The Natural Functions of Headwater Drainage Features

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Outline

• What are Headwater Drainage Features?
• Literature Review – Science and Functions
• Emerging Research on HDFs
• Interim Headwater Guideline
• Case Studies
• Next Steps
Vulnerability of Headwaters

Photo Credit: Shelley Gorenc
What is a Headwater drainage feature (HDF)?:

- ill-defined, temporary, zero and first order swales or streams that may not have “defined bed or banks”, also wetlands
- Can occur anywhere, not just in the upper reaches of watersheds
- Functions of permanently-flowing headwater streams generally well recognized
- Uncertainty around the importance of small, temporary streams
Examples of Headwater Drainage Features

no defined bed or banks, ephemeral, overland flow, grass and emergent cover
Examples of Headwater Drainage Features

Ephemeral/ intermittent flow, very small feature
grass and emergent cover
Examples of Headwater Drainage Features

intermittent, no vegetation within the channel
Flow Functions

- Watershed
- Runoff
- Ephemeral
- Intermittent
- Perennial

Recharge and Storage

Event Based:
- Frozen / Melt & Storm only
- Flow “conveyance dominated”

Delayed Storage
- Vernal / Palustrine Wetland

Seasonally High Ground Water (Shallow)

Ground Water (Deep)
Completed in March 2007 to examine the state of the science with respect to the natural functions of temporary streams

Examined thousands of published and unpublished scientific research papers, government documents, and theses from Canadian and International studies

Referenced over 200 papers in the literature review

Examined all potential functions that HDFs may have, including:

Aquatic – groundwater functions, subsidies of detritus and invertebrates, woody material and leaf litter contributions, organic debris dams, riparian shading, direct habitat for fish and mussels

Terrestrial - habitat provision for terrestrial taxa, terrestrial-aquatic reciprocal relationships

Physical – hydrologic (natural flow regime and flood control), sediment control/contribution, water quality
Literature Review Findings

General Findings

• Majority of the headwater literature focused on permanently-flowing features

• Very few papers discussed intermittent or ephemeral systems, and most ephemeral systems were located in arid or semi-arid settings

• Most research was conducted in high-gradient forested catchments—not low-gradient agricultural settings as in Southern Ontario
Hydrology and Flood Control

• Growing body of evidence in support of using swales as at-source control of flooding

• Promote water storage, delay flows, and promote infiltration

• Gorenc et al. in support of maintaining drainage density to help attenuate flow

➢ Drainage density is the ratio of the total length of all watercourses in a drainage basin to the total basin area
• Headwater Streams constitute >50 to 80% of the length of rivers (Schlosser 1982)

• 90% of a river’s flow may be derived from catchment headwaters (Saunders et al. 2002)

• Headwater basins act as “hydrologically active areas” (Gomi et al. 2002)

• The spatial extent of headwaters can account for 70-80% of the total catchment area within a watershed (Gomi et al. 2002)
Literature Review - Specific Findings

Water Quality

• Engineered swales are effective at removing most chemical parameters

• Some evidence that areas with intact riparian zones effective at removing nitrogen

• Some evidence that well-defined streams effective at phosphorus trapping via sediment adsorption, indirect evidence for HDFs
Sediment Regulation

• Ongoing work by Gorenc et al. to prove or disprove whether HDFs help to maintain sediment supply to downstream areas

• Also examine whether HDF can be replicated by SWM practices

• Anecdotal claims made that HDFs trap sediment, some evidence from mountainous regions
Aquatic Functions

• Studies support terrestrial inputs of detritus and invertebrates can be important to downstream area

• aquatic invertebrate production can be higher in intermittent than perennial streams; export important from nearly intermittent mountainous forest streams

• Evidence that intermittent streams can provide unique invertebrate niches
Terrestrial Functions

- Confirmed function for amphibians; use intermittent streams for breeding purposes - reduced predation from fish, while avoiding desiccation
- Small maneuverable bats use intermittent streams for drinking and foraging
Research Priorities

1. How hydrology is influenced by land use in headwaters (Les Stanfield)
2. How land use influences export of detritus and invertebrates (Dr. David Barton), and how this affects downstream productivity (Dr. David Barton)
3. The cumulative impacts of landscape alteration in headwaters on downstream fisheries
What else have we learned?

Quick Summary!
Organic Drift Study – UofW/TRCA

- Study examining drift of invertebrates and detritus in intermittent and ephemeral streams
- Runoff from cultivated catchments closely reflects precipitation, no response in forested catchments
- HDFs transport large amounts of invertebrates
- Intermittent channels export more invertebrates than do ephemeral channels
- Forested HDFs tend to export greater masses of invertebrates during runoff events than do cultivated basins

Photo Credit: Rachel Martens
Ephemeral Channels

Intermittent Channels

Mean number of animals

Forest
Row Crops
Forest
Row Crop

Terrestrial
Aquatic

Graphic Source: Dr. David Barton
Fish use perennial, intermittent and ephemeral, stream reaches and provide important spawning and seasonal habitat for fish. Fish were captured at 83% of sites, and evidence of breeding fish were observed at almost 60% of our sites. Nine out of 12 perennial, 3 of 7 intermittent, and 7 of 17 ephemeral stream reaches contained fish. Amphibians were observed to be abundant around almost all (75%) our study sites. Headwater drainage features provide many more kilometers of direct seasonal fish habitat over our existing monitoring datasets.
Total Number of Fish Captured

Season

- Adults
- Juveniles

April/May
- Ephemeral
- Intermittent
- Perennial

Early June

Late June

Early July

Late July
• Previous work indicated protecting direct fish habitat may not be enough

• Looked at how landuse, rainfall, and surfical geology influences stream response in HDFs

• HDF response was highly variable and difficult to predict

• Showed reduction in vegetative cover and tight surficial geology corresponds to an increase in flashiness of HDF response

• Because traditional hydrologic models rely on a strong correlation between rainfall and discharge these are unlikely to predict HDF responses
• Looked at sediment transport within 3 swales in Northwest Brampton
• SWM ponds too efficient at removing sediment?
• HDFs produce sediment—downstream geomorphic processes
• End-of-pipe SWM solutions not working: increase flow volumes, increase erosion, and change response pattern in HDFs
• Maintenance of an open channel—drainage density
• Maintenance of contributing drainage area to channels
Headwater drainage features:

- are highly variable with regard to flow and contributions
- more frequently “hydrologically active”
- appear to provide both indirect and direct (seasonal) fish habitat
- regulate sediment and downstream geomorphic processes
- likely cannot be replicated by SWM ponds
- Need to protect functions
- Solutions?: Maintaining open channels and LID
Headwater Drainage Features:
Interim Headwater Guidelines

Laura Del Giudice (TRCA)
Interim Headwater Guidelines

- Town of Markham developed guidelines for urban development – Markham Small Stream Study
- TRCA Guidelines were adapted from CVC work on the Gateway West Subwatershed Study, 1999 - Functional Assessment of Drainage Channels (FADC)
- Document has been modified to reflect needs of TRCA and CVC
- “Interim” document to be used until research gaps are addressed
- Eventually, the guideline will be finalized
Interim Headwater Guidelines

- Reflects consultation with federal, provincial, conservation authority and consulting biologists and ecologists
- Are to be used to prepare and review development studies and applications – from MESP to subdivisions to site plans
- Establish criteria and standards for site evaluations, feature classification, and management requirements
- Guideline updated March 2009 to reflect some preliminary research findings
Evaluation Criteria

- **Field Work** - timing of work, accepted protocols, and surveyor qualifications
- **Flow** - defines permanent, intermittent and ephemeral flow, and surface and groundwater contributions
- **Fish Habitat Assessment** - identifies information to be collected
- **Vegetation** - attributes and functions of riparian and instream vegetation
- **Linkage** - recognition of connections to other aquatic and terrestrial features - wildlife habitat, including corridors, etc.
- **Channel Form** - even ill-defined features may have morphological characteristics that can be described
# Classification

1. **Permanent** - direct habitat onsite  
   - year round groundwater discharge and/or permanent standing water in a storage features, i.e. wetlands, ponds - includes critical fish habitat

2. **Seasonal** - limited direct habitat onsite  
   - seasonally high groundwater discharge or extended surface flows that support intermittent or ephemeral flow conditions - may be permanent refuge habitat within the reach

3. **Contributing** - provides indirect habitat to downstream reaches  
   - **complex contributing habitat** - result of intermittent or ephemeral flows - influences hydrologic functions, water quality and sediment, food (invertebrates) and organic matter/nutrients (i.e. dissolved nutrients and cover)  
   - **simple contributing habitat** - result of ephemeral or intermittent flows - influences hydrologic functions (e.g. flow conveyance, storage and timing)

4. **Not Fish Habitat** - no fish habitat and/or hydrological functions associated with feature is identified - may be characterized by cultivation, furrowing, seasonal crops, lack of natural vegetation, flow, etc.

5. **Recharge Zone** - Coarse-textured soils described as sand and/or gravel have been confirmed through field verification; majority of potential flow will be infiltrated. No direct fish habitat or indirect contributions through surface flow conveyance, allochthonous or sediment transport provided.
Management Recommendations

1. **Protection** - permanent fish habitat, critical fish habitat and SAR habitat

   *Protection 1* - critical habitat - permanent groundwater discharge or wetland surface flows
   preserve feature and flow sources - incorporate shallow groundwater and baseflow protection techniques - feature must connect to downstream watercourse/habitat

   *Protection 2* - permanent habitat - surface storage flows
   preference is to maintain surface water source and/or replicate natural channel design to replace/enhance existing fish habitat - feature must connect to downstream watercourse/habitat
2. **Conservation** - seasonal fish habitat

*Conservation 1* - seasonal habitat supported by extended groundwater flows or from surface storage areas - may include some permanent refuge habitat in reach

- maintain or replicate groundwater/surface contributions - natural channel design to replace existing habitat - feature must connect to downstream habitat

*Conservation 2* - seasonal habitat supported by surface storage areas - replicate surface flows, natural channel design to replace existing habitat - feature must connect to downstream habitat
Management Recommendations

3. Mitigation - contributing habitat

*Mitigation 1* - Complex Contributing Habitat - hydrologic functions, plus water quality/sediment, foods, organic/nutrient inputs
- replicate functions with Low Impact Development measures or constructed wetland
- prefer a feature that connects to downstream habitat, if feasible
- flows must be conveyed directly to downstream habitat

Photo Credit: Cam Portt and George Coker
3. **Mitigation** - contributing habitat

*Mitigation 2* - Simple Contributing Habitat - hydrologic functions (flow conveyance, storage and timing)
- replicate functions with Low Impact Development measures (bioswales, enhanced swales, etc.)

Photo Credit: Cam Portt and George Coker
4. **No Management Recommendation Required** - not considered fish habitat

5. **Recharge Protection** - No direct habitat or indirect habitat providing surface flow, sediment transport, or allochthonous contribution to downstream fish habitat. Maintain overall water balance by providing mitigation measures to infiltrate clean stormwater

Photo Credit: Cam Portt and George Coker
Key Message of Guideline

• To protect existing functions
• To maintain open, vegetated features post-development
EXAMPLE #1 Taunton-Westney Commercial, Town of Ajax

- Existing grades would not allow in-situ protection

Existing Headwater Conditions:
- Minimal riparian cover
- Ploughed through
- Ephemeral flow
- Piped downstream
- Simple contributing habitat

- Mitigation 2 – replicate functions by wetland or LID
Design Techniques:

- Constructed wetland
- Accepts flows from external lands and on-site SWM pond
- Over-excavate substrate and replace with sand to enhance recharge - soakaway
- Vegetated Filtersoxx for water quality improvement
- Green gabions where grades too steep
- Designed to enhance amphibian breeding
- Monitoring drift, w/q
EXAMPLE #2

40 Freel Lane, Stouffville

- Retirement Home Site Plan
- Constrained site – sandwiched between GO station and valley
- Proposed elimination of HDF
- Undevelopable land to north purchased to realign and enhance feature
Existing Headwater Feature:

- Feature accepts untreated stormflows from upstream development
- Good riparian cover, but non-native
- Garbage and debris in channel
- Entrenched, erosion problems
- Complex contributing habitat
- Directly connected to downstream fish habitat

- Mitigation 1- replicate functions through vegetated swales or wetland
Design Techniques

- Enhanced headwater stream design
- Designed to enhance fish habitat. Pool-riffle sequence appropriate for flows
- Incorporate wetland at u/s end to slow and deflect flow, reduce erosion, and partially treat flows
- Construction complete - fish observed in new channel!
Next Steps

• Headwater Website
• Complete scientific studies to fill remaining gaps:
  – Cumulative watershed impacts – threshold?
  – Downstream fish productivity
  – Others? Do SWM practices replicate functions?
• Test monitoring protocol – OSAP
  – Sediment transport/storage
• Finalize Headwater Guideline by 2013? – incorporate other functions
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