Planning to Reduce Nutrient Loading through Street Sweeping

Pilot Workshops – November 2013

Objectives of this morning:
1. Present final results from the University study “Quantifying nutrient removal by street sweeping.”
2. Introduce and provide a tutorial for the new Planning Calculator for Estimating Nutrient Removal through Street Sweeping.
3. Discuss barriers for street sweeping and regulatory challenges in acquiring credit towards clean water goals for street sweeping.

Extension provides practical education and research you can trust, to help people, businesses and communities solve problems, develop skills and build a better future.

University of Minnesota Extension MISSION: Making a difference by connecting community needs and university resources to address critical issues in Minnesota.
1. INTRODUCTIONS
2. PRESENTATION - INTRODUCTION TO STREET SWEEPING & THE BENEFICIAL USES OF THIS RESEARCH PROJECT
3. PRESENTATION - QUANTIFYING NUTRIENT REMOVAL THROUGH STREET SWEEPING
BREAK
4. DEMONSTRATION - INTRODUCTION AND TUTORIAL: PLANNING CALCULATOR FOR ESTIMATING NUTRIENT REMOVAL THROUGH STREET SWEEPING
5. DISCUSSION - PRACTICAL CONSIDERATIONS, REGULATORY ISSUES, AND CREDITS

Discussion questions

1. How might you use the research findings and calculator tool?
2. What are the barriers or constraints to implementing street sweeping OR enhancing your current street sweeping program?
3. Input on 2014 comprehensive street sweeping training program – what topics should be incorporated?

Discover more at extension.umn.edu/stormwater
Quantifying Nutrient Load Recovery through Targeted, Intensive Street Sweeping

Questions to think about for discussion period

What is new about the Prior Lake study?

<table>
<thead>
<tr>
<th>Prior Lake study</th>
<th>Historical studies</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sampled from snowmelt to snow fall</td>
<td>Limited duration, rarely extending into autumn</td>
</tr>
<tr>
<td>Included coarse organic matter</td>
<td>Discarded sieved coarse material</td>
</tr>
<tr>
<td>Quantified solids and nutrient removal in sweepings</td>
<td>Measured changes in stormwater loadings resulting from sweeping</td>
</tr>
<tr>
<td>Factorial design: tree canopy cover x frequency</td>
<td>Generally just with and without sweeping</td>
</tr>
<tr>
<td>Compiled cost efficiency, $/lb removed</td>
<td>Generally did not estimate cost efficiency</td>
</tr>
</tbody>
</table>
Background: Sweeper Types

Mechanical Sweepers
- Cost: $140,000+
  - Lower power requirement
  - Able to pick up wet and hard-packed material, coarse-grained particles.
  - Not as effective for fine material
- Applications: Appearance, Road Maintenance, Safety

Regenerative Air Sweepers
- Cost: $175,000 – 250,000
  - Removes fine & entrained sediment (limitations)
  - Vacuum material from gutters
  - Higher power requirement, maintenance
- Applications: Appearance, Road Maintenance, Safety, Air and Water Quality

Vacuum Assist Sweepers
- Cost: $175,000 – 250,000
  - Removes fine & entrained sediment (limitations)
  - Vacuum material from gutters
  - Higher power requirement, maintenance
- Applications: Appearance, Road Maintenance, Safety, Air and Water Quality

Study Design

Nine Study Routes

<table>
<thead>
<tr>
<th>LOW Canopy</th>
<th>MEDIUM Canopy</th>
<th>HIGH Canopy</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 X, 2X, 4X/month</td>
<td>1 X, 2X, 4X/month</td>
<td>1 X, 2X, 4X/month</td>
</tr>
</tbody>
</table>

What is the relationship between overhead tree canopy and recovered solids, nutrients?

Distribution of Sweeping Routes

Focus on Recovered Material

Collection Protocol
- WEIGH
- INSPECT
- DUMP
- INSPECT
- SAMPLE
- INSPECT

Material removed from the street is not available for transport to storm sewers.
**Lab Methods:** Unique Fractionation Scheme Suited to Focus on Nutrients

<table>
<thead>
<tr>
<th>Fines (&lt;2mm)</th>
<th>Coarse Organics (≥22mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP, TN, TOC (Leached during separation process)</td>
<td>TS, TP, TN, TOC, % Organic</td>
</tr>
</tbody>
</table>

* Dry mass only, nutrient contribution assumed negligible.

**Quantification of Tree Canopy**

Buffers chosen to reflect scales of the landscape:

- **Street**
  - Near Street (5ft, 10 ft)
  - Front Yard (20, 50 ft)
- **Lot Size** (100 ft, 250 ft)

**Tree Canopy Analysis Results**

- Overhead Canopy Cover vs. Buffer Distance from Curb (ft)

**Seasonal Pattern in Solids Recovery**

- Total Dry Solids (lb)
- Influence of month/season on load intensity is significant.
Seasonal Patterns in Recovered Nutrients

Nutrient loading follows vegetation cycle

Role of Coarse Organics

Coarse organics are a significant source of nutrients.

Correlation between Tree Canopy Cover and Recovered Phosphorus

R² = 0.84

General Model for Predicting Recoverable Loads

Goal: Produce a tool for estimating nutrient recovery based on readily obtained inputs.

TIMING of sweeping event

FREQUENCY of sweeping events

CANOPY COVER for sweeping route

E(Load | m, f, c) = β₀ + β₁(month) + β₂(frequency) + β₃(canopy)
Model Validation

Predicted Study Load, Five Fold Cross-Validation

<table>
<thead>
<tr>
<th>Constituent</th>
<th>Measured</th>
<th>MLR Prediction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fresh Solids</td>
<td>853,855</td>
<td>826,950 (-3.6%)</td>
</tr>
<tr>
<td>Dry Solids</td>
<td>618,622</td>
<td>640,636 (+3.2%)</td>
</tr>
<tr>
<td>Total Phosphorus</td>
<td>505</td>
<td>525 (+4.0%)</td>
</tr>
<tr>
<td>Total Nitrogen</td>
<td>1,945</td>
<td>1,895 (+5.3%)</td>
</tr>
</tbody>
</table>

Planning Sweeping Operations for Nutrient Recovery

In high canopy areas, phosphorus can be recovered for less than $100/lb.
Cost of Street Sweeping Operations

**Total Cost = $Labor-Related + $Vehicle-Related**

- Labor-related Costs = $60/hr
  - Labor: $20-40/hr (wages + benefits + overhead) depending on staff level. Combined staffing (driver, engineering, maintenance, admin.)
- Vehicle-related Costs = $5.25/mile
  - Maintenance: $15,000/year average
    - Replacement of all sweeping parts once over life of the vehicle
    - Engine/systems maintenance of the vehicle.
  - Capital Depreciation: (Total Cost of Vehicle + Refurbishment – Resale/Salvage) / Vehicle Life
    - Assumed 8-10 year life of sweeping components
    - Assumed 16-20 year life of vehicle
- Fuel: 4.8 gal/hr, brush on
  - 1.0 gal/hr, travel and idle mode

Do you know the annual cost of current sweeping operations?
Initial Estimate Cost Estimate:
- Annual Cost ($) / Total curb-miles swept = $/curb-mile

Do you track the cost of sweepings as $/hr?
Initial Estimate Cost Estimate:
- Annual Cost ($) / 4 mph† = $/curb-mile

† Typical operational speed in sweep mode

Implementation: Tracking Nutrient Recovery

<table>
<thead>
<tr>
<th>Five –Fold Cross-Validation Exercise using Measured Load, Predicted P-concentrations</th>
<th>P (lb)</th>
<th>% error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Measured Recovered Phosphorus</strong></td>
<td>505</td>
<td></td>
</tr>
<tr>
<td><strong>Estimate based on measured:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Curb-miles Swept (predicted recovery)</td>
<td>525</td>
<td>(+4.0%)</td>
</tr>
<tr>
<td>Fresh Load (lb)</td>
<td>524</td>
<td>(+3.7%)</td>
</tr>
<tr>
<td>Dry Load (lb)</td>
<td>516</td>
<td>(+2.1%)</td>
</tr>
</tbody>
</table>

Five –Fold Cross-Validation Exercise using Measured Load, Predicted P-concentrations

<table>
<thead>
<tr>
<th>Actual P (lb)</th>
<th>P (lb)</th>
<th>% error</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Estimate based on measured:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dry fines (lb) + Dry Coarse (lb)</td>
<td>452</td>
<td>455</td>
</tr>
<tr>
<td>Dry fines (lb)</td>
<td>164.4</td>
<td>163.9</td>
</tr>
<tr>
<td>Dry Coarse Organics (lb)</td>
<td>287</td>
<td>291</td>
</tr>
<tr>
<td>Dry fines (lb) + Dry Coarse (lb) - TP Prediction (includes soluble)</td>
<td>505</td>
<td>501.5</td>
</tr>
</tbody>
</table>
Conclusions

- Large fractions of N and P are in the coarse organic fraction (tree leaves, etc.).
- Nutrient load reduction by sweeping are highest for streets with high canopy in the fall.
- We can readily quantify nutrient load recovery in the planning and implementation phases.
- Under some conditions, the cost of P removal can be less than $100/lb P.
- Coarse organic P may be an important component of watershed P yield and may reduce clarity in some lakes.

Next Steps

- EXTRAPOLATE
- OPTIMIZE
- QUANTIFY
References

Berretta C, Raje S, Sansalone JJ. Quantifying nutrient loads associated with urban particulate matter (PM), and Biogenic/Litter recovery through current MS4 source control and maintenance practices. University of Florida, College of Engineering, Gainsville, Florida: Florida Stormwater Association Education Foundation (FSAEF); 2011 Final Report: 31 may 2011.

Calculator Limitations

• Calculator tool does not predict effect on downstream water quality
• Prediction range is now limited to 30% canopy
• Extrapolation to other cities assumes similar relationship between canopy cover and sweeping removal
• Calculator estimates are based on efficiency of Tymco Model 600 regenerative air sweeper