Does Impervious Cover Reduction Really Work?
Urban Watershed Renewal in Berry Brook

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Acknowledgement

* NHDES 319 Watershed Assistance
* NHDES Aquatic Resource Mitigation Funds
* City of Dover, NH
* US EPA

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Project Objectives

To foster habitat restoration through urban watershed renewal by restoring and reconnecting a small highly urbanized watershed of a 1st order stream by :

1. Physical stream and wetland restoration
2. Low Impact Development (LID) stormwater management to reduce existing hydromodification and improve water quality.

3

Urban Watershed Renewal through LID and Stream Restoration

LID Stormwater Management

Outcome: water quality treatment, volume reduction, and baseflow augmentation

Wetland and Stream Restoration

Outcome: stream provides aquatic habitat, reduce/eliminate fish passage barriers, restore ecosystem services

4

Stormwater Management

5

Hypothesis

- Reduction of *effective* impervious cover will lead to improvements in stream health as measured by a range of response parameters including:
  - Water chemistry,
  - Biology, and
  - Hydrology.
- Parameter response will vary with respect to time and location

6

Land Use and Water Quality

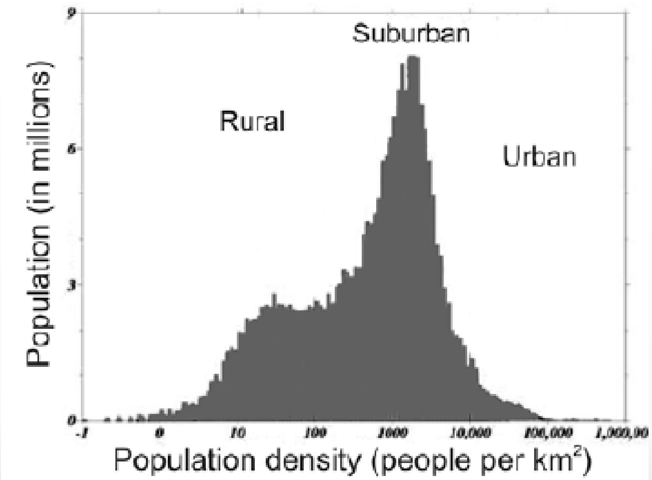


FIGURE. U.S. population based on 2000 Census. Modified from Pozzi & Small (2005), ASPRS (2005).

7

Changes to Magnitude of Flow Extremes

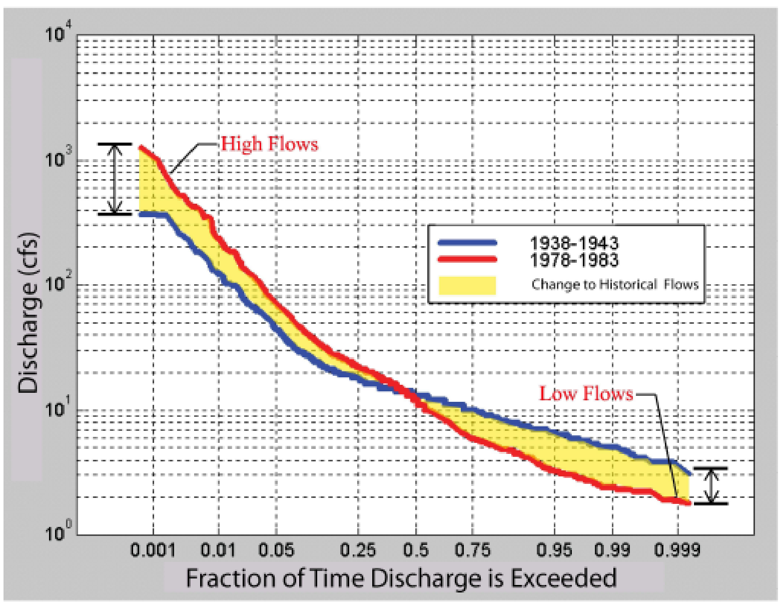
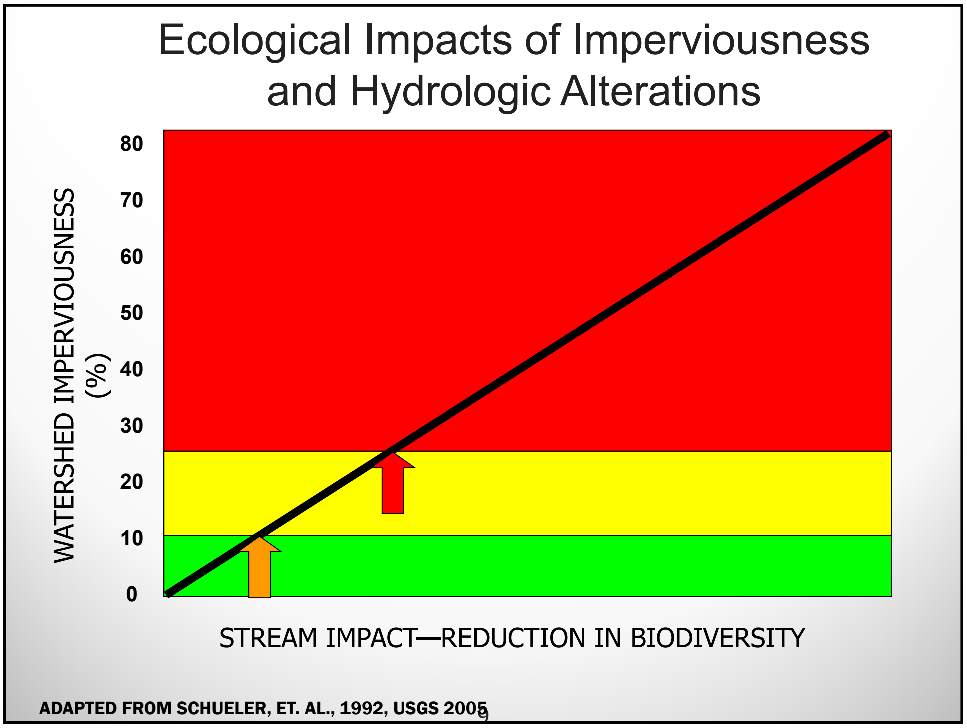
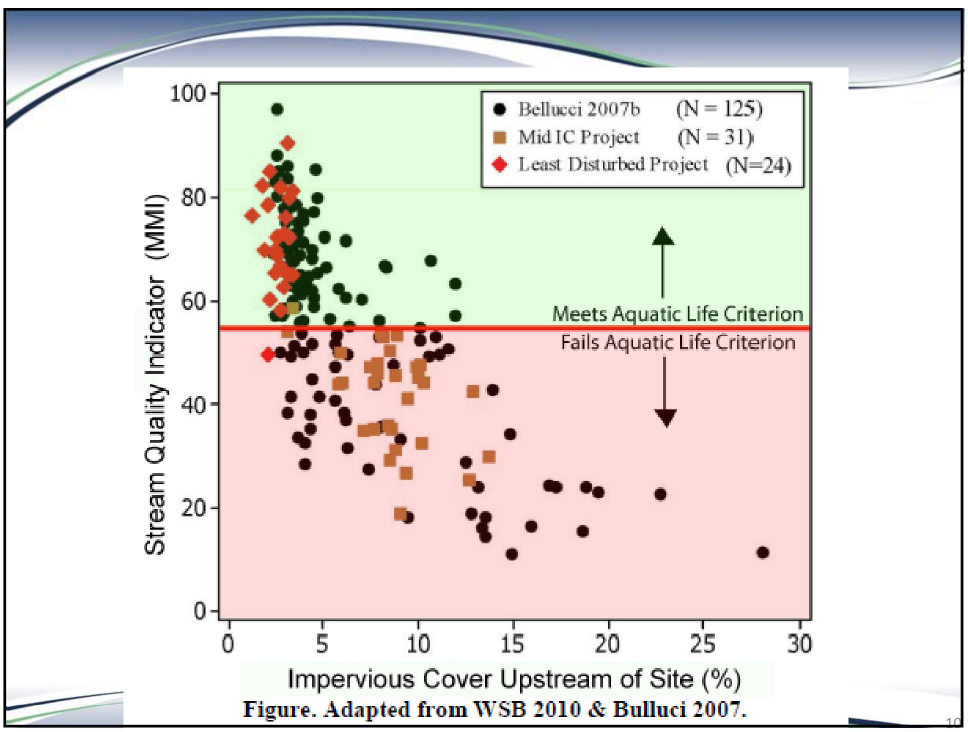


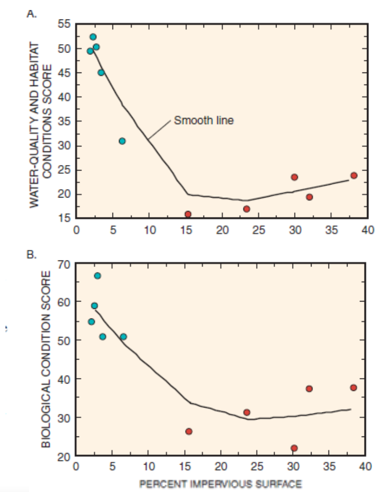
Figure. Influences of Urbanization on Flow Extremes. Adapted from Moglen (2010)

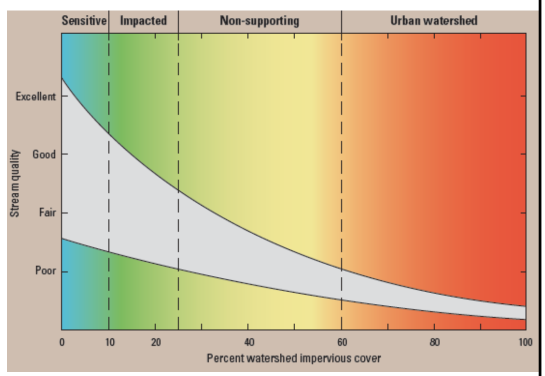
8


Ecological Impacts of Imperviousness and Hydrologic Alterations
WATERSHED IMPERVIOUSNESS (%)
80
70
60
50
40
30
20
10
0
STREAM IMPACT—REDUCTION IN BIODIVERSITY
ADAPTED FROM SCHUELER, ET. AL., 1992, USGS 2005


Stream Quality Indicator (MMI)
100
80
60
40
20
0
Bellucci 2007b (N = 125)
Mid IC Project (N = 31)
Least Disturbed Project (N=24)
Meets Aquatic Life Criterion
Fails Aquatic Life Criterion
0
5
10
15
20
25
30
Impervious Cover Upstream of Site (%)
Figure. Adapted from WSB 2010 & Bulluci 2007.

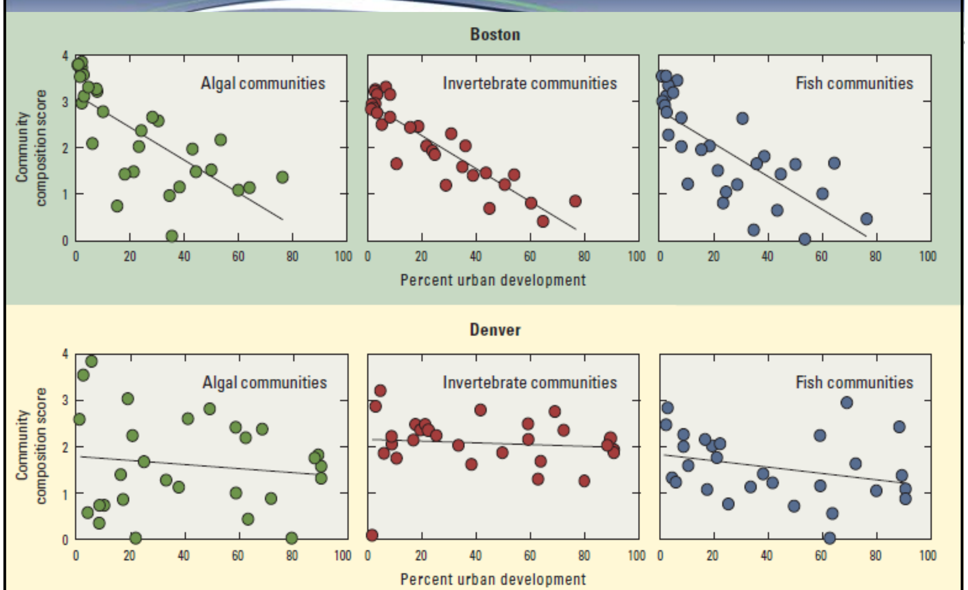
Impervious Cover and Stream Impairments





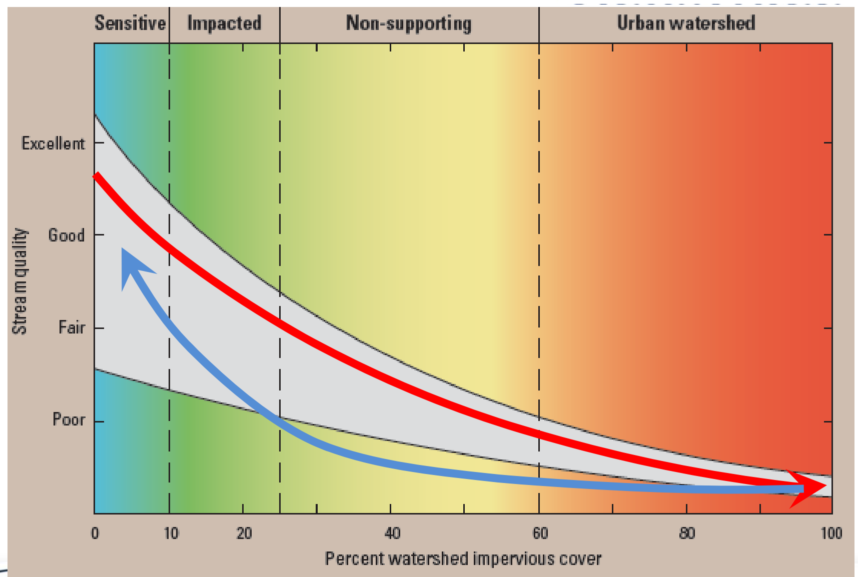
Source: Impacts of Impervious cover on Aquatic Systems, CWP March 2010.

Source: Effects of Urbanization on Stream Quality at Selected Sites in the Seacoast Region in New Hampshire, 2001-03, USGS 2005



Coles, J.F., McMahon, Gerard, Bell, A.H., Brown, L.R., Fitzpatrick, F.A., Scudder Eikenberry, B.C., Woodside, M.D., Cuffney, T.F., Bryant, W.L., Cappiella, Karen, Fraley-McNeal, Lisa, and Stack, W.P., 2012, Effects of urban development on stream ecosystems in nine metropolitan study areas across the United States: U.S. Geological Survey

Is It Reversible? Probably Hysteretic



What’s the big deal?

- Nationally Stormwater runoff is the #1 pollution source, out of fourteen identified non-point sources (303D)
- NH Shellfish beds are closed after >1/2 inch of rainfall in 24 hours
- Contaminated stormwater discharges are responsible for the impairment of one-third of all assessed waters in the United States, according to the EPA.
- Urban stormwater is the second largest source of water quality impairment in estuaries.
- Stormwater was identified as the cause for over 1,550 of the 1998 reported beach closings (30%).
- 40% of our rivers, lakes, and estuaries are still too polluted for safe fishing or swimming.

Berry Brook Watershed Renewal Project

Berry Brook Dover, NH

- NHDES named Berry Brook to the 303d list of impaired surface waters due to lack of aquatic life support.

Project Comprised of 2 Components

1) Stream and wetland restoration (~800ft)
2) Stormwater management (24 LID Systems)
   - Treatment of 20.7 IC acres

Berry Brook Watershed area ~185acres

Berry Brook stream length is approx. 1.15 miles

Urbanized - high density area (30% EIC)

Berry Brook Watershed –Delineation and Monitoring Locations

Data Collection

Instruments

- Aqua TROLL 200 (5)
  - Depth, Conductivity, Temp.
- ISCO Water Sampler (3)
  - Nutrients, Me, TPH, TSS
- Surber Sampler (4)
  - Macro Invertebrates

Aqua TROLL 200

Aqua TROLL 200

ISCO Water Sampler

Invertebrate sampling with the Surber

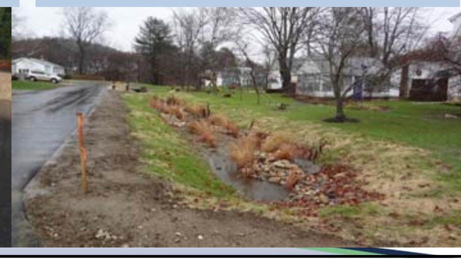
Berry Brook Green Infrastructure

Page Ave. - Swale

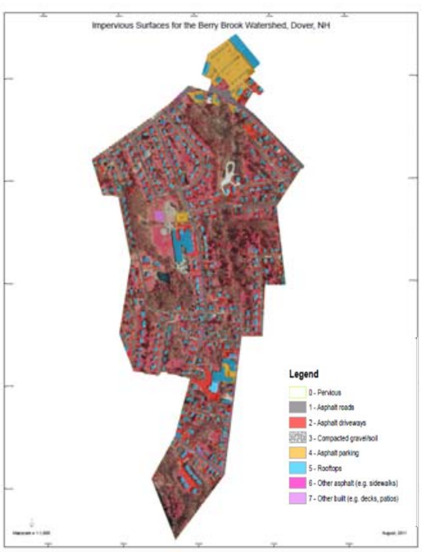
Horne St. School - Bioretention

Central Ave - Subsurface Gravel Wetland

Snow Ave. – Bioretention & Bioswale

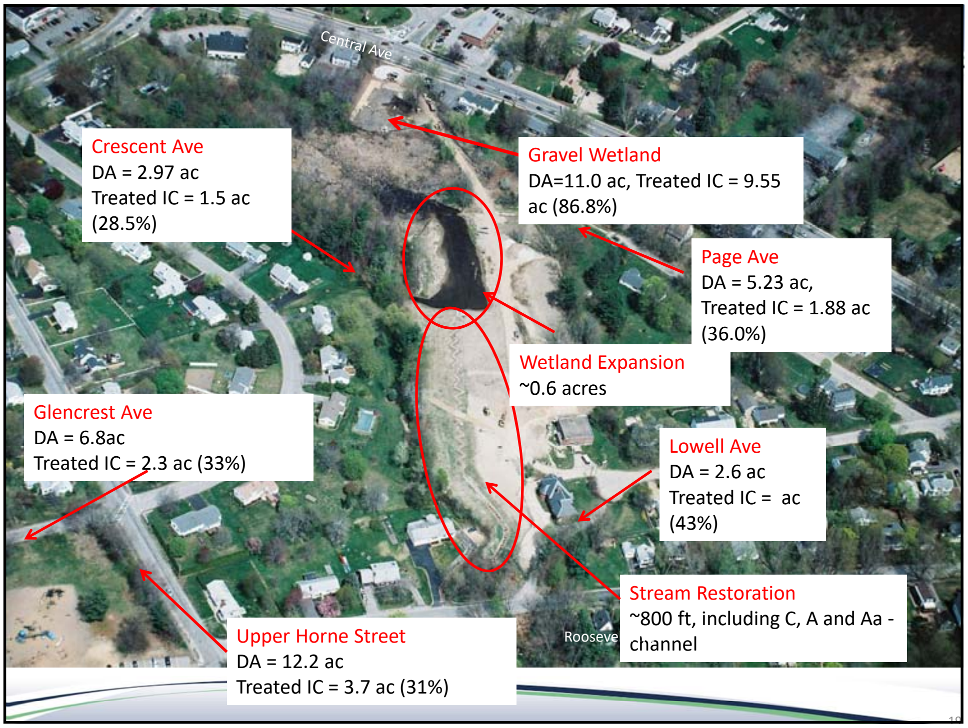


Berry Brook Watershed Overview Impervious Surfaces



Surface	Area (acres)
Total Watershed	185
Pervious	129.4
Asphalt Roads	14.3
Asphalt Driveways	12.4
Compacted Soil	1.0
Parking Lots	7.0
Rooftops	17.6
Other Asphalt	1.7
Other (decks, patios)	1.3
Impervious Total	55.3 (30%)

Source: Adapted from Mapping Impervious Surfaces in the Berry Brook Watershed Complex Systems Research Center, August, 2011



Retrofits through 2016

The Power of Infiltration

The Kristar TreePod – Tree Filter

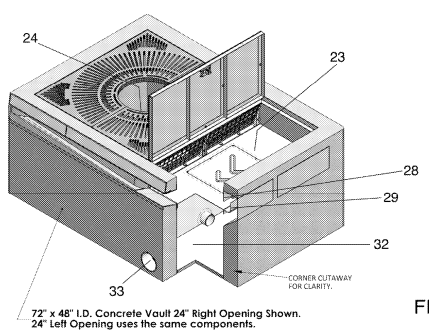
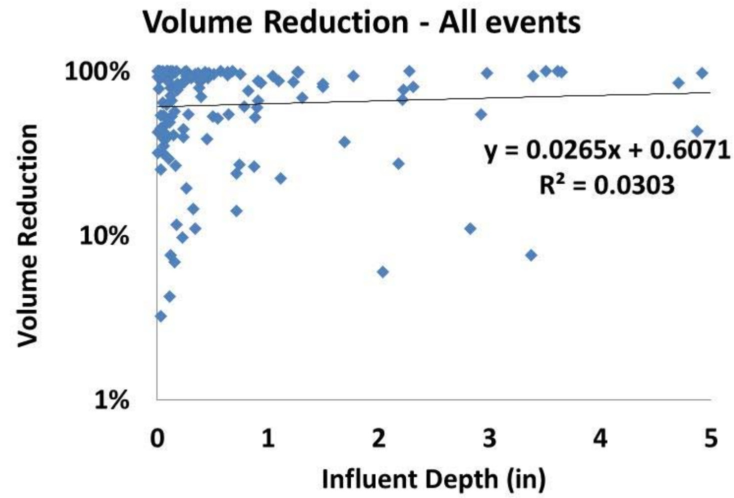


FIG. 4

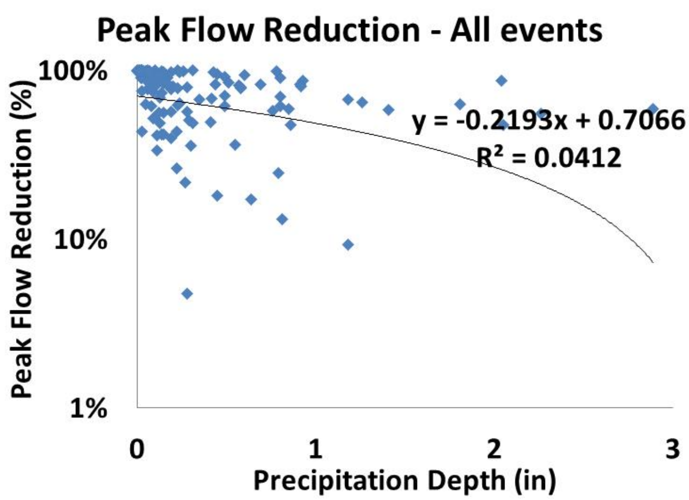
Installed System

Tree Box Watershed ~ 0.5 acre, Tc ~ 6 min

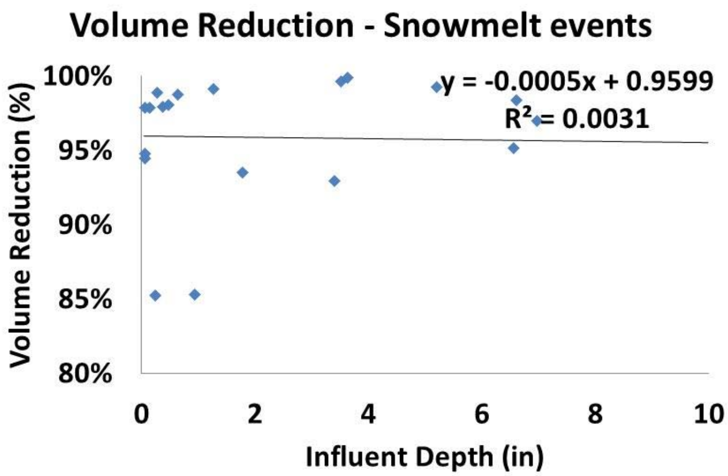
Overall Hydraulic Performance – tree box filter all data



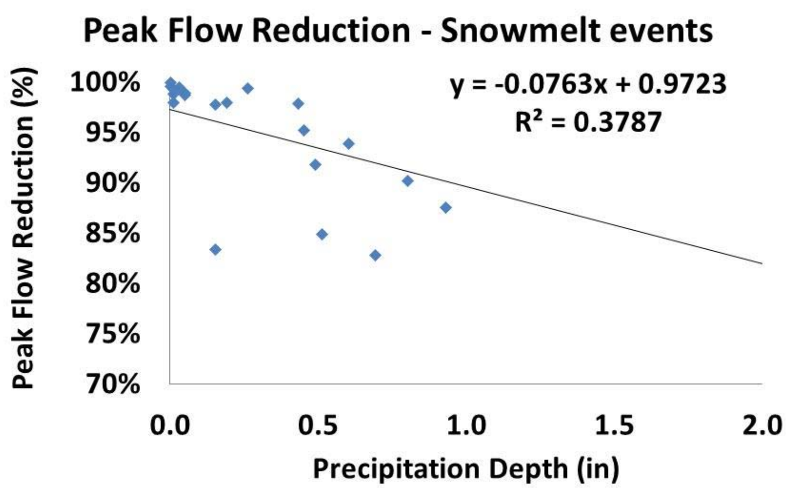
Overall Hydraulic Performance – tree box all data



Overall Hydraulic Performance – tree box filter snowmelt



Overall Hydraulic Performance – tree box filter snowmelt



Tree filter retrofit

Tie-in to Existing Storm Sewer

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Subsurface Storage and Infiltration

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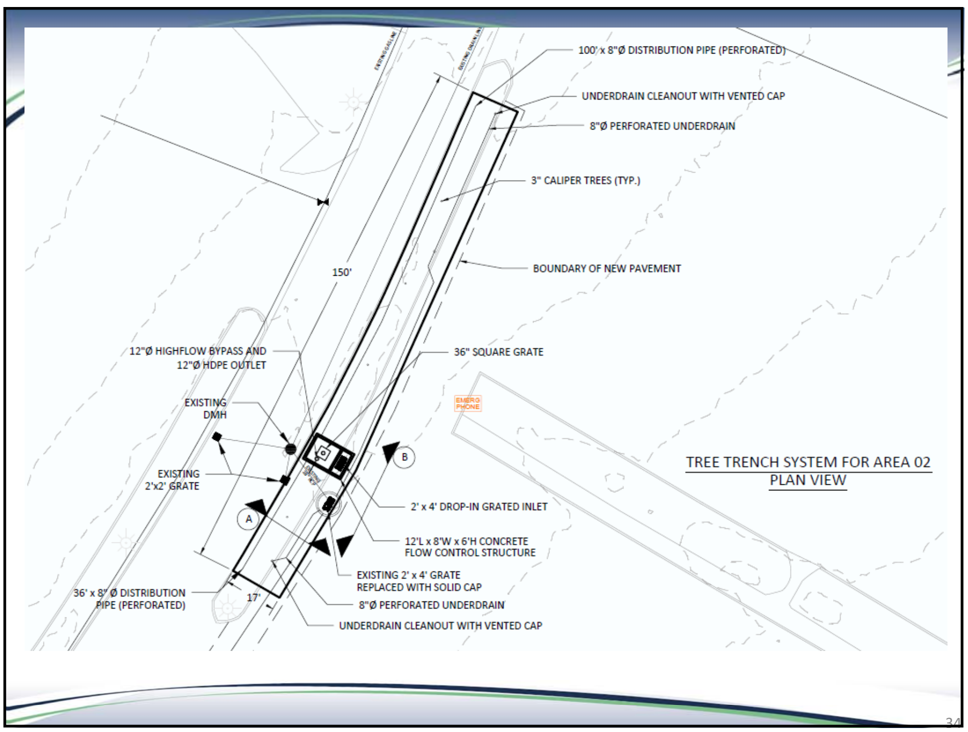
CB3
BASIN 3a:
25472 SF
0.58 AC
BASIN 3b:
78047 SF
1.79 AC
BASIN 3pro:
103519 SF
2.38 AC

33


100' x 8"Ø DISTRIBUTION PIPE (PERFORATED)
UNDERDRAIN CLEANOUT WITH VENTED CAP
8"Ø PERFORATED UNDERDRAIN
3" CALIPER TREES (TYP.)
BOUNDARY OF NEW PAVEMENT
150'
12"Ø HIGHFLOW BYPASS AND
12"Ø HDPE OUTLET
36" SQUARE GRATE
EXISTING
DMH
EMERG
PHONE
EXISTING
2'x2' GRATE
A
B
TREE TRENCH SYSTEM FOR AREA 02
PLAN VIEW
2' x 4' DROP-IN GRATED INLET
12'L x 8'W x 6'H CONCRETE
FLOW CONTROL STRUCTURE
EXISTING 2' x 4' GRATE
REPLACED WITH SOLID CAP
36' x 8" Ø DISTRIBUTION
PIPE (PERFORATED)
17'
8"Ø PERFORATED UNDERDRAIN
UNDERDRAIN CLEANOUT WITH VENTED CAP

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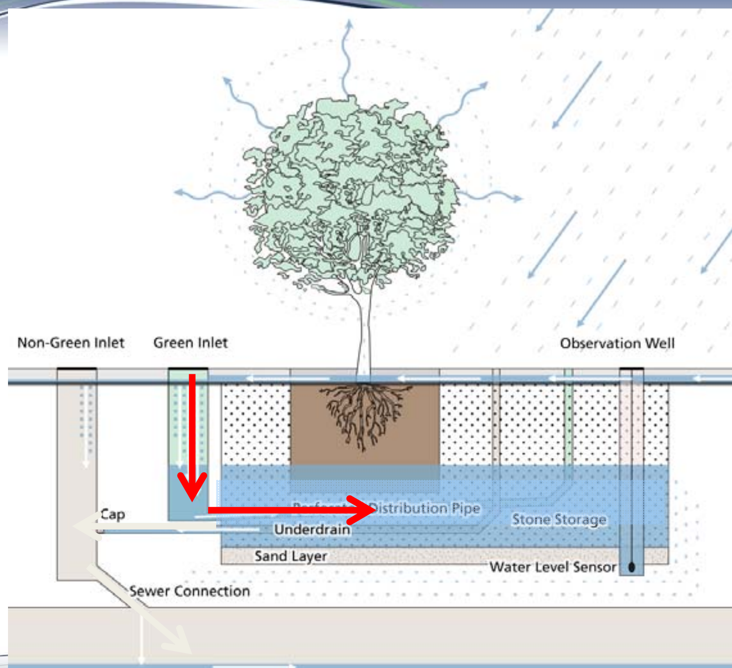

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Pre-Existing Site

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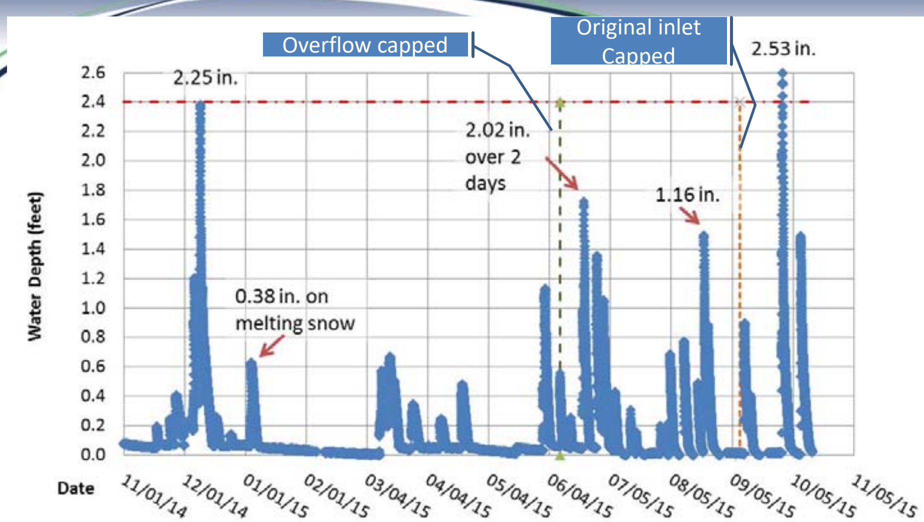
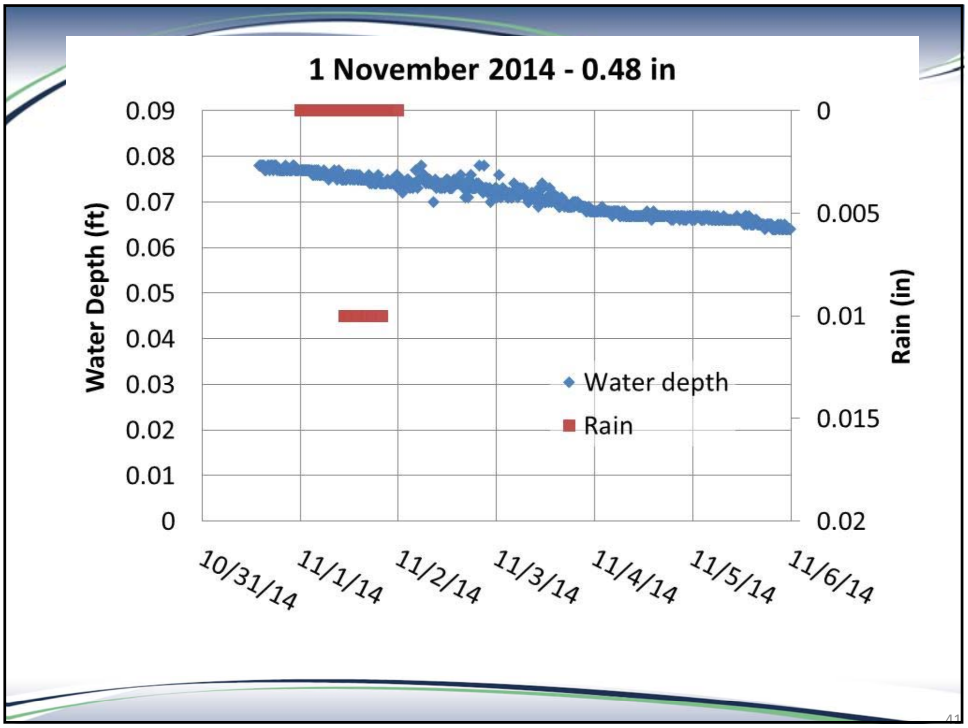
Location	Turf Tec (in/hr)	Double Ring (in/hr)
1	0.13	0.03
2	1.27	-
3	0.36	-
4	1.98	-

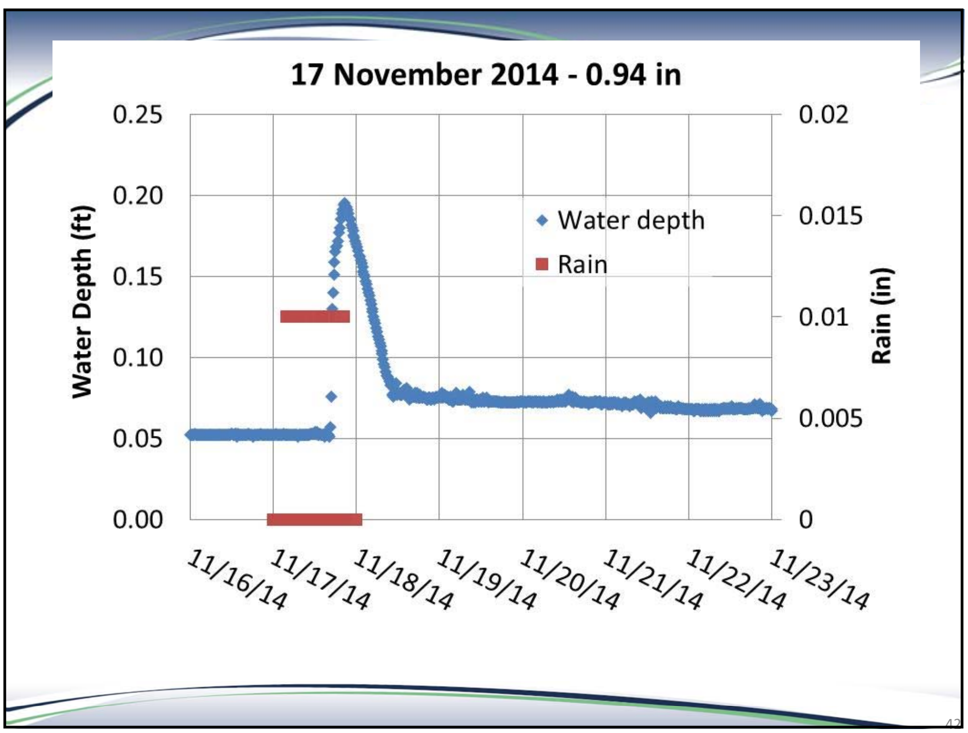
Median = 0.8 in/hr


2014/07/31

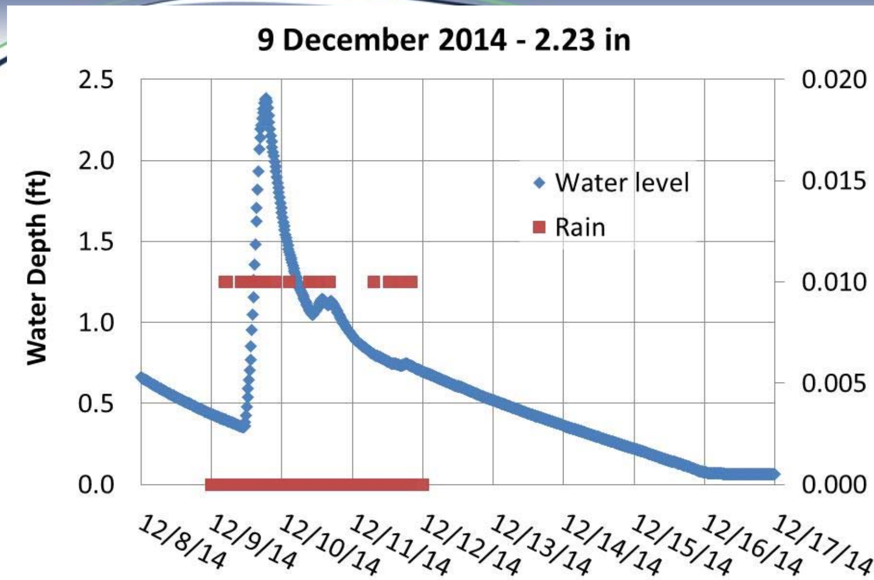

Overflow capped
Original inlet Capped
2.53 in.
2.25 in.
2.02 in. over 2 days
1.16 in.
0.38 in. on melting snow
Water Depth (feet)
Date
2.6
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
11/01/14
12/01/14
01/01/15
02/01/15
03/04/15
04/04/15
05/04/15
06/04/15
07/05/15
08/05/15
09/05/15
10/05/15
11/05/15



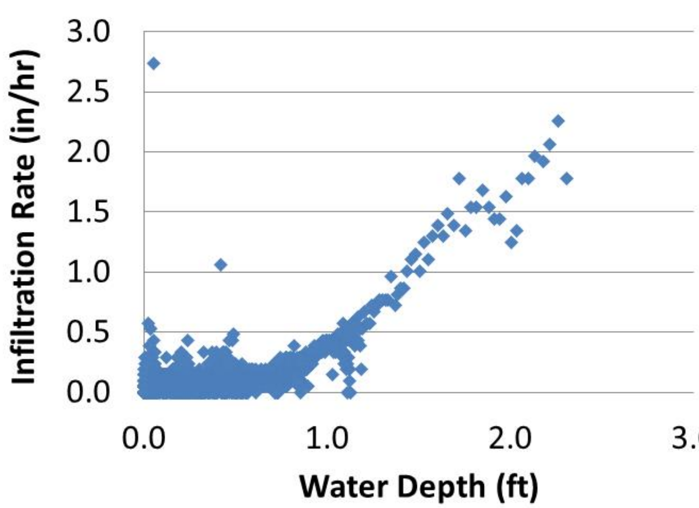
1 November 2014 - 0.48 in
Water Depth (ft)
Rain (in)
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.005
0.01
0.015
0.02
Water depth
Rain
10/31/14
11/1/14
11/2/14
11/3/14
11/4/14
11/5/14
11/6/14



17 November 2014 - 0.94 in
Water Depth (ft)
Rain (in)
0.25
0.20
0.15
0.10
0.05
0.00
0.02
0.015
0.01
0.005
0
Water depth
Rain
11/16/14
11/17/14
11/18/14
11/19/14
11/20/14
11/21/14
11/22/14
11/23/14



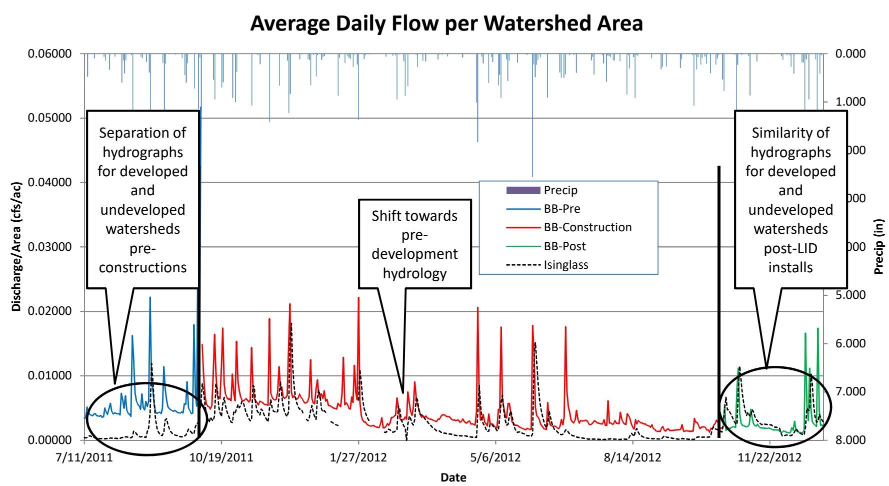
Changing Infiltration Rate



Infiltrated Volume

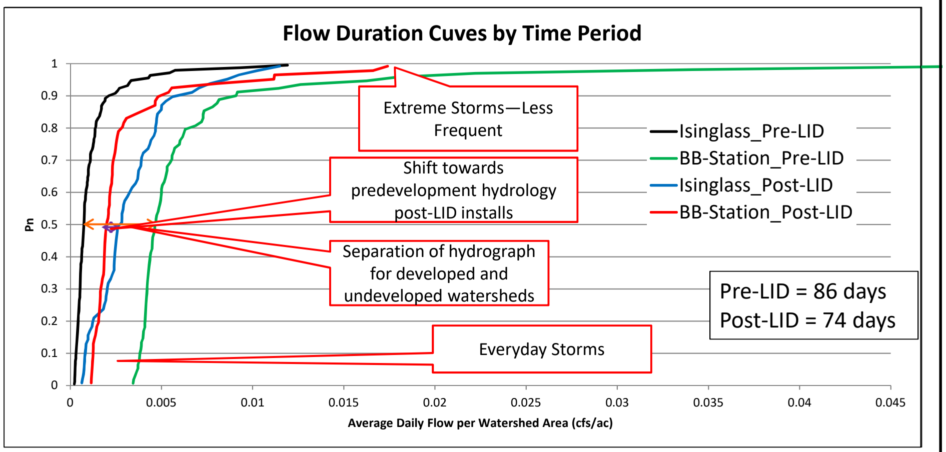
- For the 366 day period
  - 41.47 in. precip.
  - Precip. Volume = 87,300 ft^3
  - Runoff volume (C = 0.92) = 80,330 ft^3
  - Infiltrated volume = 64,583 ft^3 (estimated from water depth)
  - Volume reduction = 80% (20% lost in 2 events)

Hydrology---Benefits of LID Retrofits



Average Daily Area Weighted Flow Comparison of Berry Brook-Lower Watershed (Station, DA = 184.8 acres) and Isinglass River (DA = 73.6 sq.miles)

Low Impact Development Hydrology



Average daily area weighted flow duration curves for Berry Brook-Lower Watershed (Station, DA = 184.8 acres) and Isinglass River (DA = 73.6 sq.miles)

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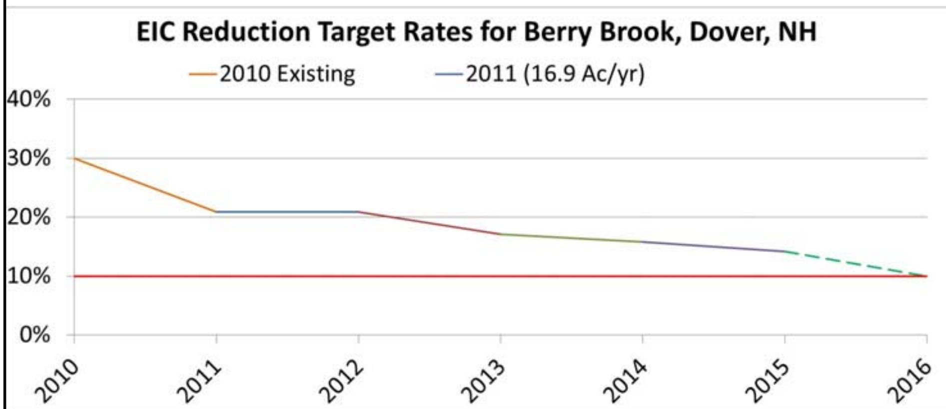
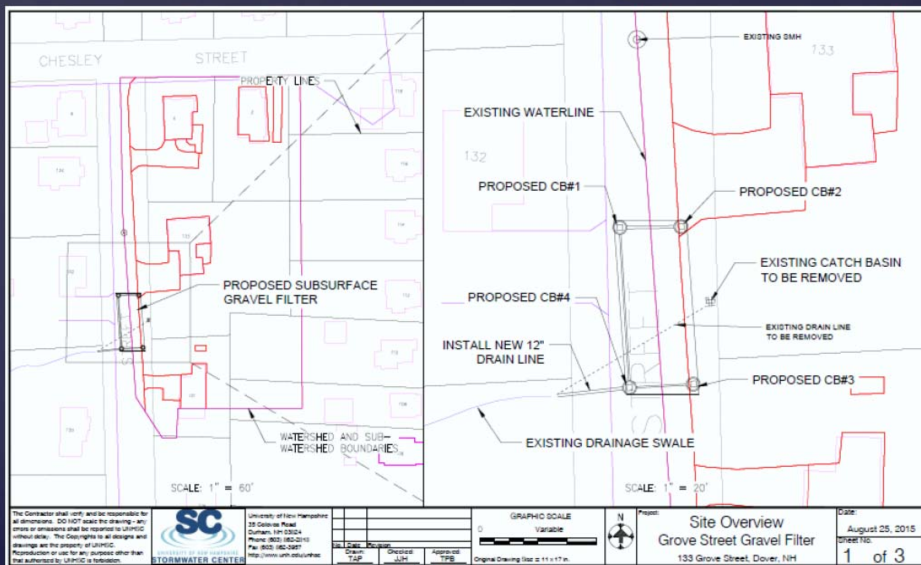
…and now for something completely different

Getting to 10%



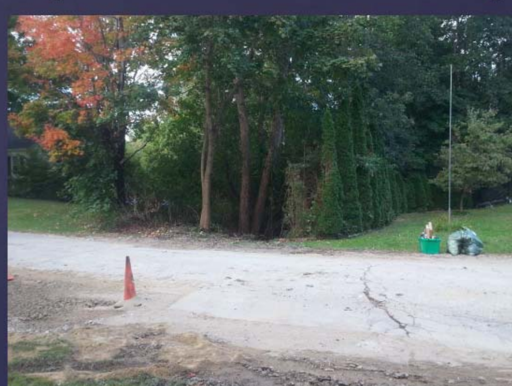
What do you do after getting at the low hanging fruit?

Grove Street Design Set



Pre-existing road

Pre-existing conditions



October 5, 2015

Excavation

Excavation 90% complete

October 7, 2015

Placement of ¾″ stone

October 7, 2015

Catch basin #4 with cores and lower pipes installed. Begin constructing outfall swale.

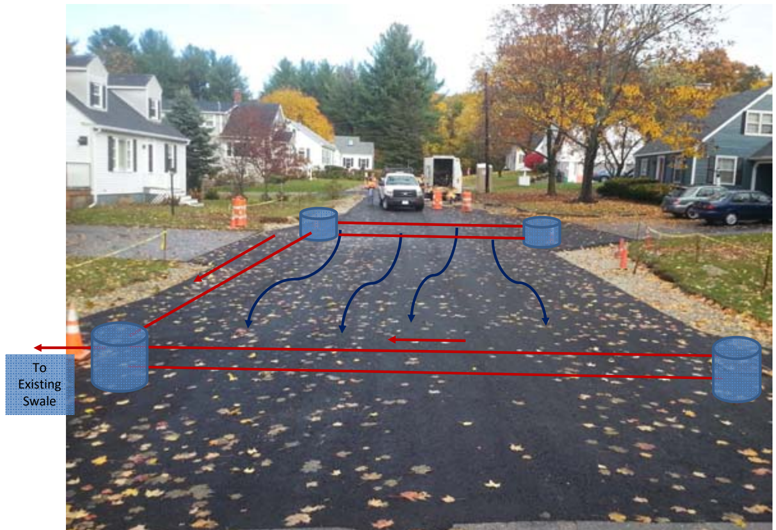
October 8, 2015

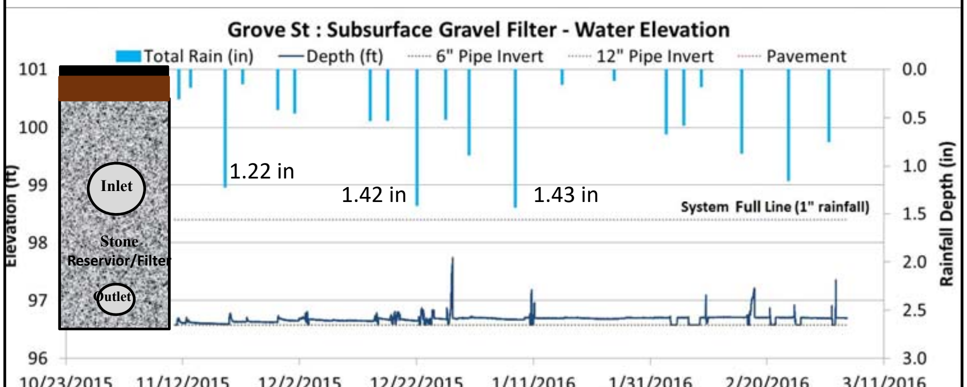
Pre-existing outfall swale

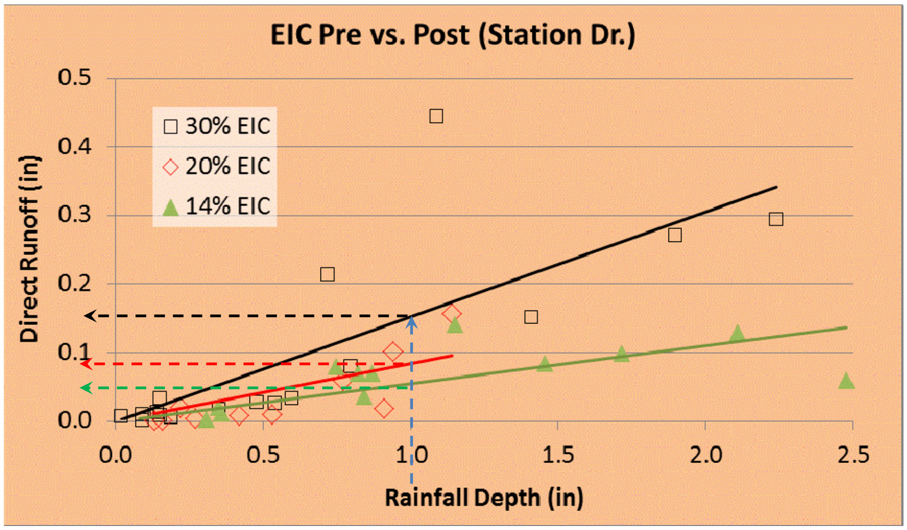
Completion of outfall swale

October 13, 2015

GI: Subsurface Gravel Filter





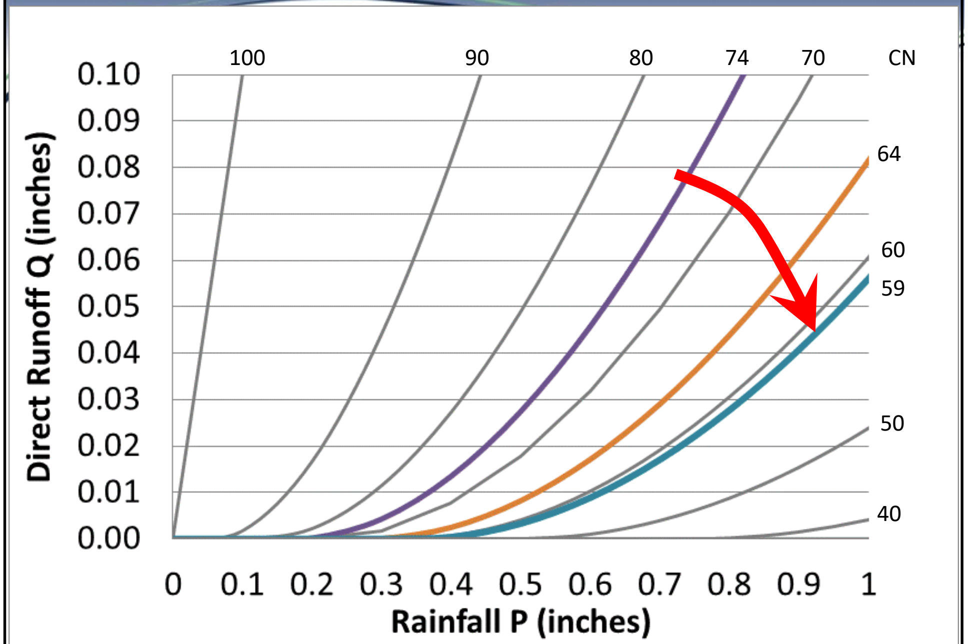


Results for Berry Brook at Station Drive

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

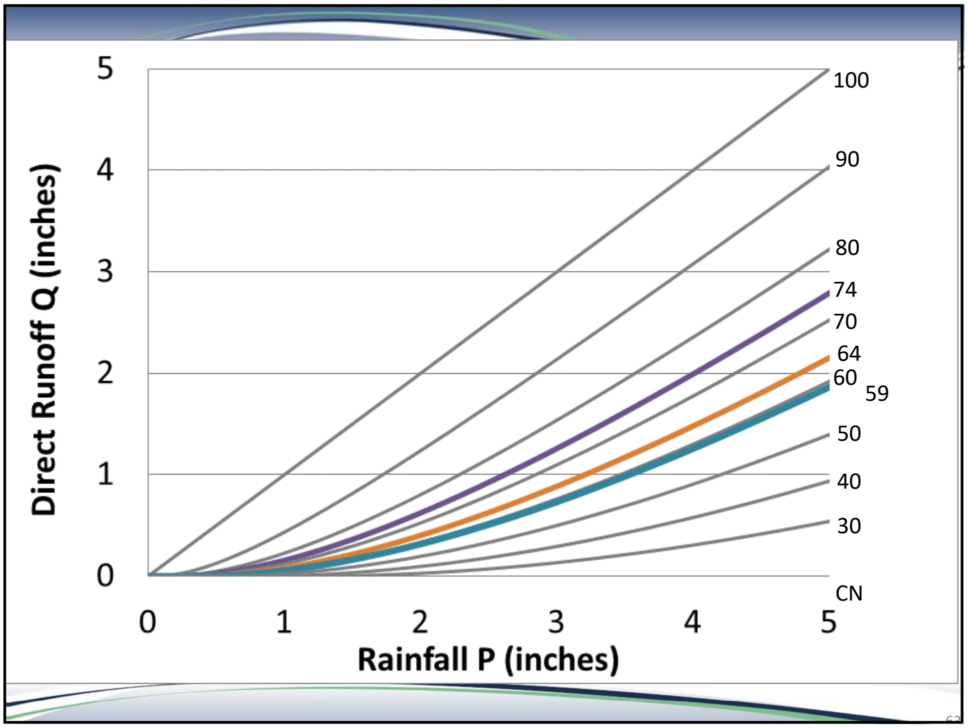
Year	% IC	P (in)	Q (in)	S (in)	CN	Q Reduction
2011	30	1.00	0.153	3.59	74	
2012	20	1.00	0.084	5.54	64	45.3%
2015	14	1.00	0.055	7.02	59	64.0%

[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".

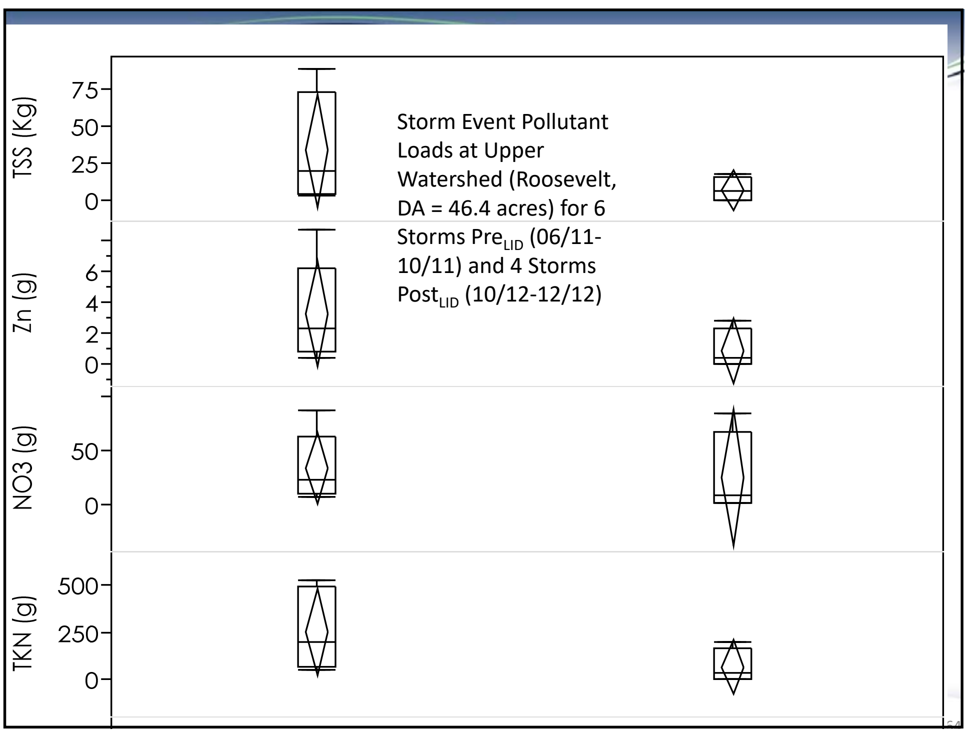


Effect of Reducing Watershed CN

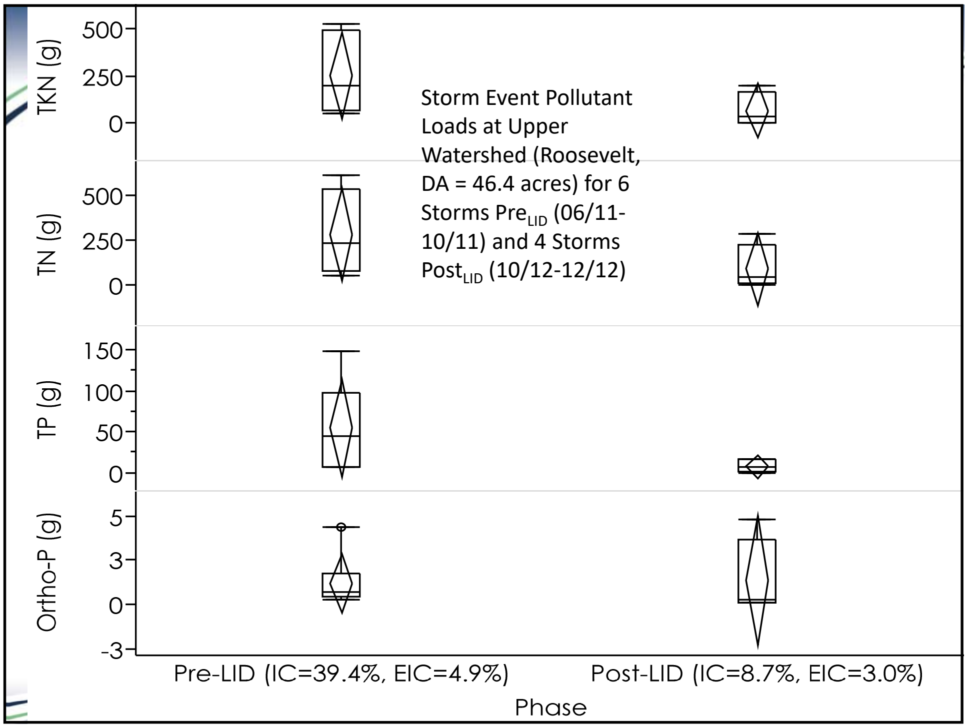
CN	Amount of Rain to Generate Runoff (in)	Pn	Pe
74	0.6	68.1%	31.9%
64	0.5	74.4%	25.6%
59	0.4	80.1%	19.9%

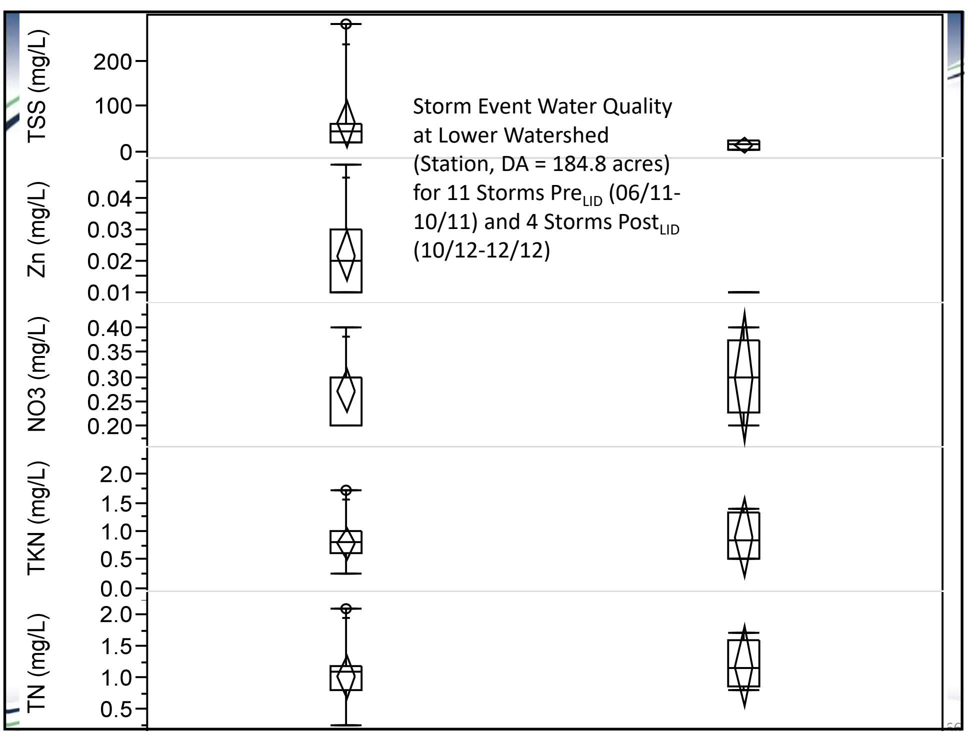


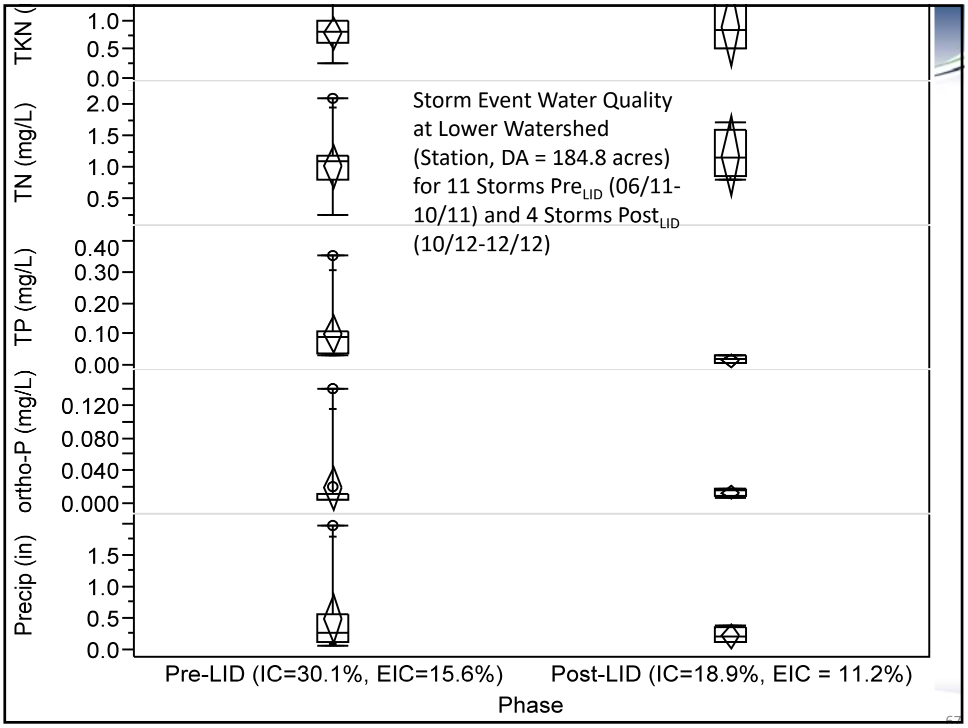
Direct Runoff Q (inches)
Rainfall P (inches)
0
1
2
3
4
5
100
90
80
74
70
64
60
59
50
40
30
CN



TSS (Kg)
Zn (g)
NO3 (g)
TKN (g)
75
50
25
0
6
4
2
0
50
0
500
250
0
Storm Event Pollutant Loads at Upper Watershed (Roosevelt, DA = 46.4 acres) for 6 Storms Pre$_{LID}$ (06/11-10/11) and 4 Storms Post$_{LID}$ (10/12-12/12)


TKN (g)
500
250
0
TN (g)
500
250
0
TP (g)
150
100
50
0
Ortho-P (g)
5
3
0
-3
Storm Event Pollutant Loads at Upper Watershed (Roosevelt, DA = 46.4 acres) for 6 Storms Pre$_{LID}$ (06/11-10/11) and 4 Storms Post$_{LID}$ (10/12-12/12)
Pre-LID (IC=39.4%, EIC=4.9%)
Post-LID (IC=8.7%, EIC=3.0%)
Phase


TSS (mg/L)
200
100
0
Zn (mg/L)
0.04
0.03
0.02
0.01
NO3 (mg/L)
0.40
0.35
0.30
0.25
0.20
TKN (mg/L)
2.0
1.5
1.0
0.5
0.0
TN (mg/L)
2.0
1.5
1.0
0.5
Storm Event Water Quality at Lower Watershed (Station, DA = 184.8 acres) for 11 Storms Pre$_{LID}$ (06/11-10/11) and 4 Storms Post$_{LID}$ (10/12-12/12)



Fish Counts Monitoring

Upper Site - Upstream of the Ash St. crossing

Hough Street

Lower - Upstream of the Sixth St crossing

Data Source: Courtesy of Ben Nugent and Matt Carpenter, NHFG (5/26/11)

Aquatic Organism Response

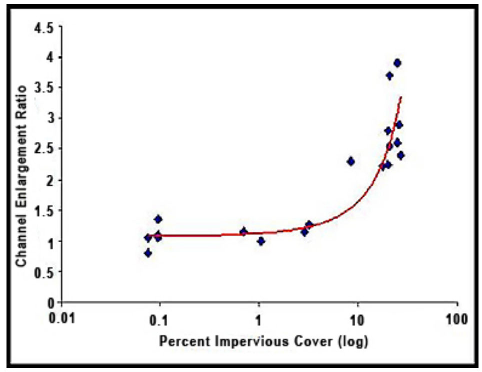
Data Source: Courtesy of Ben Nugent and Matt Carpenter, NHFG (5/26/11) and John Magee, Matt Carpenter, and Chelsea Lloyd (10/10/12)

Urbanization and Stream Reactions

- More runoff volume → bed erosion (incision)
- Faster Runoff (“Flashier”) → higher peak flow
- Higher peak flow → incision
- Incision → bank instability (widening)
- Incision → hanging infrastructure
- Incision → loss of floodplain utility
- Incision → increased sediment loads
- Incision → loss of property
- Incision → incision of tributaries

Incision

- Vertical downcutting of the stream



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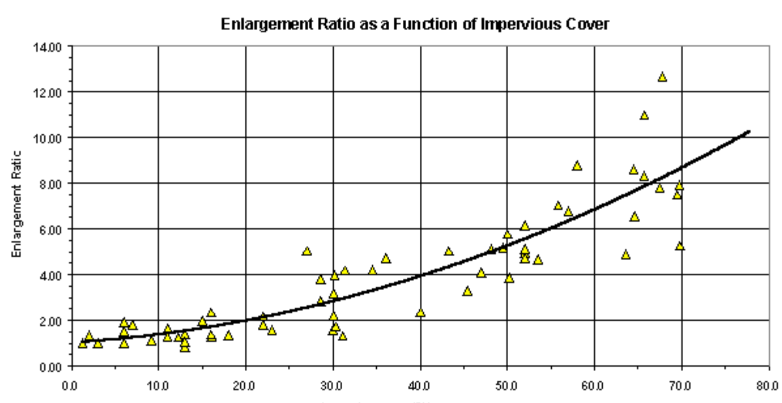
Channel Enlargement Reacts to Impervious Cover in Alluvial Streams



(MacRae and DeAndrea, 1999; Brown and Claytor, 2000)

This chart illustrates the relationship between impervious cover and stream cross section.

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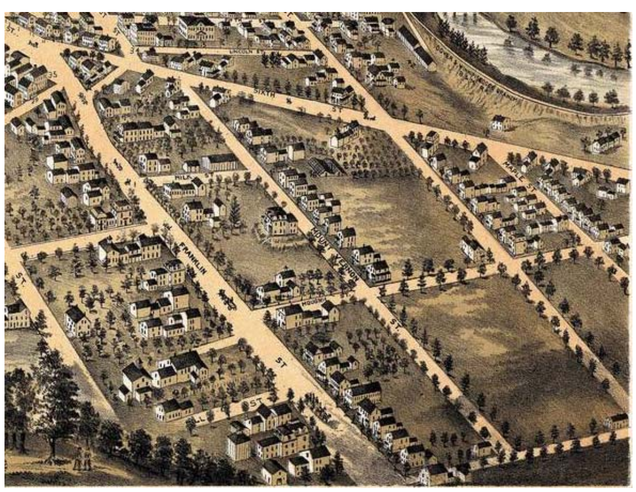
Stream Restoration Objective

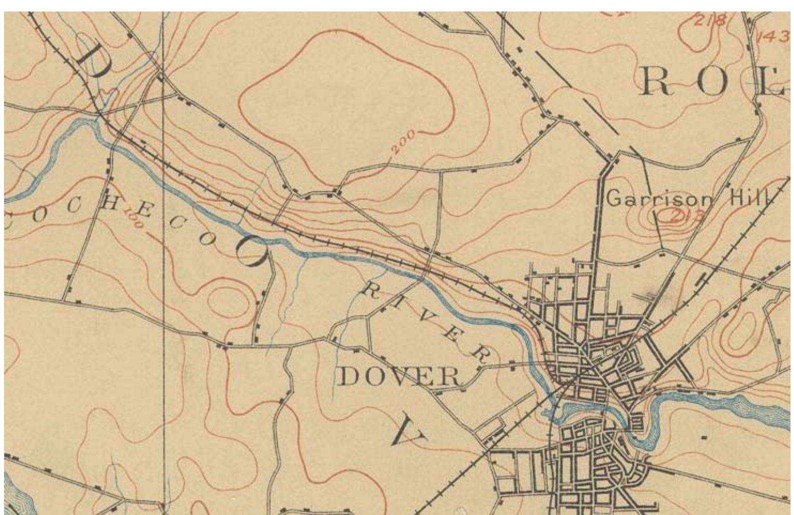
Recreate a stream last seen in the 1800’s

1877

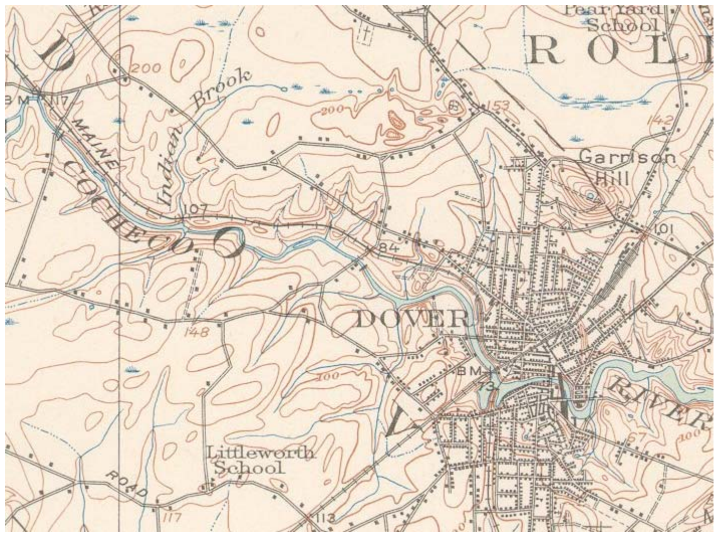


1888 Site developed into Public Infrastructure

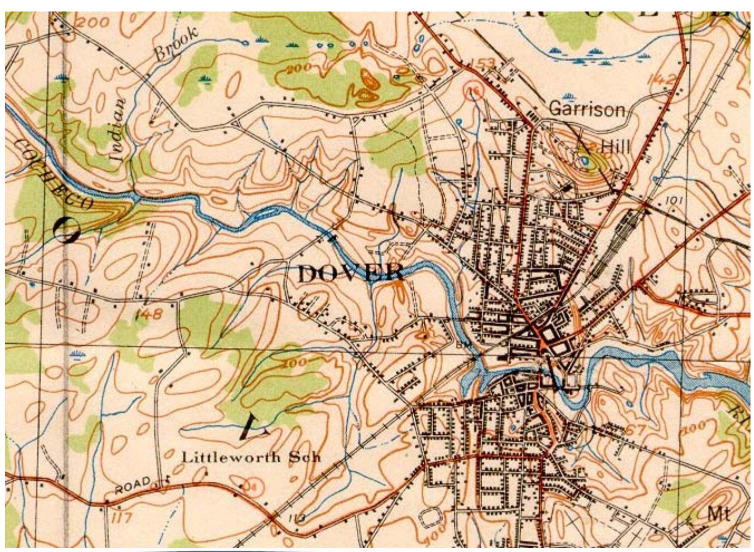
1893



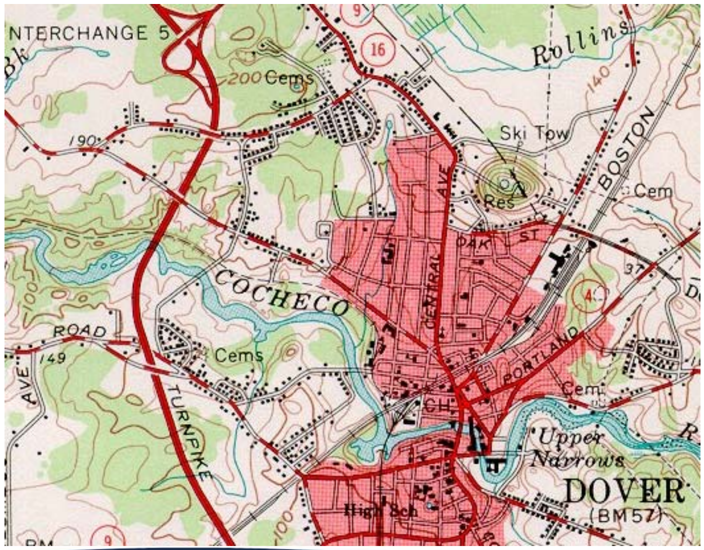
1916


Pear Yard School
R O L
Brook
Indian
MAINE
COCHECO
Garrison Hill
DOVER
RIVER
Littleworth School
ROAD
200
148
107
153
142
101
117
113

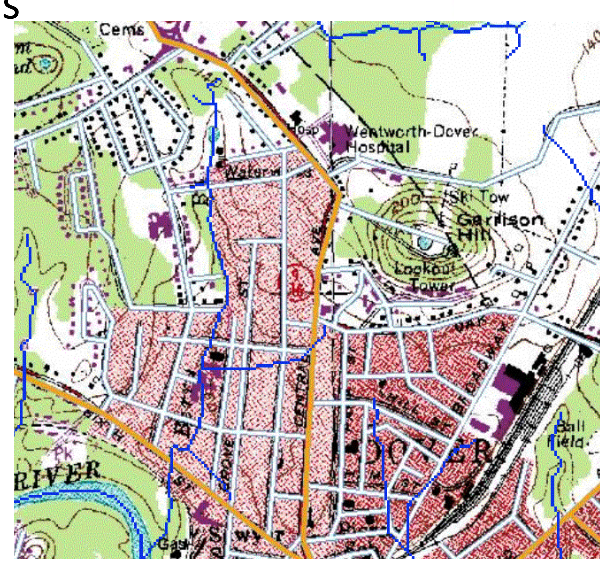
1941

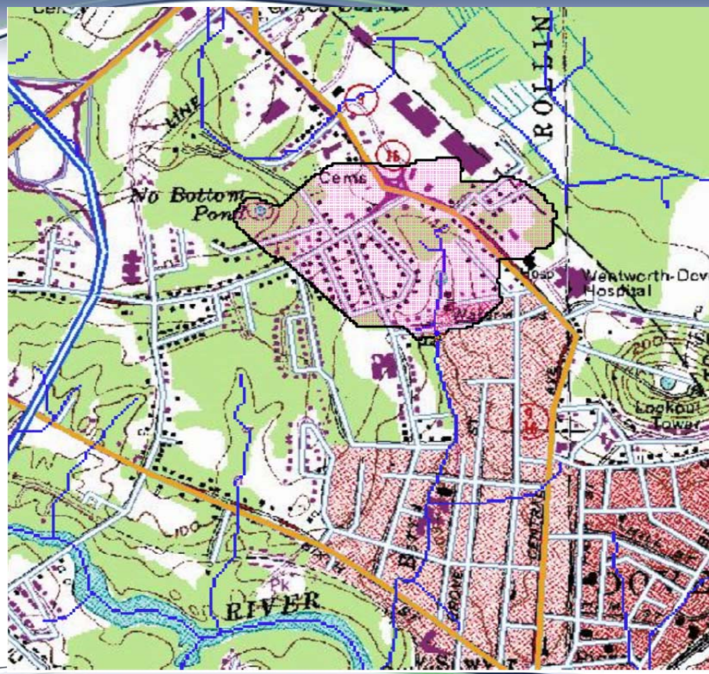

Brook
Indian
COCHECO
Garrison
Hill
DOVER
Littleworth Sch
ROAD
Mt
200
148
153
142
101
117

1956

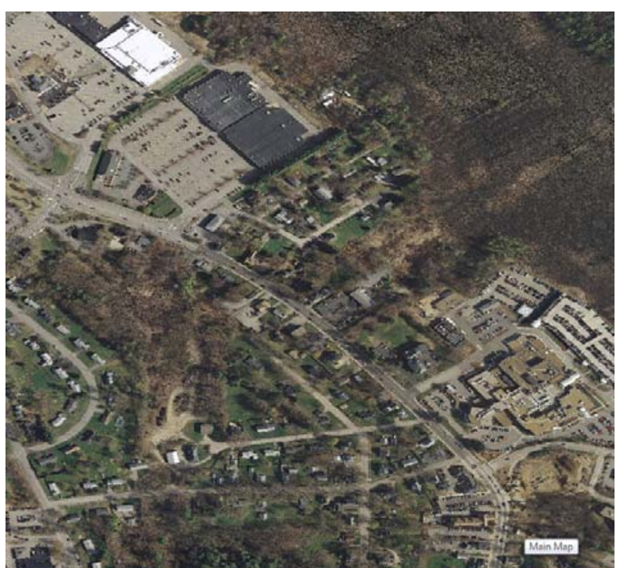

NTERCHANGE 5
Rollins
Cems
Ski Tow
BOSTON
Cem
Res
CENTRAL
AVE
OAK ST
COCHECO
ROAD
Cems
PORTLAND
Cem
TURNPIKE
Upper Narrows
DOVER
(BM57)
High Sch

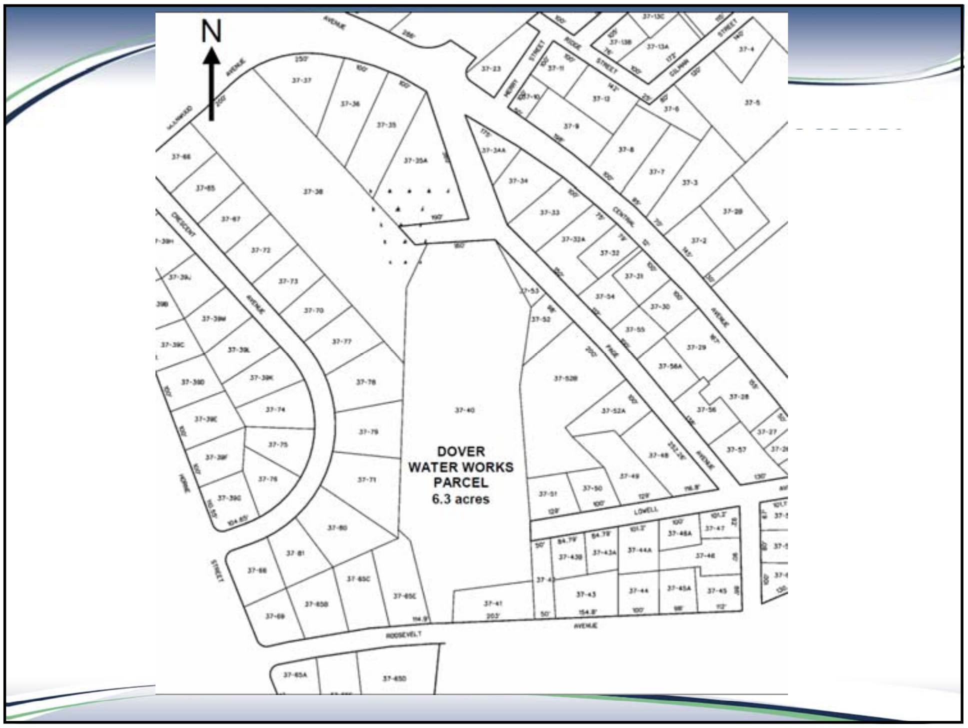
1990's

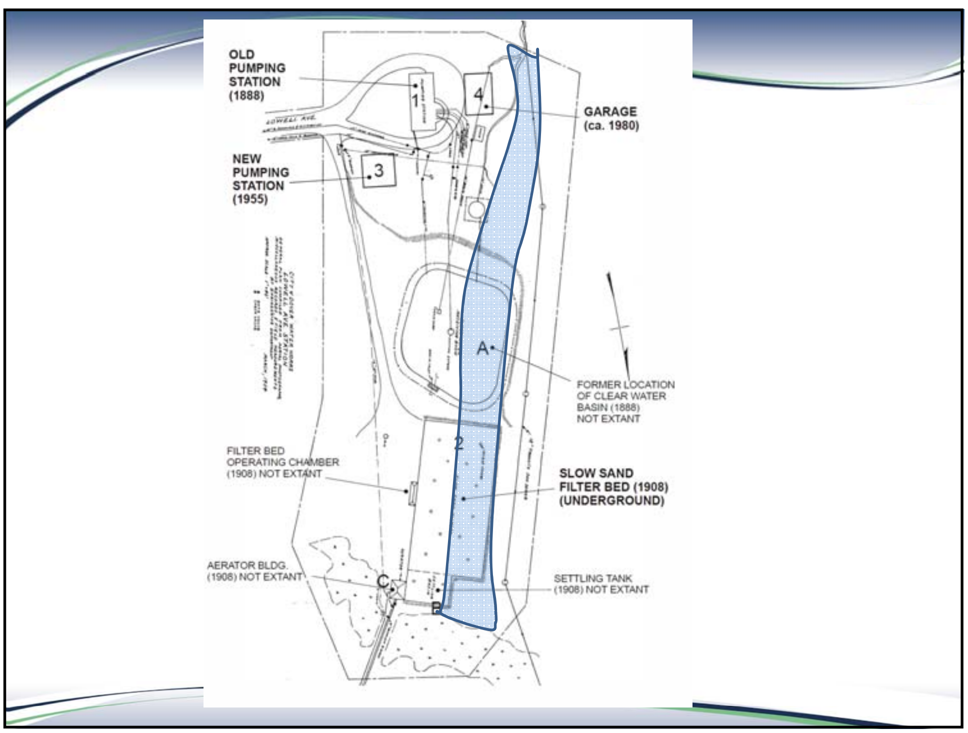

Cems
Wentworth-Dover Hospital
Ski Tow
Garrison Hill
Lookout Tower
RIVER
Ball Field


No Bottom Pond
Cems
ROLLIN
Wentworth-Dove
Hospital
Lookout
Tower
RIVER

2010


Main Map


N
DOVER
WATER WORKS
PARCEL
6.3 acres

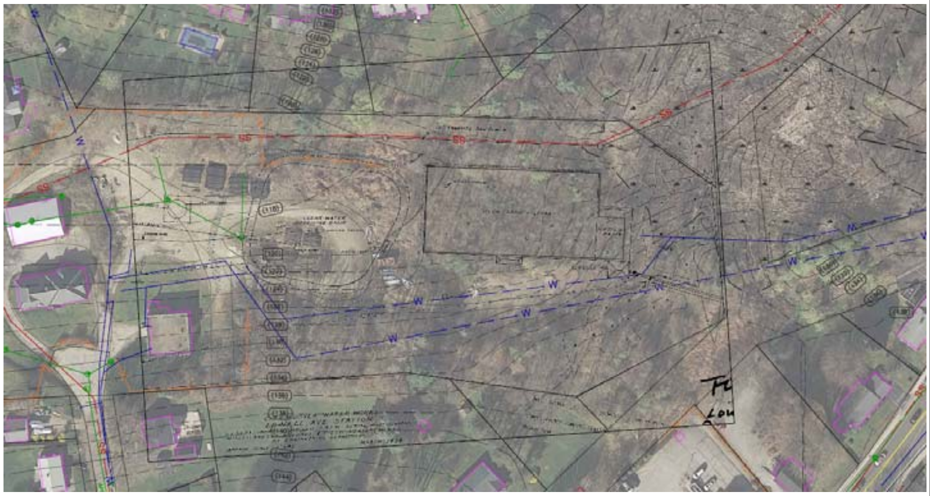

OLD
PUMPING
STATION
(1888)
GARAGE
(ca. 1980)
NEW
PUMPING
STATION
(1955)
FORMER LOCATION
OF CLEAR WATER
BASIN (1888)
NOT EXTANT
FILTER BED
OPERATING CHAMBER
(1908) NOT EXTANT
SLOW SAND
FILTER BED (1908)
(UNDERGROUND)
AERATOR BLDG.
(1908) NOT EXTANT
SETTLING TANK
(1908) NOT EXTANT

Stream Headwaters

Wetland Outflow to Buried Pipe

Wetlands Followed by Storage Yard

Most of Upper Site Water Plant



Slow Sand Filter

Inside Slow Sand Filter

Buried Finished Water Storage Reservoir

Slope Transition

Steep Section at End

Connect to Existing Headwater

Materials Storage

Existing Infrastructure Controls on Grade

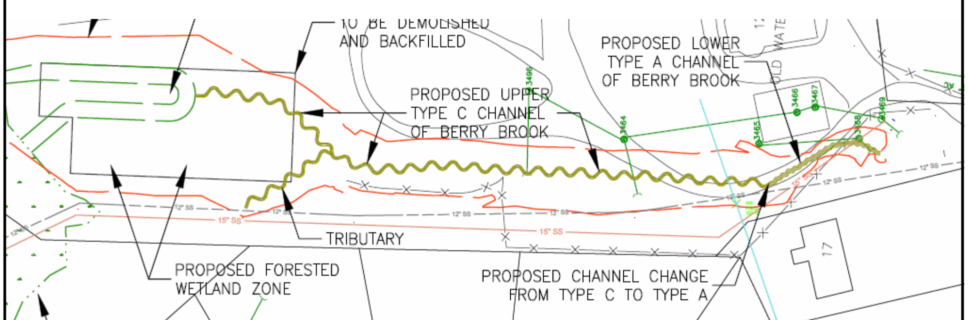
Accommodating Constraints

Demolition

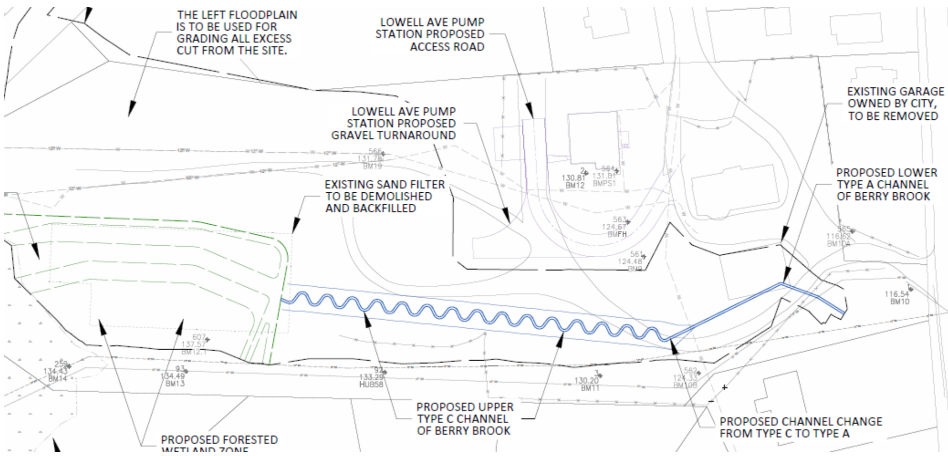
Design

- Hydrology – StreamStats
- Geomorphology – Regional Curves
- Hydraulics – HEC-RAS
- Incipient Motion – Shields, LWM
- Sediment Transport – MPM, EB
- Stream Design – Regional equations (Johnson)

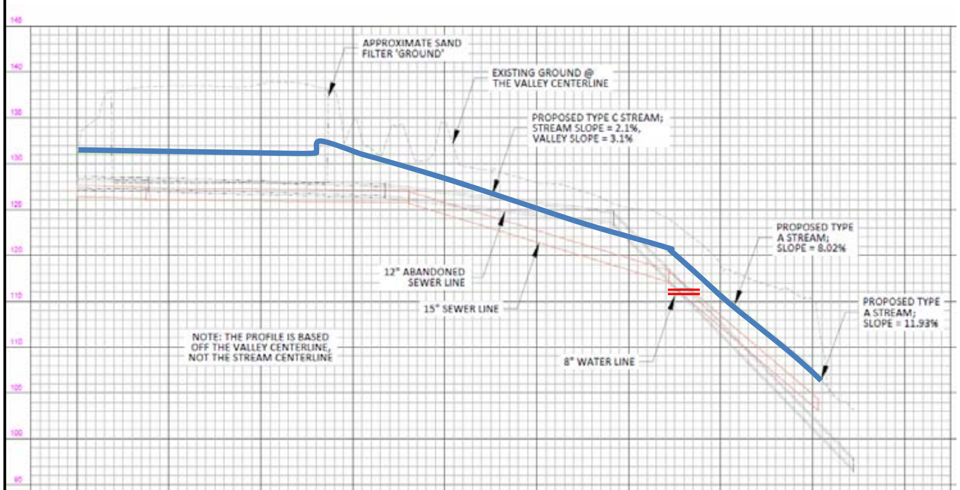
Initial Design



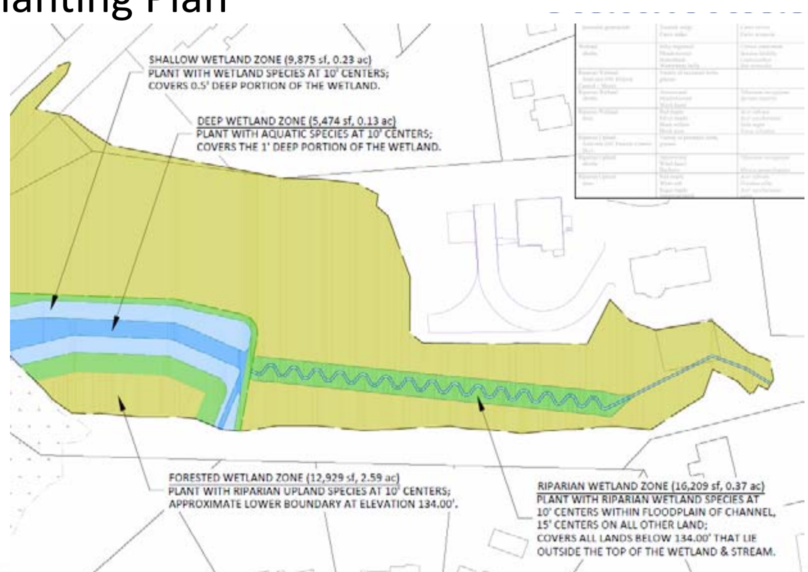
Expanded Wetlands, Shrinking Stream



Design Profile



Planting Plan



OVERVIEW OF PHOTO POINTS

29 April 2011 BM10-N

21 March 2012 BM10-N

29 April 2011 BM10B-S

21 March 2012 BM10B-S

29 April 2011 BM10B-E

21 March 2012 BM10B-E

29 April 2011 BM10B-N

21 March 2012 BM10B-N

29 April 2011 BM17-SW

21 March 2012 BM17-SW

18 August 2011 NEWetland-S

21 March 2012 NEWetland-S

29 April 2011 Pile-NNW

21 March 2012 Pile-NNW

29 April 2011 Pile-NW

21 March 2012 Pile-NW


29 April 2011
Pile-W


21 March 2012
Pile-W

29 April 2011 Pile-SW

21 March 2012 Pile-SW

Construct Aa Step-Pools

Wetland Outlet Structure

At-Grade Stream Crossing

Transition From Mild to Steep Slope


2013/06/09

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Questions?

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