Quantification of Processes within a Headwater Channel Network

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Credit Valley Conservation Authority
Headwater Features

• Urban development in Southern Ontario has progressed from the Lakes and major waterways outward – urban planning (until recently) has dealt with larger systems

• Initially, headwater drainage features were replaced with traditional stormwater management (nutrients and particulate removal)

• Headwater stream corridors filter sediment, capture nutrients and other pollutants, retain water and organic matter, and provide habitat and corridors for animal migration
Headwater Features

• Obstacles to developing and appropriate and defensible management tool for headwater systems:
  – Generally poorly defined
  – Lack continuous flow
  – Typically altered due to land practices
  – Difficult to defend on an individual basis
  – Minimal quantitative research available regarding their contributions
Overview

- Focus on quantifying physical processes
- Evaluation of functions
  - Hydrology
  - Sediment movement
- Culminate in land use management recommendations (tool)
The Northwest Brampton Study Area

LEGEND
- Study Area
- Swale Monitoring Station
- Channel Monitoring Station

Swale Site 1
Swale Site 2
Swale Site 3
HV9
HV29
HV6
HV24
HV3
HV18
HV2
F15

BRAMPTON
ONTARIO
Study Area

- Northwest Brampton
  (Huttonville Creek & Fletchers Creek)
- Halton Till
- Agricultural land use
- Low gradient
- Catchment areas of approximately 20 Ha.
Add Catchment Maps

Basin Area km²

<table>
<thead>
<tr>
<th>Region</th>
<th>Area</th>
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<tbody>
<tr>
<td>Western</td>
<td>0.54</td>
</tr>
<tr>
<td>Central</td>
<td>0.32</td>
</tr>
<tr>
<td>Eastern</td>
<td>0.19</td>
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</table>
Western – Site 1
Central – Site 2
Eastern – Site 3
Methods

- Three ‘nested’ sites
  - First order into second order
- Monumented cross-sections
- In-situ sediment traps
- Flow gauge
Example of a typical swale monitoring site configuration

- Sediment Trap Location
- Erosion Pin Location
Methods (Cont)

- Repeated field sampling / monitoring
- TSS sampling
- Linked with broader study
  - Downstream stations
Swale Site 3 Monitoring Station - View of nearly filled sediment trap after significant flow event
Results
Combined hydrograph from pressure transducer data from October 6 to October 28, 2006
Hydrology

- Very responsive to rain events
- Appeared to produce more flow per unit area than downstream stations
- Duration of flow was relatively short

[Graph showing discharge over Julian days for different sites, including H1, H2, H3, H5, F3, Western Swale Site, Central Swale Site, and Eastern Swale Site.]
Hydrology

- Actual trend once compared to contributing drainage area
- Flow delivery is consistent
- BUT... you need to consider zero order streams
Monitoring cross-section results for Swale Sites 1 and 3.
**Sediment**

- Change in cross-sectional area propagated into annual volume flux of sediment

- Annual values mask the seasonal fluxes that occur

- Largest sediment production at Central site

<table>
<thead>
<tr>
<th>Site</th>
<th>Order</th>
<th>Volumetric Changes (m³/yr)</th>
<th>Total Losses (m³/yr)</th>
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<tbody>
<tr>
<td></td>
<td></td>
<td>Max</td>
<td>Min</td>
</tr>
<tr>
<td>Western</td>
<td>2nd order 0 &amp; 1st order</td>
<td>5.6</td>
<td>2.8</td>
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<td></td>
<td></td>
<td>1263.9</td>
<td>-1269.4</td>
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<tr>
<td>Central</td>
<td>2nd order 0 &amp; 1st order</td>
<td>241.8</td>
<td>-79.0</td>
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<td></td>
<td></td>
<td>-363.6</td>
<td>-591.1</td>
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<tr>
<td>Eastern</td>
<td>2nd order 0 &amp; 1st order</td>
<td>-20.1</td>
<td>-88.7</td>
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<tr>
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<td></td>
<td>1348.4</td>
<td>-700.9</td>
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</table>
### Sediment

- Comparison of field and bed traps to determine dominant source of sediment within each system

- Sediment input from adjacent fields comprised majority of bedload

- **BUT** – features are also sourcing own sediment

- **ALL** of this sediment is being transported downstream

<table>
<thead>
<tr>
<th>Site</th>
<th>Maximum bedload trap particle size ($D_{90}$) (mm)</th>
<th>Maximum field trap particle size ($D_{90}$) (mm)</th>
<th>Equivalent Ds in bedload trap</th>
<th>% of bedload data not explained by field sediments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Western</td>
<td>0.54</td>
<td>0.30</td>
<td>$D_{90.9}$</td>
<td>9.10</td>
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<tr>
<td>Central</td>
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<td>$D_{82.7}$</td>
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<tr>
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<td>4.97</td>
<td>1.16</td>
<td>$D_{75.9}$</td>
<td>24.10</td>
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</table>
Additional Findings

- Seasonal fisheries
- Small areas make sites dynamic and sensitive to change
Drainage Density – 1st Order

\[
\log(y) = 1.0129 \log(x) + 0.4859 \\
R^2 = 0.9515
\]
Drainage Density – Zero Order

![Graph showing the relationship between drainage area and stream length. The graph indicates that as the drainage area increases, the stream length also increases. There are two sets of data points: one for Orders 1-5 and another for 0 Order included.]
Interpretation

• Not possible to classify headwater systems without consideration of zero order streams (implications to land use management and planning – drainage density)

• Headwater drainage features have a shorter lag time and duration of flow events than higher order streams (similar to an urban system but for different reasons)
Interpretation

• In this study, headwater features were less sensitive to low intensity precipitation events than higher order streams.

• Systems are more than capable of transporting all sediment derived within the system.

• Suspended load likely the main form of sediment transport in swales.
Interpretation

• Is all sediment equal? Preferential maintenance of swales producing higher quality coarse sediment in a post-development scenario?
Management Implications

- Functions
  - Conveyance of flow
  - Sediment contribution
- Maintenance of open channel
- Maintenance of contributing area to channels
Drainage Density as a Management Tool

- Ontario Base Mapping provides an accessible and comparable resource for determining stream lengths.
- Targets are regionally-derived, producing a more robust management tool (database continues to grow).
- Targets are developed on a sub-catchment basis which is consistent with the existing Subwatershed Management approach.
- Quantitative targets are established that can be measured and monitored (i.e., how much).
- Allows flexibility in achieving the target length (i.e., where).
Thank You