Emerging Research Breakout Session

4th Annual Puget Sound Green Infrastructure Summit

March 22nd, 2019 | Cascadia College/U.W. Bothell
Green Infrastructure:
Smith Cove Blue Carbon Pilot Project
Blue Carbon?

- Carbon captured by inshore and shoreline area processes
- Stored in biomass and sediments
- Marsh, seagrass and algae
Green Shoreline Infrastructure?

- Environmental stewardship
- Compensatory mitigation
- Source control
- Climate Adaptation/Resilience
  - Carbon sequestration
  - Ocean acidification (OA) refugia
  - Sea-level rise and shoreline stabilization
• Nineteen habitat restoration & public shoreline access sites
• Over 100 acres
• One-third already restored
• Mostly estuarine and marine
• 15.1 miles of shoreline
Alternative Shoreline Stabilization

- Removed structures/fill
- +20' MLLW
- +16' MLLW
- +12' MLLW
1. SECTION THROUGH OUTER SHELF AND INTERTIDAL BERM

Kelp & Eelgrass

LOWER DUWAMISH RIVER CHANNEL

OFF-CHANNEL HABITAT AREA

PORTfolio
Can Kelp Save The Pacific Ocean?

CREDIT: AP PHOTO/MANUEL VALDES
Project Goals

Carbon
  – Generate biomass
  – Increase retention time

Water quality
  – Remove nutrients/contaminants
  – Moderate temperature
  – Raise pH

Habitat
  – Forage
  – Refugia
  – Reproduction
<table>
<thead>
<tr>
<th>Habitat Type</th>
<th>Carbon (tC/ac/yr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Riparian vegetation</td>
<td>1.08</td>
</tr>
<tr>
<td>Intertidal marsh</td>
<td>0.98</td>
</tr>
<tr>
<td>Intertidal mudflat</td>
<td>0.19</td>
</tr>
<tr>
<td>Shallow subtidal (eelgrass)</td>
<td>0.28</td>
</tr>
<tr>
<td>Deep subtidal (kelp)</td>
<td>0.36</td>
</tr>
</tbody>
</table>
Smith Cove Pilot Project

Install “blue carbon”:
- Riparian (2 acres)
- Marsh (1 acre)
- Shellfish (2 acres)
- Eelgrass (5 acres)
- Kelp (5 acres)
- Mussel collectors (100 straps)

Evaluate changes:
- Water chemistry (pH)
- Biomass
- Habitat
Riparian vegetation (> +12’ MLLW)
Oysters (+1’ to -3’ MLLW)
Emergent marsh (+12’ to +8’ MLLW)
Eelgrass (-1’ to -10’ MLLW)
Bull kelp (-12’ to -24’ MLLW)
## Estimated Costs

<table>
<thead>
<tr>
<th></th>
<th>Plots</th>
<th>Size</th>
<th>Cost</th>
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</thead>
<tbody>
<tr>
<td>Baseline survey</td>
<td>NA</td>
<td>Sitewide</td>
<td>$35,000</td>
</tr>
<tr>
<td>Eelgrass transplant</td>
<td>15</td>
<td>20'x20'</td>
<td>$100,000</td>
</tr>
<tr>
<td>Kelp substrate/seeding</td>
<td>15</td>
<td>variable</td>
<td>$100,000</td>
</tr>
<tr>
<td>Olympia oyster substrate/spat</td>
<td>10</td>
<td>10'x20'</td>
<td>$115,000</td>
</tr>
<tr>
<td>Mussel collectors</td>
<td>NA</td>
<td>NA</td>
<td>$75,000</td>
</tr>
<tr>
<td>Long-term study</td>
<td>NA</td>
<td>NA</td>
<td>$175,000</td>
</tr>
<tr>
<td>Gear</td>
<td>NA</td>
<td>NA</td>
<td>$175,000</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td><strong>$750,000</strong></td>
</tr>
</tbody>
</table>
Restoration Hatchery
Oyster Broodstock
Oyster Seeding
Kelp Harvest for Test Plots
Kelp Propagation @ Hatchery
Kelp Substrate
Eelgrass Restoration
Monitoring

- pH Sensor
- Maverick
- Sgt Pepper
- Ringo
- Z-Boat
Milestones 2018-2023

- Kelp test plots (Mar-June 2018)
- Oysters installed (Oct 2018)
- Water quality sensors installed (Jan 2019)
- Kelp substrate, anchors & line (Feb 2019)
- Oyster tiles (May 2019)
- Eelgrass restoration (June 2019)
- Shoreline restoration w/ City of Seattle (2020)
- Monitoring study (2019-2023)
Green Infrastructure Summit
Using Data to Identify Opportunity
March 22, 2019
Seattle 2030 District Basics

- Developers/Owners/Managers: 64
- Professional Stakeholders: 55
- Community Stakeholders: 19
- Strategic Partners: 10
2030 Challenge Goals

The 2030 Challenge for Planning: Existing Buildings

Source: 2018 2030 Inc./Architecture 2030, All rights reserved
Problems Facing District Buildings

• Dense, urban neighborhoods
• Lack of space and aligned incentives
• Existing buildings – haven’t triggered stormwater code
• Inability to infiltrate
• Lack of cooperation between right-of-way and private parcels
Main Themes:

❖ Keep stormwater on-site

❖ Reuse water in buildings

❖ Incorporate water into streetscape and parks

❖ Potential “green corridor” through Belltown
Identifying Assets and Areas of Need

• Apply GBBS lessons to entire District
• Use mapping tools like Sound Impacts for reference
• Collect stormwater management contributions made by private parcels
• Incorporate public works projects and CSO Locations
• Identify areas for communal stormwater management
DISTRICT STORMWATER CALCULATOR
Next Steps to Connected Greenways

• Collect data on remaining member buildings and solicit non-member & public parcels
• Further integration with additional data layers – hydrology, sewer infrastructure, etc.
• Explore pay-for-performance to incentivize looking beyond Lot line
• Connect private parcels with public projects
• Rainwater harvesting and re-use design competition
• Tell the story
Thank you to our Funders
Puget Sound Urban Tree Canopy and Stormwater Management

A Comparison of i-Tree Hydro and Western Washington Hydrology Model
2019 Green Infrastructure Summit
Trees and Stormwater - What We Know

Tree canopy in our region provides stormwater management benefits including reductions in runoff volume and pollution loads.
Project Goals

• Further explore the relationship between trees and stormwater management by comparing two prominent hydrology models.
  ❑ Collaborative evaluation of models
  ❑ Recommendations for using models
  ❑ Develop and distribute resources
  ❑ Present findings at regional symposia

• Engage urban forest and stormwater management communities in a discussion about the role of urban tree canopy and forests in stormwater management.
# Project Team

## Project Coordination Team

<table>
<thead>
<tr>
<th>Project Lead</th>
<th>King Conservation District</th>
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</thead>
<tbody>
<tr>
<td>Consultant Team</td>
<td>The Keystone Concept</td>
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<td></td>
<td>Plan-It Geo</td>
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<td>Herrera</td>
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<td>SP Editorial</td>
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## Pilot Communities Committee

<table>
<thead>
<tr>
<th>King County</th>
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<tr>
<td>King Conservation District</td>
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<table>
<thead>
<tr>
<th>City of Kirkland</th>
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<td>City of Kent</td>
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<table>
<thead>
<tr>
<th>Snohomish County</th>
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<td>Snohomish Conservation District</td>
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<tr>
<th>City of Snohomish</th>
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<tr>
<th>Pierce County</th>
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<tbody>
<tr>
<td>Pierce Conservation District</td>
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<thead>
<tr>
<th>City of Tacoma</th>
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# Project Team

## Technical Committee

<table>
<thead>
<tr>
<th>NGO PARTNERS</th>
<th>AGENCY PARTNERS</th>
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<tbody>
<tr>
<td>Futurewise</td>
<td>WA Dept. of Natural Resources</td>
</tr>
<tr>
<td>The Nature Conservancy</td>
<td>WA Dept. of Ecology</td>
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<tr>
<td>iTree Cooperative / Davey Institute</td>
<td>Washington Stormwater Center</td>
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<td></td>
<td>King Conservation District</td>
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<td></td>
<td>King Co. Stormwater &amp; 1 Million Trees Initiative</td>
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<td></td>
<td>City of Seattle - Green Infrastructure</td>
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<tr>
<td></td>
<td>Snohomish Conservation District</td>
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<td></td>
<td>Snohomish Co. Public Works / Stormwater</td>
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<td></td>
<td>Pierce Conservation District</td>
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<tr>
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<td>Pierce County Stormwater Services</td>
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## Stakeholder Committee

<table>
<thead>
<tr>
<th>NGO PARTNERS</th>
<th>AGENCY PARTNERS</th>
</tr>
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<tbody>
<tr>
<td>The Nature Conservancy</td>
<td>King Conservation District</td>
</tr>
<tr>
<td>Futurewise</td>
<td>City of Kirkland</td>
</tr>
<tr>
<td>Puget Sound Conservation Districts Caucus</td>
<td>City of Kent</td>
</tr>
<tr>
<td>Stewardship Partners</td>
<td>City of Seattle (Urban Forest Policy &amp; Trees for Seattle)</td>
</tr>
<tr>
<td>iTree Cooperative / Davey Institute</td>
<td>King County Cities - Climate Collaborative (K4C)</td>
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<tr>
<td>The Russell Family Foundation</td>
<td>King Co 1 Million Trees Initiative / King Co. DNR</td>
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<tr>
<td></td>
<td>Snohomish Conservation District</td>
</tr>
<tr>
<td></td>
<td>City of Arlington</td>
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<tr>
<td></td>
<td>Pierce Conservation District</td>
</tr>
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<td></td>
<td>City of Tacoma</td>
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</tbody>
</table>
Project Deliverables

• Pilot City Tree Canopy Assessments
• i-Tree Hydro and WWHM Analysis and Comparison
• Technical Report
• Handbook (under development)
Model Analysis and Comparison

4 Pilot Communities
  • City of Snohomish
  • City of Kirkland
  • City of Kent
  • City of Tacoma

2 Models Evaluated
  • i-Tree Hydro
  • WWHM

4 Spatial Scales
  • City
  • Drainage Basin
  • Neighborhood
  • Site
## 3 Management Scenarios Evaluated

<table>
<thead>
<tr>
<th>Management Scenario</th>
<th>Case</th>
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<tbody>
<tr>
<td>Existing Conditions</td>
<td>Base Case</td>
</tr>
<tr>
<td>Tree Canopy Loss</td>
<td>1A. Present Tree Canopy Stormwater Benefit</td>
</tr>
<tr>
<td></td>
<td>1B. Partial Tree Canopy Loss</td>
</tr>
<tr>
<td>Development</td>
<td>2A. Build Out with Tree Preservation</td>
</tr>
<tr>
<td></td>
<td>2B. Build Out without Tree Preservation</td>
</tr>
<tr>
<td>Tree Canopy Increase</td>
<td>3A. Tree Canopy Increase: Over Pervious Area</td>
</tr>
<tr>
<td></td>
<td>3B. Tree Canopy Increase: Over Impervious Area</td>
</tr>
</tbody>
</table>
Model Analysis and Comparison

Key Findings

1. Runoff Volume Comparison
2. Canopy over Impervious Surfaces
3. Tree Retention during Development
4. Canopy Loss, Benefit Loss
5. Higher Canopy, Greater Benefit
Key Findings

Key Finding 1
In nearly all modeled scenarios, i-Tree Hydro yielded lower runoff volume outputs than WWHM.

When used alone, i-Tree Hydro may understate the contribution of Puget Sound tree canopy toward reducing stormwater runoff and pollution.
Key Findings

Key Finding 2
Increase in tree cover over impervious surfaces (Scenario 3B) results in decreased runoff volumes.

*Plant trees to overhang impervious surfaces for high stormwater runoff and pollution reduction benefits*

Key Findings

Key Finding 3
Development that includes tree retention (Scenario 2A) results in reduced runoff volume compared with development without tree retention.

Retain existing trees during new development and redevelopment for higher stormwater runoff and pollution reduction benefits
Key Finding 4
Scenarios where tree canopy is replaced (1A, 1B, 2A, and 2B) with any other land cover type (herbaceous, shrub, impervious) increases runoff volume.

Retain and plant trees wherever possible (overhanging impervious areas, increasing canopy over pervious areas) to reduce stormwater runoff volume and pollution loads.
Key Findings

Key Finding 5
Areas with higher existing tree canopy coverage experience a lower magnitude of runoff volume when tree canopy is reduced.

City Scale Results

<table>
<thead>
<tr>
<th>Mgmt. Scenario</th>
<th>Cases</th>
<th>i-Tree</th>
<th>WWHM</th>
<th>Kirkland 37% TC</th>
<th>i-Tree</th>
<th>WWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>Development</td>
<td>2A (-5% TC)</td>
<td>TRV: +2%</td>
<td>TRV: +1%</td>
<td>TRV: +0.5%</td>
<td>TRV: +2%</td>
<td></td>
</tr>
<tr>
<td></td>
<td>2B (-10% TC)</td>
<td>TRV: +3%</td>
<td>TRV: +2%</td>
<td>TRV: +2%</td>
<td>TRV: +5%</td>
<td></td>
</tr>
</tbody>
</table>

Retain and expand tree and forest canopy cover wherever possible for maximum stormwater runoff reduction benefit.
Case Study - Kirkland

Analysis and modeling performed for the City of Kirkland demonstrate a number of the project findings.
Kirkland - Tree Canopy Assessment
Kirkland -
Tree Canopy & Impervious Land Cover

• High existing city-wide tree canopy cover: **37%**
• Slightly higher amount of impervious land cover: **38%**
Kirkland - City Scale Results

- 3-4% relative change in runoff volume when 100% of canopy is replaced by herbaceous cover
- An increase in canopy cover over impervious area reduced runoff volume by 2-9%

<table>
<thead>
<tr>
<th>Scenario</th>
<th>i-Tree Hydro (Relative Change, Volume ft³)</th>
<th>WWHM (Relative Change, Volume ft³)</th>
<th>Avoided Runoff Range (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1A. Present Stormwater Canopy Benefit</td>
<td>182 million</td>
<td>139 million</td>
<td>3 to 4%</td>
</tr>
<tr>
<td>1B. Partial Tree Canopy Loss</td>
<td>57 million</td>
<td>14 million</td>
<td>0.4 to 1%</td>
</tr>
<tr>
<td>2A. Build Out with Tree Preservation</td>
<td>37 million</td>
<td>82 million</td>
<td>0.5 to 2%</td>
</tr>
<tr>
<td>2B. Build Out without Tree Preservation</td>
<td>111 million</td>
<td>164 million</td>
<td>2 to 5%</td>
</tr>
<tr>
<td>3A. Tree Canopy Increase: Over Pervious Area</td>
<td>-93 million</td>
<td>-88 million</td>
<td>-1 to -3%</td>
</tr>
<tr>
<td>3B. Tree Canopy Increase: Over Impervious Area</td>
<td>-137 million</td>
<td>-329 million</td>
<td>-2 to -9%</td>
</tr>
</tbody>
</table>
Spatial Scale Results

- High existing tree canopy at all spatial scales
- Tree retention during development (Scenario 2A) and increase in canopy over impervious (Scenario 3B) show the benefit of Kirkland’s tree canopy

<table>
<thead>
<tr>
<th>Scenario</th>
<th>Kirkland</th>
<th>Juanita Creek</th>
<th>Wolff Subdivision</th>
</tr>
</thead>
<tbody>
<tr>
<td>(Base Case % TC, Base Case % Imp)</td>
<td>(37% TC, 38% Imp)</td>
<td>(35% TC, 42% Imp)</td>
<td>(51% TC, 25% Imp)</td>
</tr>
<tr>
<td>i-Tree Hydro</td>
<td>WWHM</td>
<td>i-Tree Hydro</td>
<td>WWHM</td>
</tr>
<tr>
<td>TC Loss 1A (0%)</td>
<td>3%</td>
<td>1%</td>
<td>4%</td>
</tr>
<tr>
<td>TC Loss 1B (-10%)</td>
<td>1%</td>
<td>0.40%</td>
<td>0%</td>
</tr>
<tr>
<td>Develop 2A (-5%)</td>
<td>1%</td>
<td>2%</td>
<td>1%</td>
</tr>
<tr>
<td>Develop 2B (-10%)</td>
<td>2%</td>
<td>5%</td>
<td>2%</td>
</tr>
<tr>
<td>TC Increase 3A (+20%, 10% over impervious / 90% over pervious)</td>
<td>-1%</td>
<td>-3%</td>
<td>-1%</td>
</tr>
<tr>
<td>TC Increase 3B (+20%, 50% over impervious / 50% over pervious)</td>
<td>-2%</td>
<td>-9%</td>
<td>-2%</td>
</tr>
</tbody>
</table>
Model Recommendations

**i-Tree Hydro**

Use at a landscape scale (drainage basin or city-wide) when exploring stream or river hydrology responses with detailed urban vegetation inputs and changes in land cover in large areas.

<table>
<thead>
<tr>
<th>i-Tree</th>
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</thead>
<tbody>
<tr>
<td>• Suite of tools developed by the USDA Forest Service and the Davey Institute</td>
</tr>
<tr>
<td>• Vegetation-specific hydrology model</td>
</tr>
<tr>
<td>• Predict stream flows and water quality at a landscape scale</td>
</tr>
<tr>
<td>• Intended audience: forestry managers and communities</td>
</tr>
<tr>
<td>• Other i-Tree tools that evaluate stormwater benefits: i-Tree Eco and i-Tree Landscape</td>
</tr>
</tbody>
</table>

*Source: i-Tree Tools Website*

[www.itreetools.org/hydro/](http://www.itreetools.org/hydro/)
Model Recommendations

**WWHM**

Use at a site scale (individual parcel or neighborhood) when sizing flow control and water quality treatment BMPs and facilities, or when applying Ecology’s flow control credits for tree planting and/or tree retention (BMP T5.16).

<table>
<thead>
<tr>
<th>WWHM</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Developed by Clear Creek Solutions and funded by Ecology</td>
</tr>
<tr>
<td>• Used to size flow control and water quality treatment BMPs and facilities</td>
</tr>
<tr>
<td>• Focused on western Washington</td>
</tr>
<tr>
<td>• Intended audience: planners, engineers, developers and managers</td>
</tr>
</tbody>
</table>

Source: WA Dept of Ecology website

https://ecology.wa.gov
Moving Forward with i-Tree Hydro

Using the Model

• Understand and apply scale-specific considerations

Research Opportunities

• Compare parameter values and assumptions with tree, hydrology and stormwater best available science

• Explore differences between PNW tree impacts on city-wide runoff and other regions

• Assess affect of species composition on stormwater runoff
Moving Forward with WWHM

Using the Model

• Understand and apply scale-specific considerations

Research Opportunities

Explore land use parameters for:

• Forested areas with different tree species
• Landscaped areas with varying amounts of trees
• Impervious surfaces with overhead tree canopy coverage
Moving Forward with Tree Canopy

Other Considerations
Faced with continuing growth and development pressures on tree canopy, urban open spaces, and opportunities for GSI:

• Design and maintain multi-beneficial landscapes with vegetation layers, including trees
• Maintain existing trees and expand canopy by planting new trees
• Plan, design and develop GSI that integrates trees
Project Next Steps

Model Analysis and Comparison

GSI Community Engagement -
  • Puget Sound GI Summit, March 21, 2019
  • WA Municipal Stormwater Conference, April 24 - 25, 2019

Urban Forestry Community Engagement -
  • Urban Forest Symposium, May 21, 2019

Handbook

  • Puget Sound Conservation District
  • Jurisdiction stormwater and urban forest management programs
  • Project Partners
Funding Partners

- US EPA National Estuary Program
- USDA Forest Service Landscape Scale Restoration Program
- WA Dept. of Ecology
- WA Dept. of Natural Resources
- King Conservation District
Bioretention & Pavement Performance at WSU Puyallup – an update

Ani Jayakaran\textsuperscript{1}, Thorsten Knappenberger\textsuperscript{2}, John Stark\textsuperscript{1}

\textsuperscript{1}Washington State University, Washington Stormwater Center
\textsuperscript{2}Auburn University

4\textsuperscript{th} Annual Puget Sound Green Infrastructure Summit, Bothell WA
March 22\textsuperscript{nd}, 2019
Bioretention Mesocosm Study
Hypothesis: Mesocosm study

Compost content in bioretention mix affects nutrient and metal removal efficiencies
Nitrite & Nitrate Reduction

Compost Content

15%: 28%
20%: 15%
30%: 7%
40%: 5%
Total Phosphorus

**Compost Content**

- 15%
- 20%
- 28%
- 5%
- 40%

**Empirical Distribution Function (EDF)**

- 40%
- 28%
- 5%
- 23%

**WTR**

- Total Phosphorus
  - 40%
  - 0%
  - 20%
  - 40%
  - 60%
  - 80%
  - 100%
Orthophosphorus

Compost Content

[Graph showing empirical distribution function (EDF) with Compost Content percentages and Ortho-Phosphorus graph with Treatment comparison (Dosed vs. Natural)].
Early conclusions

• Performance of the soil mixes dependent on inflow concentrations (for NO$_2$-NO$_3$ & TKN).
• No clear effect of water treatment residuals on phosphorus retention.
• No soil mix was significantly better for nutrient reduction
• Less compost seems better
Porous Asphalt Study

1) Porous asphalt QUANTITY—ability to attenuate stormwater, and effect of maintenance on infiltration rates

   Attenuates peak flows, absorbs a LOT of rainfall

2) Porous asphalt QUALITY pollutant treatment in general, effect of drain depth

   Great for particulate matter!
Performance Goal: The Basic Treatment Menu facility choices are intended to achieve 80% removal of total suspended solids for influent concentrations that are greater than 100 mg/l, but less than 200 mg/l. For influent concentrations greater than 200 mg/l, a higher treatment goal may be appropriate. For influent concentrations less than 100 mg/l, the facilities are intended to achieve an effluent goal of 20 mg/l total suspended solids.
- Phosphorus Treatment: 50 percent removal of TP for influent concentrations ranging from 0.1 to 0.5 mg/L.
Acknowledgments

**Funding:**
National Estuary Program
Washington State Dept. of Ecology

**Technicians**
Richard Bembenek
Carly Thompson

Thank you!

anand.jayakaran@wsu.edu
Questions?

4th Annual Puget Sound Green Infrastructure Summit
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