Green Infrastructure and Flood Resiliency-Land Use Management as an Adaptation Strategy in the Built Environment:
Exeter Resilience Project

2018 Local Solutions: Eastern Climate Preparedness Conference
May 2, 2018
OVERVIEW

✓ Innovative Communication Methods
✓ Climate Adaptation Policy
✓ Resilient Stormwater Management
1. New Hampshire coastal communities have experienced rising populations resulting in an increase in impervious surfaces, stormwater runoff, and associated flooding.
2. At the same time, communities are faced with a changing climate including extreme rainfall events and sea-level rise.
3. Green infrastructure is an important form of climate adaptation which can improve water quality and avoid stormwater related flood damages.
4. The Exeter Resilience project conducted a cost impact analysis to evaluate the potential for flood damage avoidance with implementation of green infrastructure.
5. The use of green infrastructure supports other economic and quality of life benefits such as creation of attractive public spaces, and landscaping that supports walkable communities.
REGIONAL CONTEXT

• In 2009, NHDES concluded that many sub-estuaries in the Great Bay Estuary were impaired by nitrogen, and the Great Bay was placed on the Clean Water Act (CWA) Sec. 303(d) list of impaired and threatened waters (NHDES, 2009).

• New and revised discharge permits in the watershed are now subject to additional nitrogen requirements including the National Pollutant Discharge Elimination System (NPDES) permits for wastewater treatment facilities, and Municipal Separate Storm Sewer Discharge (MS4) permits for stormwater.

• 2017 NH Small MS4 issued, effective in 2018, includes significant new elements such as a focus on illicit discharge detection and elimination, and nutrient management through BMP retrofits.
Innovative Communications
Climate Change – Adaptation - Resilience

Ensuring a Successful Initiative

What is unique about the watershed or area of interest?

What resources are important, prominent, and tell the story?

What is the placed-based connection?

Who are the key stakeholders to engage?

What is the community benefit?

Identify the Audience
Maximize Exposure
Develop Impactful Message(s)
Permanent/Repeatable Installation or Event
Innovative Communications

Educational installation at Main Street and Lincoln Street Elementary Schools
Reaches students Kindergarten through grade 5, yearly reinforcement, workbooks

Exeter Resilience Project: Innovative Approaches to Stormwater Management, Communications, Policy

Water Cycle, Flooding
Surface interactions
Natural Wetlands
Constructed Wetlands
Porous Pavement
Stormwater Management
Exeter Resilience Project: Innovative Approaches to Stormwater Management, Communications, Policy

Innovative Communications
Educational installation at Swasey Parkway, Exeter

Highly Visited Area – Permanent Messaging – Expand with Future Installations

Exeter-Squamscott Rivers
Watershed Facts
Importance of Saltmarsh
Riverine Ecosystems
Impacts of Sea-level Rise
**EXETER STORMWATER RESILIENCE**

**LINCOLN STREET PHASE II PROJECT**

**Project Summary and Goals**

1. Achieve municipal, community, and area-wide planning for climate change and flood events.
2. Implement a systems approach to water resources management including economic considerations.
3. Advance green infrastructure and other effective means of adaptation implementation for flood damage avoidance and water quality improvements.

**Watershed Assessment, Flood Analysis, and Adaptation with Green Infrastructure**

1. The total annual nitrogen load from the entire Lincoln Street watershed is 2,280 pounds.
2. Installation of BMPs 2, 3, 4, 5, 6, 7, and 8 is expected to reduce the load by 255 pounds annually, a 11% reduction.
3. The SWIP cost-performance range is from $468,000 to $524,000 with a median of $515,000, or 61% reduction.
4. Flood reductions are with 50-year flood and 70% buffer for 63% flood volume.
5. These activities are limited to Great Island, the core of Exeter's downtown, and include streets, parking lots, athletic fields, and green infrastructure in the surrounding area.

**EXETER STORMWATER RESILIENCE**

**STORMWATER RETROFIT OPPORTUNITIES**

**Resilient Green Infrastructure**

1. New Hampshire coastal communities have experienced rising populations resulting in an increase in development in nitrogen pollution and flooding from rainwater runoff.
2. Green infrastructure is an effective method to both improve water quality and reduce stormwater runoff.
3. The use of green infrastructure improves other economic and quality of life benefits such as creation of attractive public spaces, and landscaping that supports walkable communities.
4. This project developed construction-ready designs for inclusion in future capital improvement projects in Exeter’s largest subwatershed.

**Performance of Stormwater Retrofits**

1. The total annual nitrogen load from the 1.7-acre Lincoln Street watershed is 2,280 pounds.
2. The project Exeter Resilience project identified green infrastructure retrofits opportunities for 14 stormwater installations expected to reduce nitrogen load by 255 pounds annually, a 11% reduction.
3. Retention costs range from $2,000 and range from $468,000 to $524,000 per pound of nitrogen in comparison with $2,000 for the new wastewater facility.
4. The estimated cost to implement green infrastructure retrofits at 14 locations is $490,000.

**EXETER STORMWATER RESILIENCE**

**ECONOMIC BENEFITS OF FLOOD AVOIDANCE**

**Green Infrastructure and Climate Adaptation**

1. New Hampshire coastal communities have experienced rising populations resulting in an increase in nitrogen pollution and stormwater runoff.
2. At the same time, communities are faced with a changed climate including extreme rainfall events and sea-level rise.
3. Green infrastructure is an important form of climate adaptation which can have significant economic benefits for flood damage avoidance.
4. The Exeter Resilience project conducted a cost impact analysis to evaluate the potential for flood damage avoidance with implementation of green infrastructure.

**Flood Damage Avoidance**

1. The cost impact analysis graphic at right shows the potential for flood damage avoidance with implementation of green infrastructure.
2. The estimated flood loss from a current 10-year storm of $1.4 million or $13.4 million with green infrastructure, a 10% reduction.
3. The total estimated cost to implement green infrastructure retrofits is $490,000.
4. The greatest benefit is from small cost management strategies that provide water quality and flood protection at no additional cost.

**EXETER STORMWATER RESILIENCE**

**FLOOD REDUCTION FROM GREEN INFRASTRUCTURE**

**Flood Reduction from Green Infrastructure**

1. Each small cost-saving management strategy can help reduce flood damage and costs.
2. Flood reductions from green infrastructure implementation are estimated at 60% for the current 10-year storm and 50% for the projected 2050 stormwater with a 2.12 feet of storm surge.
3. The figure below shows the model flood impacts with and without green infrastructure for the projected year 2049 flood with and without water quality volume management practices.
Climate Adaptation Policy (*draft*)

**Vision Statement**

*Proactive strategies are identified and implemented that address the impacts of coastal hazards and climate change to create a more sustainable and resilient community.*

**Purpose**

Unified vision, goals, and actions

Guide planning, investment, management, regulations

Support for grants and other funding sources

Living document, informed by best available science/information
Climate Adaptation Policy *(draft)*

**Goals**

Ensure the community is better prepared to protect the security, health and safety of its citizens.

Protect natural resources from the impacts of flooding from sea-level rise and storm events.

Provide for a stable and viable economic future.

Minimize the future costs of infrastructure replacement and maintenance.

Support installations of renewable energy systems and electric vehicle charging stations.
**Exeter Resilience Project:** Innovative Approaches to Stormwater Management, Communications, Policy

**Climate Adaptation Policy (draft)**

**Recipe for Process/Methods**

- Supported by Master Plan
- Audit of Zoning and Regulations
- Community Initiatives and Activities
- Capital Improvement/Infrastructure Management Plans
- Coordination with elected officials, staff, boards, commissions
- Exeter “Climate Proclamation” (to uphold principles of Paris Climate Accord)
Tasks

1. Watershed Modeling

2. Identify Green Infrastructure Retrofit Locations

3. Project Design

4. Nutrient and Flooding Reduction

5. HAZUS Damage Costing
The study area is comprised of 2 distinct watersheds in terms of drainage infrastructure, the upper watershed area to the west, and the lower area to the east of the railroad tracks.

- 179 acres with 41% impervious cover
- 1,265 lbs of nitrogen annually
- 27” storm drain underneath PEA
1. The total annual nitrogen load from the 179-acre Lincoln Street watershed is 1,265 pounds.

2. The project identified green infrastructure retrofit opportunities for 14 stormwater installations.

3. BMPs expected to reduce nitrogen load by 691 pounds annually, a 76% reduction.

4. Retrofit unit costs averaged $1,000 and ranged from $498 - $5,080 per pound of nitrogen in comparison with $1,200 for the new wastewater facility.

5. The estimated cost to implement green infrastructure retrofits at these 14 locations is $689,000.
1. Flood reductions as runoff volume from green infrastructure implementation are estimated at 60% for the current 10-year storm and 50% for the projected year 2040 storm event with 9.21 feet of storm surge.

2. The figure shows the modeled flood impact with and without green infrastructure for the projected year 2040 rainfall and storm conditions with and without water quality volume best management practices.
### Flooding Before and After—Winter & Railroad

#### PCSWMM Results for 10-year, 24-hour Storm Event (4.72 inches)

**Winter Street Detail**

<table>
<thead>
<tr>
<th>BMP #</th>
<th>Drainage Area (acres)</th>
<th>Annual TN Load (lbs)</th>
<th>Annual TN Reduction (lbs)</th>
<th>% Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>12.88</td>
<td>90.1</td>
<td>68.2</td>
<td>76%</td>
</tr>
<tr>
<td>2</td>
<td>24.56</td>
<td>157.6</td>
<td>120.2</td>
<td>76%</td>
</tr>
</tbody>
</table>

**Legend**

- **BMP#1**
- **BMP#2**
- **CEMETERY**
- **Flood Extent - Baseline**
- **Flood Extent - 1/2” WQV BMPs**

**Reduction in Flood Duration**
FLOODING BEFORE AND AFTER—RAILROAD AND LINCOLN ST

<table>
<thead>
<tr>
<th>BMP #</th>
<th>Drainage Area (acres)</th>
<th>Annual TN Load (lbs)</th>
<th>Annual TN Reduction (lbs)</th>
<th>% Load Reduction</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1</td>
<td>0.20</td>
<td>2.52</td>
<td>2.00</td>
<td>80%</td>
</tr>
<tr>
<td>3.2</td>
<td>0.13</td>
<td>1.72</td>
<td>1.30</td>
<td>76%</td>
</tr>
<tr>
<td>3.3</td>
<td>0.27</td>
<td>3.40</td>
<td>2.60</td>
<td>77%</td>
</tr>
<tr>
<td>3.4</td>
<td>0.22</td>
<td>2.85</td>
<td>2.20</td>
<td>77%</td>
</tr>
<tr>
<td>3.5</td>
<td>0.24</td>
<td>2.40</td>
<td>1.80</td>
<td>75%</td>
</tr>
<tr>
<td>3.6</td>
<td>0.78</td>
<td>7.22</td>
<td>5.70</td>
<td>79%</td>
</tr>
<tr>
<td>3.8</td>
<td>1.20</td>
<td>9.12</td>
<td>7.10</td>
<td>78%</td>
</tr>
<tr>
<td>3.9</td>
<td>0.70</td>
<td>5.62</td>
<td>4.20</td>
<td>75%</td>
</tr>
<tr>
<td>3.20</td>
<td>1.60</td>
<td>13.91</td>
<td>10.70</td>
<td>77%</td>
</tr>
<tr>
<td>3.21</td>
<td>0.24</td>
<td>1.39</td>
<td>1.00</td>
<td>72%</td>
</tr>
<tr>
<td>3.22</td>
<td>0.20</td>
<td>1.35</td>
<td>1.00</td>
<td>74%</td>
</tr>
</tbody>
</table>
### FLOODING BEFORE AND AFTER – ELM ST, FRONT ST & TAN LANE

<table>
<thead>
<tr>
<th>BMP #</th>
<th>Drainage Area (acres)</th>
<th>Annual TN Load (lbs)</th>
<th>Annual TN Reduction (lbs)</th>
<th>% Load Reduction</th>
<th>25% Design Cost Estimate</th>
<th>$/LBS NITROGEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>34.7</td>
<td>275</td>
<td>206</td>
<td>75%</td>
<td>$312,000</td>
<td>$1,500</td>
</tr>
<tr>
<td>7</td>
<td>7.4</td>
<td>58</td>
<td>43</td>
<td>75%</td>
<td>$35,000</td>
<td>$800</td>
</tr>
<tr>
<td>8</td>
<td>16.0</td>
<td>108</td>
<td>82</td>
<td>76%</td>
<td>$84,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>9</td>
<td>5.9</td>
<td>48</td>
<td>36</td>
<td>76%</td>
<td>$38,000</td>
<td>$1,000</td>
</tr>
<tr>
<td>Total</td>
<td>64.0</td>
<td>489</td>
<td>367</td>
<td>75%</td>
<td>$469,000</td>
<td>-</td>
</tr>
</tbody>
</table>
HAZUS Analysis and Damage Cost Avoidance
1. The cost impact analysis graphic at right shows the potential for flood damage avoidance with implementation of green infrastructure.

2. The estimated flood loss from a current 10-year storm is $6.11 million or $3.43 million with green infrastructure, a 51% reduction.

3. The total estimated cost to implement green infrastructure at 14 sites is $689,000.

4. The greatest benefit is from small sized Best Management Practices that provide water quality and flood protection for a 0.5” storm, the most frequent annual rainfall event.
RIGHT-OF-WAY INFILTRATION
RIGHT-OF-WAY INFILTRATION

- LOW COST PRETREATMENT INSTALLED IN EXISTING CATCH BASINS AND DRAINAGE INFRASTRUCTURE AND INFILTRATION IN RIGHT-OF-WAY
- MAINTENANCE IS BY STANDARD VACTOR TRUCKS WITH NO SPECIAL EQUIPMENT OR TRAINING
TREE PLANTERS

- LOW COST PRETREATMENT INSTALLED IN EXISTING CATCH BASINS AND DRAINAGE INFRASTRUCTURE AND PLANTERS UNDERNEATH SIDEWALK FOR MAXIMUM PEDESTRIAN USAGE
- MAINTENANCE IS BY STANDARD VACTOR TRUCKS WITH NO SPECIAL EQUIPMENT OR TRAINING
Low Maintenance Asset Management With Pretreatment

- In urban environments return on investment may be 1-2 years
- Goal is to use existing staff, equipment for standard catch basin cleaning
- Land-use and trash and debris load
- Aesthetics
- Cost to maintain versus cost of pretreatment

SOURCE: NYC OFFICE OF GREEN INFRASTRUCTURE

Condition Shortly After Install

Anderson Street Bioswale

Pretreatment by ACF

Condition After Winter

SOURCE: NYC OFFICE OF GREEN INFRASTRUCTURE
### Table 7: Engineering Cost Estimates for BMPs 1, 2, 3, 4, 5, 7, 8 and 9

<table>
<thead>
<tr>
<th>LOCATION</th>
<th>BMP #</th>
<th>DRAINAGE AREA (ACRES)</th>
<th>ANNUAL TN REDUCTION (LBS)</th>
<th>% LOAD REDUCTION</th>
<th>95% DESIGN COST ESTIMATE</th>
<th>$/LBS NITROGEN</th>
</tr>
</thead>
<tbody>
<tr>
<td>WINTER STREET</td>
<td>1</td>
<td>12.9</td>
<td>68.2</td>
<td>76%</td>
<td>$45,900</td>
<td>$680</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>24.6</td>
<td>120.2</td>
<td>76%</td>
<td>$79,000</td>
<td>$660</td>
</tr>
<tr>
<td></td>
<td>-</td>
<td>37.4</td>
<td>188.4</td>
<td>76%</td>
<td>$124,900</td>
<td>-</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>LINCOLN STREET</td>
<td>3.1</td>
<td>0.2</td>
<td>2.0</td>
<td>80%</td>
<td>$8,000</td>
<td>$4,000</td>
</tr>
<tr>
<td>NORTH</td>
<td>3.2</td>
<td>0.1</td>
<td>1.3</td>
<td>76%</td>
<td>$6,600</td>
<td>$5,080</td>
</tr>
<tr>
<td></td>
<td>3.3</td>
<td>0.3</td>
<td>2.6</td>
<td>77%</td>
<td>$12,000</td>
<td>$4,620</td>
</tr>
<tr>
<td></td>
<td>3.4</td>
<td>0.2</td>
<td>2.2</td>
<td>77%</td>
<td>$9,900</td>
<td>$4,500</td>
</tr>
<tr>
<td></td>
<td>3.5</td>
<td>0.2</td>
<td>1.8</td>
<td>75%</td>
<td>$7,000</td>
<td>$3,890</td>
</tr>
<tr>
<td></td>
<td>3.6</td>
<td>0.8</td>
<td>5.7</td>
<td>79%</td>
<td>$21,800</td>
<td>$3,830</td>
</tr>
<tr>
<td></td>
<td>3.8</td>
<td>1.2</td>
<td>7.1</td>
<td>78%</td>
<td>$22,000</td>
<td>$3,100</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$103,900</td>
<td></td>
</tr>
<tr>
<td>LINCOLN STREET</td>
<td>3.9</td>
<td>0.7</td>
<td>4.2</td>
<td>75%</td>
<td>$13,600</td>
<td>$3,240</td>
</tr>
<tr>
<td>SOUTH</td>
<td>3.22</td>
<td>0.2</td>
<td>1.0</td>
<td>77%</td>
<td>$3,000</td>
<td>$3,000</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$35,800</td>
<td></td>
</tr>
<tr>
<td>FRONT STREET</td>
<td>3.20</td>
<td>1.6</td>
<td>10.7</td>
<td>77%</td>
<td>$33,000</td>
<td>$3,090</td>
</tr>
<tr>
<td></td>
<td>3.21</td>
<td>0.2</td>
<td>1.0</td>
<td>72%</td>
<td>$2,800</td>
<td>$2,800</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$35,800</td>
<td></td>
</tr>
<tr>
<td>PHASE 2</td>
<td>5</td>
<td>20.3</td>
<td>71.7</td>
<td>52%</td>
<td>$45,200</td>
<td>$640</td>
</tr>
<tr>
<td></td>
<td>4</td>
<td>32.43</td>
<td>230</td>
<td>90%</td>
<td>$259,900</td>
<td>$1,130</td>
</tr>
<tr>
<td></td>
<td>7</td>
<td>7.41</td>
<td>7</td>
<td>12%</td>
<td>$33,100</td>
<td>$4,560</td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>15.99</td>
<td>107</td>
<td>99%</td>
<td>$53,500</td>
<td>$500</td>
</tr>
<tr>
<td></td>
<td>9</td>
<td>5.86</td>
<td>47</td>
<td>99%</td>
<td>$33,600</td>
<td>$700</td>
</tr>
<tr>
<td><strong>Subtotal</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$380,000</td>
<td>$970</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>$689,825</td>
<td></td>
</tr>
</tbody>
</table>
## Nutrient Removal Unit Cost Comparison

<table>
<thead>
<tr>
<th>Nutrient Control Strategy</th>
<th>Total Annual Cost</th>
<th>Life Cycle Cost Estimate</th>
<th>Lbs N Reduced Per Year</th>
<th>Unit Cost $/Lb N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Durham WW 5 mg/L</td>
<td>$971,140</td>
<td>$13,800,000</td>
<td>5,254</td>
<td>$2,627</td>
</tr>
<tr>
<td>Durham WW 3 mg/L</td>
<td>$1,680,340</td>
<td>$23,200,000</td>
<td>8,757</td>
<td>$2,649</td>
</tr>
<tr>
<td>WW Incremental Increase¹</td>
<td>$709,200</td>
<td>$9,400,000</td>
<td>3,503</td>
<td>$2,683</td>
</tr>
<tr>
<td>Durham NPS IC Program¹</td>
<td>$95,000</td>
<td>$475,000</td>
<td>250</td>
<td>$1,900</td>
</tr>
<tr>
<td>WISE NPS @ IP 3/5/8 mg/L²</td>
<td>$453,333</td>
<td>$13,600,000</td>
<td>17,000</td>
<td>$800</td>
</tr>
<tr>
<td>WISE WW @ IP 3/5/8 mg/L²</td>
<td>$3,046,667</td>
<td>$91,400,000</td>
<td>95,000</td>
<td>$962</td>
</tr>
<tr>
<td>WISE Total @ IP 3/5/8 mg/L²</td>
<td>$3,500,000</td>
<td>$105,000,000</td>
<td>112,000</td>
<td>$938</td>
</tr>
<tr>
<td>Exeter WW 3 mg/L³</td>
<td>$5,789,000</td>
<td>$115,780,000</td>
<td>95,400</td>
<td>$1,214</td>
</tr>
</tbody>
</table>

### Notes and Assumptions

- Data is from 2012 Oyster River Watershed Integrated Management Plan by VHB, NOS data generated by VHB, WW data by Wright Pierce Facilities Plan Draft
- WW data reported is based on 7 month period. It was not adjusted for 12 months as perhaps should be considered for direct comparison with NPS
- Assumes 20 Yr SRF Loan for Exeter @3.25% with no state or federal aid
- Life Cycle includes capital and operations and maintenance
- Present worth is capital at 20-yr;
- Data sources: ¹ ORWIMP 2014; ² WISE 2015, ³ Wright Pierce 2014
Thank you!

Robert M. Roseen, PE  
(603) 686-2488(c)  
rroseen@waterstone-eng.com

Julie LaBranche, Senior Planner  
(603) 778-0885  www.rpc-nh.org

Rockingham Planning Commission