Evolving Research for Stormwater Management
James Houle, UNH Stormwater Center
Providing Data to Protect Water Quality Since 2004
Hydrodynamic Separator
Isolator Row
Subsurface Infiltration
Filter Unit
Porous Asphalt
Pervious Concrete
Retention Pond
Stone Swale
Veg Swale
Gravel Wetland
Sand Filter
Bioretention Unit
Tree Filter
Common Pollutant RE’s
31 Communities and organizations served in 16 states and countries

40 Stormwater treatment systems tested

2,686 Students educated

3,680 Professionals trained

42 Bodies of water protected
Decadal Reflections: Cart Before the Horse

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.
Cuyahoga inlet to Lake Erie circa 1920
• Cuyahoga caught fire at least 13 times!
• First, 1868 – Last, 1969
• 5 deaths 1912
• Largest was in 1952

Cuyahoga River Fire Nov. 3, 1952. Courtesy of Cleveland Press Collection at Cleveland State University Library.
June 22, 1969: Umm, the Cuyahoga River’s on Fire ... Again
Modern Day Equivalent: Priorities and Water Quality
NPS is Part of the Problem and managing it is part of the solution

90%
Impact of Impervious Cover

Adapted from Schueler
Water Cycle

TYPICAL ANNUAL WATER BUDGET: DEVELOPED WATERSHED

- Precipitation
- Evapo-Transpiration (25%)
- Surface Runoff (43%)
- Groundwater (32%)
ACTON WAKEFIELD WATERSHED ALLIANCE
Buildout Buildings
2054
Full Buildout

Legend
- Full Buildout (2,922)
- Existing Buildings (1,317)

Towns
Watershed Boundaries
Lakes & Ponds
Streams
Watershed Roads

Total Buildings = 4,239
Yes, climate change gives us pause to think, but IC is the 800-pound gorilla.
If we know what the problem is...
...and science informs us what we can do...
...Then how are we doing on implementation?
Conceptual Model Factors Influencing Adoption

- Events
- Education
- Drivers
- Regulations
- Municipal Context
- Social Support
- Timing
- Tech Support
- Public Participation
- Municipal Character
- Size/Proximity
- Leadership/Mgmt Approach

ADOPION
Technical

Systems failed 2/3 of the time!

- 34% Of the time systems offered some kind of treatment
- 26% Of the time systems did nothing
- 40% Of the time systems exported more pollutants
Conventional Stormwater Management

- Retention/Detention---flood control
- Conveyance---swales, catch basins, gutters
- No recharge or water quality components
Conventional System Design
Shortcomings of Traditional Stormwater Management

1. Inadequate pollutant removal
2. Inadequate cooling
3. Inadequate stream channel protection
4. Lack of maintenance
5. Ready-fire-aim
Low Impact Development

Modeling designs after natural systems
Low Impact Development

LID is an approach to land development (or re-development) that works with nature to manage stormwater as close to its source as possible. LID employs principles such as preserving and recreating natural landscape features, minimizing effective imperviousness to create functional and appealing site drainage that treat stormwater as a resource rather than a waste product.

Goal:  **HYDROLOGIC TRANSPARENCY FOR DEVELOPMENT**
How Do They Really Work?
43 in rainfall event in 3 minutes!
LID Designs

- Infiltration
- Sand filters
- Bioretention
- Tree Filter
- Subsurface Gravel Wetland
- Pervious Pavements
- Ecoroof
School Street School, Rochester NH
Durham innovative bioretention system, Durham, NH.
“Bioretention Design”

- 381,000 results
Terminology

• Bioretention – Holds WQV. Typically has underdrain, high flow bypass, and hydraulic design

• Rain garden – Holds WQV or less. Commonly for very small watersheds (residential), often do not have an underdrain

• Tree filter – Very little storage. Urban installations include high rate media designed on WQF. For Very small drainage areas, underdrain to storm sewer
System Design

• Above-ground volume
• Inlet
• Layers
  – Media
  – thicknesses
• Surface area
  – Dynamic sizing
• Hydraulic structures
  – Media hydraulic conductivity
  – Secondary
  – Emergency/flood
Bioretention Soil Mix – Many Variations

• Sand: 50-85%
• Wood chips/shredded wood: 20%
• Compost: 10 – 20%  \{no compost due to P issue\}
• Soil: 10-30%

• Preferably fines less than 5% (some specs still want 8 – 12%)  UNHSC prefers <2%
• 5.5 < pH < 6.5
• Phosphorus index  10-30
• CEC > 10
UNHSC Bio Mix

- 50% Sand,
- 30% loam
- 20% wood chips

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Soil Mix Amendments

- Zero Valent Iron
- Alum sludge
- Limestone sand
- Slag
- Expanded Shale
- Zeolite
- Proprietary
Column Study of Nutrient Removal

• Amendments for Phosphorus
  – Alum sludge
  – Zero valent iron
  – Limestone sand
  – Electric blast furnace slag
• Internal storage volume for nitrogen
• Effect of compost
Phosphorus Results

Phase 2 - Phosphorus as PO4-P

PO4 (µg/l)

Control  5% WTR  10% WTR  3% Fe  6% Fe  3% Slag  5% Slag  5% Limestone  10% Limestone  Influent
Optimization Results

Phase 4 - Phosphorus as PO4-P

PO4 (µg/l)

90% loam + 10% sand
75% loam + 25% sand
60% loam + 40% sand
45% loam + 55% sand
30% loam + 70% sand
15% loam + 85% sand
100% sand
0.5% Fe2 + 99.5% UNHSC
2% WTR + 98% UNHSC
Influent
Internal Storage Volume

• Promotes denitrification
  – May need liner at base in high K soils
  – > 1 ft thickness
  – Need to create plug flow through ISV
  – The longer the residence time, the better
    • > 1/3 of WQV
    • > 12 hours
Nitrogen Results

DIN (mg/l)
Media Thickness

• Depends on plant root depths:
  – 12 in. for grasses, forbs
  – 18 – 24 in. for shrubs (NHDES min 18”
  – > 30 in. for trees

Do not want roots to clog stone layer and drain pipe below the soil
Vegetation

• Native plants always the best
• Cooperative Extension, USDA, NRCS good sources

• Forest
• Meadow
• Transition
• Ornamental
Plants

• There is little consensus and data WRT bioretention system plantings.
• Most manuals are out of step and out of date
• Planting decisions should be based on owner perceptions of O&M
NDP
Comparison of Pollutant Removal Efficiency
Planted vs Grassed Bioretention

- **TSS**: 90% for Planted Bio, 100% for Grassed Bio
- **TP**: 10% for Planted Bio, 20% for Grassed Bio
- **DIN**: 40% for Planted Bio, 60% for Grassed Bio
- **TN**: 40% for Planted Bio, 60% for Grassed Bio
Grassed vs Planted Surface IR

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

Infiltration Rate (in/hr)

Grassed Bioretention  Plant Bioretention
Some Pitfalls of Including Habitat in BMP Designs. Any Questions?
Outstanding Civil Engineering Achievement Award, 2010

American Society of Civil Engineers, NH Section

Transformation of State Street, Portsmouth, NH.

Complete reconstruction of utilities, including wastewater/stormwater separation and stormwater treatment, with construction of pedestrian- and business-friendly streetscape.
What is the impact seven years later?

<table>
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<th>Drainage Area</th>
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<td>1.8</td>
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Maintenance Basics

GI Vs Conv St Drainage Outfall Monitoring

Concentration (mg/l)

- TSS: GI Street (green), Conv Street (blue)
- TN: GI Street (green), Conv Street (blue)
- TP: GI Street (green), Conv Street (blue)
Regulatory

Number of impaired waterways by state

EPA Water Quality Assessment, National Summary
Regulatory – up-to-date code
Population Growth & Quality Problem

Last 20 years
- Population Growth, 19%
- Impervious Cover, 120%

Next 30 years
- Population Growth, 26%

From 1990 to 2010 (Source: US Census; UNH earth systems research center; PREP; 2010-2040 Projections, UNHSC)
Projected Future IC Area by 2040

- **TOTALS**: 520 acres
- **NOTTINGHAM**: 6 acres
- **MADBURY**: 24 acres
- **LEE**: 28 acres
- **UNH**: 99 acres
- **DURHAM**: 262 acres
- **DOVER**: 52 acres
- **BARRINGTON**: 39 acres

Projected Increase in IC Area (acres)
Assumes Oyster River Watershed Ratios are consistent throughout the GB
GB Community SW Standards Adoption

- **Adopted**
- **Pending**
- **Partial**
- **Outdated**
- **Total**

Map showing the distribution of standards adoption across different areas.
Potential Reduction Credits

Pollutant Load Reduction Credit per permit term (5 yrs)

% Reduction of Total Existing Load

- TSS
- TP
- TN

14.18 tons/yr =
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**System TSS TN TP**

**Conv. Bioretention Average (4)** 91% 36% 34%

**Durham Bioretention (23% IBSC)** 81% 27% 45%

**Conv. Subsurface Gravel Wetland** 96% 54% 58%

**Subsurface Gravel Wetland (10% SGWSC)** 75% 23% 53%
physical storage capacity - runoff depth from IA (in)

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Social

Conceptual Model Factors Influencing Adoption
Diffusion of Innovation

- Diffusion of innovation is the process by which an innovation is communicated through certain channels over time among the members of a social system (Rogers, 2003)
Results from Ryan and Gross on farmer adoption patterns of hybrid corn.

Source: Ryan & Gross (1943), “The Diffusion of Hybrid Seed Corn in Two Iowa Communities,” Rural Sociology 8 (March): 15.
Gartner-Hype – how disruptive technologies adapt over time

- Peak of Inflated Expectations
- Plateau of Productivity
- Slope of Enlightenment
- Trough of Disillusionment

Gartner Hype Cycle vs. Time
Innovation Decision Process

Knowledge → Persuasion → Decision → Implementation → Confirmation

Ability to reinvent to reflect local needs and foster ownership
It is not only about water quality!

$$$$$$$$$$$$$$$$$$$$$$
Priorities and Water Quality
Advocates Fear Scott Administration Is Weakening Landmark Water Quality Law

By PETER HIRSCHFELD • JAN 17, 2018

The Vermont Clean Water Act will hold more than 1,000 properties across the state to stricter stormwater standards, but environmental advocates say the Scott administration is trying to undermine some key provisions.
“The study really revealed that the penalty for so-called under-sizing a system was not as great as we believed it would be,” Houle says. “It means that there’s a lot of benefit for doing what you can where you can how you can.”

So does that mean Vermont can get away with holding legacy sites to a lower volume standard? Here’s how Houle answers that question:

“Managing stormwater is relatively recent science, and the way I look at it is, we can benefit from implementation, whatever that implementation is,” Houle says. “I would be less likely to promote one sizing criteria over another, and more likely to say, ‘We have a major problem that we’ve swept under the rug for decades, and it’s time that we start to implement. And however you want to get to implementation, I think I’m fine with for now.”
Dover, NH

- 2,800 catch basins
- 65 miles of pipe
- 200 outfalls
Questions???