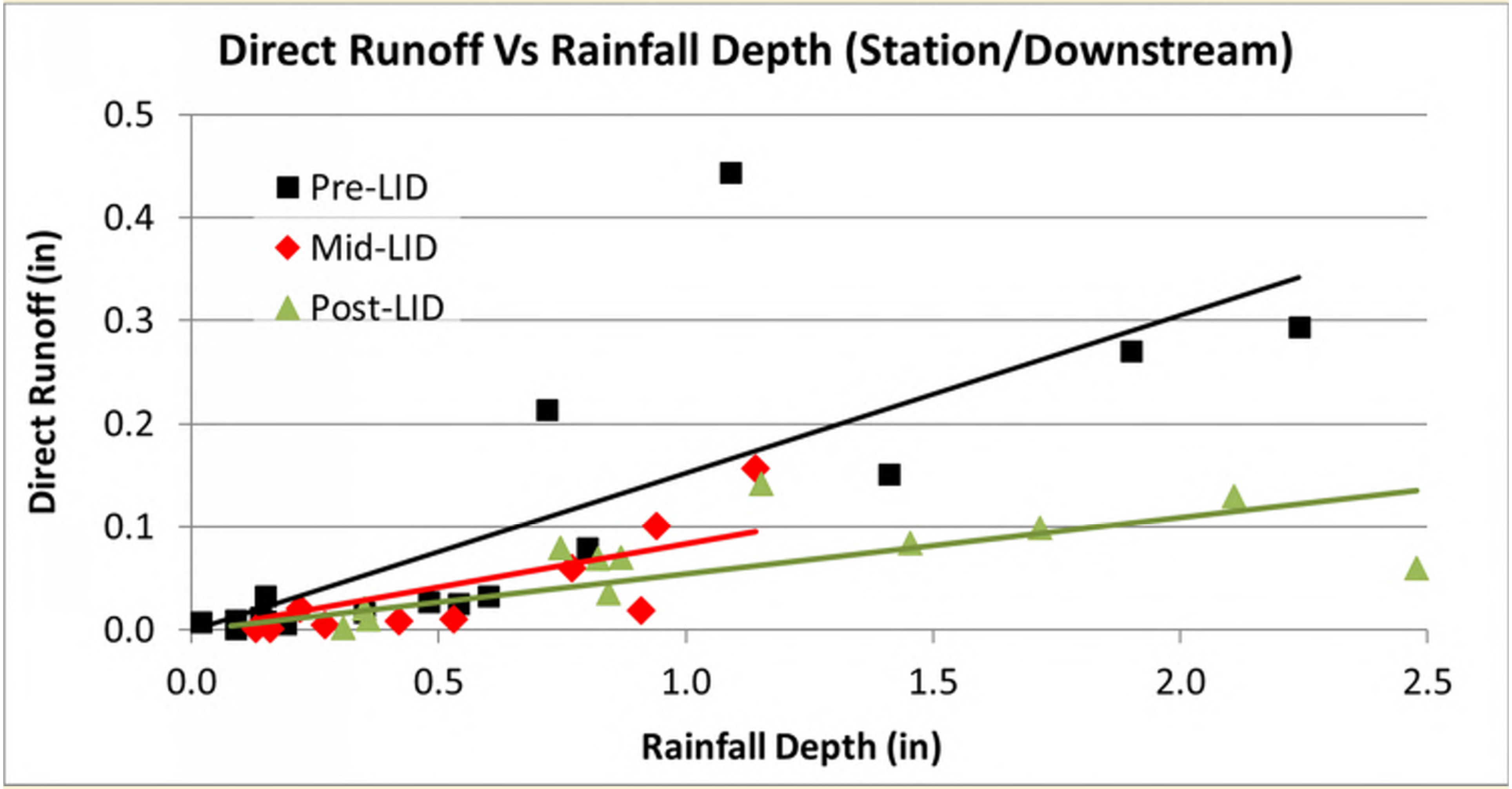
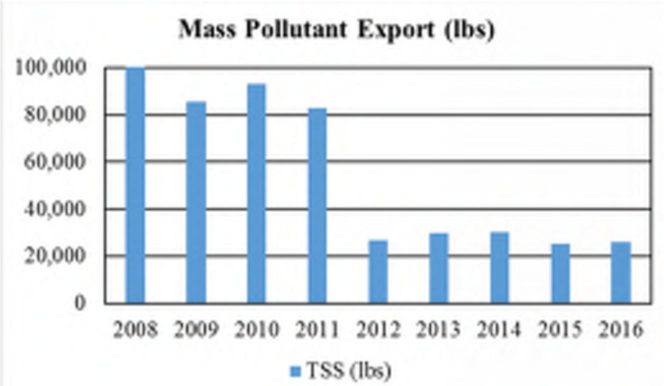
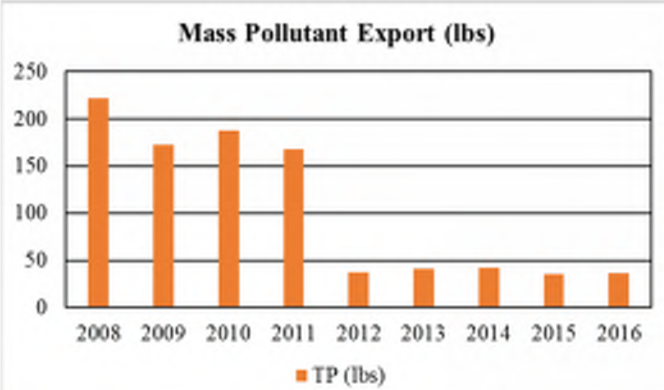
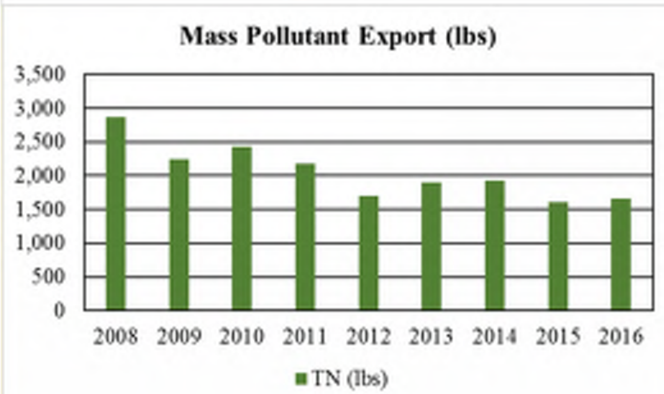


Modeled Water Quality







Results for Berry Brook at Station Drive

1-Inch Storm, Ia = 0.05 S[1]

Year	% IC	P (in)	Q (in)	S (in)	CN	Q Reduction
2011	30	1.00	0.153	3.59	74	
2012	20	1.00	0.084	5.54	64	45.3%
2015	14	1.00	0.055	7.02	59	64.0%

[1]Hawkins, R.H.; Jiang, R.; Woodward, D.E.; Hjelmfelt, A.T.; Van Mullem, J.A. (2002). "Runoff Curve Number Method: Examination of the Initial Abstraction Ratio".

27

Year	A	P	CN	TSS (lbs)	TP (lbs)	TN (lbs)
2008-20011	185	56.14	74	92,719	188	2,428
20012-2016	185	42.20	62	27,575	38	1,762
Annual Reductions (lb./yr.)				65,144	149	667
Simple Method (lb./yr.)				57,223	201	1,127

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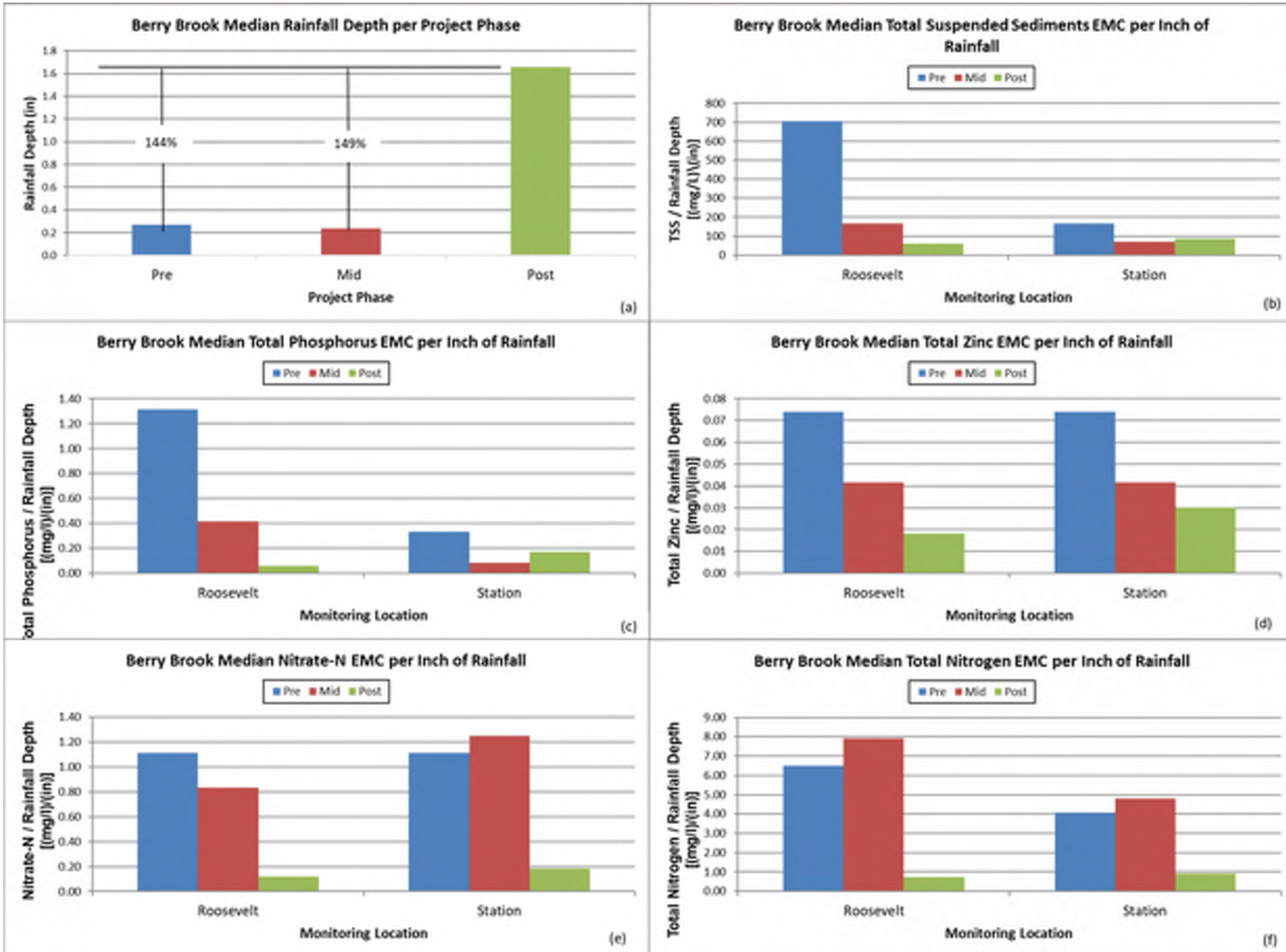
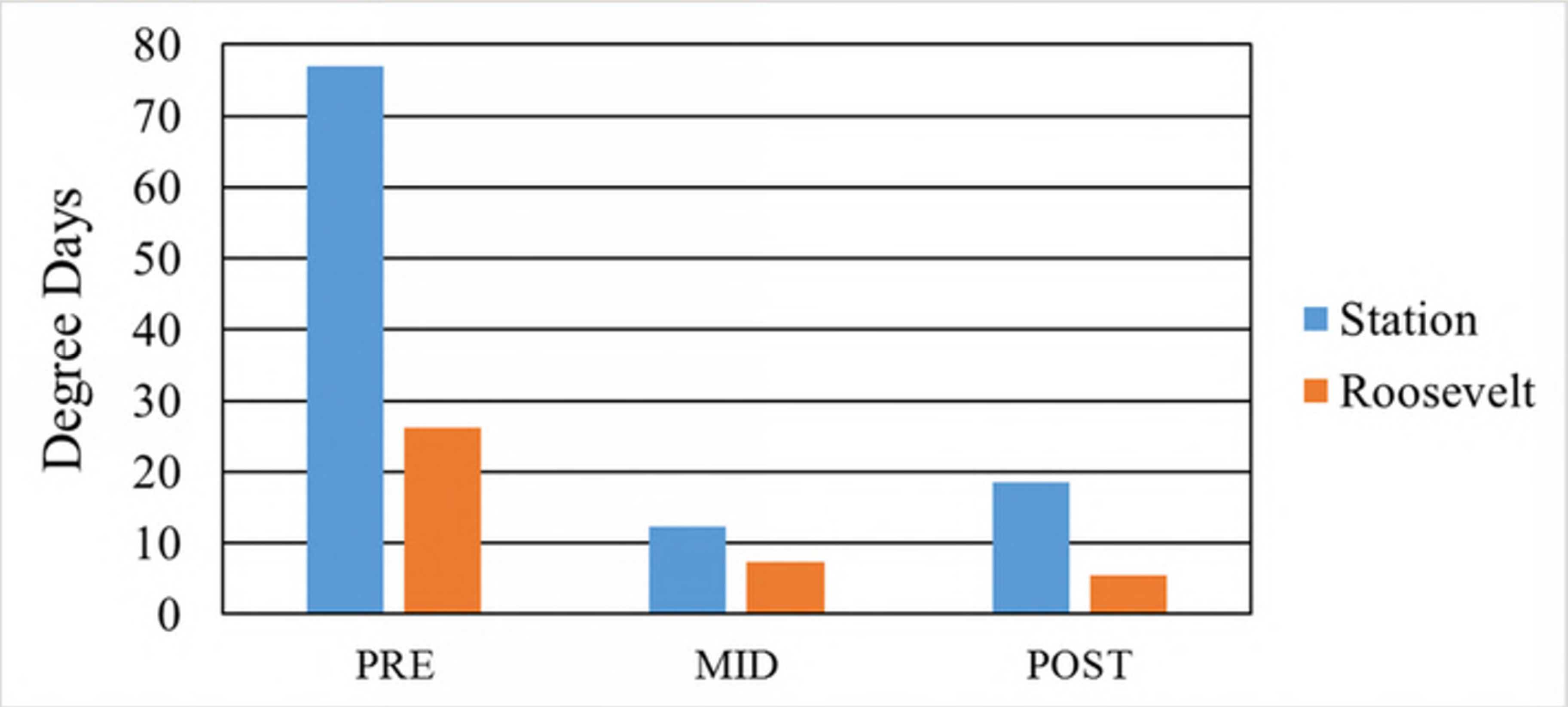


		TSS (mg/l) / (in)			Zinc (mg/l) / (in)			Nitrate-N (mg/l) / (in)			Total Nitrogen (mg/l) / (in)			Total Phosphorus (mg/l) / (in)		
		Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post	Pre	Mid	Post
Roosevelt	Weighted EMC	704	167	60	0.07	0.04	0.02	1.1	0.8	0.1	6.5	7.9	0.7	1.31	0.42	0.06
	% Difference		123%	168%		56%	121%		29%	161%		-20%	160%		104%	182%
Station	Weighted EMC	167	69	85	0.07	0.04	0.03	1.1	1.3	0.2	4.1	4.8	0.9	0.33	0.08	0.17
	% Difference		83%	65%		56%	84%		-12%	144%		-16%	127%		120%	65%
Average	% Difference		103%	117%		56%	103%		8%	152%		-18%	144%		112%	124%

Temperature Data



One degree day is a day when the average stream temperature is one degree Fahrenheit above 65 degrees F. This is important as the temperature that a Brook Trout begins to feel heat stress is 65 °F. Therefore a day with an average daily stream temperature of 71 degrees would represent 6 degree days.

End? More Cart Before the Horse?

Are we inadvertently modeling optimized system performance ahead of long term operation and maintenance?

Operation and Maintenance

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ISCO

System Performance

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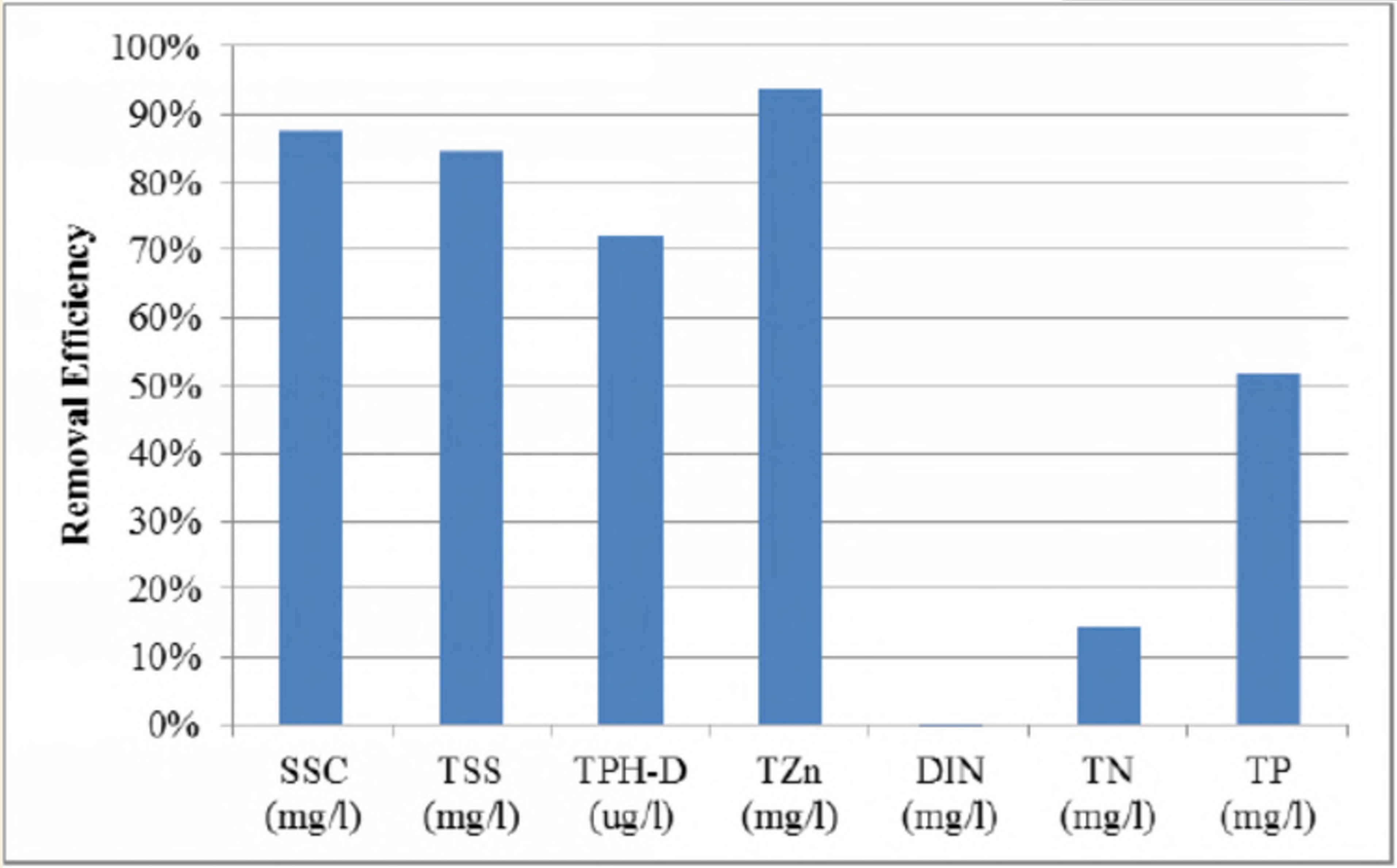
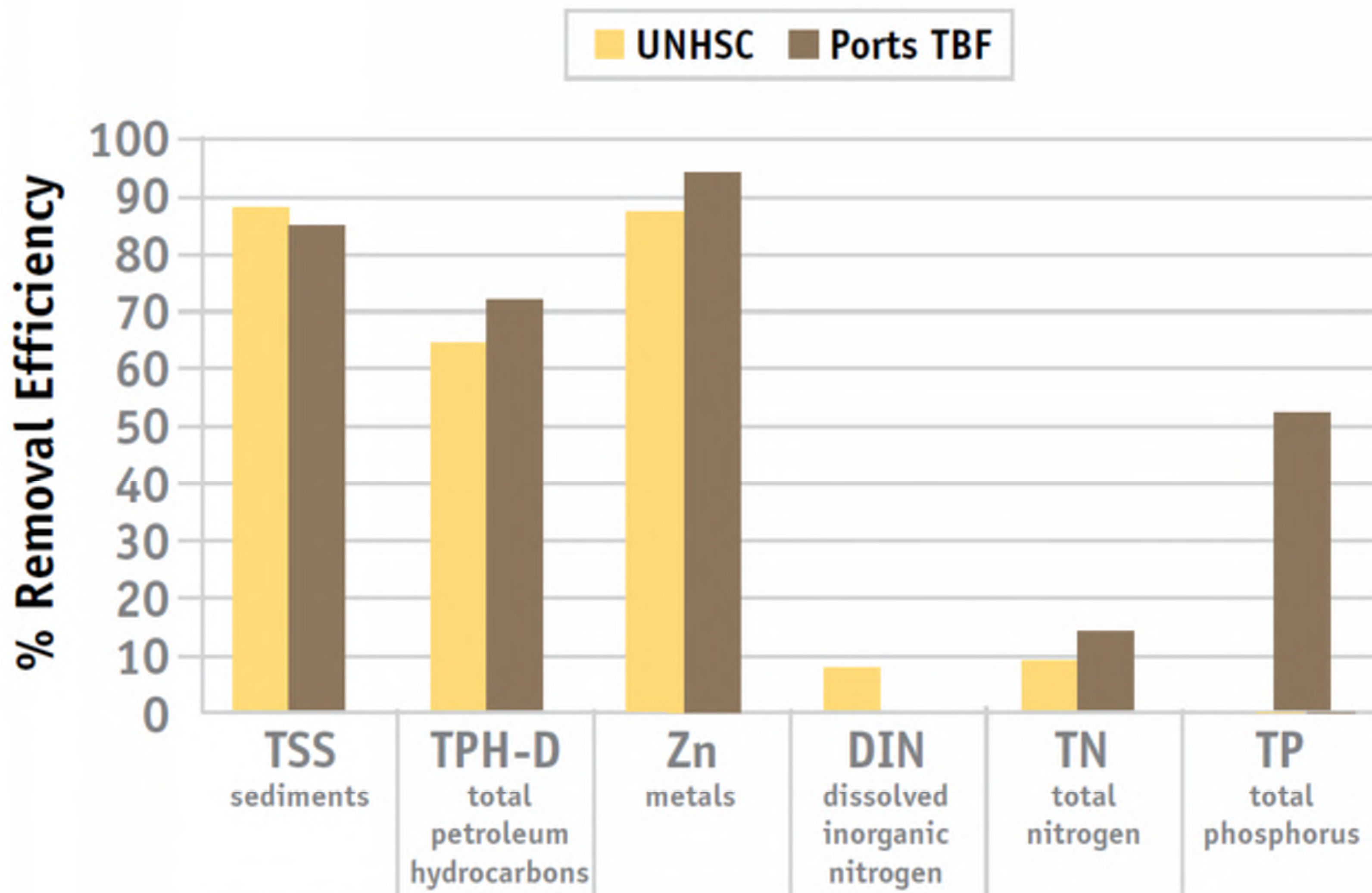
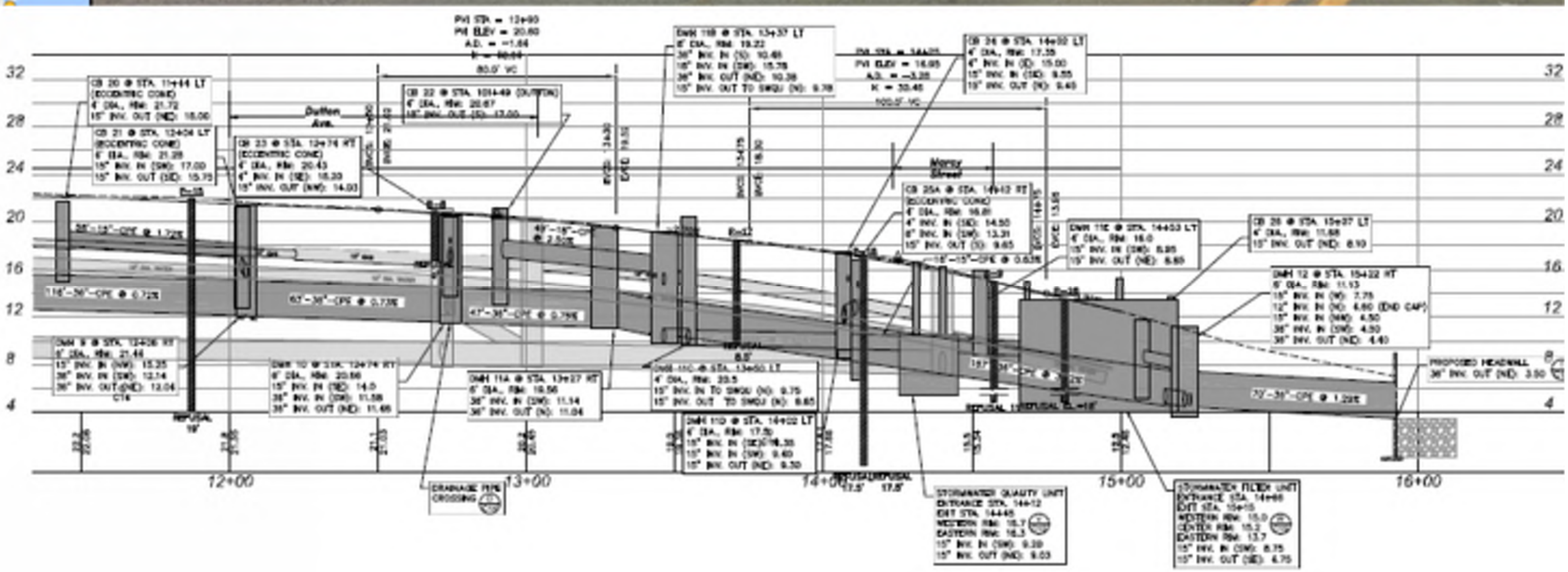


TREE FILTER PERFORMANCE



Median Annual Influent Event Mean Concentrations (EMC) in mg/L

	TSS	TPH-D	Zn	DIN	TN	TP
UNHSC	31	631	0.04	0.2	1.3	0.07
Ports TBF	39	520	0.10	0.2	1.5	0.21


32
28
24
20
16
12
8
4
12+00
13+00
15+00
16+00
Dutton Ave.
PROPOSED HEADWALL
DRAINAGE PIPE CROSSING

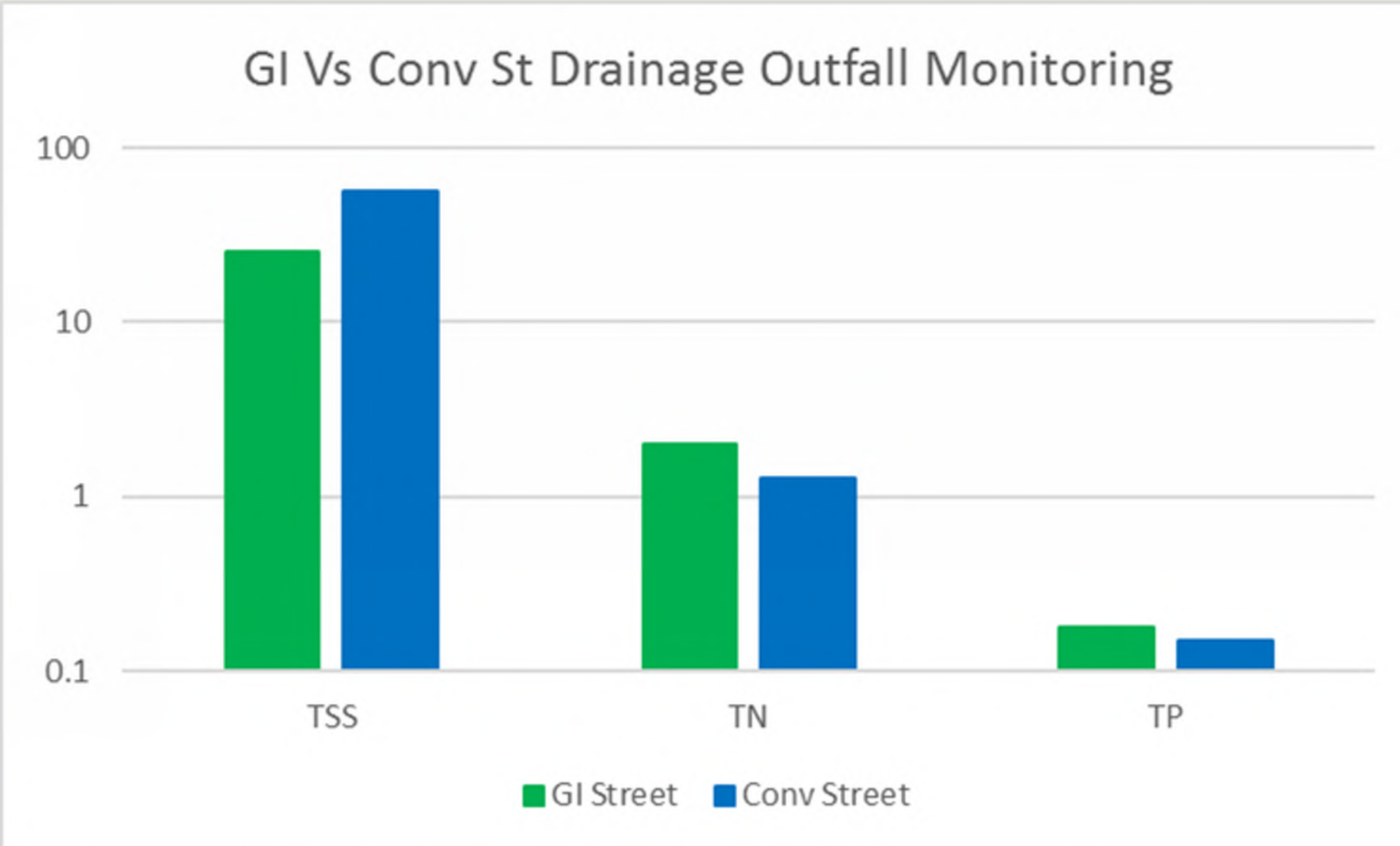
Maintenance Basics

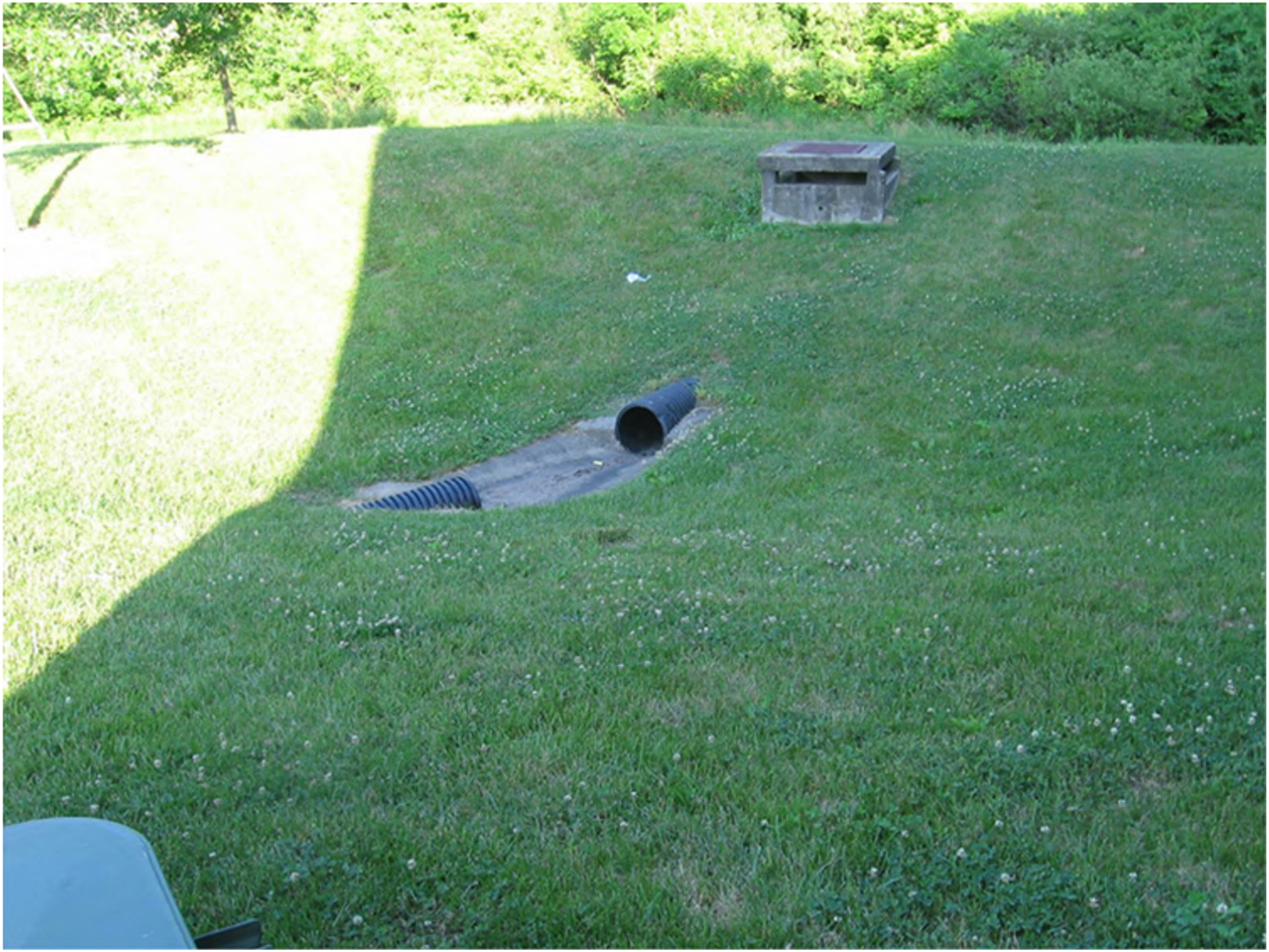
Maintenance Basics

Pic rd
the ny
ma ling.


INTERNATIONAL
S66
7400
PUBLIC WORKS
WATER / SEWER DIVISION

Maintenance Basics






Brian

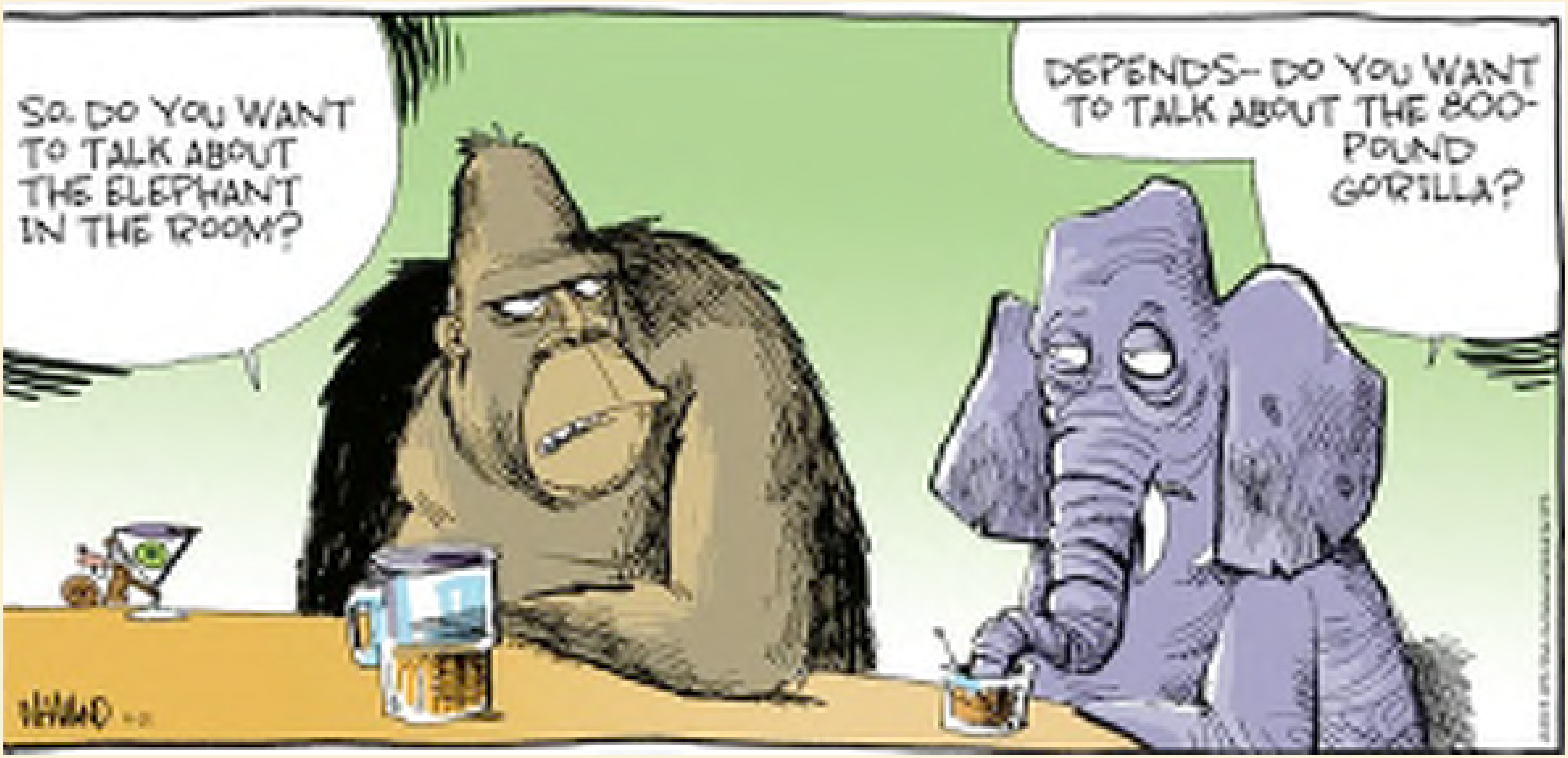
End? More Cart Before the Horse?

UNIVERSITY OF NEW HAMPSHIRE
STORMWATER CENTER

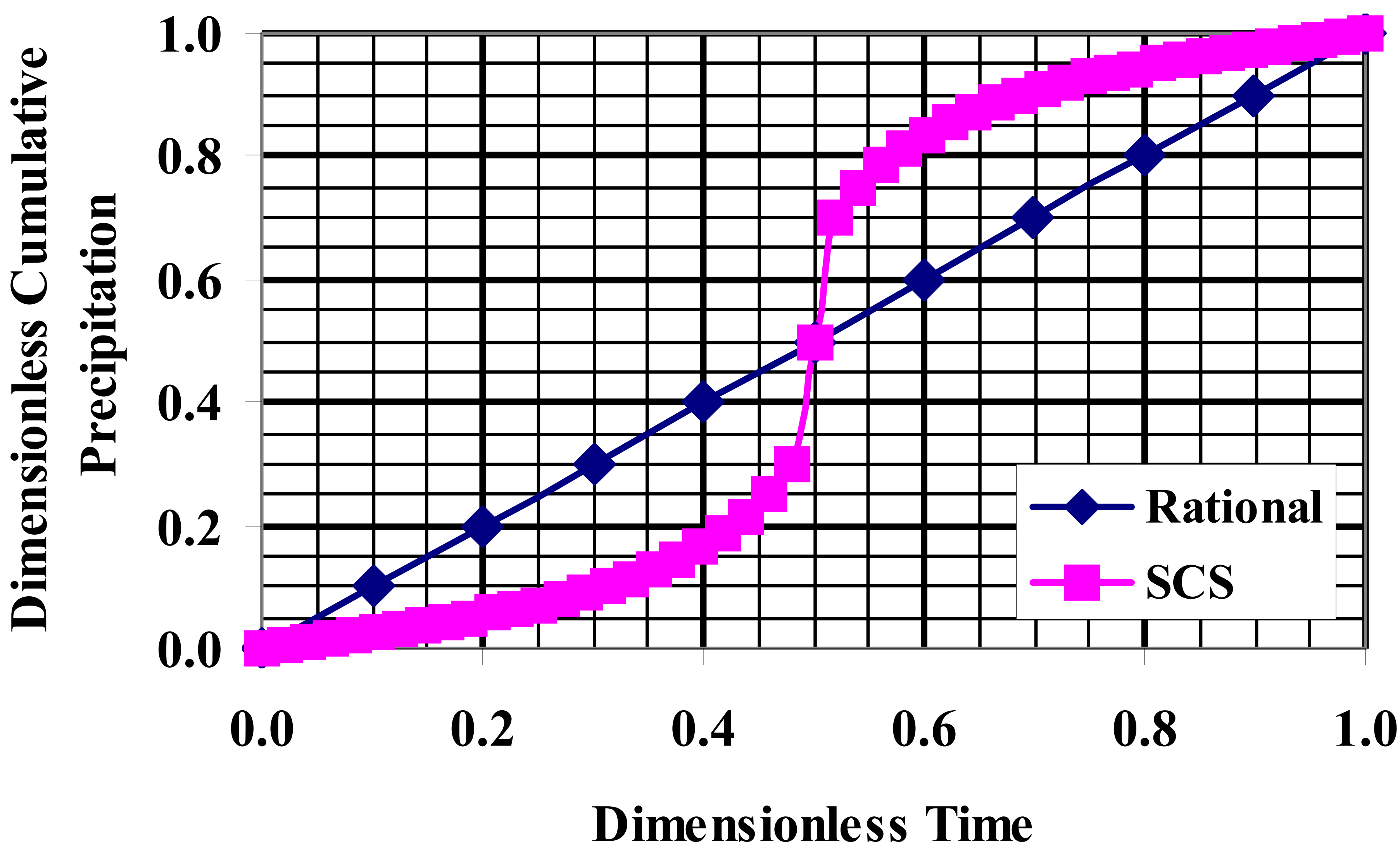
Stormwater Modeling

Do we know what we are doing?

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

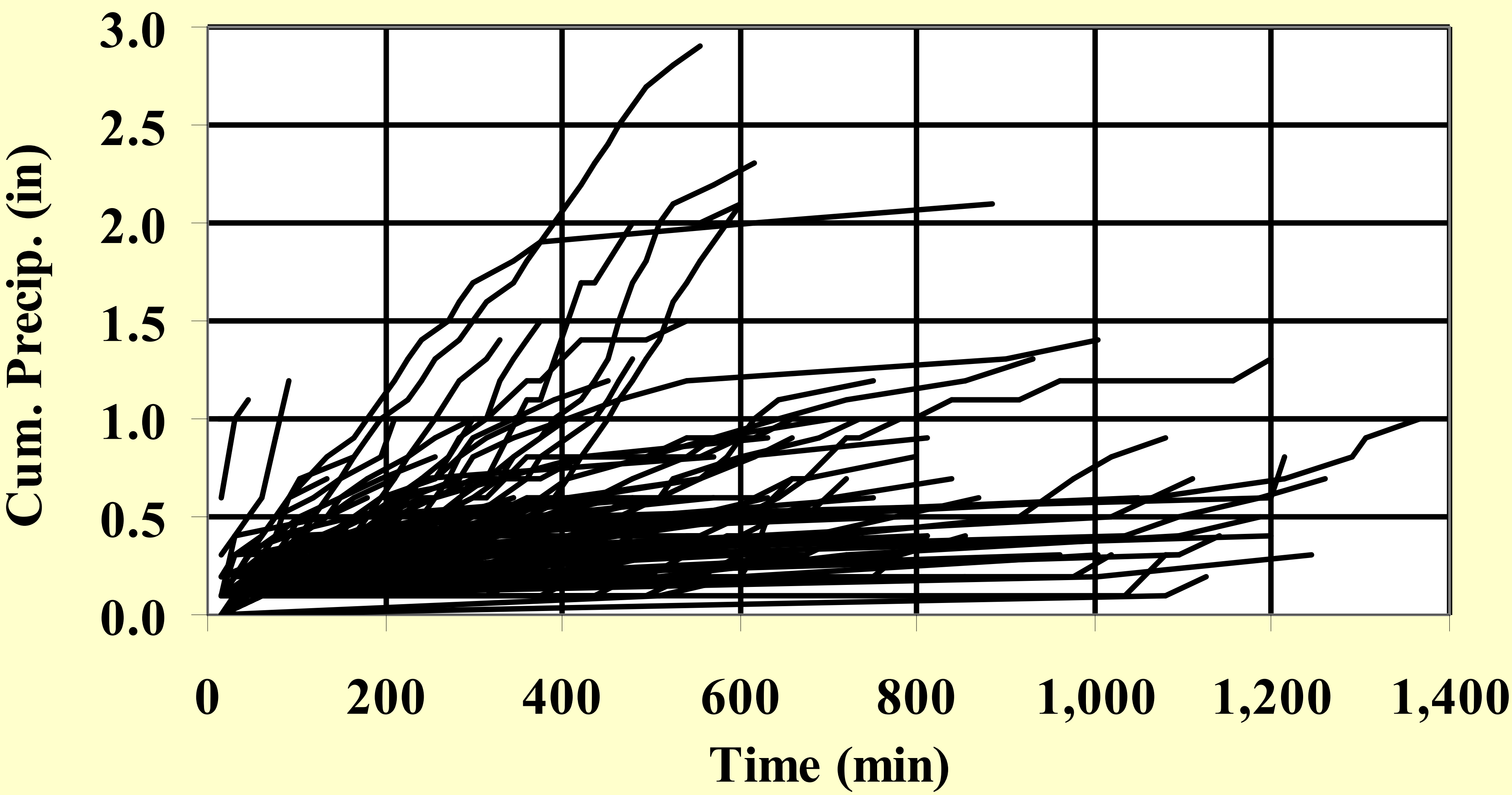


Design Dimensionless Hyetographs



Sampling of Observed Hyetographs

Durham, NH NOAA Gage



Sizing for Performance

Sizing Details

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

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

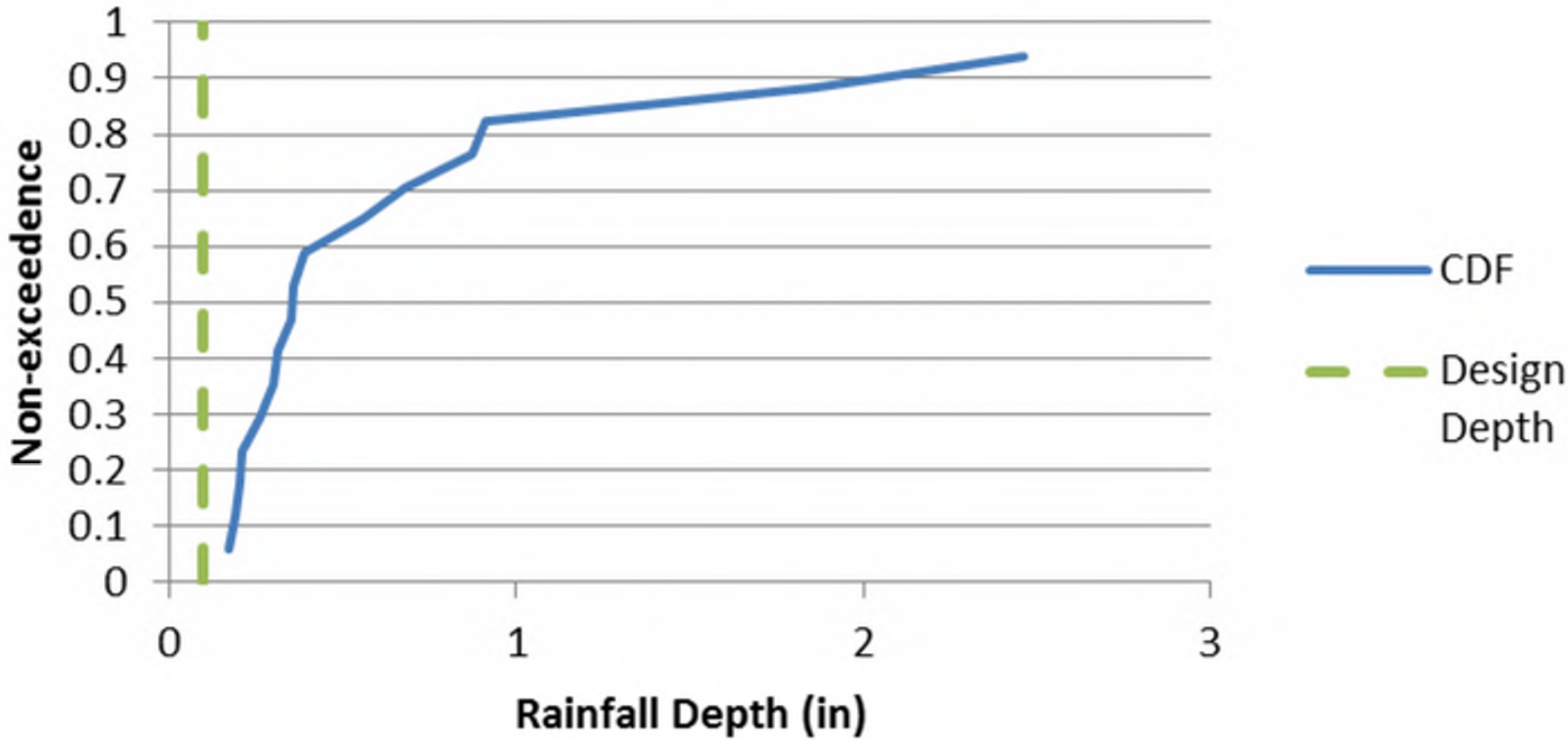
Dynamic Bioretention Sizing

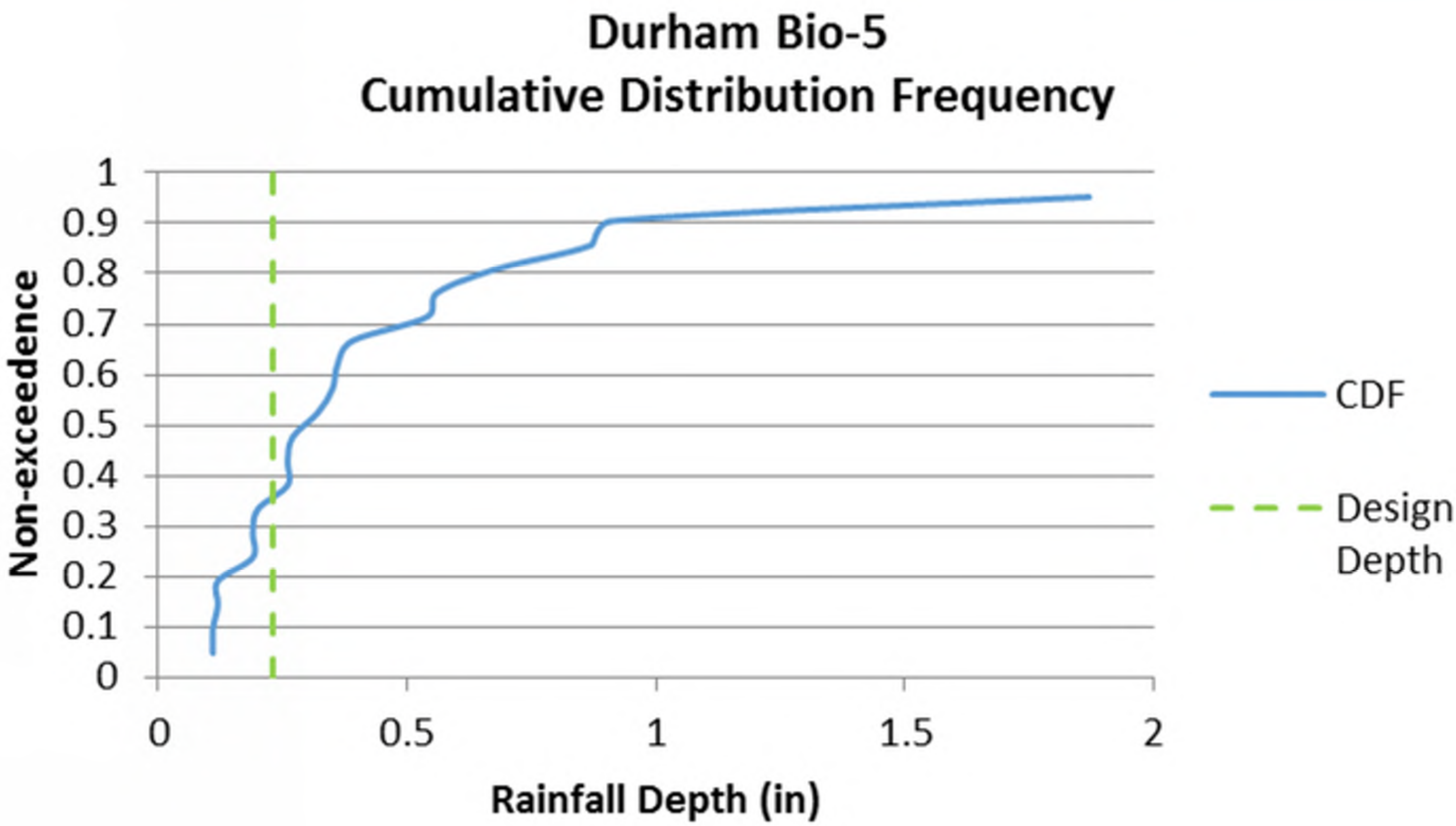
$$Af = Vwq * \frac{df}{(i(hf + df)tf)}$$

Static SGW System Sizing

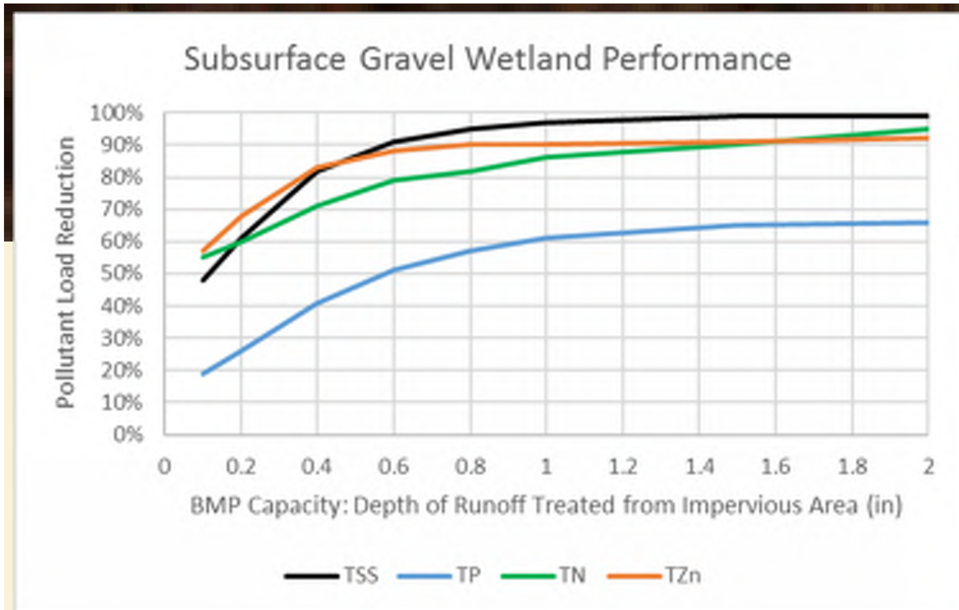
$$Q = CdA\sqrt{2gh}$$

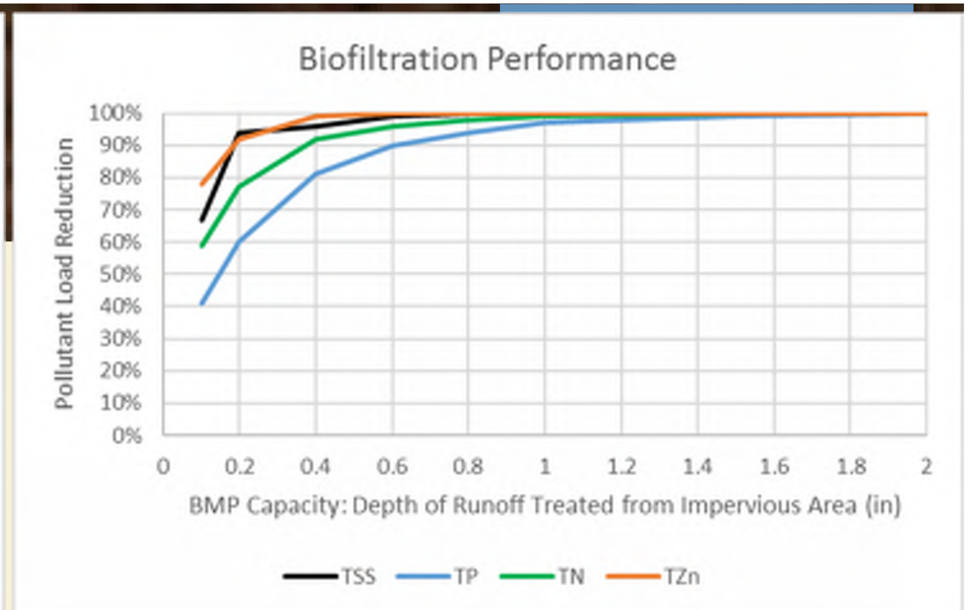
Oyster River Road
Cumulative Distribution Frequency





Durham Bio-5
Cumulative Distribution Frequency
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
Non-exceedence
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 ($\$/ft^3$) [1]	Cost ($\$/ft^3$) – 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


Questions???